Freebooks.pk

BIOLOGY CLASS 9 — PUNJAB BOARD (PECTAA)

Biology Class 9 Complete Notes

All 11 Chapters — English Medium

© freebooks.pk — Original educational content

Table of Contents

Chapter 1	The Science of Biology
Chapter 2	Biodiversity
Chapter 3	The Cell
Chapter 4	Cell Cycle
Chapter 5	Tissues, Organs and Organ Systems
Chapter 6	Biomolecules
Chapter 7	Enzymes
Chapter 8	Bioenergetics
Chapter 9	Plant Physiology
Chapter 10	Reproduction in Plants
Chapter 11	Biostatistics

These notes are prepared by Freebooks.pk and provided free for educational use.

FBPK-BIO9-2026-11-FULLBOOK

Chapter 1: The Science of Biology

Chapter 1 of the new Biology Class 9 book (Punjab, 2025-26 edition) is an introduction to biology as a science. It explains what biology studies, how the subject is split into fields and branches, how it overlaps with physics, chemistry, mathematics, geography, economics and computing, and which careers are open to students who continue with biology after matric.

The second half of the chapter is about how biologists actually find things out. It walks through the scientific method step by step, separates the ideas of hypothesis, theory and law, and then shows the whole method in action through the story of how scientists worked out the cause of malaria and how it spreads. These notes summarise each part in simple language, add a few memory aids, and finish with practice questions and MCQs written for revision.

Learning Objectives

- Define biology and name its three major fields.
- Describe the main branches of biology and what each one studies.
- Explain how biology connects with other sciences such as chemistry, physics, mathematics and geography.
- List career options for students of biology and the degree each needs.
- Recall the Quranic verses quoted in the chapter that point towards the study of life.
- Give examples showing that modern science is a team effort across different fields.
- Describe the steps of the scientific method and use the terms hypothesis, deduction, theory and law correctly.
- Explain the malaria investigation as a worked example of the biological method.

Key Concepts

1.1 Biology and Its Major Fields

Biology is the science of life. The name joins two Greek words: bios, meaning life, and logos, meaning study. Biologists look at how living things are built, how they work and how they interact with each other and with their surroundings. Knowledge of biology is used to solve problems of health, food supply and the environment.

Because life is so varied, biology is divided into three major fields. Zoology deals with animals, botany deals with plants, and microbiology deals with microorganisms such as bacteria and microscopic fungi, including their effect on health and the environment.

1.1 Branches (Sub-fields) of Biology

Structure-based branches: morphology looks at the form and outward appearance of organisms as well as their organs; anatomy looks at internal structure, especially of the human body; histology is the microscopic study of tissues; cytology is the study of cells and cell division.

Function and development branches: physiology studies how body parts work, for example how

blood carries materials around the body; embryology follows the development of an organism from the fertilised egg; genetics studies how characteristics pass from parents to offspring; molecular biology studies biological molecules such as carbohydrates, proteins, lipids and nucleic acids.

Diversity and environment branches: taxonomy classifies organisms into groups on the basis of similarities and differences; palaeontology studies fossils to understand the history of life; ecology studies how organisms relate to their environment; marine biology studies life in the oceans.

Health-related branches: pathology studies diseases, their causes and effects; immunology studies the immune system and how it defends the body; pharmacology studies drugs and their effects, which helps in developing new medicines such as antibiotics.

1.2 Relation of Biology with Other Sciences

Living things obey the same chemical and physical rules as non-living matter, so biology overlaps with many other subjects. Biochemistry studies the chemical substances and reactions inside living things, such as the reactions of photosynthesis and respiration. Biophysics applies physics to life, for example using the principles of levers to explain how bones, joints and muscles move.

Computational biology uses mathematical models, algorithms and computer simulations to handle biological data, for example the order of amino acids in a protein. Biostatistics applies statistics to biological and health data. Biogeography studies where living things are found across the world and how climate change shifts their distribution.

Biotechnology uses living organisms or their parts to make useful products, the classic example being bacteria engineered to make human insulin for diabetic patients. Bio-economics looks at living things from an economic angle, such as working out the cost and profit of developing a new crop variety.

1.3 Careers in Biology

After FSc with biology, students can enter medicine and surgery (5-year MBBS), dentistry (4-year BDS), pharmacy (BS Pharmacy or Pharm-D), physiotherapy (4-year BS) and veterinary medicine. These careers focus on diagnosing and treating disease in humans or animals.

Other careers include agriculture, horticulture (fruits, vegetables and ornamental plants), forestry, animal husbandry (breeding and caring for livestock), fisheries and wildlife, and farming. Science-based options include biotechnology, forensic science (analysing evidence from crime scenes), microbiology, genetic counselling, nutrition and dietetics, public health, biomedical engineering and bioinformatics.

1.4 Quranic Instructions about the Study of Life

The chapter quotes verses that invite people to reflect on life. Surah Al-Anbiya (21:30) states that every living thing was made from water; biologists note that most organisms are 60 to 90 percent water. Surah Ar-Rahman (55:14) mentions the creation of man from clay like that of pottery.

Surah Al-Mu'minun (23:14) describes the stages of human development in the womb, from a drop to a clot, to a lump, to bones and then flesh covering the bones. Surah An-Nur (24:45) says that Allah created every animal from water and that some creep on their bellies, some walk on two legs and some on four. The book presents these verses as encouragement to study and think about

living things.

1.5 Science as a Collaborative Field

Big scientific problems are now solved by teams in which each member brings expertise from a different discipline. Working together lets the team check each other's ideas and reach answers faster.

Examples given in the chapter: the Human Genome Project, completed in 2003, which mapped the full human DNA sequence using molecular biologists, geneticists and computer scientists; climate change research, which joins atmospheric science, ecology, economics and sociology; cancer research, which needs oncologists, biochemists, geneticists, pharmacologists and statisticians; robotics and artificial intelligence; and space exploration programmes, which combine engineers, physicists, biologists and doctors.

1.6 The Scientific (Biological) Method

The scientific method is the set of steps scientists follow when they investigate a question; when it is used in biology it is often called the biological method. The steps are: recognising a problem, making observations, forming a hypothesis, making a deduction, testing by experiment, and then analysing and reporting the results.

Observations are made with the senses and by reading earlier research. Qualitative observations describe qualities such as colour or texture and cannot be counted; quantitative observations are measurements or counts, such as the number of birds in a tree, and are more reliable because they can be recorded exactly.

A hypothesis is a possible, testable answer to the problem that fits the observations; it must be possible to prove it wrong. A deduction is the logical consequence of a hypothesis, usually written as an if-then statement. Experiments test the deductions: they need an experimental group, which receives the condition being tested, and a control group, which is kept the same in every way except for that condition. Results are analysed, often with statistics and graphs, and shared through reports, journals and conferences.

1.7 Hypothesis, Theory and Law

When a hypothesis survives repeated experiments and is used to make further successful predictions, it becomes a theory: a well-supported explanation backed by a large amount of evidence from many researchers. The theory of evolution by natural selection is an example.

Scientists keep testing theories and try to disprove them. A theory that is confirmed again and again until it is accepted as a constant pattern of nature is called a law or principle. Mendel's laws of inheritance and the Hardy-Weinberg law are examples of laws in biology.

1.8 Malaria: The Biological Method in Action

Problem 1 was the cause of malaria. Doctors knew that malaria was linked with marshy areas, that quinine treated it, and that drinking marsh water did not cause it. In 1880 the French army doctor Alphonse Laveran saw tiny organisms, later named Plasmodium, in the blood of malaria patients.

Free notes: freebooks.pk

The hypothesis was that Plasmodium causes malaria; the deduction was that if this is true, malaria patients should carry Plasmodium in their blood. Blood tests comparing patients (experimental group) with healthy people (control group) supported the hypothesis.

Problem 2 was how Plasmodium enters human blood. In 1883 the American doctor A. F. A. King listed observations such as: people who slept outdoors caught malaria more often, people under fine nets caught it less, and people sleeping near smoky fires rarely caught it. He proposed that mosquitoes carry Plasmodium. The deduction was that if this is true, Plasmodium should be found inside mosquitoes.

Ronald Ross, a British army doctor in India, tested this in 1897-1898. He found Plasmodium developing in the stomach of a mosquito that had fed on a malaria patient, and then used birds to avoid risking human lives: Culex mosquitoes that fed on infected sparrows carried the parasite to their salivary glands and passed malaria to healthy sparrows. In 1898 Italian scientists confirmed the same in humans using Anopheles mosquitoes. Together these results established that mosquitoes transmit malaria.

Important Definitions

Biology
The scientific study of living things: their structure, functions, development and interactions.

Zoology
The major field of biology that studies animals.

Botany
The major field of biology that studies plants.

Microbiology
The major field of biology that studies microorganisms such as bacteria and microscopic fungi.

Morphology
The study of the form, shape and outward features of organisms and their organs.

Anatomy
The study of the internal structure of organisms, especially the human body.

Physiology
The study of how the parts of a living body work.

Histology
The microscopic study of tissues.

Cytology
The study of cells, their organelles and cell division.

Embryology
The study of how an organism develops from a fertilised egg.

Genetics
The study of how characteristics are passed from parents to offspring.

Palaeontology
The study of fossils, the preserved remains or traces of ancient organisms.

Taxonomy
The branch that names and classifies organisms into groups based on similarities and differences.

Ecology
The study of the relationships between organisms and their environment.

Pathology
The study of diseases, their causes and their effects.

Immunology
The study of the immune system and its role in defending the body.

Pharmacology
The study of drugs and their effects on the body.

Hypothesis
A tentative, testable answer to a scientific problem that agrees with the available observations.

Deduction
A logical prediction drawn from a hypothesis, usually in the form of an if-then statement.

Theory
A hypothesis that has been supported by many experiments and a large body of evidence.

Law (principle)
A theory that has been confirmed so many times that it is accepted as a constant pattern of nature.

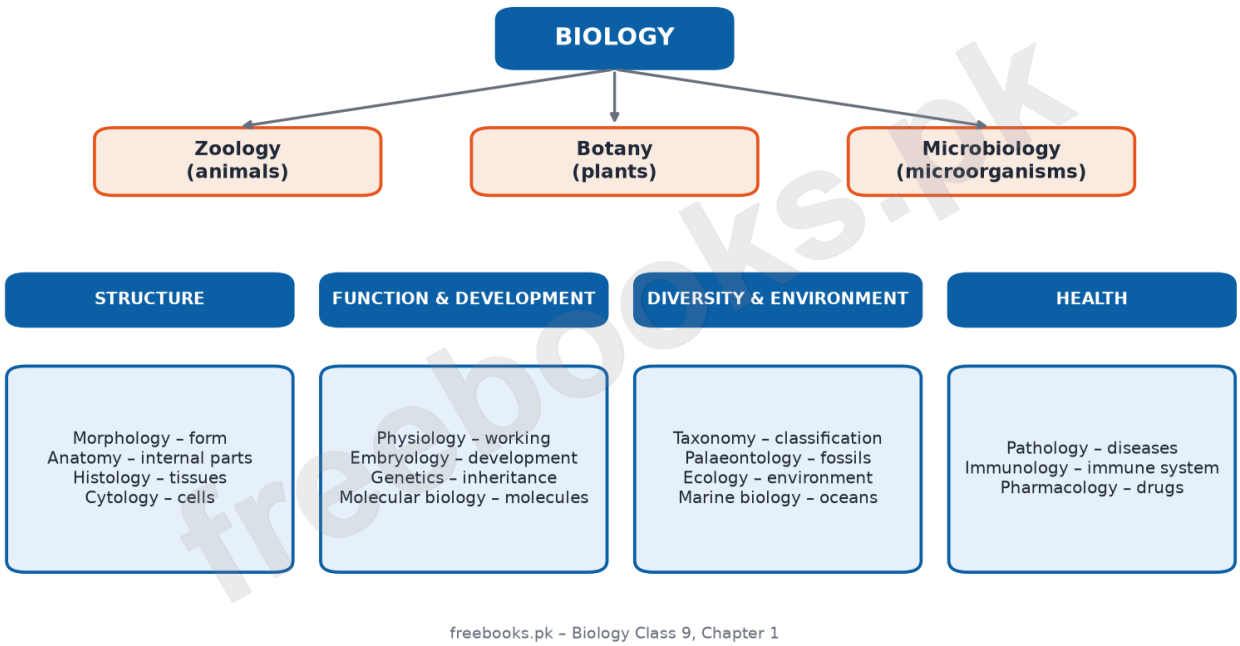
Control group
The group in an experiment that is kept under normal conditions for comparison with the experimental group.

Key Facts at a Glance

Topic	Key point
Origin of the word biology	bios = life, logos = study (Greek)
Three major fields	Zoology, Botany, Microbiology
Cells in the human body	More than 30 trillion
Oldest known fossil	A cyanobacterium, about 3.5 billion years old
Water in organisms	About 60% to 90% of body mass
Human Genome Project	Completed in 2003
Steps of scientific method	Problem → Observation → Hypothesis → Deduction → Experiment → Results
Hypothesis → Theory → Law	Each stage needs more repeated experimental support
Plasmodium seen in blood	Laveran, 1880
Mosquito hypothesis	A. F. A. King, 1883 (20 observations)
Mosquito transmission shown	Ronald Ross, 1897-1898 (Culex and sparrows)
Human malaria vector	Female Anopheles mosquito
Dengue vector	Aedes mosquito
Insulin from bacteria	Example of biotechnology

Diagrams

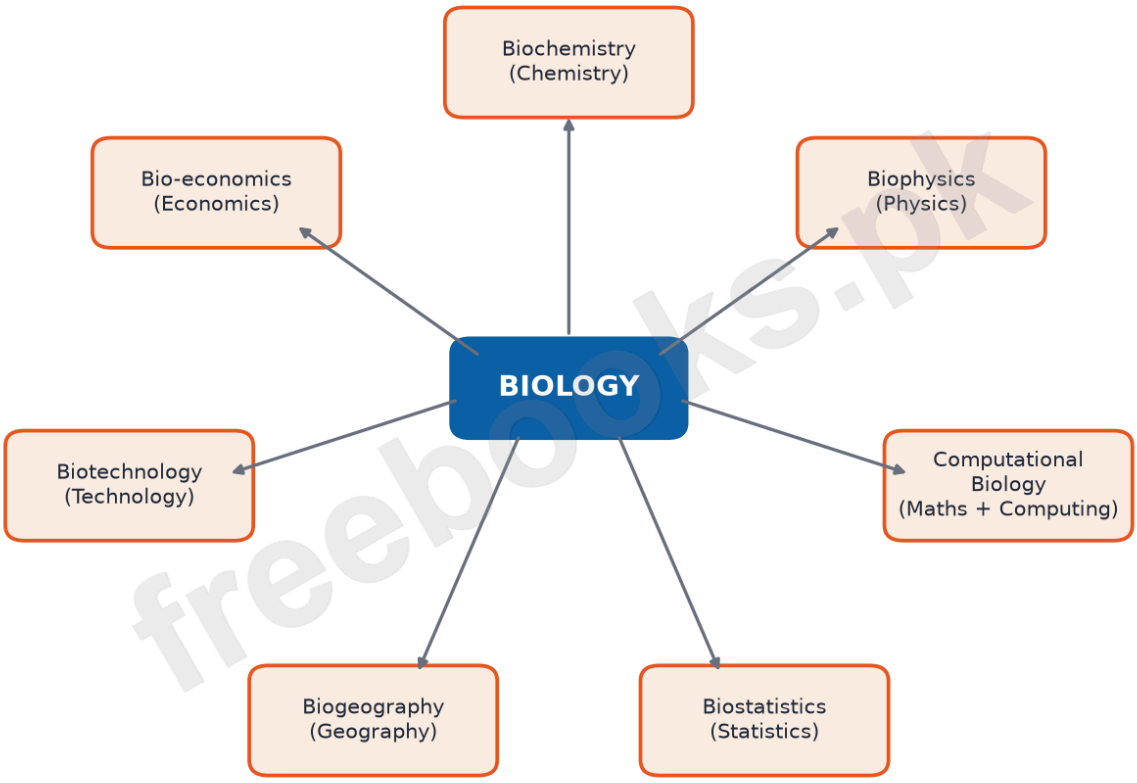
Fields and branches of biology: A map placing the three major fields at the top and grouping the main branches by what they study: structure, function and development, diversity and environment, and health.



Biology and other sciences: A hub diagram showing the interdisciplinary fields formed when biology meets chemistry, physics, mathematics and computing, statistics, geography, technology and economics.

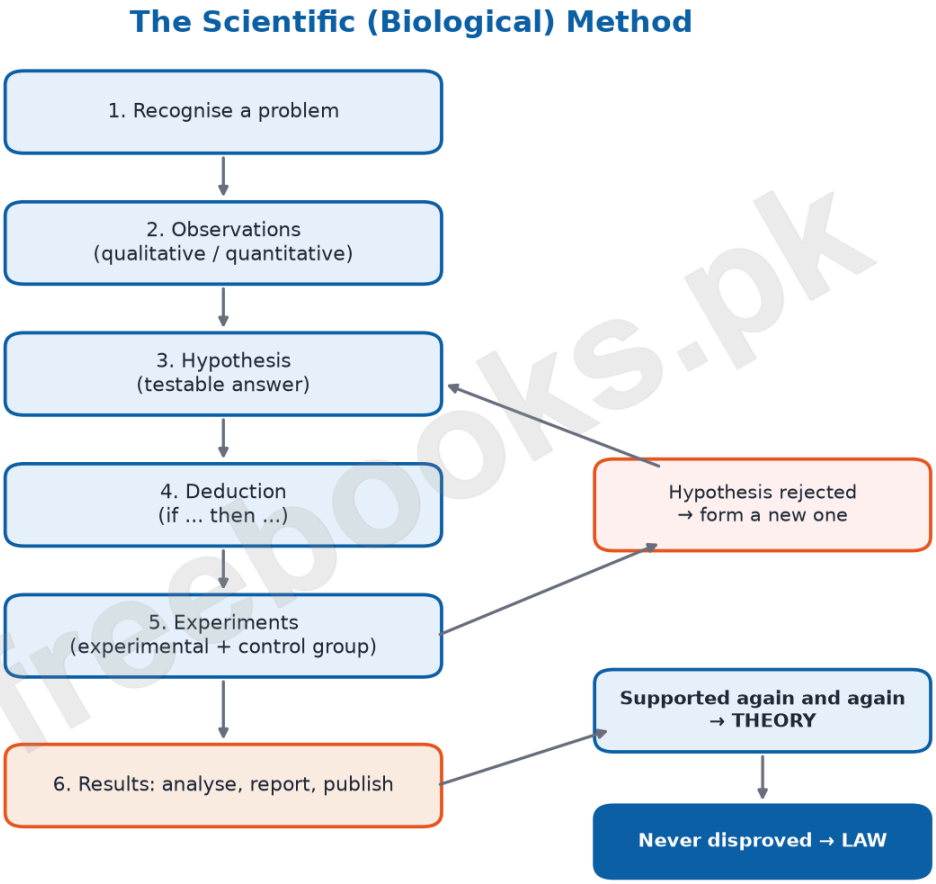
freebooks.pk

Biology and Other Sciences

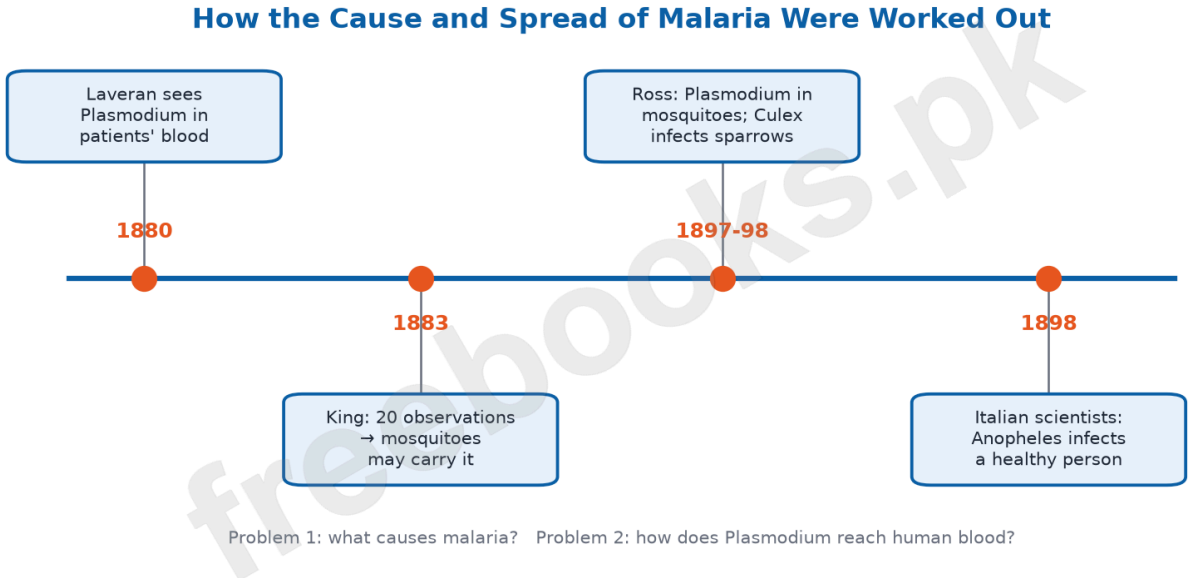


Flowchart of the scientific method: The steps from recognising a problem to reporting results, including what happens when a hypothesis is rejected and how a supported hypothesis can grow into a theory and then a law.

freebooks.pk



Timeline of the malaria investigation: Key observations and experiments from Laveran's discovery of Plasmodium to the confirmation of mosquito transmission in humans.



Short Questions and Answers

Why is biology called the science of life?

Because it studies everything about living things: how they are built, how their bodies work, how

freebooks.pk

they grow and reproduce, and how they interact with each other and their environment.

Name the three major fields of biology with one example of what each studies.
Zoology studies animals (for example the behaviour of birds), botany studies plants (for example how a seed germinates) and microbiology studies microorganisms (for example bacteria that cause disease).

How does anatomy differ from morphology?
Morphology looks at the overall form and outward appearance of an organism, while anatomy examines its internal structure, such as the arrangement of organs inside the body.

How are histology and cytology related but different?
Both are studied with a microscope. Cytology focuses on individual cells and their organelles, while histology studies tissues, which are groups of similar cells working together.

Which branch would study a newly found dinosaur bone, and why?
Palaeontology, because it studies fossils, the preserved remains of organisms that lived long ago, to understand the history of life.

Give one example each of biochemistry and biophysics.
Biochemistry: studying the chemical reactions of photosynthesis or respiration. Biophysics: using the principle of levers to explain how bones and muscles produce movement.

What does a computational biologist do?
A computational biologist uses mathematical models, computer programs and simulations to analyse biological data, such as the sequence of amino acids in a protein.

Why is insulin production by bacteria called biotechnology?
Because it uses living organisms (bacteria) to manufacture a useful product (human insulin) for medical treatment, which is exactly what biotechnology means.

How is a veterinary doctor's work different from animal husbandry?
A veterinary doctor diagnoses and treats diseases of animals, while animal husbandry is about breeding, feeding and caring for livestock to improve their quality and productivity.

Why is science described as a collaborative field?
Because complex problems such as mapping the human genome or understanding climate change need experts from several disciplines who share data, check each other's ideas and combine their skills.

What is the difference between qualitative and quantitative observations?
Qualitative observations describe qualities such as colour, smell or texture. Quantitative observations are numerical, such as length, mass or a count, and are more reliable because they can be measured and recorded exactly.

List the characteristics of a good hypothesis.
It proposes an answer to the problem, agrees with the observations already made, can be tested by experiment, and can in principle be shown to be wrong.

Why is a control group needed in an experiment?
The control group shows what happens under normal conditions. Comparing it with the experimental group proves that any difference is caused by the factor being tested and not by something else.

Why did people who slept near smoky fires rarely get malaria?
Smoke drives mosquitoes away, so these people were bitten less often and the parasite had fewer chances to enter their blood.

Why did Ronald Ross use sparrows instead of humans?
Infecting healthy people with malaria on purpose would have been dangerous and unethical, so he used birds, which suffer from a similar malaria carried by Culex mosquitoes.

Long Questions and Answers

Describe the major fields and the main branches of biology.

What are the major fields of biology?

Biology has three major fields. Zoology covers animals, botany covers plants and microbiology covers microorganisms such as bacteria and microscopic fungi. Each field studies the structure, functions, reproduction and environment of its own group of organisms.

Which branches deal with the structure of organisms?

Morphology studies form and outward appearance, anatomy studies internal structure, histology studies tissues under the microscope and cytology studies cells and their organelles. Together they describe how a living body is built, from whole organs down to single cells.

Which branches deal with function, development and inheritance?

Physiology explains how organs work, embryology follows development from the fertilised egg, genetics explains how traits pass from parents to offspring and molecular biology studies biological molecules such as proteins and nucleic acids.

Which branches deal with diversity, environment and health?

Taxonomy classifies organisms, palaeontology studies fossils, ecology studies organisms and their environment and marine biology studies ocean life. Pathology, immunology and pharmacology deal with disease, the body's defences and medicines.

Explain the relationship of biology with other sciences, with examples.

Why does biology overlap with other sciences?

Living things are made of the same matter and follow the same physical and chemical rules as the

rest of nature. Their data can be measured, counted and modelled, so biology naturally borrows ideas and tools from chemistry, physics, mathematics, geography and economics.

How do biochemistry and biophysics link biology with chemistry and physics?

Biochemistry studies the chemicals and reactions inside living things, such as photosynthesis and respiration. Biophysics applies physical principles to life, for example treating bones and joints as levers to explain movement.

How do computational biology and biostatistics link biology with mathematics?

Computational biology uses models, algorithms and simulations to analyse large data sets such as protein or DNA sequences. Biostatistics applies statistical methods to biological and health data so that results can be judged reliably.

What are biogeography, biotechnology and bio-economics?

Biogeography studies the distribution of living things across regions and the effect of climate on it. Biotechnology uses organisms to make useful products such as insulin. Bio-economics weighs the costs and profits of biological projects such as new crop varieties.

Describe the steps of the scientific method.

How does a scientific investigation begin?

It begins when a scientist recognises a clear problem worth investigating, for example noticing that plants in one area grow taller than usual and asking what causes this. The problem then guides all later steps.

What role do observations play?

Observations collect information about the problem, using the senses and by reading earlier research. They can be qualitative, describing qualities, or quantitative, recording measurements; quantitative data are more reliable because they can be checked exactly.

How are a hypothesis and a deduction formed?

From the observations, the scientist proposes one or more hypotheses, which are possible answers that can be tested. A deduction is then drawn from each hypothesis as an if-then prediction, for example: if iron shortage causes yellow leaves, adding iron to the soil should make the leaves green again.

How are experiments and results handled?

Experiments test the deductions using an experimental group and a control group that differ only in the factor being tested. Hypotheses that fail are rejected and the supported one is tested further. Results are analysed with tables, graphs and statistics, then reported in journals and at conferences so other scientists can check them.

Distinguish between hypothesis, theory and law.

What is a hypothesis?

A hypothesis is a tentative explanation proposed to answer a specific problem. It is based on

observations, can be tested by experiments and may turn out to be wrong.

How does a hypothesis become a theory?

When repeated experiments support a hypothesis and it successfully predicts new results, it becomes a theory. A theory is backed by a large amount of evidence gathered by many researchers, such as the theory of evolution by natural selection.

How does a theory become a law?

Scientists keep testing theories and try to disprove them. If a theory holds true again and again without exception, it is accepted as a law or principle, a constant pattern of nature, such as Mendel's laws of inheritance or the Hardy-Weinberg law.

Explain how biologists discovered the cause of malaria and how it spreads.

What was known about malaria before the experiments?

By the late nineteenth century doctors knew that malaria was linked with marshy areas, that quinine was an effective treatment and that drinking marsh water did not cause the disease. In 1880 Laveran saw a microorganism, later named Plasmodium, in the blood of patients.

How was Plasmodium shown to cause malaria?

Biologists proposed that Plasmodium causes malaria and deduced that patients should carry it in their blood. Blood from malaria patients and from healthy people was compared under the microscope; Plasmodium was found in the patients, supporting the hypothesis.

How did King link malaria with mosquitoes?

In 1883 A. F. A. King noted that people sleeping outdoors fell ill more often, while people under fine nets or near smoky fires were protected. All of these point to an insect that bites at night, so he proposed that mosquitoes carry Plasmodium.

How did Ross and later workers prove mosquito transmission?

Ross found Plasmodium developing inside mosquitoes that had fed on patients. Using sparrows, he showed that Culex mosquitoes picked up the parasite from sick birds, carried it to their salivary glands and infected healthy birds. In 1898 Italian scientists showed the same in humans with Anopheles mosquitoes.

Multiple Choice Questions (MCQs)

A student examines a thin slice of a leaf under a microscope to see how its tissues are arranged. This work belongs to: (A) Histology (B) Ecology (C) Taxonomy (D) Embryology
Correct answer: (A) Histology. Histology is the microscopic study of tissues.

Which branch would explain how the kidneys filter blood? (A) Morphology (B) Physiology (C) Palaeontology (D) Taxonomy
Correct answer: (B) Physiology. Physiology deals with how body parts and organs work.

Studying why some children inherit their parents' eye colour is part of: (A) Immunology

(B) Genetics (C) Pharmacology (D) Cytology
Correct answer: (B) Genetics. Genetics studies the transfer of characteristics from parents to offspring.

Using the principle of levers to explain the movement of the forearm is an example of: (A) Biochemistry (B) Biophysics (C) Biogeography (D) Bio-economics
Correct answer: (B) Biophysics. Biophysics applies physical principles to living systems.

A scientist predicts how rising temperatures will change where a bird species lives. This falls under: (A) Biogeography (B) Histology (C) Embryology (D) Pathology
Correct answer: (A) Biogeography. Biogeography studies the distribution of organisms and how climate affects it.

Which degree is needed to become a dentist in Pakistan? (A) MBBS (B) BDS (C) Pharm-D (D) BS Forestry
Correct answer: (B) BDS. Dentists complete the 4-year Bachelor of Dental Surgery (BDS).

A testable, possible answer to a scientific problem is called a: (A) Law (B) Theory (C) Hypothesis (D) Result
Correct answer: (C) Hypothesis. A hypothesis is a tentative answer that can be tested.

'If iron shortage causes yellow leaves, then adding iron will make them green.' This statement is a: (A) Observation (B) Deduction (C) Law (D) Control
Correct answer: (B) Deduction. Deductions are if-then predictions drawn from a hypothesis.

Counting the number of seeds in a pod is a: (A) Qualitative observation (B) Quantitative observation (C) Hypothesis (D) Theory
Correct answer: (B) Quantitative observation. It produces a number, so it is a quantitative observation.

In an experiment on the need for light in photosynthesis, the plant kept in normal light is the: (A) Experimental group (B) Control group (C) Hypothesis (D) Variable group
Correct answer: (B) Control group. The control group stays under normal conditions for comparison.

Mendel's laws of inheritance are examples of: (A) Hypotheses (B) Deductions (C) Scientific laws (D) Observations
Correct answer: (C) Scientific laws. They have been confirmed repeatedly and are accepted as laws.

Who first saw Plasmodium in the blood of malaria patients? (A) Ronald Ross (B) A. F. A. King (C) Alphonse Laveran (D) Gregor Mendel
Correct answer: (C) Alphonse Laveran. Laveran observed the parasite in patients' blood in 1880.

Ronald Ross showed malaria transmission in sparrows using which mosquito? (A) Aedes

(B) Culex (C) Anopheles (D) Housefly
Correct answer: (B) Culex. Bird malaria is carried by Culex mosquitoes; human malaria by Anopheles.

Which mosquito spreads dengue fever? (A) Aedes (B) Culex (C) Anopheles (D) None of these
Correct answer: (A) Aedes. Dengue is transmitted by the Aedes mosquito.

The Human Genome Project is a good example of: (A) Science as a collaborative field (B) A single scientist's work (C) Palaeontology (D) Bio-economics
Correct answer: (A) Science as a collaborative field. It joined molecular biologists, geneticists and computer scientists.

Quick Revision Summary

- Biology = study of life (bios + logos). Major fields: zoology, botany, microbiology.
- Structure branches: morphology, anatomy, histology, cytology. Function/development: physiology, embryology, genetics, molecular biology.
- Diversity/environment: taxonomy, palaeontology, ecology, marine biology. Health: pathology, immunology, pharmacology.
- Interdisciplinary fields: biochemistry, biophysics, computational biology, biostatistics, biogeography, biotechnology, bio-economics.
- Careers: MBBS (5 yr), BDS (4 yr), Pharm-D/BS Pharmacy, physiotherapy, agriculture, horticulture, forestry, animal husbandry, biotechnology, forensics and more.
- Scientific method: problem → observations → hypothesis → deduction → experiments (experimental + control group) → results and reporting.
- Hypothesis (testable guess) → theory (well-supported) → law (confirmed again and again).
- Malaria: Laveran found Plasmodium (1880); King linked mosquitoes (1883); Ross proved transmission with Culex and sparrows (1897-98); confirmed in humans with Anopheles (1898).

Exam Tips

- Learn the branches in four groups (structure, function, diversity, health); it is much easier than memorising a list of fifteen names.
- When a question gives an example and asks for the branch, look for the key word: tissue = histology, fossil = palaeontology, drug = pharmacology, classification = taxonomy.
- Always write a deduction as an if-then sentence; examiners look for that pattern.
- In the malaria example, keep the two problems separate: Problem 1 is the cause (Plasmodium), Problem 2 is the carrier (mosquito).
- Remember the mosquito pairs: Anopheles → human malaria, Culex → bird malaria, Aedes → dengue.
- For hypothesis vs theory vs law, write one line on each and give one example of a theory and one of a law.

Note on Facts

Some printed sources give 1878 for Laveran's discovery and the 1880s for Ross's mosquito work. The commonly cited dates are 1880 for Laveran and 1897-1898 for Ross, and these notes use those dates. If your teacher or board key uses the textbook's dates, follow them in the exam.

Chapter 2: Biodiversity

Chapter 2 deals with the huge variety of life on Earth and the way biologists sort it into groups. It starts with what biodiversity means and why it matters, then explains classification: its aims, its advantages and the ladder of taxonomic ranks from domain down to species.

The middle of the chapter traces how classification grew from Aristotle's two groups to the modern three-domain system, and describes the main features of Archaea, Bacteria and the four eukaryotic kingdoms. It closes with two special topics: why viruses are left out of the classification system, and how binomial nomenclature gives every species one scientific name used across the world.

Learning Objectives

- Define biodiversity and classification and explain why classification is useful.
- List the taxonomic ranks in order and define species.
- Trace the history of classification from Aristotle to Carl Woese.
- Compare the two-kingdom, three-kingdom, five-kingdom and three-domain systems.
- Describe the main features of the three domains and the four eukaryotic kingdoms.
- Explain why viruses, viroids and prions are not placed in any kingdom.
- State the rules of binomial nomenclature and write scientific names correctly.

Key Concepts

2.1 Biodiversity and Its Importance

Biodiversity is the variety of living things in an area. It is judged by how many different kinds of organisms live there and how much variation exists within each kind. About two million kinds have been described so far, but the real number is thought to be far higher. Biodiversity is uneven: warm, wet tropical regions hold many more species than cold polar regions, because climate, altitude and soil all affect what can live in a place.

Biodiversity keeps ecosystems stable and drives cycles such as the carbon and nitrogen cycles; plants and algae absorb carbon dioxide and help regulate climate; it supplies food, medicines, timber and fuel; and it supports agriculture, tourism and the pharmaceutical industry. The United Nations marks 22 May as International Day for Biological Diversity.

2.2 Classification: Aims and Advantages

Classification is the arrangement of organisms into groups and subgroups according to their similarities and differences. Its two main aims are to make the study of so many organisms manageable and to reveal evolutionary relationships between them. Traditionally organisms were grouped by visible features; today genetic (DNA) similarities are also used.

Advantages: similar organisms can be studied together; species can be compared within a clear framework; relationships between groups become visible; newly discovered species can be placed

Free notes: freebooks.pk

quickly; and biologists everywhere share one common system, which also helps in conservation planning.

2.3 Taxonomic Ranks

The levels used in classification are called taxonomic ranks or taxa (singular taxon). Carl Linnaeus set up a system of seven ranks in 1735: kingdom, phylum (called division for plants and fungi), class, order, family, genus and species. Domain was later placed above kingdom, so the full ladder is domain, kingdom, phylum, class, order, family, genus, species.

Moving down the ladder, each group contains fewer kinds of organisms that are more similar to each other. Species is the basic unit: a group of similar organisms that can interbreed in nature and produce fertile offspring. For example, humans are Eukarya, Animalia, Chordata, Mammalia, Primates, Hominidae, Homo, Homo sapiens; the pea plant is Eukarya, Plantae, Magnoliophyta, Magnoliopsida, Fabales, Fabaceae, Pisum, Pisum sativum.

2.4 History of Classification

Aristotle (384-322 BC) divided living things into plants and animals. The Arab scholar Al-Jahiz described about 350 kinds of animals and wrote in detail on ants. Andrea Caesalpino grouped plants into fifteen genera, Tournefort introduced further groupings for plants, and Carl Linnaeus (1707-1778) built the seven-rank hierarchy still used today.

Two-kingdom system: organisms that make their own food went into Plantae and those that eat food into Animalia, which placed bacteria and fungi among plants. It failed for organisms like Euglena, which has chlorophyll yet can feed like an animal in darkness and has no cell wall, and it ignored the prokaryote-eukaryote difference.

Three-kingdom system (Ernst Haeckel, 1866): added kingdom Protista for Euglena-like organisms and bacteria, but fungi stayed in Plantae even though fungi absorb food and have chitin, not cellulose, in their walls. Five-kingdom system (Robert Whittaker, 1969): used cell organisation and mode of nutrition to create Monera, Protista, Fungi, Plantae and Animalia; Margulis and Schwartz (1988) kept the same five kingdoms but added genetic evidence. Three-domain system (Carl Woese): split prokaryotes into Archaea and Bacteria and put all eukaryotes in Eukarya.

2.5 The Three Domains

Archaea are prokaryotes whose cell walls lack peptidoglycan and whose membranes contain unusual lipids that let many of them live in extreme places such as hot springs, salt lakes and very acidic or alkaline water, though they also live in soil and oceans. Their ribosomal RNA is closer to that of eukaryotes than to bacteria. Examples include methanogens (release methane), halophiles (salt-loving), thermophiles (heat-loving) and acidophiles (acid-loving). They form kingdom Archaebacteria.

Bacteria are prokaryotes with peptidoglycan cell walls, found in soil, water, air and inside other organisms. Most are heterotrophs, but cyanobacteria photosynthesise. Some cause disease while many are useful, for example as decomposers that recycle nutrients. They form kingdom Eubacteria. Eukarya includes every organism whose cells have a true nucleus and membrane-bound organelles, divided into kingdoms Protista, Fungi, Plantae and Animalia.

2.6 Kingdoms of Domain Eukarya

Protista are unicellular, colonial or simple multicellular eukaryotes without multicellular sex organs. Algae are plant-like protists with cellulose walls and chlorophyll (Euglena, diatoms); protozoans are animal-like protists that ingest food and have no wall (Amoeba, Paramecium); fungus-like protists such as slime moulds and water moulds absorb food but have cellulose walls. Some protists cause disease, for example Plasmodium (malaria) and Entamoeba (amoebic dysentery).

Fungi are heterotrophs that absorb food from dead or decaying matter and have cell walls of chitin. Most are multicellular (mushrooms, rusts, smuts, moulds) while yeast is unicellular. Fungi are used in making bread and cheese, and the antibiotic penicillin comes from Penicillium. Plantae are multicellular autotrophs with cellulose walls and multicellular sex organs that form embryos (mosses, ferns, conifers, flowering plants). Animalia are multicellular heterotrophs without cell walls that ingest and internally digest food and develop from embryos (invertebrates and vertebrates).

2.7 Status of Viruses

Viruses sit on the border between living and non-living. They have no cells and no organelles: a virus is just DNA or RNA inside a protein coat. They cannot carry out metabolism or reproduce on their own; they must enter a host cell of a plant, animal or bacterium and use its machinery. Since they share none of the defining features of the three domains, they are not placed in the classification system. Examples are bacteriophages, the influenza virus and the coronavirus that caused COVID-19.

Viroids (small circles of RNA with no protein coat) and prions (infectious proteins with no nucleic acid) are even simpler disease-causing particles and are also left out of classification. COVID-19, first identified in late 2019, spreads through droplets and contaminated surfaces; masks, hand washing and vaccination reduce its spread.

2.8 Binomial Nomenclature

Binomial nomenclature, introduced by Carl Linnaeus, gives each species a two-part scientific name: the genus name first, then the species name, for example Homo sapiens (human), Allium cepa (onion), Solanum tuberosum (potato) and Panthera tigris (tiger).

Scientific names are needed because common names differ from region to region (onion is piyaz, ganda or bassal in different parts of Pakistan), one common name can be used for several organisms (bluebell, blackbird), and common names can be misleading (starfish and jellyfish are not fish). Rules: names are in Latin or Latinised form; the genus comes first and starts with a capital letter, the species comes second in small letters; each name is unique; printed names are written in italics; handwritten names have each word underlined separately.

Important Definitions

Biodiversity
The variety of living organisms in an area, including the number of kinds and the variation within each kind.

Classification
Arranging organisms into groups and subgroups on the basis of their similarities and differences.

Taxon (plural taxa)
Any group or rank used in classification, such as a genus or a family.

Species
A group of similar organisms that can interbreed and produce fertile offspring; the basic unit of classification.

Genus
A group of closely related species.

Domain
The highest taxonomic rank; all life is placed in three domains: Archaea, Bacteria and Eukarya.

Prokaryote
An organism whose cells lack a true nucleus and membrane-bound organelles, such as bacteria and archaea.

Eukaryote
An organism whose cells have a nucleus enclosed in a membrane and membrane-bound organelles.

Autotroph
An organism that makes its own food, usually by photosynthesis.

Heterotroph
An organism that obtains food from other organisms or organic matter.

Peptidoglycan
The material of the bacterial cell wall, made of sugars and amino acids.

Chitin
A tough polysaccharide that forms the cell walls of fungi.

Algae
Plant-like protists that contain chlorophyll and make their own food.

Protozoa
Animal-like protists that ingest food and have no cell wall.

Virus
An acellular particle made of DNA or RNA in a protein coat that can only multiply inside a host cell.

Viroid
An infectious particle made only of a small circle of RNA.

Prion
An infectious particle made only of protein.

Binomial nomenclature
The two-part system of scientific naming: genus name followed by species name.

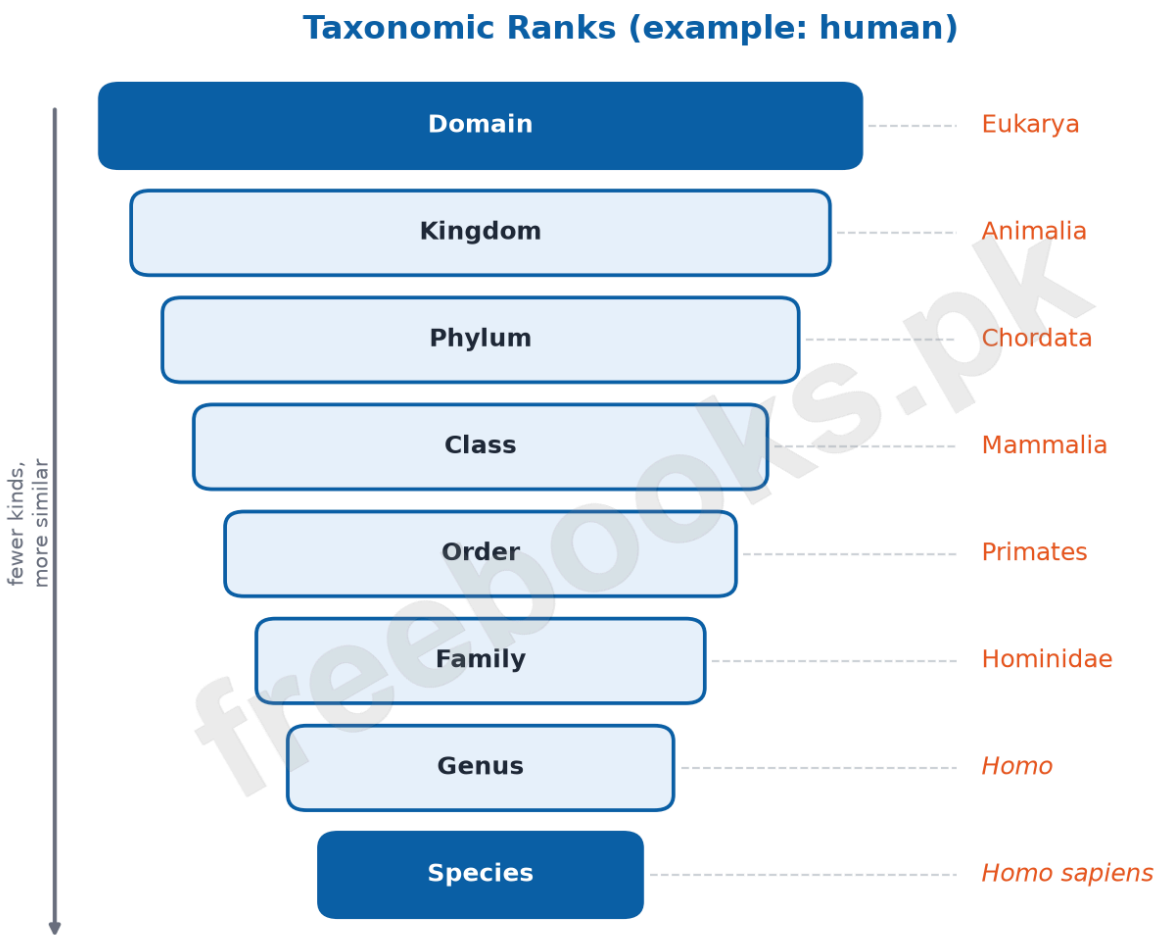
Key Facts at a Glance

Topic	Key point
Kinds of organisms described	About 2 million
International Biodiversity Day	22 May
Linnaeus' system	1735, seven ranks
Order of ranks	Domain → Kingdom → Phylum → Class → Order → Family → Genus → Species
Two-kingdom system	Aristotle's idea: Plantae and Animalia
Three-kingdom system	Ernst Haeckel, 1866 (added Protista)
Five-kingdom system	Robert Whittaker, 1969; revised by Margulis and Schwartz, 1988
Three-domain system	Carl Woese: Archaea, Bacteria, Eukarya
Cell wall: bacteria	Peptidoglycan
Cell wall: fungi	Chitin
Cell wall: plants and algae	Cellulose
Animal cells	No cell wall
Penicillin source	The fungus Penicillium
Human scientific name	Homo sapiens

Diagrams

Taxonomic ranks: The eight ranks from domain to species shown as a narrowing ladder, with the

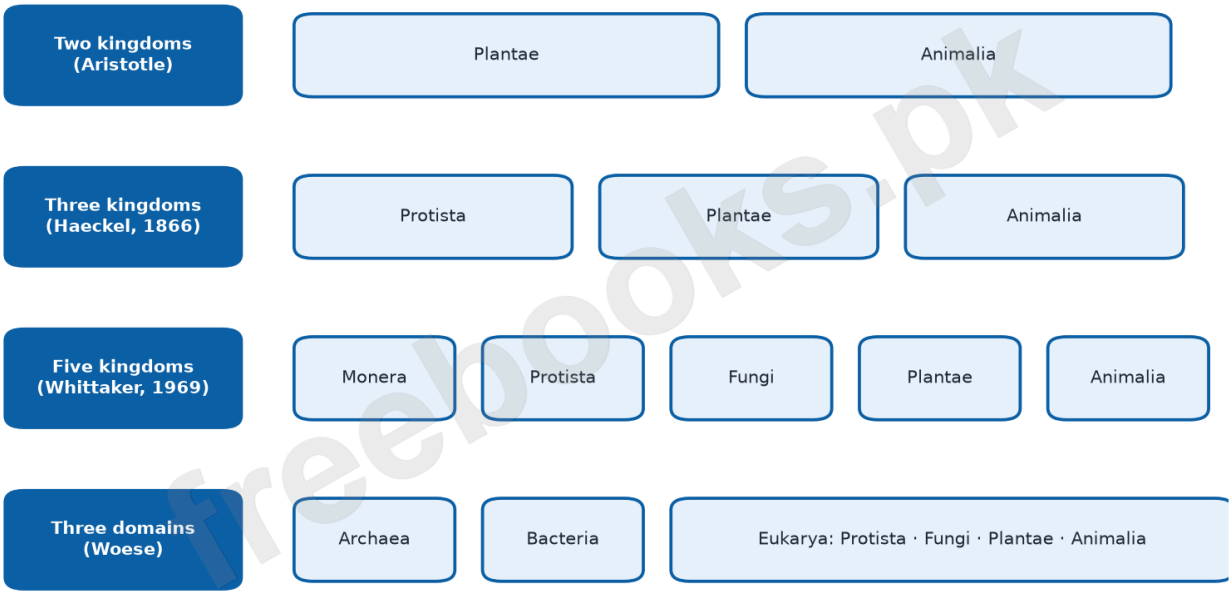
human classified at each level.



How classification systems developed: The two-kingdom, three-kingdom, five-kingdom and three-domain systems side by side, showing which groups were split off at each stage.

freebooks.pk

Development of Classification Systems



Comparison of the six kingdoms: Cell type, cell wall material and mode of nutrition for Archaebacteria, Eubacteria, Protista, Fungi, Plantae and Animalia.

Six Kingdoms at a Glance

	Archaebacteria	Eubacteria	Protista	Fungi	Plantae	Animalia
Cell type	Prokaryotic	Prokaryotic	Eukaryotic	Eukaryotic	Eukaryotic	Eukaryotic
Cell wall	No peptidoglycan	Peptidoglycan	In some	Chitin	Cellulose	None
Nutrition	Auto/hetero	Auto/hetero	Auto/hetero	Absorb food	Photosynthesis	Ingest food
Body	Unicellular	Unicellular	Mostly unicellular	Mostly multicellular	Multicellular	Multicellular

freebooks.pk

Short Questions and Answers

Why are tropical forests richer in biodiversity than polar regions?
Warm temperatures, high rainfall and long growing seasons in the tropics support more plant growth and more habitats, so many more species can live there than in cold, dry polar regions.

Give three ways in which biodiversity benefits humans.

It provides food, medicines and raw materials such as timber; plants and algae absorb carbon dioxide and help control climate; and it supports industries such as agriculture, tourism and pharmaceuticals.

What are the two main aims of classification?
To arrange organisms into groups so that their similarities and differences can be studied easily, and to show the evolutionary relationships among them.

Why is species called the basic unit of classification?
Because it is the smallest natural group: its members are alike and can interbreed to produce fertile offspring, while different species normally cannot.

Why did the two-kingdom system fail for Euglena?
Euglena has chlorophyll like a plant but no cell wall and it can feed on organic food in the dark like an animal, so it could not be placed cleanly in either kingdom.

Why were fungi finally separated from plants?
Fungi do not photosynthesise; they absorb food from organic matter, and their cell walls contain chitin rather than cellulose.

On what two bases did Whittaker build his five-kingdom system?
The level of cellular organisation (prokaryotic, unicellular eukaryotic or multicellular eukaryotic) and the mode of nutrition (photosynthesis, absorption or ingestion).

How do archaea differ from bacteria?
Archaea lack peptidoglycan in their walls, have unusual membrane lipids that suit extreme habitats, and have ribosomal RNA closer to that of eukaryotes.

Name the three types of protists with one example each.
Plant-like protists or algae (Euglena), animal-like protists or protozoa (Paramecium), and fungus-like protists (slime moulds).

Why are viruses not included in any kingdom?
They are not made of cells, have no organelles and no metabolism of their own, and can multiply only inside host cells, so they lack the features used to define the domains and kingdoms.

How are viroids different from prions?
A viroid is a small circle of RNA with no protein coat, while a prion is made only of protein and has no nucleic acid.

Why is the common name 'starfish' misleading?
A fish is a vertebrate with a backbone, fins and gills, but a starfish has none of these; it is an invertebrate, so its common name gives a wrong idea.

Write the scientific name of the potato correctly and name its genus and species.

Solanum tuberosum (italic when printed). Solanum is the genus and tuberosum is the species name.

How should a scientific name be written by hand?
The genus name starts with a capital letter, the species name with a small letter, and each of the two words is underlined separately.

Long Questions and Answers

What is classification? Explain its aims, advantages and the taxonomic ranks.

What is classification and what does it aim to do?

Classification is the grouping of organisms into categories based on similarities and differences. It aims to make the enormous number of organisms easier to study and to show how different groups are related through evolution. Modern classification uses both body features and genetic data.

What are the advantages of classification?

It lets similar organisms be studied together, gives a framework for comparing species, shows relationships among groups, helps place newly discovered species and gives biologists all over the world a common system and language, which also helps in conserving biodiversity.

What are the taxonomic ranks?

The ranks, from largest to smallest, are domain, kingdom, phylum (division), class, order, family, genus and species. Linnaeus introduced seven of them in 1735 and domain was added later above kingdom. Each lower rank holds fewer and more closely related organisms.

How is a human classified through these ranks?

Domain Eukarya, kingdom Animalia, phylum Chordata, class Mammalia, order Primates, family Hominidae, genus Homo and species Homo sapiens. This shows how the groups narrow from all eukaryotes down to one species.

Describe the history of classification systems from two kingdoms to three domains.

What was the two-kingdom system and why was it replaced?

It placed food-making organisms in Plantae and food-eating organisms in Animalia, putting bacteria and fungi with plants. Organisms like Euglena that show both plant and animal features could not be placed, and the system ignored the basic difference between prokaryotic and eukaryotic cells.

What did Haeckel's three-kingdom system add?

In 1866 Ernst Haeckel created kingdom Protista for Euglena-like organisms and also placed bacteria in it. Fungi still remained in Plantae, even though they absorb food and have chitin walls, so the system was still not satisfactory.

How did Whittaker's five-kingdom system work?

In 1969 Robert Whittaker grouped organisms by cell organisation and mode of nutrition into Monera, Protista, Fungi, Plantae and Animalia. In 1988 Margulis and Schwartz kept the five kingdoms but also used genetic evidence.

What is the three-domain system?

Carl Woese placed a new rank, domain, above kingdom and divided prokaryotes into Archaea and Bacteria because of major differences in their chemistry and genes. All eukaryotes were placed in the domain Eukarya, which contains Protista, Fungi, Plantae and Animalia.

Describe the main features of the domains and the kingdoms of domain Eukarya.

What are the features of domain Archaea?

Archaea are prokaryotes without peptidoglycan in their walls and with special membrane lipids. Many live in extreme habitats such as hot springs and salt lakes, and some produce methane. Their ribosomal RNA resembles that of eukaryotes.

What are the features of domain Bacteria?

Bacteria are unicellular prokaryotes with peptidoglycan walls that live almost everywhere. Most are heterotrophs, some like cyanobacteria photosynthesise; some cause disease while many act as decomposers that recycle nutrients.

How do Protista and Fungi differ?

Protists are unicellular or simple multicellular eukaryotes and may be plant-like, animal-like or fungus-like. Fungi are mostly multicellular heterotrophs that absorb food from organic matter and have chitin cell walls.

How do Plantae and Animalia differ?

Plants are multicellular autotrophs with cellulose walls and multicellular sex organs that form embryos. Animals are multicellular heterotrophs with no cell walls that ingest food and digest it inside the body.

What is binomial nomenclature? Explain its importance and rules.

What is binomial nomenclature?

It is the system of giving every species a two-part scientific name, introduced by Carl Linnaeus. The first part is the genus and the second part is the species, for example Panthera tigris for the tiger.

Why are scientific names better than common names?

Common names change from place to place, the same common name may be used for different organisms, and some common names are misleading. A scientific name is unique and is understood by biologists everywhere.

What are the rules for writing scientific names?

Names are Latin or Latinised. The genus is written first with a capital letter and the species second

with a small letter. Every name is unique; printed names are italicised and handwritten names have each part underlined separately.

Multiple Choice Questions (MCQs)

Which rank contains the largest number of different organisms? (A) Genus (B) Order (C) Kingdom (D) Domain
Correct answer: (D) Domain. Domain is the highest rank and includes the widest range of organisms.

Which pair of ranks lies directly between class and family? (A) Order only (B) Phylum only (C) Genus only (D) Domain only
Correct answer: (A) Order only. The sequence is class, order, family.

Organisms that interbreed in nature and produce fertile offspring belong to the same: (A) Family (B) Genus (C) Species (D) Class
Correct answer: (C) Species. This ability defines a species.

Euglena caused problems for the two-kingdom system because it: (A) Has a chitin wall (B) Shows both plant-like and animal-like features (C) Is a virus (D) Lives only in hot springs
Correct answer: (B) Shows both plant-like and animal-like features. It has chlorophyll yet can feed heterotrophically and lacks a cell wall.

Kingdom Protista was first proposed by: (A) Aristotle (B) Ernst Haeckel (C) Robert Whittaker (D) Carl Woese
Correct answer: (B) Ernst Haeckel. Haeckel proposed Protista in 1866.

The five-kingdom system is based mainly on: (A) Colour and size (B) Cell organisation and mode of nutrition (C) Habitat only (D) Number of legs
Correct answer: (B) Cell organisation and mode of nutrition. Whittaker used cell organisation and nutrition.

A microorganism lives in a boiling hot spring and has no peptidoglycan in its wall. It most likely belongs to: (A) Bacteria (B) Archaea (C) Fungi (D) Protista
Correct answer: (B) Archaea. Archaea lack peptidoglycan and many live in extreme habitats.

The cell wall of fungi is made of: (A) Cellulose (B) Peptidoglycan (C) Chitin (D) Lignin only
Correct answer: (C) Chitin. Fungal walls contain chitin.

Amoeba and Paramecium are examples of: (A) Algae (B) Protozoa (C) Fungi (D) Archaea
Correct answer: (B) Protozoa. They are animal-like protists.

Which kingdom contains multicellular autotrophs with multicellular sex organs? (A) Fungi (B) Protista (C) Plantae (D) Animalia

Correct answer: (C) Plantae. Only plants combine these features.

Viruses are not placed in any kingdom mainly because they: (A) Are too large (B) Are acellular and cannot reproduce on their own (C) Contain chlorophyll (D) Have chitin walls
Correct answer: (B) Are acellular and cannot reproduce on their own. They lack cells and independent metabolism.

An infectious particle made only of protein is a: (A) Viroid (B) Prion (C) Bacteriophage (D) Spore
Correct answer: (B) Prion. Prions consist only of protein.

Which is the correctly written scientific name? (A) homo sapiens (B) Homo Sapiens (C) Homo sapiens (D) HOMO sapiens
Correct answer: (C) Homo sapiens. Genus capitalised, species in small letters (and italic in print).

In Allium cepa, the word Allium is the: (A) Species name (B) Genus name (C) Family name (D) Common name
Correct answer: (B) Genus name. The first word is always the genus.

The antibiotic penicillin is obtained from a: (A) Bacterium (B) Fungus (C) Virus (D) Protozoan
Correct answer: (B) Fungus. It comes from the fungus Penicillium.

Quick Revision Summary

- Biodiversity = variety of life in an area; highest in the tropics; supports ecosystems, climate, resources and the economy.
- Classification groups organisms by similarities and differences; aims: easy study and evolutionary relationships.
- Ranks: Domain, Kingdom, Phylum, Class, Order, Family, Genus, Species (Linnaeus 1735 gave seven; domain added later).
- Systems: 2 kingdoms (Aristotle) → 3 kingdoms (Haeckel 1866, Protista) → 5 kingdoms (Whittaker 1969) → 3 domains (Woese).
- Archaea: no peptidoglycan, extreme habitats. Bacteria: peptidoglycan walls. Eukarya: Protista, Fungi, Plantae, Animalia.
- Walls: bacteria = peptidoglycan, fungi = chitin, plants/algae = cellulose, animals = none.
- Viruses, viroids (RNA only) and prions (protein only) are not classified.
- Binomial name = Genus (capital) + species (small), italic when printed, underlined separately by hand.

Exam Tips

- Use a memory sentence for the ranks, for example: 'Dear King Philip Came Over For Good

Soup' = Domain, Kingdom, Phylum, Class, Order, Family, Genus, Species.

- For each classification system, remember one name, one date and one reason it was replaced.
- In kingdom comparison questions, always mention cell type, cell wall and mode of nutrition; that covers most marks.
- Write scientific names carefully: one capital letter only, and underline the two words separately in handwriting.
- If asked why viruses are not classified, give at least two reasons: no cells and no independent metabolism or reproduction.

Note on Facts

The textbook dates the rank of domain to 1977. In 1977 Carl Woese and George Fox showed that archaea are a separate group; the three-domain system itself was formally proposed by Woese and colleagues in 1990. Use the date your teacher gives in the exam.

The textbook's table gives Solanum esculentum for tomato; the name used today is Solanum lycopersicum (older books use Lycopersicon esculentum).

The textbook says prions and viroids cause diseases in certain plants and cancer. In fact viroids infect plants, prions cause brain diseases in animals and humans (such as mad cow disease), and neither is known to cause cancer.

Chapter 3: The Cell

Chapter 3 is about the cell, the smallest unit that can carry out all the activities of life. A useful way to picture a cell is as a small city: the nucleus acts as the government, mitochondria are power stations, the endoplasmic reticulum and Golgi apparatus are the roads and post office, and lysosomes are the waste-disposal service.

The chapter describes each part of the cell, from the cell wall and membrane to the nucleus, cytoskeleton and organelles, and compares plant and animal cells. It then explains how cells become specialised for particular jobs (mesophyll, epidermal, muscle, nerve, red blood and liver cells), how division of labour works inside and between cells, and what makes stem cells special.

Learning Objectives

- Describe the cell as the basic structural and functional unit of life.
- Give the structure and function of the cell wall, cell membrane, cytoplasm, nucleus and cytoskeleton.
- Describe ribosomes, endoplasmic reticulum, Golgi apparatus, lysosomes, mitochondria, plastids, vacuoles, centrioles, cilia and flagella.
- Compare plant and animal cells and state the advantages of each design.
- Explain cell specialisation with examples from plants and animals.
- Explain division of labour within a cell and across cells.
- Define stem cells and give examples of their role in the body.

Key Concepts

3.1 The Cell and Its Discovery

All organisms, from bacteria to whales, are made of cells, so the cell is called the basic unit of life. Most cells are microscopic, but a few can be seen with the naked eye, such as an ostrich egg cell, the single-celled alga Acetabularia and the giant amoeba.

Robert Hooke first described cells in 1665 when he looked at a thin slice of cork through his microscope and saw tiny box-like spaces. Better microscopes in the nineteenth century revealed internal details; in 1831 Robert Brown identified the nucleus. Cells are of two basic types: prokaryotic cells have no membrane-bound organelles, while eukaryotic cells have a nucleus and many membrane-bound organelles.

3.2 Cell Wall and Cell Membrane

A cell wall is a rigid, non-living layer outside the membrane in bacteria, fungi, plants and algae. It gives shape, strength and protection. A plant cell wall has three layers: the middle lamella (pectin with calcium and magnesium) cements neighbouring cells together; the primary wall (cellulose fibres with hemicellulose and pectin) lies next to the membrane; and some cells such as xylem add a secondary wall of cellulose and lignin on the inner side. Channels called plasmodesmata pass

Free notes: freebooks.pk

through walls and connect neighbouring plant cells. Bacterial walls are made of peptidoglycan and fungal walls of chitin.

Every cell has a thin, flexible cell membrane that is selectively permeable: it lets some substances through and keeps others out. It is made of lipids and proteins with a little carbohydrate. The fluid mosaic model describes it as a double layer of lipids in which proteins float; both can move sideways, so the pattern keeps changing. Carbohydrates attach to proteins (glycoproteins) or lipids (glycolipids), and animal cell membranes also contain cholesterol.

3.2 Cytoplasm, Nucleus and Cytoskeleton

Cytoplasm is the jelly-like material between the membrane and the nucleus, made of water, proteins, enzymes and salts. It holds the organelles, allows materials to move, stores food and wastes, and is the site of reactions such as glycolysis. Its fluid part, without the membrane-bound organelles, is called cytosol.

The nucleus is the control centre of a eukaryotic cell. It is surrounded by a double nuclear envelope with nuclear pores. Inside is the nucleoplasm containing one or more nucleoli, where ribosome parts are made, and chromatin made of DNA and proteins. When the cell divides, chromatin coils into chromosomes. DNA carries genes that control the cell and pass characteristics to the next generation. Prokaryotes have no true nucleus; their DNA lies free in the cytoplasm.

The cytoskeleton is a network of protein fibres. Microtubules (tubulin) keep the cell's shape, guide organelle movement and form the spindle, cilia and flagella. Microfilaments (actin) allow movement such as muscle contraction and white blood cell crawling. Intermediate filaments (keratin, vimentin) anchor the nucleus and form cell junctions.

3.2 Organelles for Making and Processing Materials

Ribosomes are tiny granules of protein and ribosomal RNA where proteins are made. They have two subunits that join during protein synthesis, have no membrane, and are found free in the cytoplasm, on rough ER and in prokaryotes too (eukaryotic ribosomes are slightly larger).

The endoplasmic reticulum is a network of membrane channels. Rough ER carries ribosomes and makes proteins; smooth ER has no ribosomes and makes lipids, transports materials, breaks down toxic chemicals and helps muscle contraction. The Golgi apparatus, described by Camillo Golgi in 1898, is a stack of flat sacs (cisternae) that modifies proteins from rough ER and packs them into Golgi vesicles for storage or secretion.

Lysosomes, discovered by Christian de Duve, are small vesicles budded from the Golgi apparatus and filled with digestive enzymes. They fuse with food vacuoles to digest food, break down worn-out organelles and cell waste, and are mainly found in animal cells.

3.2 Energy Organelles: Mitochondria and Plastids

Mitochondria are the powerhouses of the cell, where aerobic respiration breaks down glucose using oxygen to release energy as ATP. Each has a smooth outer membrane and a folded inner membrane; the folds (cristae) increase the surface for respiration and enclose a fluid matrix. Mitochondria have their own DNA and ribosomes similar to those of prokaryotes.

Plastids occur in plants and algae. Chloroplasts are green and carry out photosynthesis; they have

a double membrane, stacks (grana) of disc-like thylakoids carrying chlorophyll, a fluid stroma, and their own DNA and ribosomes. Chromoplasts contain bright pigments such as carotenoids that colour petals and fruits, attracting pollinators and seed dispersers. Leucoplasts are colourless and store starch, oils and proteins in roots, seeds and underground stems.

3.2 Vacuoles, Centrioles, Cilia and Flagella

Vacuoles are fluid-filled sacs bounded by one membrane. Animal cells have several small temporary vacuoles; freshwater protists such as Amoeba use contractile vacuoles to pump out extra water; food vacuoles digest and store food. A mature plant cell usually has one large central vacuole, bounded by the tonoplast and filled with cell sap. It pushes the nucleus to one side and presses the cytoplasm against the wall, producing turgor pressure that keeps the cell firm.

Centrioles are barrel-shaped structures made of nine triplets of microtubules, found in pairs at right angles (a centrosome) in animal cells and most protists but not in higher plants, fungi or prokaryotes. They form spindle fibres that separate chromosomes during cell division; centrioles at the base of cilia and flagella are called basal bodies. Cilia are short and numerous while flagella are long and few; in eukaryotes both have a 9 + 2 arrangement of microtubules and are used for movement. Prokaryotic flagella are built differently, from the protein flagellin.

3.3 Plant and Animal Cells Compared

Both plant and animal cells have a membrane, cytoplasm, nucleus, mitochondria, ribosomes, ER and Golgi apparatus. Only plant cells have a cellulose cell wall, chloroplasts and a large central vacuole; animal cells have centrioles and lysosomes and lack a wall. The nucleus is central in animal cells but pushed to the side in mature plant cells.

The plant design gives support (wall), food-making (chloroplasts), storage and turgor (vacuole) and cell-to-cell links (plasmodesmata). The animal design allows accurate chromosome separation (centrioles), efficient clean-up (lysosomes), movement by cilia or flagella, and flexibility of shape because there is no rigid wall, which lets white blood cells squeeze to infection sites.

3.4 Cell Specialisation and Division of Labour

New cells made by division are similar at first; they then specialise (differentiate), developing the size, shape and contents needed for one job. Mesophyll cells in leaves are packed with chloroplasts for photosynthesis. Epidermal cells are flat and tightly fitted to protect plant organs; some become root hair cells for absorption or guard cells that open and close stomata.

Muscle cells are long and full of contractile proteins: skeletal muscle is striated and voluntary, cardiac muscle is branched, striated and involuntary, and smooth muscle is spindle-shaped, unstriated and involuntary. Neurons have a cell body, short dendrites that bring impulses in and a long axon that carries them away. Red blood cells are biconcave discs packed with haemoglobin; mammalian red cells lose their nucleus and organelles to hold more haemoglobin. Liver cells (hepatocytes) store glycogen, iron and vitamins, detoxify chemicals, make clotting proteins, recycle old red cells, turn ammonia into urea and secrete bile; they have large nuclei, many mitochondria, much smooth ER and many peroxisomes.

Division of labour means different parts doing different jobs so the whole works efficiently. Inside a

cell, organelles share the work (mitochondria release energy, ER makes proteins and lipids, lysosomes digest waste). In a multicellular body, different cell types share the work (muscle cells move, nerve cells carry messages, red blood cells carry oxygen).

3.5 Stem Cells

A stem cell is an unspecialised cell that can divide and give rise to different types of specialised cells. The zygote is the first stem cell: its descendants form separate cell lines that become skin, muscle, nerve and blood cells.

Adult stem cells remain in many tissues throughout life and replace or repair cells as needed. Skin stem cells help heal wounds, liver stem cells help the liver recover from damage, and bone marrow stem cells keep producing red blood cells, white blood cells and platelets. The gut lining and bone marrow depend on them constantly.

Important Definitions

Cell
The smallest structural and functional unit of life.

Prokaryotic cell
A cell without a nucleus or membrane-bound organelles, such as a bacterial cell.

Eukaryotic cell
A cell with a membrane-bound nucleus and membrane-bound organelles.

Middle lamella
The pectin-rich layer that cements the walls of neighbouring plant cells together.

Plasmodesmata
Channels through plant cell walls that connect the cytoplasm of neighbouring cells.

Selectively permeable
Allowing some substances to pass through while stopping others.

Fluid mosaic model
The model of the cell membrane as a moving double layer of lipids with proteins floating in it.

Cytosol
The fluid part of the cytoplasm, excluding membrane-bound organelles.

Chromatin
Thread-like material in the nucleus made of DNA and proteins, which condenses into chromosomes during division.

Nucleolus

A dense body inside the nucleus where ribosome parts are assembled.

Cytoskeleton
A network of microtubules, microfilaments and intermediate filaments that supports the cell and helps it move.

Ribosome
A small particle of RNA and protein where proteins are made.

Cisternae
The flattened sacs that are stacked to form the Golgi apparatus.

Lysosome
A membrane vesicle containing digestive enzymes.

Cristae
Folds of the inner mitochondrial membrane that increase the surface area for respiration.

Thylakoid
A flattened membrane sac in a chloroplast that carries chlorophyll; stacks of thylakoids form grana.

Tonoplast
The membrane surrounding the central vacuole of a plant cell.

Turgor pressure
The outward pressure of the vacuole's contents on the cytoplasm and cell wall, which keeps a plant cell firm.

Centrosome
A pair of centrioles lying at right angles near the nucleus of an animal cell.

Cell specialisation
The process by which a cell develops a particular structure to perform a particular function.

Division of labour
Sharing of different tasks among different parts of a system so that it works efficiently.

Stem cell
An unspecialised cell that can divide and form different kinds of specialised cells.

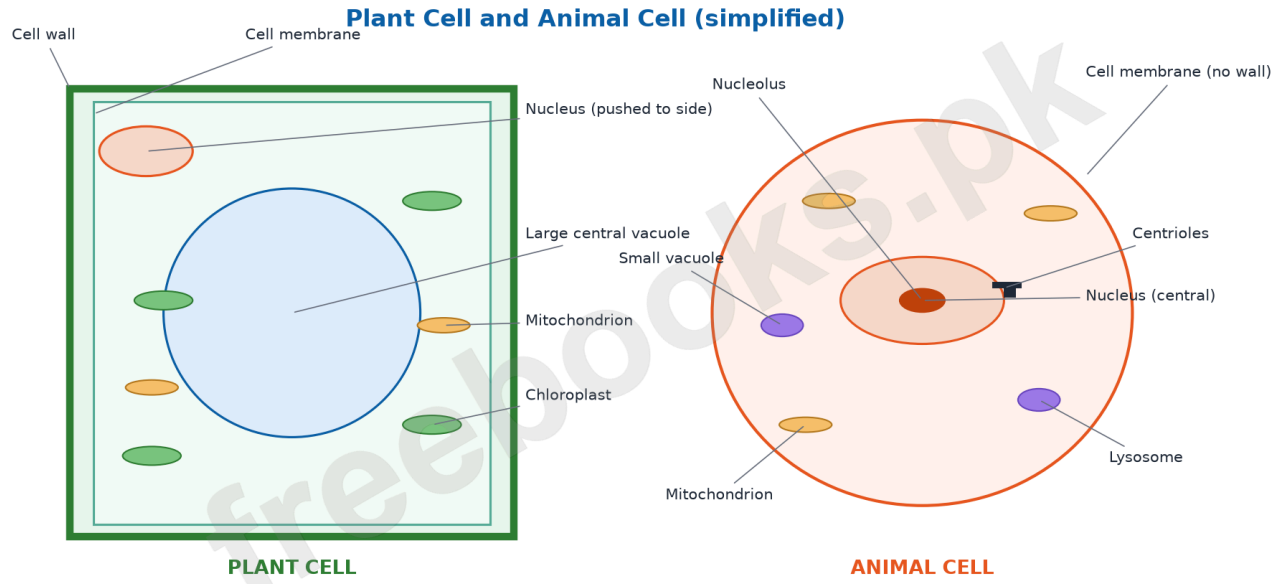
Key Facts at a Glance

Organelle	Main job

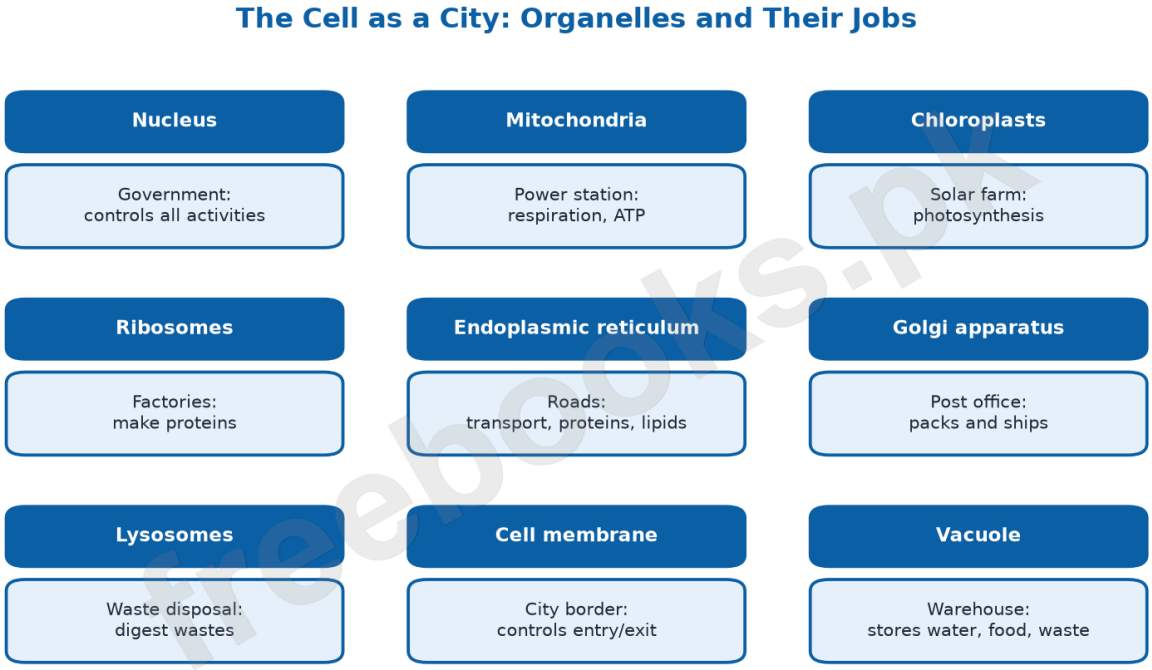
Cell wall	Shape, support, protection (plants, fungi, bacteria, algae)
Cell membrane	Controls entry and exit of substances
Nucleus	Controls cell activities; contains DNA
Nucleolus	Assembles ribosome parts
Ribosome	Protein synthesis
Rough ER	Makes proteins
Smooth ER	Makes lipids, detoxifies, transports
Golgi apparatus	Modifies and packs proteins for secretion
Lysosome	Digests food, waste and old organelles
Mitochondrion	Aerobic respiration, releases ATP
Chloroplast	Photosynthesis
Chromoplast / Leucoplast	Colour / food storage
Central vacuole	Stores cell sap, gives turgor
Centrioles	Form spindle fibres; basal bodies of cilia
Cilia and flagella	Movement (9 + 2 microtubules)

Diagrams

Plant cell and animal cell: Simplified labelled sketches of a plant cell and an animal cell side by side, showing the parts they share and the parts found in only one of them.

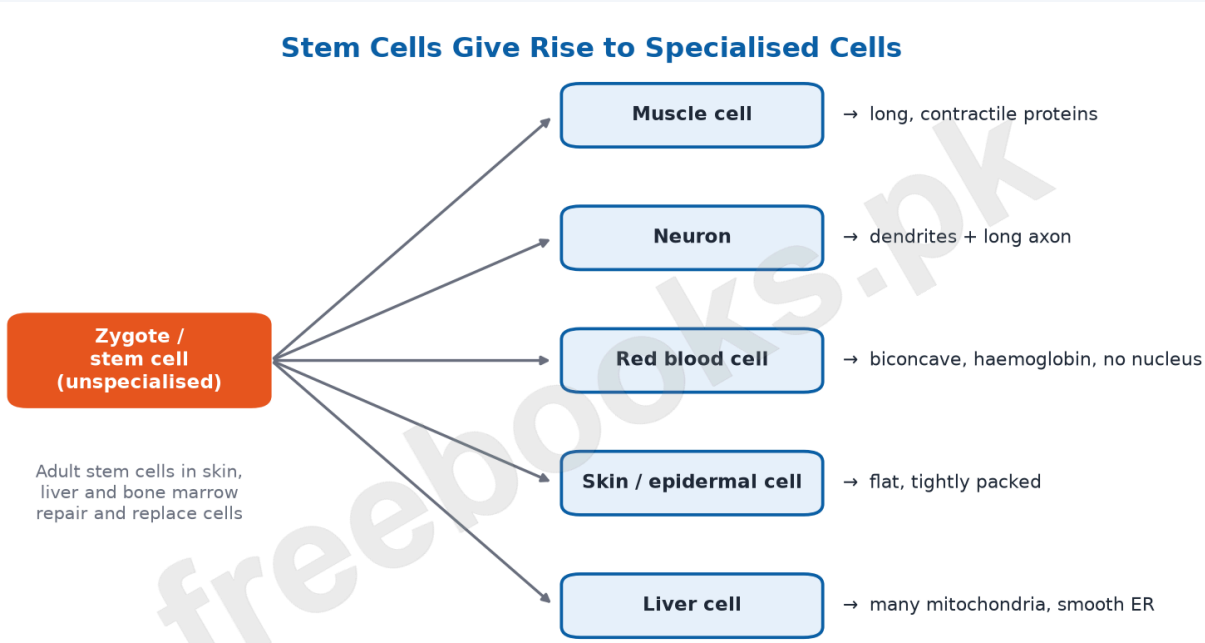


Cell organelles and their jobs: The city model of the cell: each organelle matched with its role, from the nucleus as control centre to lysosomes as waste disposal.



Stem cells and specialised cells: A zygote and adult stem cells giving rise to specialised cells such as muscle cells, neurons, red blood cells and skin cells, each with its key adaptation.

freebooks.pk



freebooks.pk

Short Questions and Answers

Why is the cell called the basic unit of life?

Because every living thing is made of cells, and the cell is the smallest unit that can carry out all life processes such as nutrition, respiration and reproduction.

What did Robert Hooke and Robert Brown discover?

Hooke described cells in 1665 by observing box-like spaces in a cork slice; Brown identified the nucleus in plant cells in 1831.

How is the secondary wall different from the primary wall?

The primary wall is thin, flexible and made mainly of cellulose, hemicellulose and pectin; the secondary wall forms later inside it in some cells such as xylem and is thicker and stronger because it also contains lignin.

Why is the cell membrane called fluid mosaic?

Its lipids form a fluid double layer in which proteins are scattered like the pieces of a mosaic, and both can move sideways, so the pattern keeps changing.

What is the difference between chromatin and chromosomes?

Chromatin is the loose thread-like form of DNA and protein in a non-dividing nucleus; chromosomes are the thick, condensed form that chromatin takes when the cell divides.

Why are mitochondria called the powerhouses of the cell?

They carry out aerobic respiration, breaking down glucose with oxygen to release energy in the form of ATP, which the cell uses for its work.

How does rough ER differ from smooth ER?

Rough ER has ribosomes on its surface and makes proteins; smooth ER has no ribosomes and makes lipids, detoxifies harmful chemicals and transports materials.

How do the Golgi apparatus and lysosomes work together?

The Golgi apparatus packages digestive enzymes into vesicles that bud off as lysosomes; these lysosomes then fuse with food vacuoles or worn-out organelles and digest them.

Why do cells in fruits and flower petals have chromoplasts?

Chromoplasts contain bright pigments that colour petals and fruits, attracting insects for pollination and animals that disperse seeds.

Why are vacuoles called the storage and waste bins of the cell?

They hold water, food, salts and waste products, keeping these substances away from the rest of the cytoplasm until they are used or removed.

How does the central vacuole keep a plant cell firm?

It fills with cell sap and presses the cytoplasm against the cell wall; this turgor pressure keeps the cell stiff and helps the plant stay upright.

Why can white blood cells change shape but plant cells cannot?

Animal cells have no rigid cell wall and use their cytoskeleton to move, so white blood cells can squeeze through gaps; plant cells are held in shape by a rigid cellulose wall.

How is a red blood cell adapted to carry oxygen?

Its biconcave disc shape gives a large surface for gas exchange, and in mammals it loses its nucleus and organelles so that it can be packed with more haemoglobin.

Why do liver cells contain many mitochondria and much smooth ER?

Liver cells do energy-hungry work such as making proteins and detoxifying chemicals; mitochondria supply the ATP and smooth ER carries out detoxification and lipid synthesis.

What is a stem cell? Give one example.

A stem cell is an unspecialised cell that can divide and form different specialised cells. Bone marrow stem cells, for example, keep producing new red and white blood cells.

Long Questions and Answers

Describe the structure and functions of the cell wall and the cell membrane.

Which cells have a cell wall and what does it do?

Bacteria, fungi, plants and algae have a rigid non-living cell wall outside the membrane. It gives the cell shape, mechanical strength and protection and prevents it from bursting.

What are the layers of a plant cell wall?

The middle lamella, made of pectin with calcium and magnesium, joins neighbouring cells. The primary wall, made of crossing cellulose fibres with hemicellulose and pectin, lies against the membrane. Some cells such as xylem add a secondary wall of cellulose and lignin inside the primary wall.

What is the cell membrane made of?

It is made of a double layer of lipids with proteins embedded in it, plus small amounts of carbohydrates attached as glycoproteins and glycolipids. Animal cell membranes also contain cholesterol.

What does the fluid mosaic model explain?

It explains that the lipids form a fluid layer in which proteins move about, so the membrane is flexible and its pattern constantly changes. The membrane is selectively permeable and controls what enters and leaves the cell.

Describe the structure and function of the nucleus.

What surrounds the nucleus?

A double membrane called the nuclear envelope surrounds the nucleus. It has many nuclear pores that allow materials such as RNA to pass between the nucleus and cytoplasm.

What is inside the nucleus?

The nucleoplasm contains one or more nucleoli, where ribosome parts are assembled, and chromatin made of DNA and proteins. During division, chromatin condenses into chromosomes.

Why is the nucleus called the control centre?

Its DNA contains genes that direct the making of proteins, and proteins carry out and control nearly all cell activities. DNA also passes characteristics to the next generation, so it is the hereditary material.

Describe the structure and functions of mitochondria and chloroplasts.

What is the structure of a mitochondrion?

A mitochondrion has a smooth outer membrane and a folded inner membrane. The folds, called cristae, enclose a fluid matrix and give a large surface for the reactions of respiration.

What do mitochondria do?

They carry out aerobic respiration, using oxygen to break down glucose and release energy stored as ATP, which powers activities such as movement and synthesis.

What is the structure of a chloroplast?

A chloroplast has a double membrane enclosing a fluid stroma. Inside are stacks called grana, each made of disc-shaped thylakoids that carry chlorophyll.

What features do mitochondria and chloroplasts share?

Both have double membranes, contain their own DNA and ribosomes, and deal with energy: chloroplasts capture light energy to make glucose, and mitochondria release the energy stored in glucose.

Compare plant and animal cells and explain the advantages of each.

What parts do plant and animal cells share?

Both have a cell membrane, cytoplasm, nucleus, mitochondria, ribosomes, endoplasmic reticulum and Golgi apparatus, because these carry out basic life processes in all eukaryotic cells.

What parts are found only in plant cells?

Plant cells have a cellulose cell wall for support, chloroplasts for photosynthesis, a large central vacuole for storage and turgor, and plasmodesmata that connect neighbouring cells.

What parts are typical of animal cells?

Animal cells have centrioles that form spindle fibres, lysosomes for digestion and clean-up, and in some cells cilia or flagella for movement. They have no cell wall.

Why is each design useful?

The plant cell is built for support and making food, which suits a plant that stays in one place. The animal cell is flexible and can change shape and move, which suits animals that must search for food and respond quickly.

What is cell specialisation? Explain with examples and describe division of labour.

What does cell specialisation mean?

After cell division, new cells are alike, but they then develop special shapes and contents to perform one particular task. This process is called specialisation or differentiation.

How are plant cells specialised?

Mesophyll cells contain many chloroplasts for photosynthesis. Epidermal cells are flat and tightly packed for protection; root hair cells grow long extensions to absorb water and guard cells control the stomata.

How are animal cells specialised?

Muscle cells are long and contractile, neurons have dendrites and a long axon to carry impulses, red blood cells are biconcave and full of haemoglobin, and liver cells have many mitochondria and much smooth ER for detoxification and synthesis.

What is division of labour within and across cells?

Within a cell, organelles divide the work: mitochondria release energy, ER makes proteins and lipids and lysosomes digest waste. Across cells, different cell types share the work of the body, which lets complex organisms perform many functions efficiently.

Multiple Choice Questions (MCQs)

The first scientist to describe cells, using a slice of cork, was: (A) Robert Brown (B) Robert Hooke (C) Camillo Golgi (D) Christian de Duve
Correct answer: (B) Robert Hooke. Hooke described cork cells in 1665.

The layer that cements two neighbouring plant cells together is the: (A) Primary wall (B) Secondary wall (C) Middle lamella (D) Cell membrane
Correct answer: (C) Middle lamella. The middle lamella is rich in pectin and joins adjacent walls.

Lignin is mainly found in the: (A) Middle lamella (B) Primary wall (C) Secondary wall (D) Cell membrane
Correct answer: (C) Secondary wall. The secondary wall contains cellulose and lignin.

Which structure is selectively permeable? (A) Cell wall (B) Cell membrane (C) Middle lamella (D) Cell sap
Correct answer: (B) Cell membrane. The membrane controls what enters and leaves the cell.

Ribosome subunits are assembled in the: (A) Nucleolus (B) Golgi apparatus (C) Lysosome (D) Vacuole
Correct answer: (A) Nucleolus. The nucleolus is where ribosome parts are made.

A cell that makes large amounts of digestive enzymes for export would have plenty of: (A) Rough ER and Golgi apparatus (B) Chloroplasts (C) Centrioles only (D) Leucoplasts
Correct answer: (A) Rough ER and Golgi apparatus. Rough ER makes the proteins and the Golgi packs them for secretion.

Which organelle detoxifies harmful chemicals in liver cells? (A) Rough ER (B) Smooth ER (C) Ribosome (D) Centriole
Correct answer: (B) Smooth ER. Smooth ER carries out detoxification.

The folds of the inner mitochondrial membrane are called: (A) Grana (B) Cristae (C) Cisternae (D) Thylakoids
Correct answer: (B) Cristae. Cristae increase the surface area for respiration.

Colourless plastids that store starch are: (A) Chloroplasts (B) Chromoplasts (C) Leucoplasts (D) Lysosomes
Correct answer: (C) Leucoplasts. Leucoplasts have no pigment and store food.

Which organelle is found in animal cells but not in higher plant cells? (A) Mitochondrion (B) Centriole (C) Ribosome (D) Golgi apparatus
Correct answer: (B) Centriole. Higher plants lack centrioles.

The membrane around the central vacuole of a plant cell is the: (A) Tonoplast (B) Nuclear envelope (C) Plasmodesma (D) Middle lamella
Correct answer: (A) Tonoplast. The tonoplast surrounds the vacuole.

Microtubules in eukaryotic cilia and flagella are arranged as: (A) 9 + 0 (B) 9 + 2 (C) 9 triplets only (D) 2 + 2
Correct answer: (B) 9 + 2. Nine outer pairs surround one central pair.

Which cell type has dendrites and an axon? (A) Muscle cell (B) Neuron (C) Mesophyll cell (D) Red blood cell
Correct answer: (B) Neuron. Neurons receive impulses through dendrites and send them along the axon.

Mature mammalian red blood cells lack a nucleus so that they can: (A) Divide faster (B) Hold more haemoglobin (C) Make more ATP (D) Move by flagella
Correct answer: (B) Hold more haemoglobin. Extra space is used for haemoglobin.

Cells in bone marrow that keep forming new blood cells are: (A) Guard cells (B) Stem cells (C) Mesophyll cells (D) Epidermal cells
Correct answer: (B) Stem cells. Bone marrow stem cells produce blood cells throughout life.

Quick Revision Summary

- Cell = basic unit of life. Hooke saw cells in cork (1665); Brown found the nucleus (1831).
- Plant wall: middle lamella (pectin) + primary wall (cellulose) + secondary wall (cellulose + lignin); plasmodesmata link cells.
- Membrane: lipid bilayer with proteins (fluid mosaic), selectively permeable.
- Nucleus: envelope with pores, nucleolus (ribosome parts), chromatin (DNA + protein) → chromosomes in division.
- Ribosome = protein synthesis; RER = proteins; SER = lipids and detox; Golgi = packaging; lysosome = digestion.
- Mitochondria = respiration (cristae, matrix); chloroplasts = photosynthesis (grana, thylakoids, stroma); both have DNA.
- Plant only: wall, chloroplasts, large vacuole. Animal only: centrioles, lysosomes (mainly), no wall.
- Specialised cells: mesophyll, epidermal, muscle, neuron, red blood cell, liver cell. Stem cells are unspecialised and can form many cell types.

Exam Tips

- Learn each organelle with three words: what it looks like, where it is found, what it does.
- Practise drawing and labelling a plant cell and an animal cell; diagram questions are common and the labels carry marks.
- Keep look-alike terms apart: cristae (mitochondria) vs grana (chloroplast) vs cisternae (Golgi).
- For specialised cell questions, always link a structural feature to the job it helps with.
- When comparing plant and animal cells, use a two-column table; it is quicker to write and easier to mark.

Note on Facts

The textbook places cholesterol on the inner side of the membrane. In fact cholesterol molecules sit within both layers of the lipid bilayer of animal cell membranes, where they help control membrane fluidity.

Chapter 4: Cell Cycle

Chapter 4 follows the life of a eukaryotic cell from the moment it is formed until it divides. This sequence is the cell cycle: a long preparation stage called interphase, followed by division. Cells divide in two ways. Mitosis makes two identical cells and is used for growth, repair and asexual reproduction; meiosis makes four cells with half the chromosomes and is used to form gametes and spores.

The notes below explain each stage of interphase, the four phases of mitosis and how cytokinesis differs in plant and animal cells, the two rounds of meiosis with synapsis and crossing over, the importance of both divisions, what happens when they go wrong (tumours and non-disjunction), and a side-by-side comparison of mitosis and meiosis.

Learning Objectives

- Describe the cell cycle and the events of G1, S, G2 and G0.
- Explain the four phases of mitosis and cytokinesis in animal and plant cells.
- State the significance of mitosis and the result of errors in mitosis.
- Explain the phases of meiosis I and meiosis II, including synapsis and crossing over.
- State the significance of meiosis and the result of non-disjunction.
- Compare mitosis and meiosis.

Key Concepts

4.1 The Cell Cycle and Interphase

The cell cycle is the ordered series of events in a eukaryotic cell from its formation to its own division into two daughter cells. It has two main parts: interphase, which takes about 90 percent of the time, and the M (division) phase. Special genes control the cycle so that its stages happen in the right order.

Interphase has three stages. In G1 (first gap) the cell grows, makes proteins and organelles, and produces the enzymes needed to copy DNA. In S (synthesis) each DNA molecule is replicated, so every chromosome now has two identical sister chromatids, though the chromosome count stays the same. In G2 (second gap) the cell keeps growing, makes proteins needed for division, checks and repairs any DNA damage and organises its contents for mitosis.

Some cells leave the cycle after division and enter G0, a resting state in which they do their special job without dividing. Neurons stay in G0 more or less permanently, liver and kidney cells can return to the cycle when needed, while cells such as those of epithelium keep dividing throughout life.

4.2 Mitosis: Karyokinesis

Mitosis is cell division in which one cell forms two daughter cells, each with exactly the same number and kind of chromosomes as the parent. It takes place in body (somatic) cells of eukaryotes; prokaryotes divide by a simpler process called binary fission. Walther Flemming

described the stages of mitosis in the 1880s. Mitosis has two parts: karyokinesis (division of the nucleus) and cytokinesis (division of the cytoplasm).

Prophase: chromatin condenses into visible chromosomes, each made of two sister chromatids joined at a centromere; the nucleolus and nuclear envelope disappear. In animal cells the centrosome duplicates and the two centrosomes move apart, building spindle fibres between them; plant cells, which have no centrioles, build the spindle from fibres in the cytoplasm.

Metaphase: spindle fibres from opposite poles attach to the kinetochore at the centromere of each chromosome, and the chromosomes line up across the middle of the cell, forming the metaphase plate. Anaphase: the spindle fibres shorten, the centromeres split and the sister chromatids are pulled to opposite poles, giving two identical sets. Telophase: a nuclear envelope forms around each set, nucleoli reappear and the chromosomes unwind into chromatin.

4.2 Cytokinesis in Animal and Plant Cells

In animal cells a ring of actin microfilaments under the membrane at the equator contracts, creating a cleavage furrow that deepens until the cell is pinched into two.

In plant cells the rigid wall prevents pinching. Instead, Golgi vesicles carrying wall material gather at the middle of the cell and fuse to form a cell plate, which grows outwards until it joins the existing wall and membrane, separating two daughter cells.

4.2 Significance of Mitosis and Errors

Mitosis allows growth, because organisms grow by adding cells; it replaces cells that wear out, such as red blood cells, skin cells and the lining of the intestine; it allows regeneration of lost parts, as when a sea star regrows an arm; and it is the basis of asexual reproduction, for example budding in Hydra. Every body cell formed from the zygote receives a complete, identical set of chromosomes because of mitosis.

If sister chromatids fail to separate in anaphase, one daughter cell gets an extra chromosome and the other gets one too few. If the genes controlling division are mutated, cells divide without stopping and form a lump called a tumour. A benign tumour stays where it formed; a malignant tumour (cancer) invades other tissues and spreads, a process called metastasis.

4.3 Meiosis I

Meiosis is cell division in which a diploid cell (chromosomes in homologous pairs) gives rise to four haploid cells (one chromosome from each pair). It was first described by Oscar Hertwig in 1876 and consists of two divisions, meiosis I and meiosis II, after a single round of DNA replication.

Prophase I: chromosomes condense, each already made of two chromatids. Homologous chromosomes come together side by side in synapsis, forming a group of four chromatids called a tetrad (bivalent). Non-sister chromatids touch at points called chiasmata, where they exchange segments; this crossing over recombines genes. The nuclear envelope and nucleolus disappear and the spindle forms.

Metaphase I: homologous pairs, not single chromosomes, line up at the equator. Anaphase I: the members of each homologous pair are pulled to opposite poles; sister chromatids stay together. Telophase I: nuclear envelopes may re-form and cytokinesis produces two haploid cells, each

chromosome still having two chromatids.

4.3 Meiosis II

Meiosis II looks like mitosis but starts with haploid cells. In prophase II the chromosomes condense again and a spindle forms; in metaphase II they line up singly at the equator; in anaphase II the sister chromatids finally separate and move to opposite poles; in telophase II nuclei re-form and cytokinesis follows.

The final result is four haploid daughter cells, each genetically different from the parent and from each other because of crossing over and the random way homologous pairs line up in metaphase I.

4.3 Significance of Meiosis and Errors

Meiosis keeps the chromosome number constant from one generation to the next. Gametes made by meiosis carry half the chromosomes, and fertilisation restores the full diploid number in the zygote, which then grows by mitosis. In flowering plants meiosis produces haploid spores inside the flower, which give rise to the gamete-forming stage.

Meiosis also creates genetic variety. Crossing over and independent arrangement of chromosome pairs give every gamete a unique gene combination, so offspring differ from their parents and from each other. If chromosomes or chromatids fail to separate properly (non-disjunction), gametes end up with too many or too few chromosomes, and a zygote formed from them may develop serious disorders.

4.4 Mitosis and Meiosis Compared

Similarities: DNA is copied in the S phase before both; both have prophase, metaphase, anaphase and telophase; both use a spindle; sister chromatids separate in both (anaphase of mitosis, anaphase II of meiosis); both end with cytokinesis.

Differences: mitosis has one division producing two identical diploid cells, while meiosis has two divisions producing four haploid, genetically varied cells. Homologous chromosomes pair and cross over only in meiosis. Mitosis occurs in body cells for growth, repair and asexual reproduction, while meiosis occurs in reproductive (germ-line) cells to form gametes or spores.

Important Definitions

Cell cycle
The sequence of events in a eukaryotic cell from its formation to its division into two daughter cells.

Interphase
The long preparatory stage of the cell cycle made up of G1, S and G2.

G0 phase
A resting state in which a cell leaves the cycle and stops dividing.

Sister chromatids
The two identical copies of a chromosome formed by DNA replication and joined at the centromere.

Centromere
The point where sister chromatids are joined and where spindle fibres attach through the kinetochore.

Spindle fibres
Microtubules that attach to chromosomes and move them during cell division.

Metaphase plate
The plane at the cell's equator where chromosomes line up during metaphase.

Karyokinesis
Division of the nucleus.

Cytokinesis
Division of the cytoplasm to form two separate cells.

Cell plate
The new partition formed from Golgi vesicles at the middle of a dividing plant cell.

Binary fission
The simple division of a prokaryotic cell into two.

Tumour
A mass of cells formed by uncontrolled cell division.

Metastasis
The spread of cancer cells from their original site to other tissues.

Diploid (2n)
Having chromosomes in homologous pairs.

Haploid (n)
Having only one chromosome from each pair.

Homologous chromosomes
A pair of chromosomes, one from each parent, carrying genes for the same characters.

Synapsis
The pairing of homologous chromosomes in prophase I.

Tetrad

A synapsed pair of homologous chromosomes, made of four chromatids.

Chiasma (plural chiasmata)
The X-shaped point where non-sister chromatids cross and exchange segments.

Crossing over
The exchange of segments between non-sister chromatids of homologous chromosomes.

Non-disjunction
The failure of chromosomes or chromatids to separate properly during division.

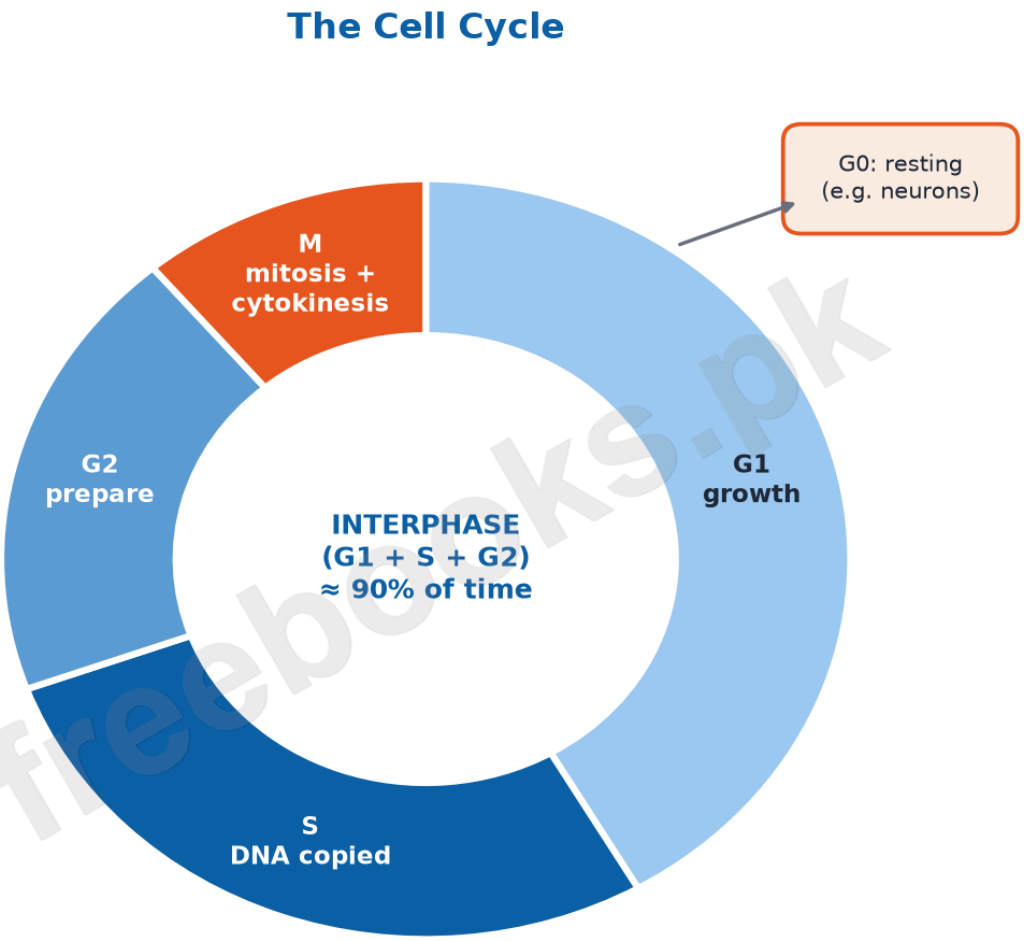
Key Facts at a Glance

Topic	Key point
Interphase share of cycle	About 90%
DNA replication	S phase
Phases of mitosis	Prophase → Metaphase → Anaphase → Telophase (PMAT), then cytokinesis
Mitosis described by	Walther Flemming, 1880s
Meiosis described by	Oscar Hertwig, 1876
Mitosis result	2 identical daughter cells, same chromosome number
Meiosis result	4 haploid, genetically different cells
Crossing over	Prophase I, at chiasmata
Homologues separate	Anaphase I
Sister chromatids separate	Anaphase (mitosis) and anaphase II (meiosis)
Animal cytokinesis	Cleavage furrow by a ring of microfilaments
Plant cytokinesis	Cell plate from Golgi vesicles
Cells that stay in G0	Neurons
Asexual reproduction by mitosis	Budding in Hydra

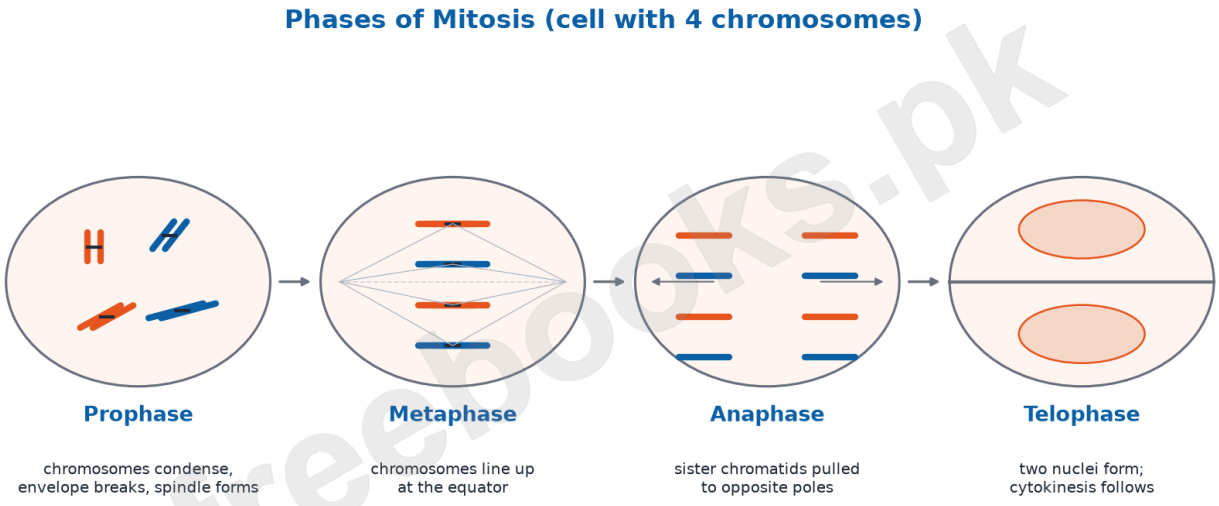
Diagrams

The cell cycle: A circular chart of the cell cycle showing G1, S and G2 of interphase, the M phase

and the exit into G0.

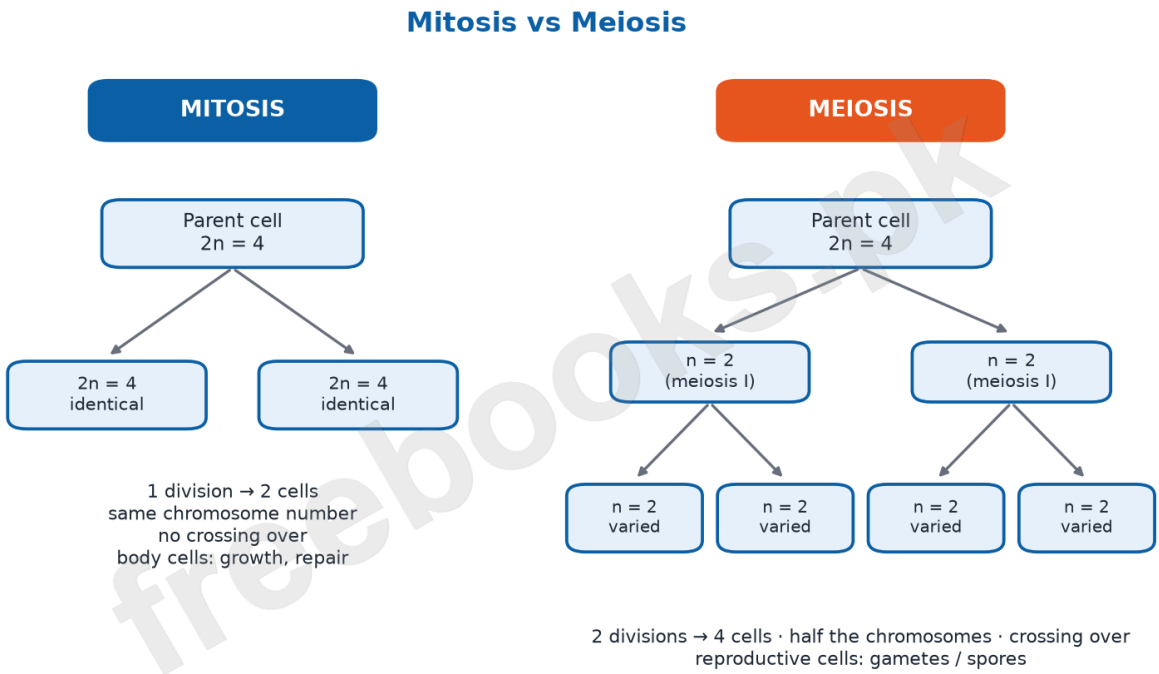


Phases of mitosis: Simplified sketches of prophase, metaphase, anaphase and telophase with the key event of each phase.



freebooks.pk

Mitosis vs meiosis: A flow comparison showing one division giving two identical diploid cells against two divisions giving four varied haploid cells.



Short Questions and Answers

Why is interphase not a resting phase?

During interphase the cell is very active: it grows, makes proteins and organelles, copies its DNA in the S phase and checks and repairs it in G2 before dividing.

What happens to the chromosome number in the S phase?

The DNA is copied so each chromosome comes to have two sister chromatids, but the number of chromosomes stays the same.

Name a cell that stays in G0 and one that keeps dividing.

Mature neurons stay in G0 and normally do not divide, while skin epithelial cells keep dividing throughout life.

What is the role of the kinetochore?

It is a protein structure at the centromere to which spindle fibres attach, allowing the chromosome to be moved during division.

Why do plant cells form a cell plate instead of a cleavage furrow?

Their rigid cell wall cannot be pinched inwards, so they build a new wall from Golgi vesicles at the middle of the cell.

freebooks.pk

How does a plant cell form a spindle without centrioles?
It assembles spindle fibres from microtubules already present in its cytoplasm.

Give two uses of mitosis in the human body.
Growth of the body by increasing cell number, and replacement of worn-out cells such as red blood cells and skin cells.

How is a malignant tumour different from a benign tumour?
A benign tumour stays in the place where it formed, while a malignant tumour invades nearby tissues and spreads to other parts of the body.

What is the difference between diploid and haploid cells?
Diploid cells have chromosomes in homologous pairs (2n); haploid cells have only one chromosome from each pair (n), as in gametes.

What is a tetrad and when does it form?
A tetrad is a pair of homologous chromosomes lying together, made of four chromatids; it forms during synapsis in prophase I of meiosis.

Why is meiosis called reduction division?
Because its first division separates homologous chromosomes, halving the chromosome number so that the daughter cells are haploid.

How does crossing over create variation?
Non-sister chromatids exchange segments, so each chromosome ends up with a new mixture of genes from both parents.

Why must gametes be haploid?
So that when two gametes fuse at fertilisation the zygote gets the normal diploid number, keeping the chromosome number constant from generation to generation.

What is non-disjunction and what can it cause?
It is the failure of chromosomes or chromatids to separate properly in division; it produces gametes with extra or missing chromosomes, which can lead to serious disorders in the offspring.

Long Questions and Answers

Describe the cell cycle.

What is the cell cycle and what are its main parts?

The cell cycle is the series of events from the formation of a cell to its division into two. It has a long interphase, taking about 90 percent of the time, and a shorter M phase in which the nucleus and cytoplasm divide.

What happens in G1 and S phases?

In G1 the cell grows, makes proteins and organelles and produces enzymes for DNA replication. In the S phase every DNA molecule is copied, so each chromosome comes to have two sister chromatids.

What happens in G2 phase?

The cell continues to grow, makes proteins needed for division, checks the copied DNA for errors and repairs them, and arranges its contents ready for mitosis.

What is G0 phase?

Some cells leave the cycle and enter G0, where they work without dividing. Neurons remain in G0 permanently, liver and kidney cells can return to the cycle, and epithelial cells generally never enter G0.

Describe the phases of mitosis.

What happens in prophase?

Chromatin condenses into chromosomes made of two sister chromatids, the nuclear envelope and nucleolus disappear, and the spindle begins to form between the two centrosomes in animal cells or from cytoplasmic microtubules in plant cells.

What happens in metaphase?

Spindle fibres from both poles attach to the kinetochore of each chromosome, and the chromosomes line up at the equator to form the metaphase plate.

What happens in anaphase and telophase?

In anaphase the centromeres split and sister chromatids are pulled to opposite poles. In telophase a new nuclear envelope forms around each set, the nucleoli reappear and the chromosomes unwind.

How does cytokinesis complete mitosis?

In animal cells a contracting ring of microfilaments forms a furrow that pinches the cell in two. In plant cells Golgi vesicles fuse at the centre to form a cell plate that grows outward to divide the cell.

Explain the significance of mitosis and what happens when it goes wrong.

How does mitosis help in growth and repair?

It increases the number of cells, which makes an organism grow, and it replaces cells that die or wear out, such as skin and blood cells, with exact copies.

How does mitosis help in regeneration and asexual reproduction?

Animals such as sea stars regrow lost parts by mitosis in the remaining cells, and Hydra produces buds by repeated mitosis that grow into new individuals.

What can go wrong in mitosis?

Sister chromatids may fail to separate, giving one cell an extra chromosome and the other one

less, or chromosomes may be damaged. Mutations in the genes that control division can make cells divide without stopping.

How do tumours and cancer form?

Uncontrolled division forms a mass called a tumour. If it stays in place it is benign; if its cells invade other tissues and spread through the body (metastasis) it is malignant, which is cancer.

Describe meiosis and explain its significance.

What happens in prophase I?

Chromosomes condense and homologous chromosomes pair up in synapsis to form tetrads. Non-sister chromatids cross at chiasmata and exchange segments in crossing over; the nuclear envelope breaks down and the spindle forms.

What happens in the rest of meiosis I?

In metaphase I homologous pairs line up at the equator; in anaphase I the members of each pair move to opposite poles; in telophase I two haploid cells form, each chromosome still having two chromatids.

What happens in meiosis II?

Each haploid cell divides again like mitosis: chromosomes line up singly, sister chromatids separate in anaphase II, and four haploid daughter cells are formed.

Why is meiosis important?

It halves the chromosome number in gametes so that fertilisation restores the normal number, and crossing over plus random arrangement of chromosome pairs create genetic variety in the offspring.

Compare mitosis and meiosis.

How are mitosis and meiosis similar?

In both, DNA is copied beforehand, chromosomes condense in prophase, a spindle forms, sister chromatids separate at some stage, and cytokinesis divides the cytoplasm.

How do they differ in the number of divisions and products?

Mitosis has one division and gives two identical cells with the parent's chromosome number. Meiosis has two divisions and gives four cells with half the chromosome number.

How do they differ in pairing and variation?

Homologous chromosomes pair and cross over only in meiosis, so meiosis creates variation while mitosis produces genetically identical cells.

Where and why does each occur?

Mitosis occurs in body cells for growth, repair and asexual reproduction. Meiosis occurs in reproductive cells to form gametes in animals and spores in plants.

Multiple Choice Questions (MCQs)

In which phase is DNA replicated? (A) G1 (B) S (C) G2 (D) M
Correct answer: (B) S. DNA synthesis happens in the S phase.

A nerve cell that no longer divides is in the: (A) G1 phase (B) S phase (C) G0 phase (D) M phase
Correct answer: (C) G0 phase. Cells that leave the cycle enter G0.

Chromosomes line up at the equator during: (A) Prophase (B) Metaphase (C) Anaphase (D) Telophase
Correct answer: (B) Metaphase. Metaphase forms the metaphase plate.

Sister chromatids move to opposite poles during: (A) Prophase (B) Metaphase (C) Anaphase (D) Interphase
Correct answer: (C) Anaphase. Centromeres split and chromatids separate in anaphase.

The nuclear envelope re-forms during: (A) Telophase (B) Metaphase (C) S phase (D) Prophase
Correct answer: (A) Telophase. Nuclei rebuild in telophase.

In a dividing onion root cell, the cytoplasm divides by: (A) A cleavage furrow (B) A cell plate (C) Binary fission (D) Budding
Correct answer: (B) A cell plate. Plant cells form a cell plate from Golgi vesicles.

Bacteria divide by: (A) Mitosis (B) Meiosis (C) Binary fission (D) Budding only
Correct answer: (C) Binary fission. Prokaryotes use binary fission.

A tumour whose cells spread to other organs is: (A) Benign (B) Malignant (C) Haploid (D) Dormant
Correct answer: (B) Malignant. Malignant tumours invade and spread (metastasis).

If a body cell has 46 chromosomes, a gamete formed by meiosis has: (A) 92 (B) 46 (C) 23 (D) 12
Correct answer: (C) 23. Meiosis halves the number: 46 / 2 = 23.

Crossing over takes place during: (A) Prophase I (B) Metaphase II (C) Anaphase I (D) Telophase II
Correct answer: (A) Prophase I. It occurs between synapsed homologues in prophase I.

Homologous chromosomes separate during: (A) Anaphase of mitosis (B) Anaphase I (C) Anaphase II (D) Telophase II
Correct answer: (B) Anaphase I. Anaphase I separates the members of each pair.

How many daughter cells are formed by one complete meiosis? (A) One (B) Two (C) Four

(D) Eight
Correct answer: (C) Four. Two divisions give four cells.

Which process produces genetically identical cells? (A) Meiosis (B) Mitosis (C) Crossing over (D) Fertilisation
Correct answer: (B) Mitosis. Mitosis copies the parent's chromosome set exactly.

Hydra reproducing by budding is an example of: (A) Meiosis (B) Mitosis in asexual reproduction (C) Non-disjunction (D) Crossing over
Correct answer: (B) Mitosis in asexual reproduction. The bud forms by repeated mitosis.

Gametes with an extra chromosome usually result from: (A) Crossing over (B) Non-disjunction (C) Cytokinesis (D) Synapsis
Correct answer: (B) Non-disjunction. Failure of separation gives abnormal chromosome numbers.

Quick Revision Summary

- Cell cycle = interphase (G1 → S → G2, ~90% of time) + M phase. G0 = resting, non-dividing state.
- S phase: DNA copied, each chromosome gets two sister chromatids; number of chromosomes unchanged.
- Mitosis: PMAT. Prophase (condense, envelope breaks, spindle) → Metaphase (plate) → Anaphase (chromatids separate) → Telophase (nuclei re-form).
- Cytokinesis: furrow (animal, actin ring) vs cell plate (plant, Golgi vesicles).
- Mitosis uses: growth, replacement, regeneration, asexual reproduction. Uncontrolled division → tumour; malignant tumour spreads (metastasis).
- Meiosis: 2n → four n cells. Prophase I: synapsis, tetrads, chiasmata, crossing over. Anaphase I: homologues separate. Anaphase II: chromatids separate.
- Meiosis keeps chromosome number constant and creates variation; non-disjunction gives abnormal gametes.

Exam Tips

- Remember PMAT for the phases, and add 'I' or 'II' for meiosis.
- The commonest mistake: in anaphase I homologous chromosomes separate, not sister chromatids. Chromatids separate in anaphase II and in mitosis.
- Practise drawing a cell with 4 chromosomes (2 pairs) through each phase; it makes the difference between mitosis and meiosis obvious.
- In comparison questions, write at least five differences in a table: number of divisions, number of cells, chromosome number, pairing/crossing over, where it occurs.
- Link each error to its result: mitosis error → tumour/cancer; meiosis error (non-disjunction) → abnormal chromosome number in offspring.

Note on Facts

The textbook says the human body has about 200 trillion cells, while Chapter 1 and Chapter 3 of the same book say over 30 trillion. Current scientific estimates are about 30 to 37 trillion human cells.

The key points of the textbook say anaphase I forms 'two diploid sets'. The sets formed in anaphase I are haploid (one chromosome from each pair), as the main text of the chapter correctly states.

The textbook calls the structure formed from Golgi vesicles in a dividing plant cell the phragmoplast. Strictly, the vesicles fuse to form the cell plate; the phragmoplast is the framework of microtubules that guides them there.

Chapter 5: Tissues, Organs and Organ Systems

Chapter 5 explains how a multicellular organism is built in layers. Cells with the same job form tissues, different tissues work together in an organ, organs form organ systems, and systems together make the whole organism. Each new level has abilities that the level below it does not have on its own.

The notes use two worked examples, the leaf of a plant and the human stomach, to show how several tissues combine in one organ. They then describe the root and shoot systems of plants, the main human organ systems, and homeostasis: how the systems keep the internal environment steady.

Learning Objectives

- List the levels of organisation from atom to organism and explain emergent properties.
- Describe the tissues of a leaf and relate each to its function.
- Describe the root and shoot systems of a plant.
- Describe the tissues in the wall of the stomach and their roles.
- Name the main human organ systems and state the role of each.
- Explain homeostasis with examples of organ systems working together.

Key Concepts

5.1 Levels of Organisation

Living things are organised in a hierarchy. Atoms join to form molecules, such as water and proteins; molecules make up organelles; organelles work together in a cell, the basic unit of life. In multicellular organisms, similar cells working together form a tissue; two or more tissues combine in an organ; organs that cooperate for one main function make an organ system; and all the systems together make the organism.

At every level new characteristics appear that are not present in the parts alone. These are called emergent properties. A single heart muscle cell can contract, but only the whole heart, with muscle, nerve and connective tissues together, can pump blood around the body.

5.2 Plant Organs: The Leaf

The main organs of a flowering plant are roots, stems and leaves (vegetative organs) and flowers, fruits and seeds (reproductive organs). The leaf is the main site of photosynthesis, and its structure shows how different tissues share the work.

The upper and lower epidermis are single layers of cells that protect the leaf. They secrete a waxy cuticle that reduces water loss. The lower epidermis has many stomata, each surrounded by two guard cells that open and close the pore to control gas exchange and transpiration.

The mesophyll lies between the two epidermal layers. Palisade mesophyll, just below the upper epidermis, has tall, closely packed cells full of chloroplasts, so most photosynthesis happens here.

Free notes: freebooks.pk

Spongy mesophyll, below it, has loosely arranged cells with air spaces that allow carbon dioxide and oxygen to diffuse.

Veins run through the mesophyll. Each contains xylem, which brings water and minerals from the root, and phloem, which carries the sugar made in the leaf to other parts of the plant.

5.2 Plant Organ Systems

A flowering plant has two organ systems. The root system lies mostly underground and anchors the plant, absorbs water and minerals and, in plants such as carrot and radish, stores food.

The shoot system lies above ground and is made of the stem, leaves, buds, flowers and fruits. The stem supports the leaves and carries materials between root and leaves, the leaves make food, and the flowers, fruits and seeds carry out reproduction.

5.3 Animal Organs: The Stomach

Major human organs include the brain, heart, lungs, stomach, liver, kidneys and skin. The stomach, a muscular J-shaped bag in the upper left abdomen, stores food, churns it and begins the digestion of proteins. Its wall contains four kinds of tissue.

The innermost layer is epithelial tissue. It forms gastric glands that secrete hydrochloric acid, which kills microbes and activates enzymes, and pepsinogen, which becomes the protein-digesting enzyme pepsin. Other cells secrete mucus, which protects the stomach wall from its own acid.

Beneath the epithelium is connective tissue carrying blood vessels and nerves. Then come three layers of smooth muscle (arranged in different directions) whose contractions churn food and mix it with gastric juice. A thin outer layer of connective tissue covers and protects the stomach.

5.3 Human Organ Systems

The digestive system (mouth, oesophagus, stomach, intestines, liver, pancreas) breaks food down and absorbs nutrients. The respiratory system (nose, trachea, lungs) takes in oxygen and removes carbon dioxide. The circulatory system (heart, blood, blood vessels) transports materials. The excretory system (kidneys, ureters, bladder) removes nitrogenous wastes and balances water and salts.

The nervous system (brain, spinal cord, nerves) detects changes and coordinates rapid responses, while the endocrine system (glands such as pancreas, thyroid and adrenals) controls slower processes with hormones. The skeletal and muscular systems give support and movement, the integumentary system (skin, hair, nails) protects the body, the immune system defends against disease, and the reproductive system produces offspring.

5.4 Homeostasis

Homeostasis is the maintenance of a steady internal environment, for example a constant body temperature, blood glucose level and water content, despite changes outside. No single system can do this alone; several systems work together.

Temperature: when the body heats up, the nervous system triggers sweating from the skin and wider blood vessels near the surface, so heat is lost; in cold, muscles shiver to produce heat and

skin vessels narrow. Blood glucose: after a meal the pancreas releases insulin, which makes the liver and muscles take up glucose. Exercise: muscles need more oxygen, so the breathing rate and heart rate rise together to deliver it and remove carbon dioxide.

Important Definitions

Tissue
A group of similar cells that work together to perform a particular function.

Organ
A structure made of two or more tissues that work together to perform specific functions.

Organ system
A group of organs working together to perform a major function of the body.

Emergent property
A new characteristic that appears at a higher level of organisation and is absent in the separate parts.

Cuticle
A waxy layer on the epidermis of a leaf that reduces water loss.

Guard cells
A pair of bean-shaped cells that surround a stoma and control its opening and closing.

Stomata
Small pores, mainly in the lower epidermis of leaves, for gas exchange and transpiration.

Palisade mesophyll
Tall, tightly packed, chloroplast-rich cells below the upper epidermis where most photosynthesis occurs.

Spongy mesophyll
Loosely packed leaf cells with air spaces that allow gases to diffuse.

Xylem
Vascular tissue that carries water and minerals upward from the roots.

Phloem
Vascular tissue that carries food made in the leaves to other parts of the plant.

Root system
The underground part of a plant that anchors it, absorbs water and minerals and may store food.

Shoot system

The above-ground part of a plant: stem, leaves, buds, flowers and fruits.

Gastric glands
Glands in the stomach lining that secrete hydrochloric acid, pepsinogen and mucus.

Pepsin
A protein-digesting enzyme formed in the stomach from pepsinogen.

Smooth muscle
Involuntary muscle found in the walls of internal organs such as the stomach.

Homeostasis
The maintenance of a stable internal environment in the body.

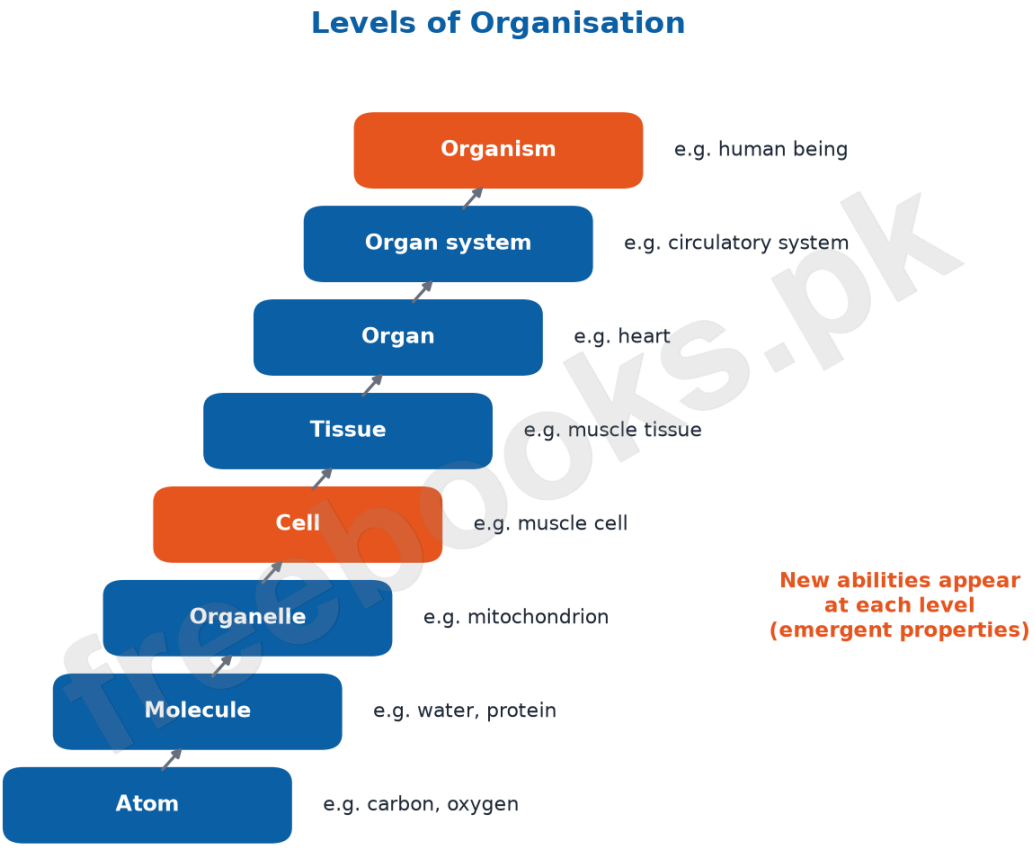
Insulin
A hormone from the pancreas that lowers blood glucose by helping cells take it up.

Key Facts at a Glance

Organ system	Main organs → main role
Digestive	Stomach, intestines, liver → digest food, absorb nutrients
Respiratory	Trachea, lungs → take in O2, remove CO2
Circulatory	Heart, blood vessels → transport materials
Excretory	Kidneys, bladder → remove wastes, balance water
Nervous	Brain, spinal cord, nerves → fast coordination
Endocrine	Pancreas, thyroid → hormones, slow control
Skeletal + Muscular	Bones, muscles → support, movement
Integumentary	Skin, hair, nails → protection
Immune	White blood cells, lymph nodes → defence
Reproductive	Testes / ovaries → produce offspring
Plant root system	Roots → anchor, absorb, store
Plant shoot system	Stem, leaves, flowers → support, food, reproduction

Diagrams

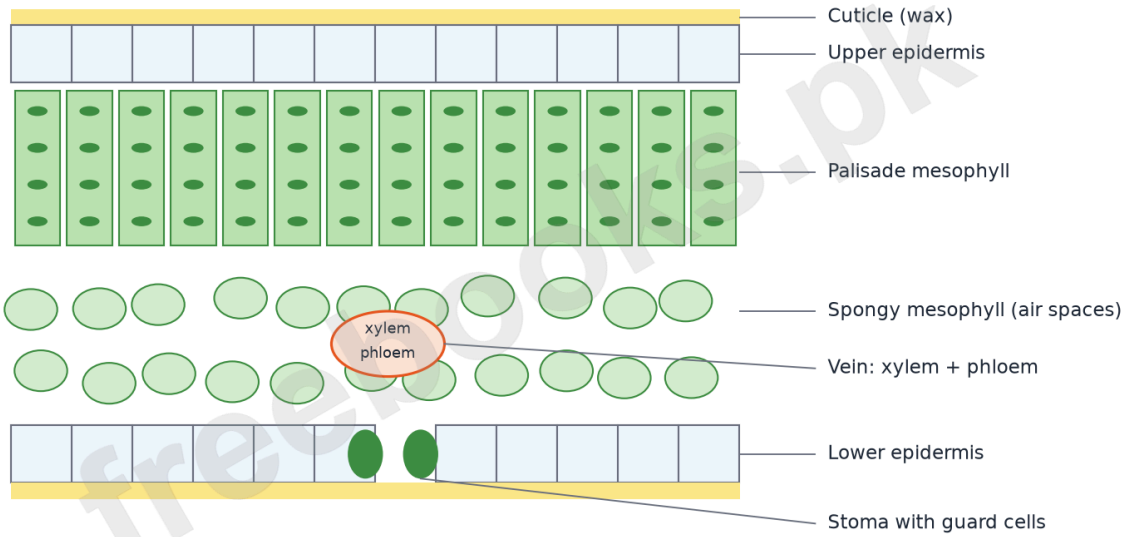
Levels of organisation: A ladder from atom to organism with a human example at each level.



Tissues of a leaf: A simplified section of a leaf showing cuticle, epidermis, palisade and spongy mesophyll, vein and stoma.

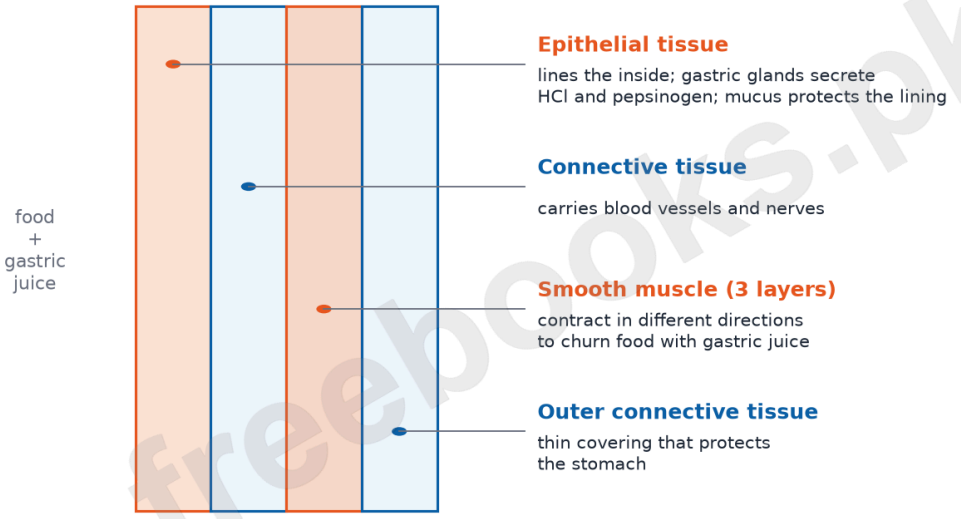
freebooks.pk

Simplified Section of a Leaf



Tissues of the stomach wall: The four layers of the stomach wall from inside to outside with the job of each.

Tissues of the Stomach Wall (inside → outside)



Short Questions and Answers

Why is a cell called the basic unit of life?

Because it is the smallest level of organisation that shows all the characteristics of life; molecules

Free notes: freebooks.pk

and organelles alone are not alive.

Give an example of an emergent property.
Individual heart muscle cells can contract, but only the whole heart, with its muscle, nerve and connective tissues, can pump blood.

Why are most stomata found in the lower epidermis?
The lower surface is shaded and cooler, so less water is lost by transpiration when the stomata are open.

Why is palisade mesophyll the main site of photosynthesis?
It lies just under the upper surface where light is strongest, and its tall cells are packed with chloroplasts.

What is the role of air spaces in spongy mesophyll?
They let carbon dioxide reach the photosynthesising cells and let oxygen and water vapour move out through the stomata.

Name the two transport tissues in a leaf vein and their roles.
Xylem brings water and minerals into the leaf; phloem carries sugars made in the leaf to the rest of the plant.

State two functions of the root system.
It anchors the plant in the soil and absorbs water and minerals; in some plants it also stores food.

Why does the stomach not digest its own wall?
Mucus secreted by epithelial cells covers the lining and protects it from acid and pepsin.

What are the two main secretions of gastric glands and their roles?
Hydrochloric acid kills microbes and provides acidic conditions; pepsinogen is converted into pepsin, which digests proteins.

What is the job of smooth muscle in the stomach wall?
Its three layers contract in different directions to churn food and mix it with gastric juice.

How does the nervous system differ from the endocrine system?
The nervous system sends rapid electrical signals through nerves, while the endocrine system releases hormones into the blood for slower, longer-lasting control.

What happens to body temperature control on a hot day?
The skin produces sweat, which cools the body as it evaporates, and blood vessels near the skin widen to release heat.

How does insulin keep blood glucose steady?
After a meal the pancreas releases insulin, which makes liver and muscle cells take up glucose,

lowering its level in the blood.

Long Questions and Answers

Explain the levels of organisation in a multicellular organism.

What are the chemical and cellular levels?

Atoms combine to form molecules such as water, glucose and proteins. Molecules build organelles such as mitochondria and ribosomes, and organelles together form a cell, the basic unit of life.

What are tissues and organs?

A tissue is a group of similar cells doing one job, such as muscle tissue. An organ, such as the stomach or a leaf, is made of two or more tissues working together.

What are organ systems and the organism?

Organs that work together for one major function form an organ system, such as the digestive system. All the organ systems together make the complete organism.

What are emergent properties?

At each level new abilities appear that the separate parts do not have; for example, the coordinated pumping of the heart emerges only when its tissues work together.

Describe the leaf as an organ made of different tissues.

What protects the leaf?

The upper and lower epidermis protect the inner tissues. They secrete a waxy cuticle that reduces water loss.

How are gases exchanged?

Stomata, mostly in the lower epidermis, allow carbon dioxide in and oxygen and water vapour out. Each stoma is controlled by two guard cells.

Where does photosynthesis take place?

Mainly in the palisade mesophyll, whose tall, tightly packed cells are full of chloroplasts. The spongy mesophyll, with its air spaces, helps gases diffuse to these cells.

How are materials transported?

Veins containing xylem bring water and minerals to the leaf, and phloem carries the sugars made in photosynthesis to other parts of the plant.

Describe the tissues of the stomach and the role of each.

What is the stomach and what does it do?

The stomach is a muscular J-shaped organ in the upper left abdomen. It stores food, churns it and starts the digestion of proteins.

What is the role of the epithelial tissue?

It lines the stomach and forms gastric glands that secrete hydrochloric acid and pepsinogen, while mucus-secreting cells protect the lining.

What are the roles of connective tissue and muscle?

Connective tissue under the epithelium carries blood vessels and nerves. Three layers of smooth muscle contract to churn food and mix it with gastric juice.

What covers the outside of the stomach?

A thin outer layer of connective tissue covers and protects the stomach and attaches it to surrounding structures.

Explain how organ systems work together to maintain homeostasis.

What is homeostasis?

It is the keeping of a stable internal environment, such as steady temperature, blood glucose and water balance, even when conditions outside change.

How is body temperature controlled?

When the body is hot, the nervous system causes sweating and widening of skin blood vessels so heat is lost. When cold, muscles shiver to produce heat and skin vessels narrow to conserve it.

How is blood glucose controlled?

After a meal blood glucose rises; the pancreas (endocrine system) releases insulin, which makes the liver and muscles take up and store glucose.

How do systems cooperate during exercise?

Working muscles need more oxygen and produce more carbon dioxide, so the respiratory system speeds up breathing and the circulatory system raises the heart rate to supply oxygen and remove wastes.

Multiple Choice Questions (MCQs)

Which sequence is correct? (A) Cell → organ → tissue → system (B) Cell → tissue → organ → organ system (C) Tissue → cell → organ → system (D) Organ → tissue → cell → system

Correct answer: (B) Cell → tissue → organ → organ system. Cells form tissues, tissues form organs, organs form systems.

Most photosynthesis in a leaf occurs in the: (A) Upper epidermis (B) Palisade mesophyll (C) Spongy mesophyll (D) Phloem

Correct answer: (B) Palisade mesophyll. Palisade cells are packed with chloroplasts.

The waxy cuticle mainly helps to: (A) Absorb light (B) Reduce water loss (C) Make food (D) Transport sugar

Correct answer: (B) Reduce water loss. Wax prevents evaporation.

Stomata are opened and closed by: (A) Palisade cells (B) Guard cells (C) Xylem vessels (D) Root hairs
Correct answer: (B) Guard cells. Guard cells control the pore.

Sugar made in the leaf is carried by: (A) Xylem (B) Phloem (C) Cuticle (D) Stomata
Correct answer: (B) Phloem. Phloem transports food.

Which of these belongs to the shoot system? (A) Root hair (B) Tap root (C) Flower (D) Root cap
Correct answer: (C) Flower. Flowers are part of the above-ground shoot.

A carrot stores food in its: (A) Leaf (B) Stem (C) Root (D) Flower
Correct answer: (C) Root. The carrot is a swollen storage root.

The stomach lining is protected from its own acid by: (A) Pepsin (B) Mucus (C) Insulin (D) Bile
Correct answer: (B) Mucus. Mucus forms a protective layer.

Pepsinogen is converted into: (A) Insulin (B) Pepsin (C) Mucus (D) Glucose
Correct answer: (B) Pepsin. Pepsin digests proteins.

Churning of food in the stomach is done by: (A) Epithelial tissue (B) Smooth muscle (C) Nervous tissue (D) Bone
Correct answer: (B) Smooth muscle. Three layers of smooth muscle churn the food.

Which system removes nitrogenous waste? (A) Respiratory (B) Excretory (C) Digestive (D) Skeletal
Correct answer: (B) Excretory. The kidneys remove urea in urine.

Hormones are produced by the: (A) Nervous system (B) Endocrine system (C) Integumentary system (D) Skeletal system
Correct answer: (B) Endocrine system. Endocrine glands secrete hormones.

Shivering on a cold day is an example of: (A) Digestion (B) Homeostasis (C) Excretion (D) Reproduction
Correct answer: (B) Homeostasis. It produces heat to keep body temperature steady.

After a meal, which hormone lowers blood glucose? (A) Adrenaline (B) Insulin (C) Thyroxine (D) Pepsin
Correct answer: (B) Insulin. Insulin promotes glucose uptake.

Quick Revision Summary

- Atom → molecule → organelle → cell → tissue → organ → organ system → organism. New abilities appear at each level (emergent properties).
- Leaf = organ: epidermis + cuticle (protection), guard cells/stomata (gas exchange), palisade (most photosynthesis), spongy (air spaces), veins (xylem water, phloem food).
- Plant organ systems: root system (anchor, absorb, store) and shoot system (stem, leaves, flowers, fruits).
- Stomach wall: epithelium (HCl, pepsinogen, mucus) → connective tissue → three smooth muscle layers → outer connective tissue.
- Human systems: digestive, respiratory, circulatory, excretory, nervous, endocrine, skeletal, muscular, integumentary, immune, reproductive.
- Homeostasis = steady internal environment; examples: sweating/shivering, insulin after a meal, faster breathing and heartbeat during exercise.

Exam Tips

- Learn the levels of organisation in order; a jumbled sequence is a favourite MCQ trap.
- When describing an organ, always name the tissue first and then link it to its job (structure → function).
- Draw and label a simple leaf section: cuticle, upper epidermis, palisade, spongy mesophyll, vein, lower epidermis, stoma, guard cells.
- For the stomach, list the layers from inside to outside; examiners often ask which layer secretes acid or mucus.
- In homeostasis answers, name the organ systems involved and what each one does, not just the change.

Note on Facts

The textbook lists the stomach wall as epithelial tissue, connective tissue, muscle and an outer connective layer. Standard anatomy names these layers mucosa, submucosa, muscularis externa (three smooth muscle layers) and serosa; the descriptions match, only the names differ.

The textbook describes six human organ systems (skeletal, digestive, respiratory, muscular, nervous and blood circulatory) as examples. These notes also mention the excretory, endocrine, integumentary, immune and reproductive systems for completeness; for exam answers, the six in the textbook are the core list.

Chapter 6: Biomolecules

Chapter 6 introduces the large molecules that living things make and depend on. Biochemistry studies the chemical processes inside organisms, while molecular biology studies the structure and work of their molecules. The four main groups of biomolecules are carbohydrates, proteins, lipids and nucleic acids.

These notes cover each group in turn: what it is made of, its main types, where it comes from in the diet and what it does in the body. The chapter ends with how DNA stores hereditary information and how that information is copied into RNA and used to build proteins.

Learning Objectives

- Define biochemistry, molecular biology, biomolecules and metabolism.
- Classify carbohydrates into monosaccharides, disaccharides and polysaccharides with examples.
- Describe the structure of an amino acid and the functions of proteins.
- Describe fatty acids, fats, oils and phospholipids and the functions of lipids.
- Describe the structure of DNA and RNA and the roles of the three types of RNA.
- Explain transcription and translation (the central dogma).

Key Concepts

6.1 Biomolecules and Metabolism

Biomolecules are the molecules made by living organisms. Most are very large and are called macromolecules. Carbohydrates mainly supply and store energy; proteins build structures and act as enzymes and hormones; lipids store energy, insulate and build membranes; DNA stores genetic information and RNA helps use that information to make proteins.

Biomolecules make up about 93 percent of the dry mass of protoplasm. Proteins form the largest share (about half), followed by nucleic acids, carbohydrates and lipids. The remaining dry mass is vitamins and inorganic substances such as salts.

All the chemical reactions of an organism together are called metabolism. Anabolism builds complex molecules from simple ones and uses energy; catabolism breaks complex molecules into simpler ones and releases energy.

6.2 Carbohydrates

Carbohydrates are compounds of carbon, hydrogen and oxygen in which hydrogen and oxygen are in the ratio 2:1, as in water. Their general formula is Cn(H2O)n, and they are also called saccharides (sugars).

Monosaccharides are single sugar units with 3 to 7 carbon atoms. They dissolve easily and taste sweet. Pentoses (5 carbons) include ribose and deoxyribose; hexoses (6 carbons, C6H12O6) include glucose, fructose and galactose.

Free notes: freebooks.pk

Disaccharides are made of two monosaccharides. They are less soluble and less sweet. Sucrose (table sugar) is glucose + fructose, maltose is glucose + glucose, and lactose (milk sugar) is found in dairy products.

Polysaccharides contain hundreds to thousands of sugar units. They are insoluble and tasteless. Starch stores food in plants; glycogen, the highly branched 'animal starch', is stored in liver and muscles; cellulose forms plant cell walls and is the most abundant carbohydrate; chitin is found in the exoskeletons of insects and crabs and in fungal cell walls.

Carbohydrates are the main source of energy: glucose is broken down in cellular respiration. Indigestible cellulose acts as dietary fibre and helps bowel movement, ribose and deoxyribose are parts of RNA and DNA, and plants move sugar around their bodies as sucrose.

6.3 Proteins

Proteins are polymers of amino acids and are the most abundant biomolecules in a cell. The number and order of amino acids differ from protein to protein; for example insulin has 51 amino acids, while haemoglobin has several hundred.

An amino acid has a central carbon atom attached to four groups: an amino group (NH2), a carboxyl group (COOH), a hydrogen atom and a side group called R. The R group is different in each amino acid: it is H in glycine and CH3 in alanine. About 20 kinds of amino acids build most proteins. Nine are essential (must come from food) and eleven are non-essential (the body can make them).

Good sources are meat, fish, eggs, milk, pulses and beans. Proteins build membranes and structures such as hair and nails (keratin) and cartilage (collagen); act as enzymes and some hormones; carry oxygen (haemoglobin); cause muscle contraction (actin and myosin); clot blood (fibrin); and defend the body (antibodies).

6.4 Lipids

Lipids are organic compounds that do not dissolve in water but dissolve in organic solvents such as alcohol and ether. Most are made of glycerol (a three-carbon alcohol with three -OH groups) and fatty acids (long hydrocarbon chains ending in a carboxyl group).

Saturated fatty acids have only single bonds between carbon atoms and are solid at room temperature. Unsaturated fatty acids have one or more double bonds and are liquid at room temperature.

Fats and oils contain one glycerol and three fatty acids. Fats (mostly animal) contain saturated fatty acids and are solid; oils (mostly plant, such as olive and corn oil) contain unsaturated fatty acids and are liquid. Phospholipids have one glycerol, two fatty acids and a phosphate group, and form the basic structure of all membranes.

Lipids are the richest store of energy and are kept in adipose tissue as a long-term reserve. They also build membranes, insulate the body and cushion organs, form steroid hormones from cholesterol, and help absorb fat-soluble vitamins A, D, E and K.

6.5 Nucleic Acids: DNA and RNA

Nucleic acids are made of nucleotides. Each nucleotide has a pentose sugar, a nitrogenous base and a phosphate group.

DNA nucleotides contain deoxyribose and one of four bases: adenine (A), thymine (T), cytosine (C) and guanine (G). In 1953 James Watson and Francis Crick proposed the double helix model: two strands of nucleotides coil around each other, held by hydrogen bonds between bases. Pairing is specific: A pairs with T (two hydrogen bonds) and C pairs with G (three hydrogen bonds).

The sequence of bases in DNA is the hereditary information. A segment of DNA that codes for one protein (polypeptide) is a gene. DNA is passed from parents to offspring, carrying this information to the next generation.

RNA is single-stranded. Its nucleotides contain ribose, and the base uracil (U) replaces thymine. Messenger RNA (mRNA) carries the copied gene to the ribosome; transfer RNA (tRNA) brings the correct amino acids; ribosomal RNA (rRNA) forms part of the ribosome itself.

6.6 How DNA and RNA Work

Transcription: the base sequence of a gene is copied into a molecule of mRNA in the nucleus. Translation: the mRNA travels to a ribosome, which reads its sequence and joins amino acids, delivered by tRNA, in the matching order to build a protein.

This one-way flow of information, DNA → RNA → protein, is called the central dogma of molecular biology.

Important Definitions

Biochemistry
The study of the chemical substances and processes in living organisms.

Molecular biology
The study of the structure and functions of biomolecules.

Biomolecules
Molecules produced by living organisms, such as carbohydrates, proteins, lipids and nucleic acids.

Metabolism
All the chemical reactions taking place in an organism.

Anabolism
Metabolism that builds complex molecules from simpler ones, using energy.

Catabolism
Metabolism that breaks complex molecules into simpler ones, releasing energy.

Monosaccharide
A single sugar unit, such as glucose or ribose.

Disaccharide
A sugar made of two monosaccharide units, such as sucrose.

Polysaccharide
A large carbohydrate made of many sugar units, such as starch or cellulose.

Glycogen
A highly branched storage polysaccharide of glucose found in animal liver and muscles.

Amino acid
The building unit of proteins, with an amino group, a carboxyl group, a hydrogen atom and an R group on a central carbon.

Essential amino acids
Amino acids the body cannot make, which must be obtained from food.

Saturated fatty acid
A fatty acid with only single bonds between its carbon atoms.

Unsaturated fatty acid
A fatty acid with one or more carbon-carbon double bonds.

Phospholipid
A lipid of glycerol, two fatty acids and a phosphate group that forms membranes.

Nucleotide
The unit of nucleic acids, made of a pentose sugar, a nitrogenous base and a phosphate.

Gene
A segment of DNA whose base sequence codes for a particular protein.

Transcription
Copying of a gene's DNA sequence into messenger RNA.

Translation
Building of a protein at the ribosome according to the sequence of mRNA.

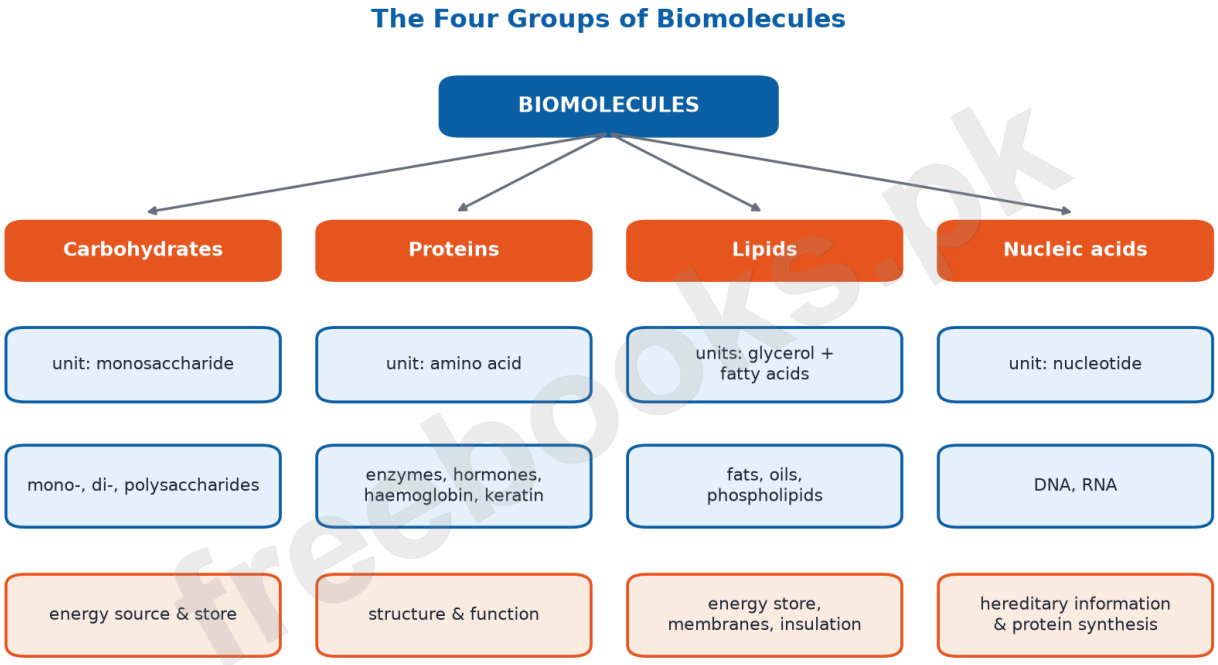
Key Facts at a Glance

Topic	Key point
Biomolecules in dry protoplasm	About 93%
Largest share of dry mass	Proteins, about 50%

Carbohydrate formula	Cn(H2O)n; H:O = 2:1
Sucrose	Glucose + fructose
Maltose	Glucose + glucose
Most abundant carbohydrate	Cellulose
Amino acids in most proteins	20 (9 essential, 11 non-essential)
Insulin	51 amino acids
Fat / oil	1 glycerol + 3 fatty acids
Phospholipid	1 glycerol + 2 fatty acids + phosphate
DNA model	Double helix, Watson and Crick, 1953
Base pairs	A=T (2 H-bonds), C≡G (3 H-bonds)
RNA differs from DNA	Ribose sugar, uracil instead of thymine, single strand
Central dogma	DNA → (transcription) → mRNA → (translation) → protein

Diagrams

The four groups of biomolecules: A classification chart showing carbohydrates, proteins, lipids and nucleic acids with their units, types and main roles.



Building units: The general structure of an amino acid and of a nucleotide, with each part

labelled.

Building Units: Amino Acid and Nucleotide

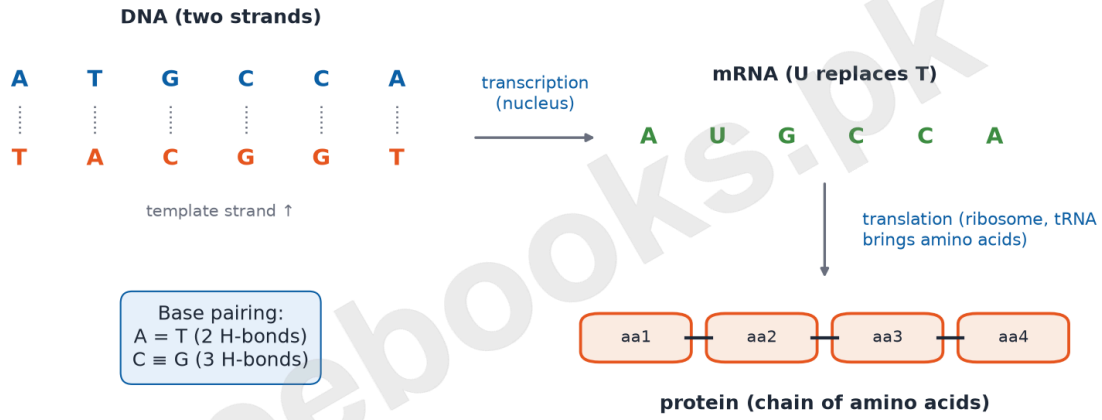


General amino acid
Amino group + carboxyl group + H + R group

Nucleotide
Phosphate + pentose sugar + nitrogenous base
DNA: deoxyribose; A, T, C, G | RNA: ribose; A, U, C, G

DNA, RNA and protein: Base pairing in a DNA segment, transcription into mRNA and translation into a chain of amino acids.

From DNA to Protein (Central Dogma)



Short Questions and Answers

Why are carbohydrates called 'hydrated carbons'?
Because hydrogen and oxygen are present in them in the same 2:1 ratio as in water, so they look like carbon combined with water: Cn(H2O)n.

freebooks.pk

How does the taste and solubility change from monosaccharides to polysaccharides?
Monosaccharides are sweet and dissolve easily, disaccharides are less sweet and less soluble, and polysaccharides are tasteless and insoluble.

Why is cellulose useful in our diet even though we cannot digest it?
It acts as dietary fibre, adding bulk to food and helping regular bowel movement.

Compare starch and glycogen.
Both store glucose. Starch is the storage form in plants and has straight and branched chains; glycogen is stored in animal liver and muscles and is much more highly branched.

What makes one amino acid different from another?
Only the side group (R group) differs; the amino group, carboxyl group and hydrogen atom are the same in all.

Why must essential amino acids be included in our diet?
Our body cannot make these nine amino acids, so without them in food it cannot build all the proteins it needs.

Name four proteins and state the job of each.
Haemoglobin carries oxygen, actin and myosin cause muscle contraction, fibrin helps blood to clot, and antibodies defend against pathogens.

Why is butter solid while olive oil is liquid at room temperature?
Butter is rich in saturated fatty acids with only single bonds, while olive oil is rich in unsaturated fatty acids whose double bonds keep it liquid.

Why are lipids a better long-term energy store than carbohydrates?
Lipids are the most energy-rich biomolecules, so a given mass of fat stores more energy; it is held in adipose tissue until needed.

If one strand of DNA reads A-T-G-C, what is the opposite strand?
T-A-C-G, because A always pairs with T and G always pairs with C.

Give three differences between DNA and RNA.
DNA is double-stranded, has deoxyribose and contains thymine; RNA is single-stranded, has ribose and contains uracil instead of thymine.

What is a gene?
A segment of DNA whose sequence of nucleotides carries the information to make one particular protein.

What is the role of tRNA in protein synthesis?
It brings specific amino acids to the ribosome so they are added in the order set by the mRNA.

Long Questions and Answers

Describe the three classes of carbohydrates.

What are monosaccharides?

Single sugar units with 3 to 7 carbons that are sweet and soluble. Examples are the pentoses ribose and deoxyribose and the hexoses glucose, fructose and galactose.

What are disaccharides?

Sugars made of two monosaccharides, less sweet and less soluble. Sucrose is glucose + fructose (from sugar cane and beet), maltose is two glucose units (in cereals), and lactose is found in milk.

What are polysaccharides?

Large, insoluble, tasteless chains of many sugar units: starch (plant store), glycogen (animal store), cellulose (plant cell walls) and chitin (insect exoskeletons, fungal walls).

What are the main roles of carbohydrates?

They are the main fuel for respiration, they store energy, cellulose gives plants support and provides dietary fibre, and pentose sugars form part of DNA and RNA.

Describe the structure and functions of proteins.

What are proteins made of?

Proteins are long chains of amino acids joined in a specific number and order. About 20 kinds of amino acids make most proteins.

What is the structure of an amino acid?

A central carbon carries an amino group (NH_2), a carboxyl group ($COOH$), a hydrogen atom and an R group. The R group differs: H in glycine, CH_3 in alanine.

What structural roles do proteins have?

They form part of every cell membrane, and proteins such as keratin and collagen make up hair, nails and cartilage.

What other functions do proteins perform?

They act as enzymes and some hormones, haemoglobin carries oxygen, actin and myosin contract muscles, fibrin clots blood and antibodies fight pathogens.

Describe lipids, their types and functions.

What are lipids made of?

Most lipids are made of glycerol, a three-carbon alcohol, joined to fatty acids, which are long hydrocarbon chains with a carboxyl group.

How do saturated and unsaturated fatty acids differ?

Saturated fatty acids have only single carbon-carbon bonds and are solid at room temperature;

unsaturated fatty acids have one or more double bonds and are liquid.

What are fats, oils and phospholipids?

Fats and oils have one glycerol and three fatty acids; fats are solid (saturated), oils are liquid (unsaturated). Phospholipids have one glycerol, two fatty acids and a phosphate and form membranes.

What are the functions of lipids?

They store energy long-term in adipose tissue, build membranes, insulate and cushion organs, form steroid hormones and help absorb vitamins A, D, E and K.

Explain the structure of DNA and how its information is used to make proteins.

What is a nucleotide?

The unit of nucleic acids, made of a pentose sugar, a nitrogenous base and a phosphate group.

What is the double helix model?

Proposed by Watson and Crick in 1953, it shows DNA as two nucleotide strands coiled around each other and joined by hydrogen bonds between their bases.

How are bases paired?

Adenine always pairs with thymine through two hydrogen bonds, and cytosine always pairs with guanine through three hydrogen bonds.

How is a protein made from a gene?

In transcription the gene's sequence is copied into mRNA. In translation the ribosome reads the mRNA and tRNA brings amino acids, which are joined in the matching order to form a protein.

Multiple Choice Questions (MCQs)

Which of these is a pentose sugar? (A) Glucose (B) Fructose (C) Ribose (D) Galactose
Correct answer: (C) Ribose. Ribose has five carbons.

Table sugar (sucrose) is made of: (A) Glucose + glucose (B) Glucose + fructose (C) Glucose + galactose (D) Fructose + fructose
Correct answer: (B) Glucose + fructose. Sucrose = glucose + fructose.

Glycogen is stored mainly in: (A) Liver and muscles (B) Bones (C) Skin (D) Plant seeds
Correct answer: (A) Liver and muscles. Glycogen is animal starch.

The cell wall of fungi is made of: (A) Cellulose (B) Starch (C) Chitin (D) Glycogen
Correct answer: (C) Chitin. Fungal walls contain chitin.

In alanine, the R group is: (A) H (B) CH3 (C) OH (D) COOH
Correct answer: (B) CH3. Glycine has H; alanine has CH3.

How many essential amino acids must come from food? (A) 5 (B) 9 (C) 11 (D) 20
Correct answer: (B) 9. Nine are essential.

The protein that helps blood to clot is: (A) Keratin (B) Fibrin (C) Myosin (D) Insulin
Correct answer: (B) Fibrin. Fibrin forms the clot.

A fatty acid with double bonds between carbons is: (A) Saturated (B) Unsaturated (C) A phospholipid (D) Glycerol
Correct answer: (B) Unsaturated. Double bonds = unsaturated.

A phospholipid contains: (A) 3 fatty acids (B) 2 fatty acids and a phosphate (C) Amino acids (D) Ribose
Correct answer: (B) 2 fatty acids and a phosphate. Glycerol + 2 fatty acids + phosphate.

Steroid hormones are made from: (A) Glucose (B) Cholesterol (C) Cellulose (D) RNA
Correct answer: (B) Cholesterol. Cholesterol is the starting lipid.

Cytosine pairs with: (A) Adenine (B) Thymine (C) Guanine (D) Uracil
Correct answer: (C) Guanine. C pairs with G by three hydrogen bonds.

Which base occurs in RNA but not in DNA? (A) Adenine (B) Uracil (C) Thymine (D) Guanine
Correct answer: (B) Uracil. Uracil replaces thymine in RNA.

Copying a gene into mRNA is called: (A) Translation (B) Replication (C) Transcription (D) Mutation
Correct answer: (C) Transcription. DNA → mRNA is transcription.

The RNA that brings amino acids to the ribosome is: (A) mRNA (B) tRNA (C) rRNA (D) DNA
Correct answer: (B) tRNA. Transfer RNA carries amino acids.

Breaking glucose to release energy is an example of: (A) Anabolism (B) Catabolism (C) Transcription (D) Photosynthesis
Correct answer: (B) Catabolism. Breakdown releasing energy is catabolism.

Quick Revision Summary

- Biomolecules: carbohydrates, proteins, lipids, nucleic acids (≈93% of dry protoplasm; proteins ≈50%).
- Metabolism = anabolism (build, uses energy) + catabolism (break, releases energy).
- Carbohydrates Cn(H2O)n: mono- (glucose, ribose), di- (sucrose, maltose, lactose), poly- (starch, glycogen, cellulose, chitin).
- Protein = chain of amino acids; amino acid = NH2 + COOH + H + R on a central carbon; 20

types, 9 essential.
- Lipids = glycerol + fatty acids; saturated (solid, single bonds) vs unsaturated (liquid, double bonds); phospholipids build membranes.
- Nucleotide = sugar + base + phosphate. DNA: double helix, deoxyribose, A-T and C-G. RNA: single strand, ribose, U instead of T; mRNA, tRNA, rRNA.
- Gene → transcription → mRNA → translation at ribosome → protein.

Exam Tips

- Make a three-column table (type, example, source/function) for carbohydrates; it answers most short questions.
- Practise drawing the general amino acid structure and the glycerol + fatty acid structure; they are common drawing questions.
- Remember the base-pair rule with 'AT 2, CG 3' (number of hydrogen bonds).
- Do not mix up transcription (DNA → mRNA, in nucleus) and translation (mRNA → protein, at ribosome).
- For 'DNA vs RNA', give at least three differences: strands, sugar, base (T vs U).

Note on Facts

The textbook names only James Watson and Francis Crick for the double helix. The 1962 Nobel Prize was shared with Maurice Wilkins, and the X-ray images made by Rosalind Franklin were key evidence for the model.

The textbook says enzymes catalyse all biochemical reactions and that all enzymes are proteins. Chapter 7 of the same book notes that some RNA molecules (ribozymes) also act as catalysts.

The textbook calls chitin a modified form of cellulose. It is better described as a cellulose-like polysaccharide: its sugar units carry nitrogen-containing groups that cellulose does not have.

Chapter 7: Enzymes

Chapter 7 is about enzymes, the biological catalysts that make the chemical reactions of life fast enough to keep an organism alive. Without enzymes most of these reactions would happen far too slowly.

The notes first separate metabolism into catabolism and anabolism, then describe the characteristics of enzymes, the two models that explain how an enzyme binds its substrate, the effect of temperature, pH and substrate concentration on enzyme activity, and the two kinds of enzyme inhibition.

Learning Objectives

- Define metabolism, catabolism and anabolism with examples.
- Define enzymes and describe their main characteristics, including cofactors.
- Explain the lock and key model and the induced fit model of enzyme action.
- Describe how temperature, pH and substrate concentration affect enzyme activity.
- Distinguish competitive and non-competitive inhibition.

Key Concepts

7.1 Metabolism

Metabolism is the total of all chemical reactions that keep an organism alive. It has two parts. Catabolism breaks large molecules into smaller ones and releases energy; examples are cellular respiration, in which glucose is broken into carbon dioxide and water, and lipolysis, in which fats are broken into fatty acids and glycerol.

Anabolism builds large molecules from smaller ones and uses energy; examples are photosynthesis, in which carbon dioxide and water form glucose using light energy, and protein synthesis, in which amino acids are joined into proteins.

7.2 Enzymes and Their Characteristics

Enzymes are biological catalysts: they speed up reactions in living things without being used up. The molecule an enzyme acts on is its substrate. Enzymes can make reactions millions of times faster than they would be without a catalyst.

Nature and shape: almost all enzymes are proteins, usually of 100 to 1,000 amino acids, folded into a three-dimensional globular shape. This shape creates the active site. A few RNA molecules, called ribozymes, also work as catalysts, mainly in ribosomes.

Specificity: each enzyme acts on a particular substrate and catalyses a particular reaction; for example, amylase breaks starch into sugars but does not act on proteins.

Location: intracellular enzymes work inside cells (such as respiratory enzymes), while extracellular enzymes are released outside cells (such as digestive enzymes secreted into the stomach cavity).

Cofactors: many enzymes need a non-protein helper. Inorganic cofactors are metal ions such as iron and magnesium. Organic cofactors are either prosthetic groups, which are tightly bound (for example biotin and the haem group), or coenzymes, which are loosely bound and may leave after the reaction (for example many vitamins and NAD, NADP).

Enzymes often work in sequences, the product of one enzyme becoming the substrate of the next. They are also used widely in industry: in baking (breaking starch into sugars), cheese making, paper making, biological detergents (proteases remove protein stains, amylases remove starch) and fermentation.

7.3 Mechanism of Enzyme Action

The active site is a pocket or groove on the enzyme surface where the substrate binds and the reaction takes place. Binding forms an enzyme-substrate complex; the substrate is changed into product(s), which are then released, leaving the enzyme free to work again.

Lock and key model (Emil Fischer, 1894): the active site has a fixed, rigid shape, and only a substrate of exactly matching shape fits into it, like a key in a lock.

Induced fit model (Daniel Koshland, 1958): the active site is flexible. When the substrate binds, the active site changes shape slightly to fit it more closely, which helps the reaction. This model explains enzyme action better because it allows for the flexibility of protein molecules.

7.4 Factors Affecting Enzyme Activity

Temperature: as temperature rises, molecules move faster and collide more, so the rate increases up to the optimum temperature, which is about 37°C for most human enzymes. Above the optimum, heat breaks the bonds that hold the enzyme's shape; the active site is destroyed and the enzyme is denatured, so the rate falls rapidly.

pH: each enzyme works best at its optimum pH. A change in pH alters the charges on amino acids in the active site, slowing or stopping the enzyme. Pepsin in the stomach works best in strongly acidic conditions (pH about 1.5 to 2), while trypsin in the small intestine works best in alkaline conditions (pH about 7 to 8).

Substrate concentration: with a fixed amount of enzyme, adding more substrate raises the rate because more active sites are occupied. Eventually all active sites are busy (saturation), and adding more substrate no longer increases the rate.

7.5 Enzyme Inhibition

An inhibitor is a substance that binds to an enzyme and reduces its activity.

Competitive inhibitors resemble the substrate and compete with it for the active site. While the inhibitor occupies the active site, the substrate cannot bind. Some antibiotics work in this way by blocking bacterial enzymes.

Non-competitive inhibitors do not resemble the substrate and bind to another part of the enzyme. This changes the overall shape of the enzyme, including the active site, so the substrate no longer fits. Heavy metals such as mercury and some anticancer drugs act like this.

Important Definitions

Metabolism
The sum of all chemical reactions in an organism.

Catabolism
Breakdown of complex molecules into simpler ones, releasing energy.

Anabolism
Building of complex molecules from simpler ones, using energy.

Enzyme
A biological catalyst, usually a protein, that speeds up a reaction without being used up.

Substrate
The molecule on which an enzyme acts.

Active site
The region of an enzyme where the substrate binds and the reaction occurs.

Enzyme-substrate complex
The temporary combination of an enzyme with its substrate.

Ribozyme
An RNA molecule that acts as a catalyst.

Cofactor
A non-protein substance needed by an enzyme to be fully active.

Prosthetic group
An organic cofactor tightly bound to an enzyme.

Coenzyme
An organic cofactor loosely bound to an enzyme, such as NAD.

Optimum temperature
The temperature at which an enzyme works fastest.

Optimum pH
The pH at which an enzyme works fastest.

Denaturation
Permanent loss of an enzyme's shape, and so its activity, due to heat or extreme pH.

Saturation

The state in which all active sites are occupied, so extra substrate does not raise the rate.

Competitive inhibitor
An inhibitor that resembles the substrate and blocks the active site.

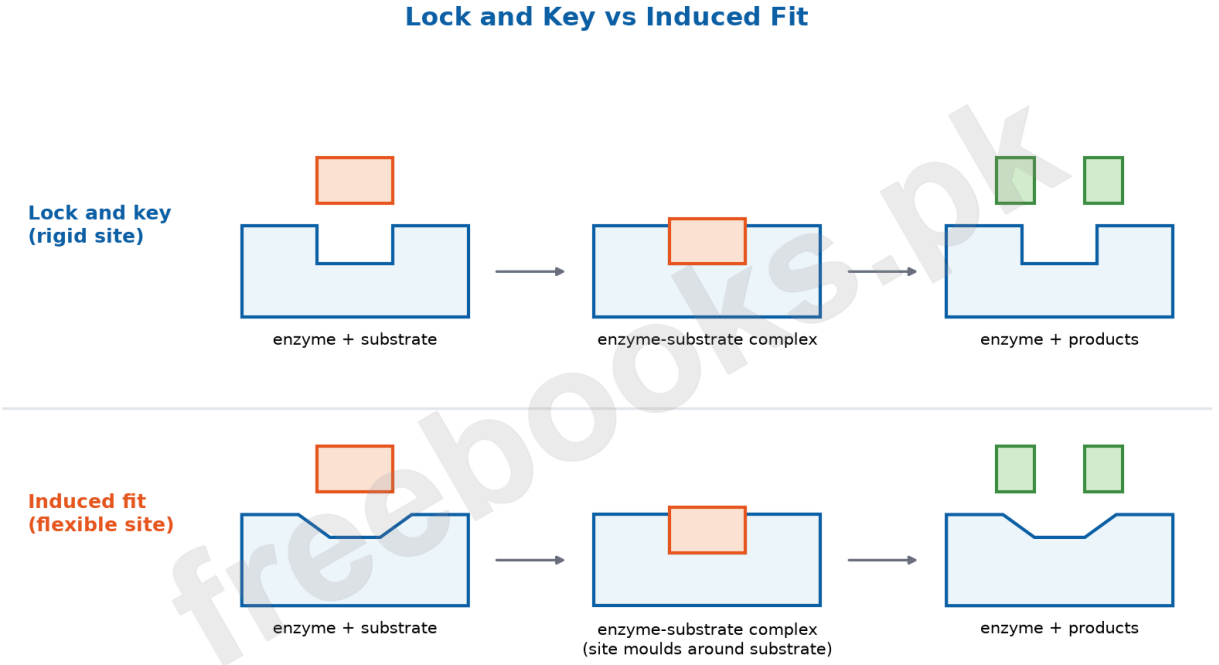
Non-competitive inhibitor
An inhibitor that binds elsewhere on the enzyme and changes the active site's shape.

Key Facts at a Glance

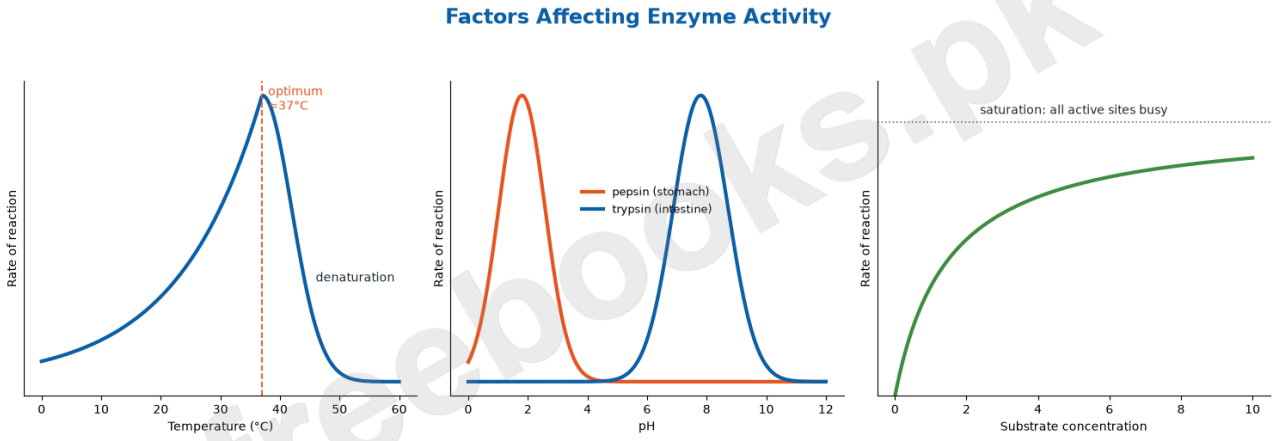
Topic	Key point
Catabolism examples	Cellular respiration, lipolysis
Anabolism examples	Photosynthesis, protein synthesis
Size of most enzymes	100–1,000 amino acids
Lock and key model	Emil Fischer, 1894 — rigid active site
Induced fit model	Daniel Koshland, 1958 — flexible active site
Optimum temperature (human)	About 37°C
Pepsin optimum pH	About 1.5–2 (acidic, stomach)
Trypsin optimum pH	About 7–8 (alkaline, small intestine)
Inorganic cofactors	Metal ions, e.g. Fe, Mg
Prosthetic groups	Tightly bound, e.g. biotin, haem
Coenzymes	Loosely bound, e.g. NAD, NADP, many vitamins
Competitive inhibition	Binds active site; e.g. some antibiotics
Non-competitive inhibition	Binds elsewhere; e.g. mercury, some anticancer drugs

Diagrams

Lock and key vs induced fit: Two simplified sequences showing the substrate fitting a rigid active site and a flexible active site moulding around the substrate.



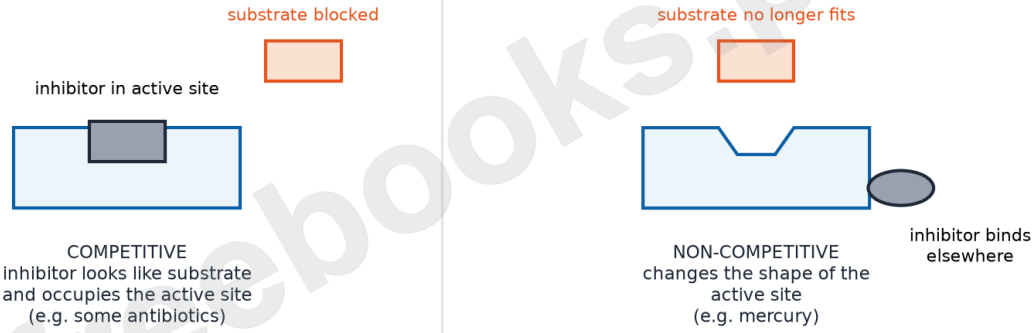
Factors affecting enzyme activity: Three graphs showing the effect of temperature, pH (pepsin and trypsin) and substrate concentration on reaction rate.



Types of enzyme inhibition: A competitive inhibitor blocking the active site and a non-competitive inhibitor binding elsewhere and changing the active site.

freebooks.pk

Types of Enzyme Inhibition



freebooks.pk

Short Questions and Answers

Why is photosynthesis called an anabolic process?
Because small molecules, carbon dioxide and water, are built into a larger molecule, glucose, and energy (light) is used in the process.

What is meant by enzyme specificity?
Each enzyme acts only on a particular substrate, because only that substrate fits the shape of its active site.

Why are enzymes said not to be used up?
After the product is released, the enzyme returns to its original form and can catalyse the same reaction again and again.

Distinguish a prosthetic group from a coenzyme.
Both are organic cofactors; a prosthetic group is tightly and permanently bound to the enzyme, while a coenzyme binds loosely and may leave after the reaction.

Give one example each of an intracellular and an extracellular enzyme.
Enzymes of cellular respiration act inside cells; pepsin is secreted into the stomach cavity and acts outside cells.

How are enzymes useful in washing powders?
Proteases digest protein stains such as blood and egg, and amylases remove starchy food residues, even at lower washing temperatures.

Why does boiling an enzyme stop its activity permanently?

High heat breaks the bonds holding the enzyme's folded shape, so the active site is destroyed (denatured) and cannot return to its original form.

Why does pepsin stop working when it reaches the small intestine?
The small intestine is alkaline, while pepsin works best at a very acidic pH; the change in pH alters its active site.

Why does the rate of reaction level off at high substrate concentration?
All the enzyme's active sites are already occupied, so extra substrate molecules have to wait; the enzyme is saturated.

How does the induced fit model improve on the lock and key model?
It treats the active site as flexible, changing shape slightly to fit the substrate, which matches the behaviour of real protein molecules.

Why is a competitive inhibitor able to block the active site?
It has a shape similar to the substrate, so it fits into the active site and keeps the real substrate out.

Where does a non-competitive inhibitor bind?
At a site other than the active site; this binding changes the enzyme's shape so the active site no longer fits the substrate.

Long Questions and Answers

Describe the characteristics of enzymes.

What is the chemical nature of enzymes?

Most enzymes are globular proteins of about 100 to 1,000 amino acids whose folded shape forms an active site. A few RNA molecules (ribozymes) also act as catalysts.

Why are enzymes specific?

The active site fits only one kind of substrate, so each enzyme catalyses one particular reaction, such as amylase breaking down starch.

What are cofactors?

Non-protein helpers needed by many enzymes: metal ions such as iron and magnesium, tightly bound prosthetic groups such as haem, and loosely bound coenzymes such as NAD.

Where do enzymes work and how are they used by humans?

Intracellular enzymes work inside cells and extracellular enzymes outside them. Industries use enzymes in baking, cheese making, paper making, detergents and fermentation.

Compare the lock and key model and the induced fit model.

What is the active site?

A pocket or groove on the enzyme surface where the substrate binds and forms an enzyme-substrate complex before being changed into product.

What does the lock and key model state?

Proposed by Emil Fischer in 1894, it states that the active site has a fixed shape into which only the exactly matching substrate fits, like a key into a lock.

What does the induced fit model state?

Proposed by Daniel Koshland in 1958, it states that the active site is flexible and changes shape when the substrate binds, gripping it more closely.

Which model is more accepted and why?

The induced fit model, because protein molecules are flexible and the change in shape helps explain how the enzyme strains bonds in the substrate to speed the reaction.

Explain the factors that affect enzyme activity.

How does temperature affect enzymes?

Rising temperature increases molecular movement and the rate, up to the optimum (about 37°C in humans). Above this the enzyme is denatured and the rate falls sharply.

How does pH affect enzymes?

Each enzyme has an optimum pH. Moving away from it changes the charges in the active site and reduces activity; pepsin works best at pH 1.5–2, trypsin at pH 7–8.

How does substrate concentration affect enzymes?

More substrate increases the rate until all active sites are occupied. At this saturation point the rate stays constant even if more substrate is added.

Why does the enzyme concentration matter at saturation?

At saturation the enzyme is the limiting factor, so only adding more enzyme, which provides more active sites, can raise the rate further.

Describe competitive and non-competitive inhibition.

What is enzyme inhibition?

The reduction of an enzyme's activity by a substance, called an inhibitor, that binds to the enzyme.

How does competitive inhibition work?

The inhibitor resembles the substrate and occupies the active site, so the substrate cannot bind. Some antibiotics block bacterial enzymes this way.

How does non-competitive inhibition work?

The inhibitor binds to another part of the enzyme and changes its overall shape, including the active site, so the substrate no longer fits. Mercury acts this way.

How can the two types be told apart?

Competitive inhibition can be reduced by adding a lot more substrate, which out-competes the inhibitor; non-competitive inhibition is not overcome by extra substrate because the active site itself has changed.

Multiple Choice Questions (MCQs)

Which of these is a catabolic process? (A) Photosynthesis (B) Protein synthesis (C) Cellular respiration (D) DNA replication
Correct answer: (C) Cellular respiration. Respiration breaks glucose down.

Most enzymes are chemically: (A) Lipids (B) Proteins (C) Carbohydrates (D) Nucleic acids
Correct answer: (B) Proteins. Enzymes are mainly globular proteins.

RNA molecules that act as catalysts are called: (A) Coenzymes (B) Ribozymes (C) Hormones (D) Antibodies
Correct answer: (B) Ribozymes. Ribozymes are catalytic RNA.

The haem group of an enzyme is an example of a: (A) Coenzyme (B) Prosthetic group (C) Substrate (D) Inhibitor
Correct answer: (B) Prosthetic group. Haem is tightly bound.

NAD is an example of a: (A) Coenzyme (B) Prosthetic group (C) Metal ion (D) Substrate
Correct answer: (A) Coenzyme. NAD binds loosely.

The lock and key model was proposed by: (A) Koshland (B) Fischer (C) Krebs (D) Calvin
Correct answer: (B) Fischer. Emil Fischer, 1894.

According to the induced fit model, the active site: (A) Is rigid (B) Changes shape when substrate binds (C) Is absent (D) Binds any molecule
Correct answer: (B) Changes shape when substrate binds. The active site is flexible.

Most human enzymes work best at: (A) 20°C (B) 37°C (C) 60°C (D) 100°C
Correct answer: (B) 37°C. Body temperature is about 37°C.

An enzyme heated to 80°C stops working because it is: (A) Saturated (B) Denatured (C) Inhibited competitively (D) Activated
Correct answer: (B) Denatured. Heat destroys its shape.

Trypsin works best in: (A) Strongly acidic medium (B) Alkaline medium (C) Neutral water only (D) Any pH
Correct answer: (B) Alkaline medium. Trypsin's optimum pH is about 7–8.

Adding more substrate does not raise the rate when: (A) Enzymes are saturated (B)

Temperature is low (C) pH is optimum (D) No inhibitor is present
Correct answer: (A) Enzymes are saturated. All active sites are occupied.

A competitive inhibitor: (A) Binds away from the active site (B) Resembles the substrate (C) Is always a metal (D) Increases enzyme activity
Correct answer: (B) Resembles the substrate. It competes for the active site.

Mercury inhibits enzymes by: (A) Competitive inhibition (B) Non-competitive inhibition (C) Acting as a coenzyme (D) Lowering temperature
Correct answer: (B) Non-competitive inhibition. It binds elsewhere and changes shape.

Protease enzymes in detergents remove: (A) Grease stains (B) Protein stains (C) Ink (D) Rust
Correct answer: (B) Protein stains. Proteases digest proteins.

Quick Revision Summary

- Metabolism = catabolism (breakdown, releases energy: respiration, lipolysis) + anabolism (build-up, uses energy: photosynthesis, protein synthesis).
- Enzymes: biological catalysts, mostly globular proteins (100–1,000 amino acids); specific; not used up; some RNA catalysts (ribozymes).
- Cofactors: metal ions (Fe, Mg); prosthetic groups (tight: biotin, haem); coenzymes (loose: NAD, NADP, vitamins).
- Active site → enzyme-substrate complex → product. Lock and key (Fischer 1894, rigid) vs induced fit (Koshland 1958, flexible).
- Temperature: rate rises to optimum (≈37°C) then denaturation. pH: optimum differs (pepsin 1.5–2, trypsin 7–8). Substrate: rate rises then saturation.
- Competitive inhibitor: substrate look-alike, blocks active site. Non-competitive: binds elsewhere, changes active site (e.g. mercury).

Exam Tips

- Learn the two models with their scientist and year: Fischer 1894 (lock and key), Koshland 1958 (induced fit).
- In graph questions, describe the curve in three parts: rising part, peak (optimum) and fall (denaturation).
- Always use the word 'denatured', not 'killed', for enzymes; enzymes are molecules, not living things.
- For inhibition, mention where the inhibitor binds (active site or elsewhere) and give one example of each.
- Practise one-line examples of catabolism and anabolism; they are frequent short questions.

Note on Facts

The textbook gives 'antibiotics' in general as examples of competitive inhibitors. Only some antibiotics act this way (sulfonamides are a classic example); others, such as penicillin, bind to their target enzyme permanently and are not simple competitive inhibitors.

The textbook's key points say enzymes are proteins, while its main text also mentions ribozymes. The accurate statement is that almost all enzymes are proteins and a few catalysts are RNA.

Chapter 8: Bioenergetics

Bioenergetics is the study of how living things obtain energy, change it from one form to another, store it and use it. Plants capture light energy in photosynthesis; all organisms release the energy stored in food by cellular respiration. In both processes energy is passed on through the cell's energy currency, ATP.

These notes explain oxidation-reduction reactions, the structure and working of ATP, the light and dark reactions of photosynthesis and the role of chlorophyll, aerobic and anaerobic respiration with the steps of glycolysis, the Krebs cycle and the electron transport chain, and finally compare respiration with photosynthesis.

Learning Objectives

- Explain oxidation-reduction reactions and their importance.
- Describe ATP as the energy currency of the cell and the ATP-ADP cycle.
- Describe photosynthesis, its equation, light and dark reactions and the role of chlorophyll.
- Describe aerobic and anaerobic respiration and the main steps of aerobic respiration.
- State the uses of respiratory energy and the importance of fermentation.
- Compare aerobic with anaerobic respiration and respiration with photosynthesis.

Key Concepts

Redox Reactions

In oxidation-reduction (redox) reactions electrons are transferred from one molecule to another. The molecule that loses electrons is oxidised; the molecule that gains them is reduced. The flow of electrons in redox reactions is what allows cells to make ATP in photosynthesis and respiration.

8.1 ATP: The Energy Currency

Adenosine triphosphate (ATP) is a nucleotide made of adenine (a nitrogenous base), ribose (a five-carbon sugar) and three phosphate groups. The bonds linking the outer phosphate groups are high-energy bonds. Fritz Lipmann proposed in 1941 that ATP is the main energy-carrying molecule of cells.

When the outermost phosphate is removed by hydrolysis, ATP becomes ADP (adenosine diphosphate) and an inorganic phosphate (Pi), releasing about 7.3 kcal of energy per mole. ADP can lose another phosphate to become AMP. Energy from the oxidation of food is used to join ADP and Pi back into ATP.

So ATP is made during energy-releasing processes and broken during energy-using processes. This continuous ATP-ADP cycle carries energy from where it is released to where it is needed.

8.2 Photosynthesis

Photosynthesis is the making of glucose from carbon dioxide and water using light energy absorbed by chlorophyll, with oxygen released as a by-product. It is carried out by plants, algae and some bacteria. Overall: $6CO_2 + 12H_2O + \text{light} \rightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O$ (carbon dioxide + water → glucose + oxygen + water).

Light reactions take place on the thylakoid membranes. Chlorophyll absorbs light and releases high-energy electrons. These pass along an electron transport chain, and the energy they release is used to make ATP. Light energy also splits water: oxygen is released, and the hydrogen ions and electrons are used to reduce NADP to NADPH.

Dark reactions (the Calvin cycle, worked out by Melvin Calvin) take place in the stroma and do not need light directly. CO_2 combines with a five-carbon compound to form an unstable six-carbon compound that splits into two three-carbon compounds. These are reduced to three-carbon sugars using ATP and NADPH. Some of these sugars make glucose; the rest regenerate the five-carbon compound, again using ATP.

8.2 Role of Chlorophyll

The thylakoid membranes contain pigments, substances that absorb visible light. Chlorophyll a is the main pigment. Chlorophyll b and carotenoids are accessory pigments that absorb other wavelengths and pass the energy on.

Chlorophyll a absorbs mainly blue and red light and reflects green, which is why leaves look green. Blue and red light therefore drive the most photosynthesis. When a pigment absorbs light, its electrons are excited and leave it; their energy is used to make ATP and NADPH.

8.3 Cellular Respiration: Aerobic and Anaerobic

Cellular respiration is the oxidation of food, mainly glucose, inside cells to release energy by breaking its C-H bonds. Aerobic respiration uses oxygen and oxidises glucose completely to carbon dioxide and water, releasing the maximum energy: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O +$ energy (ATP).

Anaerobic respiration (fermentation) occurs without oxygen. Glucose is only partly oxidised and much less energy is released. The first stage is the same as in aerobic respiration (glucose → two pyruvic acid). In alcoholic fermentation, carried out by yeast and some bacteria, pyruvic acid becomes ethanol and CO_2. In lactic acid fermentation, carried out by human skeletal muscles when oxygen is short, pyruvic acid becomes lactic acid.

Fermentation was the way the earliest organisms obtained energy when Earth's atmosphere had no oxygen, and anaerobic bacteria and fungi still depend on it. Humans use it to make yogurt and cheese (bacteria), bread and alcohol (yeast) and soy sauce (a fungus).

8.3 Mechanism of Aerobic Respiration

Glycolysis takes place in the cytoplasm and needs no oxygen. One glucose (6C) is split into two pyruvic acid (3C), giving a net gain of 2 ATP and 2 NADH.

When oxygen is present, pyruvic acid enters the mitochondrial matrix and is converted into acetyl coenzyme A, CO_2 and NADH. In the Krebs cycle (discovered by Sir Hans Krebs) acetyl CoA is completely oxidised to CO_2, producing ATP and the energy-rich carriers NADH and $FADH_2$.

In the electron transport chain on the inner mitochondrial membrane, NADH and FADH2 hand over electrons and hydrogen ions. As electrons pass along the chain they release energy that makes most of the cell's ATP. At the end, electrons and hydrogen ions combine with oxygen to form water, which is why oxygen is essential.

Respiratory energy (ATP) is used for muscle contraction, active transport, building biomolecules, DNA replication and cell division, sending nerve impulses, keeping body temperature steady and breaking down toxins.

8.4 Comparisons

Aerobic vs anaerobic: aerobic respiration needs oxygen, occurs in cytoplasm and mitochondria, gives CO2 and water and about 36 ATP per glucose (textbook figure); anaerobic respiration needs no oxygen, occurs only in the cytoplasm, gives lactic acid or ethanol + CO2 and only 2 ATP per glucose.

Photosynthesis vs respiration: photosynthesis is anabolic, stores energy in glucose, happens only in green parts with chloroplasts and only in light, and is done by plants, algae and some bacteria. Respiration is catabolic, releases the energy of food as ATP, happens in the cytoplasm and mitochondria of all living cells, at all times, in all organisms.

Important Definitions

Bioenergetics
The study of energy changes and energy flow in living organisms.

Oxidation
Loss of electrons by a molecule.

Reduction
Gain of electrons by a molecule.

ATP
Adenosine triphosphate, the nucleotide that stores and transfers energy in cells.

ADP
Adenosine diphosphate, formed when ATP loses one phosphate.

Photosynthesis
Making of glucose from CO2 and water using light energy absorbed by chlorophyll, releasing oxygen.

Light reactions
The stage of photosynthesis on thylakoids in which light energy makes ATP and NADPH and water is split.

Calvin cycle (dark reactions)
The stage in the stroma in which CO2 is reduced to sugar using ATP and NADPH.

Pigment
A substance that absorbs visible light.

Accessory pigments
Pigments such as chlorophyll b and carotenoids that help chlorophyll a capture light.

Cellular respiration
Oxidation of food inside cells to release energy as ATP.

Aerobic respiration
Complete oxidation of glucose using oxygen.

Anaerobic respiration (fermentation)
Partial breakdown of glucose without oxygen.

Glycolysis
Splitting of glucose into two pyruvic acid molecules in the cytoplasm.

Krebs cycle
A cycle of reactions in the mitochondrial matrix that completely oxidises acetyl CoA to CO2.

Electron transport chain
A series of carriers on the inner mitochondrial (or thylakoid) membrane that use electron flow to make ATP.

Anaerobes
Organisms that obtain energy by anaerobic respiration.

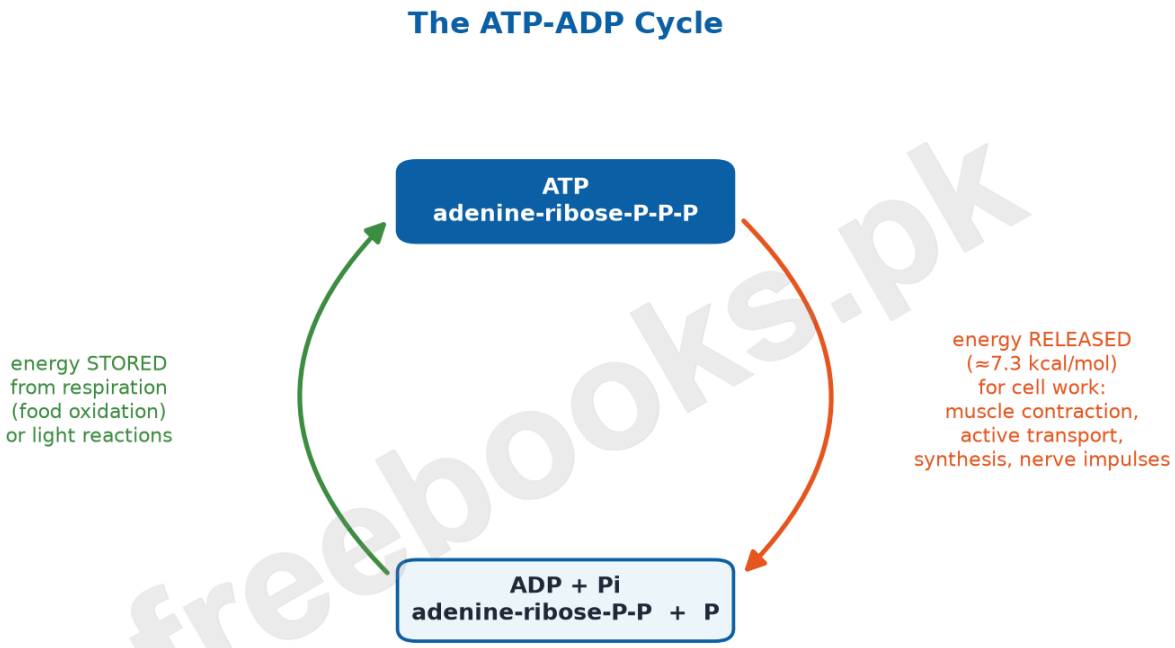
Key Facts at a Glance

Topic	Key point
ATP structure	Adenine + ribose + 3 phosphates
Energy from ATP → ADP	About 7.3 kcal per mole
ATP as energy carrier proposed by	Fritz Lipmann, 1941
Site of light reactions	Thylakoid membranes
Site of Calvin cycle	Stroma

Source of O2 in photosynthesis	Splitting of water
Main pigment	Chlorophyll a (absorbs blue and red)
Glycolysis	Cytoplasm; glucose → 2 pyruvic acid; net 2 ATP, 2 NADH
Krebs cycle	Mitochondrial matrix; Sir Hans Krebs
Electron transport chain	Inner mitochondrial membrane; O2 is final acceptor
ATP per glucose	Aerobic ≈36 (textbook) · Anaerobic 2
Alcoholic fermentation	Yeast: pyruvic acid → ethanol + CO2
Lactic acid fermentation	Muscles: pyruvic acid → lactic acid

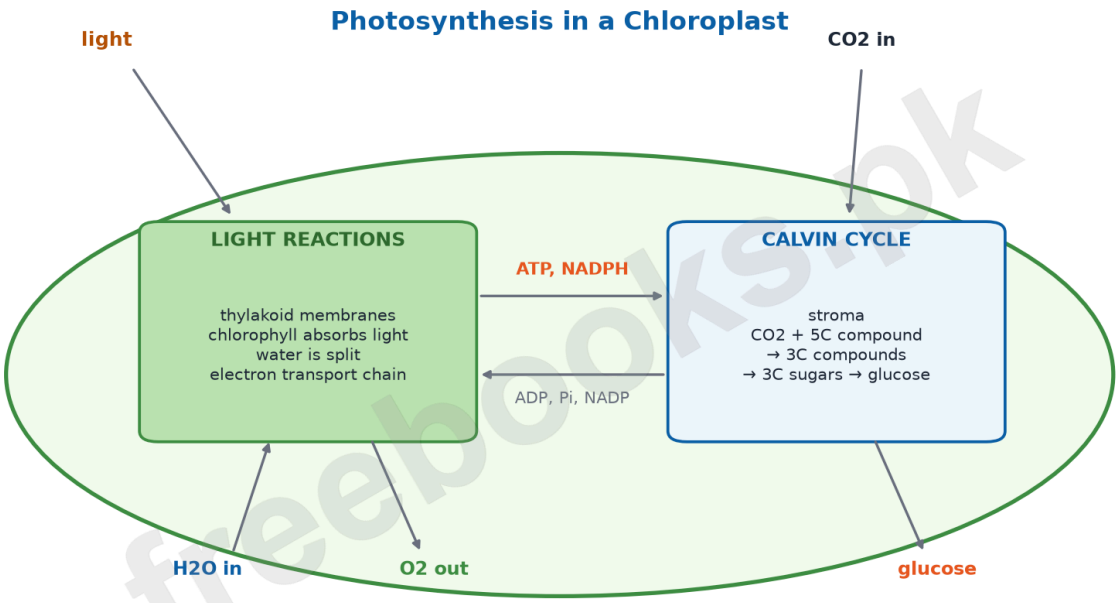
Diagrams

The ATP-ADP cycle: ATP releasing energy for cell work as it becomes ADP + Pi, and energy from food rebuilding ATP.

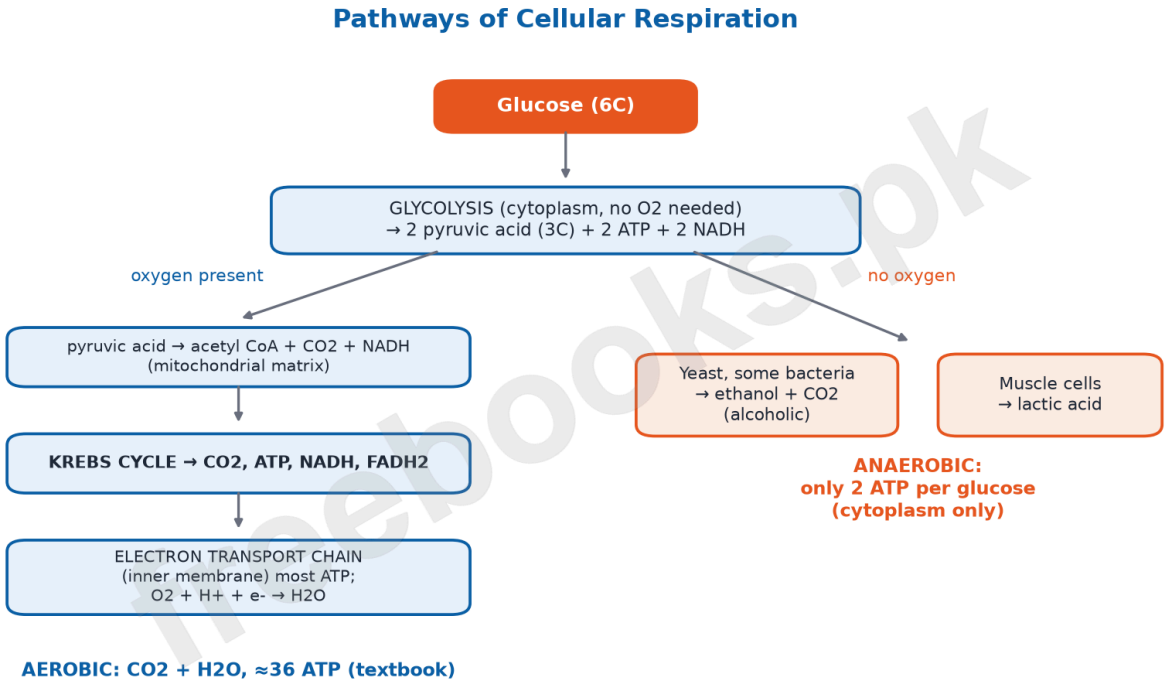


Photosynthesis in a chloroplast: Light reactions on the thylakoids producing ATP, NADPH and oxygen, feeding the Calvin cycle in the stroma that makes glucose.

freebooks.pk



Pathways of cellular respiration: Glycolysis followed either by the Krebs cycle and electron transport chain (aerobic) or by alcoholic or lactic acid fermentation (anaerobic).



Short Questions and Answers

Why is ATP called the energy currency of the cell?

Like money, it is earned in energy-releasing reactions and spent in energy-using reactions, carrying energy between them in a form every cell can use.

What happens when ATP is converted into ADP?
The outer phosphate is removed by hydrolysis, releasing about 7.3 kcal of energy per mole, which the cell uses for its work.

Where does the oxygen released in photosynthesis come from?
From water molecules, which are split by light energy during the light reactions.

Why are the dark reactions called 'dark' if they occur in daylight?
Because they do not use light directly; they use the ATP and NADPH made by the light reactions, so they are light-independent.

What are the two products of the light reactions used in the Calvin cycle?
ATP, which supplies energy, and NADPH, which supplies hydrogen (electrons) to reduce CO2 to sugar.

Why do leaves look green?
Chlorophyll absorbs mainly blue and red light and reflects green light.

What is the role of accessory pigments?
They absorb wavelengths that chlorophyll a cannot absorb well and pass the energy to it, widening the range of light used.

Why is oxygen essential for aerobic respiration?
It is the final acceptor of electrons and hydrogen ions at the end of the electron transport chain, forming water; without it the chain stops.

Why does anaerobic respiration release less energy?
Glucose is only partly broken down; many C-H bonds remain in lactic acid or ethanol, so their energy is not released.

Why do muscles ache after very hard exercise?
When oxygen supply is too low, muscles respire anaerobically and lactic acid builds up, causing fatigue and discomfort.

Name two useful products of fermentation.
Yogurt and cheese made by bacterial fermentation, and bread made by yeast fermentation.

List four uses of ATP in the human body.
Muscle contraction, active transport, synthesis of proteins and other molecules, and transmission of nerve impulses.

Long Questions and Answers

Describe ATP and its role as the energy currency of the cell.

What is the structure of ATP?

ATP is a nucleotide made of adenine, the sugar ribose and three phosphate groups; the bonds between the phosphates are high-energy bonds.

How does ATP release energy?

Hydrolysis of the outer phosphate bond gives ADP + Pi and about 7.3 kcal/mole of energy. ADP can be further broken to AMP + Pi.

How is ATP made again?

Energy released by oxidising food in respiration, or captured from light in photosynthesis, is used to join ADP and Pi back into ATP.

Why is the ATP-ADP cycle important?

It links energy-releasing and energy-using reactions, so energy can be moved quickly to wherever the cell needs it.

Describe the mechanism of photosynthesis.

What is the overall reaction?

Carbon dioxide and water, using light absorbed by chlorophyll, form glucose and oxygen: $6CO_2 + 12H_2O + \text{light} \rightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O$.

What happens in the light reactions?

On the thylakoids chlorophyll absorbs light and releases excited electrons, whose energy makes ATP through an electron transport chain. Water is split, releasing oxygen, and NADP is reduced to NADPH.

What happens in the dark reactions?

In the stroma CO_2 joins a five-carbon compound; the product splits into three-carbon compounds that are reduced to sugars using ATP and NADPH. Some sugars form glucose and the rest regenerate the five-carbon compound.

What is the role of chlorophyll?

Chlorophyll a, helped by accessory pigments, absorbs mainly blue and red light and converts it into the energy of excited electrons that drives ATP and NADPH formation.

Describe aerobic respiration and its stages.

What is glycolysis?

In the cytoplasm one glucose is broken into two pyruvic acid molecules, with a net gain of 2 ATP and 2 NADH. It needs no oxygen.

What happens in the Krebs cycle?

In the mitochondrial matrix pyruvic acid is first changed to acetyl CoA; the Krebs cycle then oxidises it fully to CO_2, forming ATP, NADH and $FADH_2$.

What happens in the electron transport chain?

On the inner mitochondrial membrane NADH and FADH2 release electrons, which pass along carriers releasing energy to make most of the ATP. Oxygen accepts the electrons and hydrogen to form water.

What is the overall equation and yield?

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + energy; the textbook gives about 36 ATP per glucose molecule.

Describe anaerobic respiration and its importance.

What is anaerobic respiration?

The breakdown of glucose without oxygen. Glycolysis gives two pyruvic acid, which is then converted to ethanol or lactic acid; only 2 ATP are gained.

What is alcoholic fermentation?

In yeast and some bacteria pyruvic acid is converted to ethanol and carbon dioxide.

What is lactic acid fermentation?

In human skeletal muscle during heavy exercise, when oxygen is short, pyruvic acid is converted to lactic acid.

Why is fermentation important?

It supplied energy to the first organisms before oxygen was present, it still powers anaerobes and oxygen-starved muscles, and it is used to make yogurt, cheese, bread and soy sauce.

Compare photosynthesis and cellular respiration.

How do they differ in type of metabolism?

Photosynthesis is anabolic and stores energy in glucose; respiration is catabolic and releases the energy of glucose as ATP.

Where do they occur?

Photosynthesis occurs only in the chloroplasts of green parts; respiration occurs in the cytoplasm and mitochondria of all living cells.

When and in which organisms?

Photosynthesis happens only in light, in plants, algae and some bacteria; respiration happens all the time in all organisms.

How are their raw materials and products related?

The products of one are the raw materials of the other: photosynthesis uses CO_2 and water and gives glucose and O_2, while respiration uses glucose and O_2 and gives CO_2 and water.

Multiple Choice Questions (MCQs)

A molecule that gains electrons is said to be: (A) Oxidised (B) Reduced (C) Hydrolysed (D)

Denatured
Correct answer: (B) Reduced. Gain of electrons = reduction.

The sugar present in ATP is: (A) Glucose (B) Deoxyribose (C) Ribose (D) Sucrose
Correct answer: (C) Ribose. ATP contains ribose.

When ATP loses one phosphate it becomes: (A) AMP (B) ADP (C) NADP (D) FAD
Correct answer: (B) ADP. ATP → ADP + Pi.

Light reactions take place in the: (A) Stroma (B) Thylakoid membranes (C) Cytoplasm (D) Matrix
Correct answer: (B) Thylakoid membranes. Pigments are in thylakoids.

The oxygen given out by plants comes from: (A) CO_2 (B) Water (C) Glucose (D) Chlorophyll
Correct answer: (B) Water. Water is split in light reactions.

The Calvin cycle uses which products of the light reactions? (A) O_2 and glucose (B) ATP and NADPH (C) CO_2 and water (D) Pyruvic acid
Correct answer: (B) ATP and NADPH. ATP and NADPH drive CO_2 reduction.

Chlorophyll a mainly absorbs: (A) Green and yellow light (B) Blue and red light (C) Only green light (D) Infrared
Correct answer: (B) Blue and red light. It reflects green.

Glycolysis takes place in the: (A) Mitochondrial matrix (B) Cytoplasm (C) Chloroplast (D) Nucleus
Correct answer: (B) Cytoplasm. Glycolysis is cytoplasmic.

The final acceptor of electrons in aerobic respiration is: (A) NAD (B) Oxygen (C) CO_2 (D) Glucose
Correct answer: (B) Oxygen. O_2 forms water at the end of the chain.

Yeast in the absence of oxygen produces: (A) Lactic acid (B) Ethanol and CO_2 (C) Water only (D) Glucose
Correct answer: (B) Ethanol and CO_2. Alcoholic fermentation.

Net ATP gained from anaerobic breakdown of one glucose is: (A) 2 (B) 4 (C) 36 (D) 38
Correct answer: (A) 2. Only glycolysis yields ATP.

The Krebs cycle occurs in the: (A) Cytoplasm (B) Mitochondrial matrix (C) Thylakoid (D) Ribosome
Correct answer: (B) Mitochondrial matrix. It is in the matrix.

Which process occurs in all living cells all the time? (A) Photosynthesis (B) Respiration

(C) Calvin cycle (D) Transpiration
Correct answer: (B) Respiration. Respiration is universal.

Making yogurt depends on: (A) Alcoholic fermentation in yeast (B) Lactic acid fermentation by bacteria (C) Photosynthesis (D) Krebs cycle
Correct answer: (B) Lactic acid fermentation by bacteria. Bacteria ferment milk sugar.

Quick Revision Summary

- Redox: oxidation = loss of electrons; reduction = gain. Electron flow powers ATP formation.
- ATP = adenine + ribose + 3 phosphates; ATP → ADP + Pi + ≈7.3 kcal/mol. ATP-ADP cycle links energy release and use.
- Photosynthesis: $6CO_2 + 12H_2O$ + light → $C_6H_{12}O_6 + 6O_2 + 6H_2O$. Light reactions (thylakoids): ATP, NADPH, O_2 from water. Calvin cycle (stroma): CO_2 → sugar using ATP + NADPH.
- Chlorophyll a = main pigment (blue, red); chlorophyll b and carotenoids = accessory pigments.
- Aerobic respiration: glycolysis (cytoplasm, 2 ATP) → Krebs cycle (matrix) → ETC (inner membrane, O_2 → H_2O); ≈36 ATP (textbook).
- Anaerobic: glycolysis → ethanol + CO_2 (yeast) or lactic acid (muscles); 2 ATP.
- Photosynthesis = anabolic, green cells, light only; respiration = catabolic, all cells, always.

Exam Tips

- Write both equations (photosynthesis and aerobic respiration) correctly balanced; they are almost always asked.
- Link each stage to its site: light reactions → thylakoid; Calvin cycle → stroma; glycolysis → cytoplasm; Krebs → matrix; ETC → inner membrane.
- In comparison questions use a table with at least five rows: type, energy, site, time, organisms.
- Remember: oxygen in photosynthesis comes from water, not from CO_2.
- Learn the two fermentation products by organism: yeast → ethanol + CO_2; muscle → lactic acid.

Note on Facts

The textbook writes the formula of lactic acid as $C_2H_6O_3$. The correct formula is $C_3H_6O_3$.

The textbook says only about 1% of the light falling on a leaf is absorbed. In fact a leaf absorbs most of the visible light that falls on it; it is only about 1% (or a few percent) of the light energy that ends up stored in sugar by photosynthesis.

The textbook gives 36 ATP per glucose in aerobic respiration. This is the traditional textbook value; current estimates are lower, about 30–32 ATP, because some energy is lost in moving materials across mitochondrial membranes. Use 36 in exams, as given in your book.

Chapter 9: Plant Physiology

Chapter 9 explains how a plant keeps itself alive without moving: how it obtains mineral nutrients, how its roots take in water and salts, how water is lost and pulled up the stem, how food is moved from leaves to the rest of the plant, and how it exchanges gases, gets rid of wastes and copes with too much or too little water.

The notes cover macronutrients and micronutrients with the special roles of nitrogen and magnesium, the internal structure of the root, transpiration and the opening and closing of stomata, the transpiration pull, the pressure flow mechanism, gaseous exchange through stomata and lenticels, plant excretion, and the adaptations of mesophytes, hydrophytes, xerophytes and halophytes.

Learning Objectives

- Classify mineral nutrients into macronutrients and micronutrients and state the roles of nitrogen and magnesium.
- Describe the structure of the root and how water and salts are absorbed.
- Describe transpiration, the opening and closing of stomata and the factors affecting transpiration.
- Explain the transport of water by transpiration pull and of food by the pressure flow mechanism.
- Describe gaseous exchange and excretion in plants.
- Explain the osmotic adjustments of mesophytes, hydrophytes, xerophytes and halophytes.

Key Concepts

9.1 Nutrition and Mineral Nutrients

Autotrophs such as plants, algae and some bacteria make their own food; heterotrophs such as animals, fungi and most bacteria obtain food from other organisms. Nutrition is the set of processes by which food is obtained or made and used for energy and growth.

Photosynthesis gives plants sugar, but to build proteins, nucleic acids and chlorophyll they also need mineral elements absorbed from the soil. Elements needed in large amounts are macronutrients; those needed in small amounts are micronutrients. The textbook lists C, H, O, N, P, K, S, Ca and Mg as macronutrients and Fe, Mo, B, Cu, Mn, Zn, Cl and Ni as micronutrients.

Some key roles: phosphorus is part of ATP and nucleic acids; potassium controls the opening and closing of stomata; calcium strengthens cell walls; sulphur is part of some proteins and vitamins; iron is needed for photosynthesis and many enzymes; molybdenum is part of the enzyme that converts nitrate.

Nitrogen is part of all proteins, enzymes, nucleic acids and chlorophyll. Roots absorb it mainly as nitrate. Lack of nitrogen slows growth and causes chlorosis, the yellowing of leaves. Carnivorous plants obtain extra nitrogen from the insects they trap.

Free notes: freebooks.pk

Magnesium is at the centre of the chlorophyll molecule and activates many enzymes. It is absorbed as Mg2+ ions. Deficiency also causes chlorosis and may lead to leaf fall. Because plants move nitrogen and magnesium from old leaves to young ones when they are scarce, yellowing appears first in the older leaves.

9.2 Transport, Root Structure and Uptake

Transport is the movement of water, minerals, food, hormones and wastes inside the body. In all land plants except mosses and liverworts, xylem carries water and salts upward and phloem carries food.

Root hairs are tiny extensions of epidermal cells that push between soil particles and give a huge surface for absorption. Root hairs take in mineral ions by active transport, using energy, because the ions are more concentrated inside than in the soil. This makes the cell sap more concentrated than soil water, so water enters by osmosis (passive transport).

From the epidermis, water passes through the cortex (a broad zone of cells), the endodermis (the innermost layer of the cortex) and the pericycle into the xylem at the centre of the root. It travels both through the cells and along cell walls and intercellular spaces. The root xylem is continuous with the xylem of the stem.

9.3 Transpiration and Stomata

Transpiration is the loss of water vapour from the aerial parts of a plant. Most occurs through stomata (stomatal transpiration); some occurs through the cuticle and through lenticels in the bark. Inside the leaf, water moves from xylem into the walls of mesophyll cells, evaporates into the air spaces and diffuses out through the stomata.

Each stoma lies between two guard cells, which are the only epidermal cells with chloroplasts. Their inner walls are thicker than the outer walls. During the day guard cells take in potassium ions by active transport and make sugar by photosynthesis; their solute concentration rises, water enters by osmosis and they become turgid. Because the thin outer walls stretch more, the cells bend apart and the stoma opens.

In the evening potassium ions leave and sugar falls, water moves out, the guard cells become flaccid and the stoma closes.

Transpiration is called a 'necessary evil': the plant loses water, but the evaporation creates the pull that lifts water and minerals up the plant and also cools the leaves. Its rate increases with higher temperature, stronger wind and larger leaf area, and decreases with higher humidity. Most stomata are on the lower leaf surface, so more water is lost from there.

9.4 Transport of Water: Transpiration Pull

Roots do not push water all the way up a tall plant. Instead, water lost from leaves by transpiration is replaced from the xylem, and this creates a pulling force, the transpiration pull, on the water in the xylem.

Water in the xylem forms a continuous column from root to leaf because water molecules attract each other (cohesion), they stick to the xylem walls (adhesion), and the xylem vessels are very narrow. When molecules leave at the top, the tension is passed down the whole column and the

column moves upward.

9.5 Translocation of Food: Pressure Flow

Food is moved in the phloem, mostly as sucrose, from sources to sinks. Sources are places that supply sugar, such as photosynthesising leaves or storage organs releasing food. Sinks are places that use or store sugar, such as growing tips, developing fruits and storage roots. Unlike xylem, phloem can carry food in either direction.

At the source, sucrose is actively loaded into the sieve tubes, with energy supplied by companion cells. The high sugar concentration draws water in from the nearby xylem by osmosis, building up pressure. At the sink, sucrose is actively unloaded and water leaves the sieve tubes, lowering the pressure. The difference in pressure pushes the sugar solution in bulk from source to sink.

9.6 Gaseous Exchange

All living plant cells respire all the time, while green cells also photosynthesise in light. During the day photosynthesis is faster than respiration, so leaves take in CO_2 and give out O_2 overall. At night only respiration occurs, so plants take in O_2 and give out CO_2.

Gases diffuse through the epidermis of young roots, stems and leaves, and especially through stomata in leaves and young stems. Woody stems are covered by bark, through which gases cannot pass, so exchange takes place through small pores in the bark called lenticels.

9.7 Excretion in Plants

Excess CO_2 at night and excess O_2 in the day are released through stomata and general surfaces. Extra water is removed mainly by transpiration (stomatal, cuticular and lenticular).

In guttation, water droplets ooze from special pores (hydathodes) at the tips or edges of leaves, usually at night or early morning when transpiration is low and water pressure in the xylem is high, as in grasses. Guttation is different from dew, which forms when water vapour in the air condenses on leaves.

Other wastes are stored as harmless crystals, kept in leaves that later fall, or released as latex (rubber plant), gums (kikar/Acacia), resins (conifers) and mucilage (lady finger).

9.8 Osmotic Adjustments

Mesophytes grow where water is moderate, such as maize, rose and tomato. They have well-developed roots, a cuticle, and close their stomata in hot dry periods.

Hydrophytes, such as water lily, grow in or near fresh water. They absorb water over their whole surface and have broad floating leaves with many stomata on the upper surface to lose excess water.

Xerophytes, such as cacti, live in deserts. They have deep roots, few stomata, a thick waxy cuticle, and some store water in succulent stems or roots.

Halophytes, such as many sea grasses and salt-marsh plants, live in salty water. They absorb salts to make their cells more concentrated than the surroundings, so they do not lose water, and they store extra salt or excrete it through salt glands.

Important Definitions

Nutrients
Substances an organism needs for energy, growth, repair and maintenance.

Macronutrients
Mineral elements needed by plants in large amounts, such as N, P, K, Ca and Mg.

Micronutrients
Mineral elements needed in small amounts, such as Fe, Zn, Cu and B.

Chlorosis
Yellowing of leaves due to lack of chlorophyll, often from N or Mg deficiency.

Root hairs
Fine extensions of root epidermal cells that absorb water and minerals.

Endodermis
The innermost layer of the root cortex.

Pericycle
A narrow layer of cells just inside the endodermis.

Transpiration
Loss of water vapour from the aerial parts of a plant.

Guard cells
Paired epidermal cells that open and close a stoma by changing turgor.

Lenticels
Small pores in bark through which gases are exchanged.

Transpiration pull
The upward pulling force on xylem water created by transpiration.

Translocation
Transport of food in the phloem.

Source
A part of the plant that supplies sugar to the phloem.

Sink
A part of the plant that uses or stores sugar.

Guttation

Loss of liquid water droplets from pores at leaf tips or margins.

Mesophyte
A plant adapted to moderate water supply.

Hydrophyte
A plant living in or near fresh water.

Xerophyte
A plant adapted to very dry conditions.

Halophyte
A plant adapted to salty habitats.

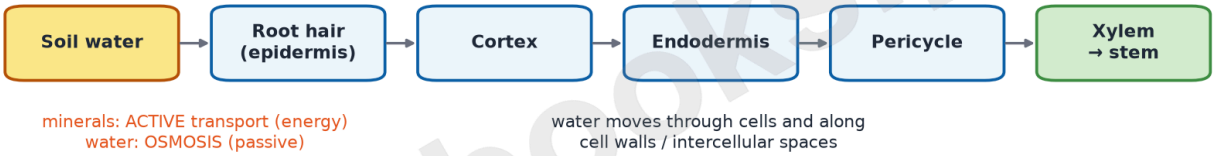
Key Facts at a Glance

Topic	Key point
Nitrogen absorbed as	Nitrate
Magnesium absorbed as	Mg2+ ions
Element at centre of chlorophyll	Magnesium
Element controlling stomata	Potassium
Deficiency symptom of N and Mg	Chlorosis, first in older leaves
Water entry into root hair	Osmosis (passive)
Mineral entry into root hair	Active transport
Path of water in root	Root hair → cortex → endodermis → pericycle → xylem
Main site of transpiration	Stomata, mostly on lower leaf surface
Water rise in xylem	Transpiration pull + cohesion + adhesion
Food transported as	Sucrose, by pressure flow, source → sink
Gas exchange in woody stems	Lenticels
Excretory products	Latex, gums, resins, mucilage, crystals

Diagrams

Water and salt uptake by the root: The path of water and minerals from soil through the root hair, cortex, endodermis and pericycle into the xylem.

Path of Water and Salts into the Root

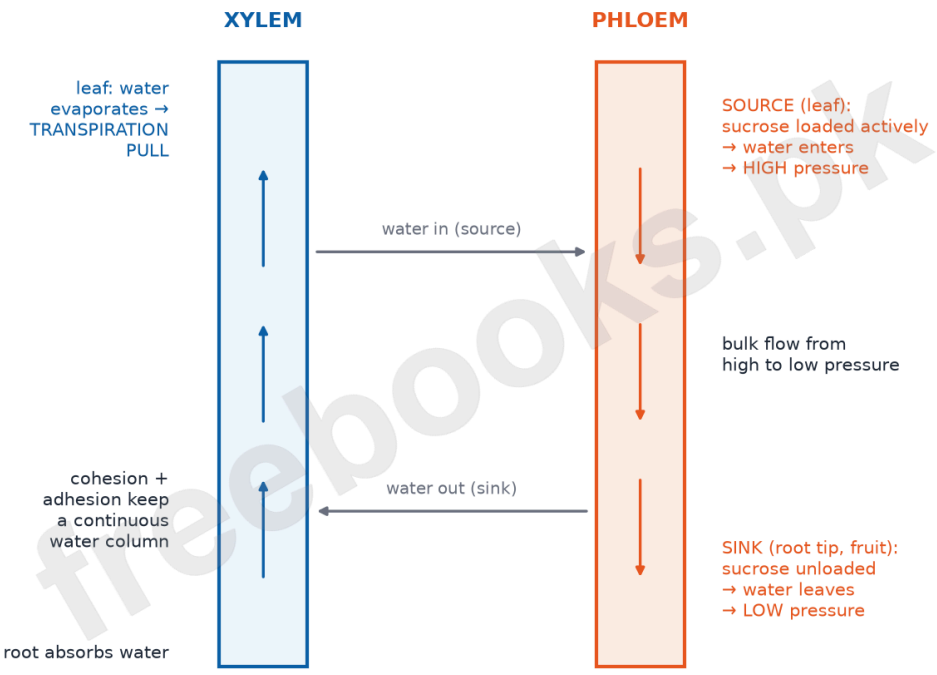


minerals: ACTIVE transport (energy)
water: OSMOSIS (passive)

water moves through cells and along cell walls / intercellular spaces

Root hairs give a very large surface area in contact with soil water.

freebooks.pk



freebooks.pk

Short Questions and Answers

Why do plants need minerals if they can make food by photosynthesis?
Photosynthesis makes only sugar; to make proteins, nucleic acids, chlorophyll and enzymes plants also need elements such as N, P, S and Mg from the soil.

Why does magnesium deficiency make leaves yellow?
Magnesium is part of chlorophyll; without it chlorophyll cannot be made and existing chlorophyll is broken down, so leaves turn yellow (chlorosis).

Why do older leaves turn yellow first when nitrogen is short?
The plant moves nitrogen from older leaves to the young growing leaves, so the old leaves lose chlorophyll first.

How do root hairs help in absorption?
They greatly increase the surface area in contact with soil water and absorb minerals actively, which then draws in water by osmosis.

Why do minerals enter root hairs by active transport?
The mineral concentration is often higher inside the root hair than in soil water, so ions must be moved against the gradient using energy.

Why is transpiration called a necessary evil?

It wastes water, but it also creates the pull that lifts water and minerals to the leaves and helps cool the plant.

How does wind increase transpiration?
It removes the humid air around the leaf, keeping the outside air drier so water vapour diffuses out faster.

Why do guard cells contain chloroplasts?
They make sugar by photosynthesis, which helps keep their solute concentration high so they stay turgid and the stoma stays open in daylight.

What makes the water column in xylem continuous?
Water molecules attract one another, stick to the xylem walls and fill very narrow tubes, so the column does not break.

Why can phloem transport food in both directions?
Food always flows from a source to a sink, and sources and sinks can be above or below one another, such as a storage root acting as a source in spring.

Why do plants give out CO2 at night?
At night there is no photosynthesis, but respiration continues, so the CO2 it produces is released.

How is guttation different from dew?
Guttation droplets come out of the plant through pores at the leaf margins; dew forms from water vapour in the air condensing on the leaf surface.

How do halophytes avoid losing water to salty surroundings?
They absorb salts to make their cells more concentrated than the surrounding water, and store or excrete extra salt through salt glands.

Long Questions and Answers

Describe mineral nutrition in plants with the roles of nitrogen and magnesium.

What are mineral nutrients?

Chemical elements absorbed from soil that plants need to make biomolecules other than sugar. They are grouped as macronutrients (needed in large amounts) and micronutrients (small amounts).

What are the roles of nitrogen?

Nitrogen is part of proteins, enzymes, nucleic acids and chlorophyll. It is absorbed as nitrate and promotes rapid growth and good seed and fruit production.

What are the roles of magnesium?

Magnesium is the central atom of chlorophyll and activates many enzymes; it helps fruit formation

and seed germination. It is absorbed as Mg^{2+}.

What happens when these elements are lacking?

Growth slows and leaves become yellow (chlorosis), starting with the older leaves; prolonged magnesium deficiency can make leaves fall.

Explain how roots absorb water and salts and pass them to the xylem.

What is the role of root hairs?

They provide a huge absorbing surface in direct contact with soil water.

How are salts and water absorbed?

Root hairs take in mineral ions by active transport using energy; the more concentrated cell sap then draws in water from the soil by osmosis.

Which tissues does water pass through?

From the epidermis water moves through the cortex, the endodermis and the pericycle to reach the xylem at the centre of the root.

What two routes does water use inside the root?

It moves through the living cells and also along the cell walls and intercellular spaces; the root xylem then carries it into the stem xylem.

Describe transpiration and the mechanism of opening and closing of stomata.

What is transpiration and where does it occur?

Loss of water vapour from aerial parts, mainly through stomata, and also through the cuticle and lenticels. Water evaporates from mesophyll cell walls into air spaces and diffuses out.

How does a stoma open?

In daylight guard cells take in K^+ ions actively and make sugar; water enters by osmosis, the guard cells become turgid and, because their inner walls are thicker, they curve apart and the pore opens.

How does a stoma close?

In the evening K^+ ions leave and sugar falls, water leaves the guard cells, they become flaccid and the inner walls come together, closing the pore.

Which factors affect transpiration?

Higher temperature, stronger wind and larger leaf area increase it; high humidity decreases it. More stomata on the lower surface mean more water is lost from there.

Explain the transport of water and food in plants.

What is transpiration pull?

Evaporation from leaves draws water out of the xylem, creating tension that pulls the whole water column upwards.

Why does the water column not break?

Cohesion between water molecules, adhesion to xylem walls and the narrowness of xylem vessels keep it continuous from root to leaf.

What happens at the source in pressure flow?

Sucrose is actively loaded into sieve tubes using energy from companion cells; water follows from the xylem by osmosis, raising pressure.

What happens at the sink?

Sucrose is actively unloaded and water leaves the sieve tubes, lowering pressure, so the sugar solution flows in bulk from source to sink.

Describe gaseous exchange, excretion and osmotic adjustment in plants.

How do plants exchange gases?

Through stomata in leaves and young stems, through the epidermis of young parts, and through lenticels in woody stems; by day CO2 is taken in and O2 given out, at night the reverse.

How do plants remove extra water?

Mainly by transpiration through stomata, cuticle and lenticels, and in some plants by guttation from pores at the leaf margins.

How are other wastes removed?

They are stored as crystals, kept in leaves that fall, or released as latex, gums, resins and mucilage.

How do different plants adjust to water conditions?

Mesophytes close stomata in dry spells; hydrophytes lose water through many upper stomata; xerophytes have deep roots, thick cuticle, few stomata and succulent organs; halophytes accumulate salts and excrete extra salt.

Multiple Choice Questions (MCQs)

Which element is the central atom of chlorophyll? (A) Iron (B) Magnesium (C) Nitrogen (D) Potassium
Correct answer: (B) Magnesium. Mg is at the centre of chlorophyll.

Which nutrient controls stomatal opening? (A) Calcium (B) Potassium (C) Zinc (D) Boron
Correct answer: (B) Potassium. K+ ions change guard cell turgor.

Which of these is a micronutrient? (A) Nitrogen (B) Phosphorus (C) Zinc (D) Calcium
Correct answer: (C) Zinc. Zinc is needed in small amounts.

Yellowing of leaves due to lack of chlorophyll is called: (A) Guttation (B) Chlorosis (C) Plasmolysis (D) Transpiration

Correct answer: (B) Chlorosis. Chlorosis.

Water enters root hairs by: (A) Active transport (B) Osmosis (C) Guttation (D) Translocation
Correct answer: (B) Osmosis. Water follows the solute gradient passively.

The innermost layer of the root cortex is the: (A) Pericycle (B) Endodermis (C) Epidermis (D) Xylem
Correct answer: (B) Endodermis. Endodermis.

Most transpiration occurs through: (A) Lenticels (B) Cuticle (C) Stomata (D) Root hairs
Correct answer: (C) Stomata. Stomatal transpiration is the main type.

Transpiration is slowest when the air is: (A) Hot and dry (B) Windy (C) Humid and still (D) Dry and windy
Correct answer: (C) Humid and still. High humidity reduces evaporation.

A stoma opens when its guard cells are: (A) Flaccid (B) Turgid (C) Dead (D) Plasmolysed
Correct answer: (B) Turgid. Turgid guard cells bend apart.

Food is translocated in the phloem mainly as: (A) Glucose (B) Starch (C) Sucrose (D) Cellulose
Correct answer: (C) Sucrose. Sucrose is the transport sugar.

Which is a sink? (A) Mature leaf in sunlight (B) Growing root tip (C) Storage root in spring (D) Photosynthesising mesophyll
Correct answer: (B) Growing root tip. Growing tips use sugar.

Gas exchange in woody stems occurs through: (A) Stomata (B) Lenticels (C) Root hairs (D) Hydathodes
Correct answer: (B) Lenticels. Bark has lenticels.

Acacia (kikar) trees excrete: (A) Latex (B) Gums (C) Resins (D) Mucilage
Correct answer: (B) Gums. Kikar produces gum.

A cactus is an example of a: (A) Hydrophyte (B) Xerophyte (C) Halophyte (D) Mesophyte
Correct answer: (B) Xerophyte. Desert plant with succulent stem.

Water lily leaves have most stomata on the: (A) Lower surface (B) Upper surface (C) Petiole (D) Roots
Correct answer: (B) Upper surface. The lower surface touches water.

Quick Revision Summary

- Macronutrients (large amounts) vs micronutrients (small amounts). N: proteins, nucleic acids, chlorophyll (as nitrate). Mg: centre of chlorophyll (as Mg^{2+}). Deficiency → chlorosis, older leaves first.
- Root hairs: minerals by active transport, water by osmosis → cortex → endodermis → pericycle → xylem.
- Transpiration: mainly via stomata; increased by heat, wind, leaf area; decreased by humidity.
- Stoma opens: K^+ in + sugar → water in → turgid guard cells curve apart. Closes: K^+ out → flaccid.
- Water rises by transpiration pull + cohesion + adhesion in narrow xylem.
- Pressure flow: sucrose loaded at source (active) → water in → high pressure → bulk flow → unloaded at sink.
- Gas exchange: stomata, epidermis, lenticels. Excretion: transpiration, guttation, latex, gums, resins, mucilage.
- Mesophytes, hydrophytes, xerophytes, halophytes: each has adaptations to its water conditions.

Exam Tips

- Learn the path of water in the root as a chain; it is often asked as a short question or flow diagram.
- In stomata answers, mention K^+ ions, osmosis, turgor and the uneven thickness of guard cell walls.
- For transport, keep it clear: xylem = water and salts, one way up; phloem = food, both ways, source to sink.
- Give one example plant for each osmotic group: maize (mesophyte), water lily (hydrophyte), cactus (xerophyte), sea grass (halophyte).
- Draw a labelled diagram of an open and closed stoma; it earns easy marks.

Note on Facts

The textbook lists carbon, hydrogen and oxygen among mineral nutrients absorbed from soil. They are essential macronutrients, but plants obtain them from carbon dioxide (air) and water, not as minerals from the soil.

The textbook's description of guttation is a little unclear. Guttation happens mainly at night or early morning, when stomata are closed and root pressure pushes water out through pores (hydathodes) at the leaf tips and edges.

The textbook's figure caption reads 'Closed stomach in the leaf of tomato'; it should read 'closed stomata'.

Chapter 10: Reproduction in Plants

Reproduction is how organisms produce new individuals of their own kind. In asexual reproduction there is no fusion of gametes, and the offspring are genetically identical to the parent. In sexual reproduction male and female gametes fuse, and the offspring show variation.

Chapter 10 first describes the main kinds of asexual reproduction (binary fission, budding, spore formation and vegetative propagation), then artificial propagation by cuttings and grafting, and finally sexual reproduction in flowering plants: alternation of generations, the parts of a flower, formation of the embryo sac and pollen grain, pollination, double fertilisation, and seed and fruit formation.

Learning Objectives

- Describe binary fission, budding, spore formation and vegetative propagation.
- Explain natural vegetative propagation by stems, suckers and leaves.
- Distinguish natural vegetative propagation from artificial propagation; describe cuttings and grafting.
- State the advantages and disadvantages of vegetative propagation.
- Explain alternation of generations and the parts of a flower.
- Describe the life cycle of a flowering plant including double fertilisation.

Key Concepts

10.1 Types of Asexual Reproduction

Binary fission: the parent cell divides into two equal daughter cells. In bacteria the DNA is copied, the copies move apart, the membrane pinches in and a new wall forms. Protists such as Amoeba and Euglena divide their nucleus and then their cytoplasm. Some flatworms such as planarians can also split into two.

Budding: a small outgrowth (bud) forms on the parent, grows and either separates or stays attached. It is common in yeast and also occurs in Hydra.

Spore formation: spores are tough, thick-walled asexual cells. Fungi such as Rhizopus (bread mould) form them in sac-like sporangia, which burst to release them. Spores survive harsh conditions and germinate when conditions improve. Some bacteria form endospores inside the cell, which can survive even if the cell dies; this is why poorly sterilised canned food can be dangerous.

Vegetative propagation: a new plant grows from a vegetative part (root, stem or leaf) of the parent. It is quicker than sexual reproduction and produces plants identical to the parent. It may be natural or artificial.

10.1 Natural Vegetative Propagation

Stolons (runners) are horizontal stems above the ground; new plants form at their nodes, as in

strawberry. Tubers are swollen underground stems with buds called 'eyes', as in potato. Rhizomes are horizontal underground stems with nodes, as in ginger and ferns.

Bulbs are very short underground stems with fleshy food-storing leaves and a bud, as in onion, tulip and lily. Corms look like bulbs but are mostly solid stem with a few thin papery leaves outside, as in dasheen (taro, arvi).

Suckers are shoots that arise from the base of the stem or from roots and later become independent, as in banana. Some leaves, as in Bryophyllum, have buds along their margins that grow into new plants when the leaf touches the soil.

10.2 Artificial Propagation

Artificial propagation means people deliberately use vegetative parts to grow new plants, for example by cuttings, grafting, layering or tissue culture. It is used to multiply plants with useful characteristics.

Cutting: a piece of stem or root is cut and planted so that it grows roots and shoots. Roses and grapevines are grown from stem cuttings and sweet potato from root cuttings.

Grafting: a bud or shoot (the scion) from one plant is joined to the rooted stem (the stock) of another plant of a related kind so that they grow as one. It combines good qualities of both, and is used for most commercial fruit trees such as plum, almond and cherry.

Advantages: many identical plants are produced quickly, and desirable qualities such as good fruit are kept. Disadvantage: all the plants are genetically the same, so a single disease or change in environment can damage all of them.

10.3 Alternation of Generations

Plants alternate between two generations. The diploid sporophyte produces haploid spores by meiosis. A spore grows into a haploid gametophyte, which produces gametes by mitosis. Gametes fuse to form a diploid zygote, which grows into the next sporophyte.

In a flowering plant the plant we see is the sporophyte; the gametophytes are tiny and live inside the flower: the pollen grain (male) and the embryo sac (female).

10.3 Parts of a Flower

The flower sits on the receptacle, the swollen end of the flower stalk. Its parts are in four whorls. The calyx (sepals) is the outermost whorl and protects the bud. The corolla (petals), often brightly coloured, attracts pollinators.

The androecium is the male whorl of stamens; each stamen has an anther, containing pollen sacs, on a stalk called the filament. The gynoecium is the female whorl of carpels; each carpel has an ovary containing ovules, a stalk called the style, and a stigma at the tip that receives pollen. One or more fused carpels form a pistil.

10.3 Life Cycle of a Flowering Plant

Female gametophyte: in the ovule, a diploid megaspore mother cell undergoes meiosis to give four haploid megaspores, of which only one survives. Its nucleus divides by mitosis to give eight nuclei.

Two of these (polar nuclei) fuse to form the fusion nucleus, and one becomes the egg. The resulting seven-celled structure is the embryo sac.

Male gametophyte: in the anther, each microspore mother cell undergoes meiosis to form four haploid microspores. Each microspore divides by mitosis into a two-celled pollen grain with a tube cell and a generative cell; the generative cell later forms two sperms.

Pollination is the transfer of pollen from an anther to a stigma. In self-pollination pollen reaches the stigma of the same flower or another flower on the same plant; in cross-pollination it reaches a flower on a different plant of the same species.

Double fertilisation: on the stigma, the tube cell grows a pollen tube down the style to the ovule, entering through the micropyle. One sperm fuses with the egg to form a diploid zygote (which becomes the embryo); the other fuses with the fusion nucleus to form a triploid nucleus (which becomes the endosperm, the food store). This double fusion is unique to flowering plants.

After fertilisation the ovule becomes the seed and the ovary becomes the fruit. Seeds are dispersed and, in suitable conditions, the embryo grows into a new sporophyte. In parthenocarpy the ovary forms a fruit without fertilisation, giving seedless fruits such as banana and seedless grapes.

Important Definitions

Asexual reproduction
Reproduction without fusion of gametes, giving offspring identical to the parent.

Sexual reproduction
Reproduction involving fusion of male and female gametes.

Binary fission
Division of a parent cell into two equal daughter cells.

Budding
Formation of a new individual from an outgrowth of the parent.

Spore
A thick-walled asexual reproductive cell that can survive harsh conditions.

Endospore
A resistant spore formed inside a bacterial cell.

Vegetative propagation
Production of a new plant from a root, stem or leaf of the parent.

Stolon (runner)
A horizontal stem growing above ground that forms new plants at its nodes.

Tuber

A swollen underground stem with buds (eyes), as in potato.

Rhizome
A horizontal underground stem with nodes, as in ginger.

Bulb
A short underground stem with fleshy leaves, as in onion.

Corm
A short, solid underground stem with a few papery leaves, as in dasheen.

Grafting
Joining a part of one plant onto another so they grow as one plant.

Alternation of generations
Alternation of a diploid sporophyte and a haploid gametophyte in a plant's life cycle.

Pollination
Transfer of pollen from an anther to a stigma.

Double fertilisation
Fusion of one sperm with the egg and the other with the fusion nucleus in flowering plants.

Endosperm
Triploid food-storing tissue of the seed.

Parthenocarpy
Development of fruit without fertilisation, giving seedless fruit.

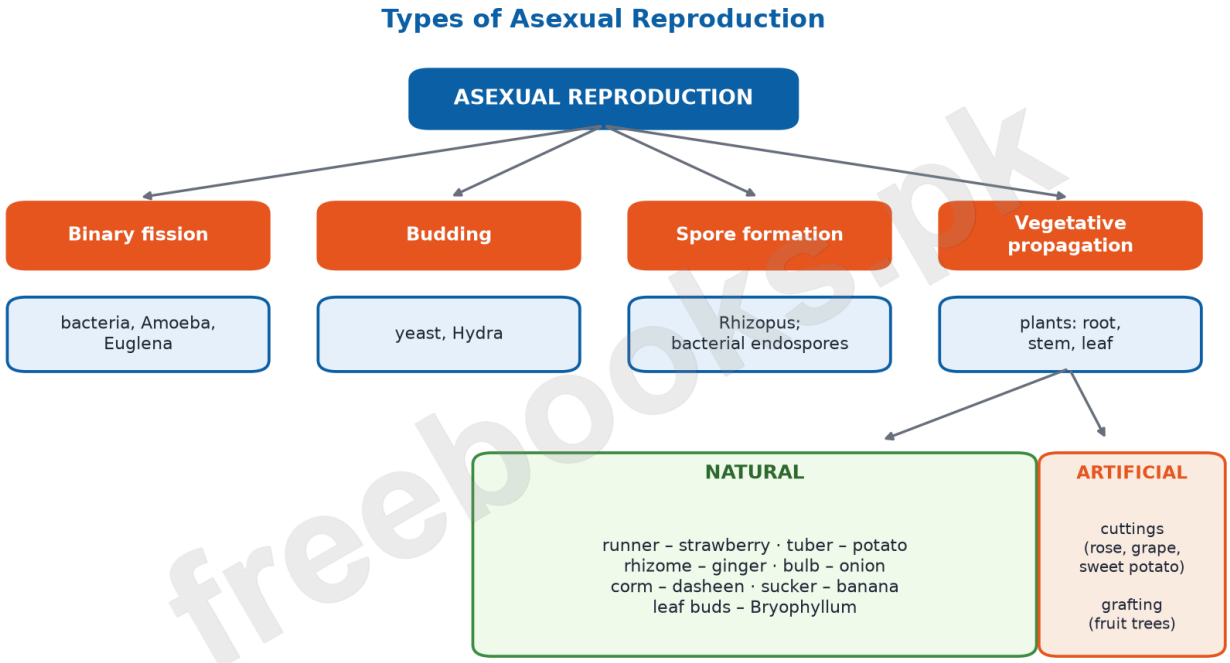
Key Facts at a Glance

Method / structure	Example
Binary fission	Bacteria, Amoeba, Euglena
Budding	Yeast, Hydra
Spores in sporangia	Rhizopus (bread mould)
Stolon / runner	Strawberry
Tuber	Potato
Rhizome	Ginger, ferns
Bulb	Onion, tulip, lily

Corm	Dasheen (arvi)
Sucker	Banana
Leaf buds	Bryophyllum
Stem cutting / root cutting	Rose, grapevine / sweet potato
Grafting	Plum, almond, cherry
Parthenocarpy	Banana, seedless grapes
Ploidy after double fertilisation	Zygote 2n · Endosperm 3n

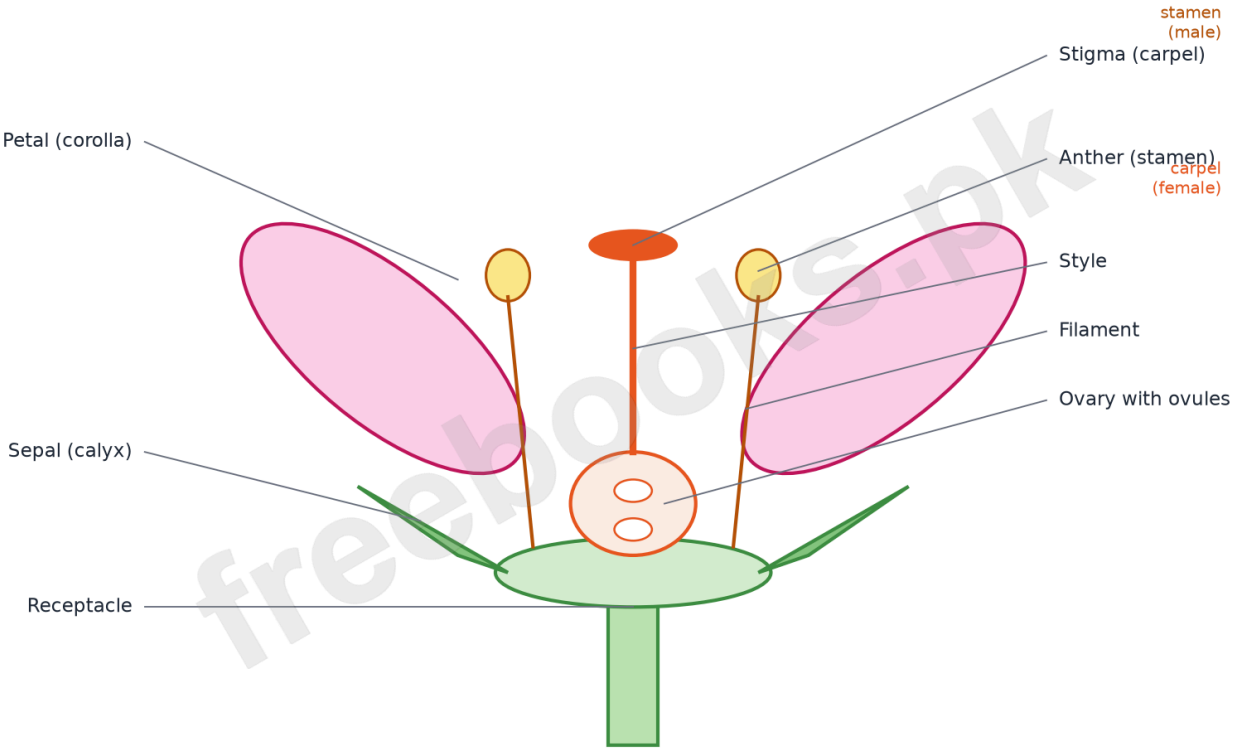
Diagrams

Types of asexual reproduction: A chart of binary fission, budding, spore formation and vegetative propagation with examples of natural and artificial methods.



Parts of a flower: A simplified section of a flower labelling sepal, petal, stamen (anther, filament) and carpel (stigma, style, ovary, ovule).

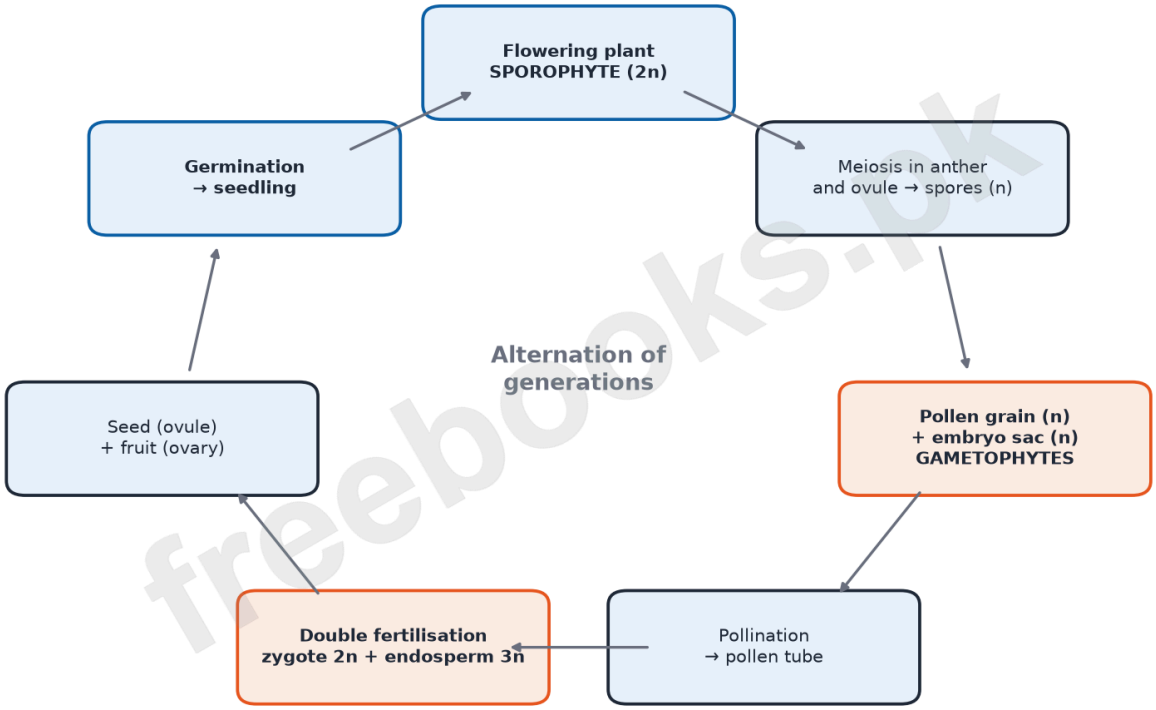
Parts of a Flower (simplified section)



freebooks.pk

Life cycle of a flowering plant: The cycle from sporophyte to spores, pollen grain and embryo sac, pollination, double fertilisation, seed and new plant.

Life Cycle of a Flowering Plant



Short Questions and Answers

Why are offspring of asexual reproduction identical to their parent?
Only one parent is involved and new cells are formed by mitosis, so the genetic material is copied exactly.

How does binary fission in bacteria differ from that in Amoeba?
Bacteria have no nucleus, so the DNA is copied and the cell pinches in and builds a new wall; Amoeba first divides its nucleus and then its cytoplasm.

Why can spores survive harsh conditions?
They have thick, tough walls that protect them from drying and heat until conditions become favourable.

Why are improperly canned foods risky?
Bacterial endospores can survive poor sterilisation, germinate inside the can and produce toxins.

How is a potato tuber recognised as a stem and not a root?
It has nodes with buds ('eyes') that grow into shoots, which is a feature of stems.

freebooks.pk

Distinguish a bulb from a corm.
A bulb is a short stem surrounded by fleshy food-storing leaves (onion); a corm is mostly solid stem with only a few thin, dry leaves (dasheen).

How does Bryophyllum reproduce vegetatively?
Buds along its leaf margins grow into small plants when the leaf falls on moist soil.

Why do farmers graft fruit trees?
To combine a good-quality fruiting variety with a strong, disease-resistant root system and to get identical high-quality trees quickly.

Give one disadvantage of vegetative propagation.
All the offspring are genetically identical, so a disease or environmental change that harms one plant can harm all of them.

What are the two gametophytes of a flowering plant?
The male gametophyte is the pollen grain and the female gametophyte is the embryo sac inside the ovule.

Name the parts of a carpel and the job of each.
The stigma receives pollen, the style connects the stigma to the ovary, and the ovary contains ovules.

Why is fertilisation in flowering plants called double?
Two fusions occur: one sperm with the egg to form the zygote and the other with the fusion nucleus to form the endosperm nucleus.

What do the ovule and ovary become after fertilisation?
The ovule becomes the seed and the ovary becomes the fruit.

Long Questions and Answers

Describe the main types of asexual reproduction.

What is binary fission?

The division of one cell into two equal daughter cells. Bacteria copy their DNA, pinch in and form a new wall; protists such as Amoeba divide their nucleus and then their cytoplasm.

What is budding?

A small outgrowth develops on the parent, grows and may separate to live independently, as in yeast and Hydra.

What is spore formation?

Fungi such as Rhizopus produce thick-walled spores inside sporangia; the spores are released,

survive bad conditions and germinate later. Some bacteria form endospores.

What is vegetative propagation?

New plants grow from roots, stems or leaves of the parent, either naturally or with human help; the offspring are identical to the parent.

Explain natural vegetative propagation with examples.

How do above-ground stems help?

Stolons (runners) grow along the soil surface and new plants form at their nodes, as in strawberry.

How do underground stems help?

Tubers (potato) have buds called eyes; rhizomes (ginger) have nodes along a horizontal stem; bulbs (onion) and corms (dasheen) store food and produce new shoots.

What are suckers?

Shoots from the base of the stem or roots that grow roots of their own and become new plants, as in banana.

How can leaves produce new plants?

In Bryophyllum, buds on the leaf margins grow into new plantlets when the leaf touches moist soil.

Describe artificial propagation and its advantages and disadvantages.

What is artificial propagation?

The deliberate use of vegetative parts by people to raise new plants, using methods such as cuttings, grafting, layering and tissue culture.

How are cuttings used?

A piece of stem or root is planted and develops roots and shoots: roses and grapevines from stem cuttings, sweet potato from root cuttings.

What is grafting?

A bud or shoot of one plant is joined onto the rooted stem of a related plant so they grow as one, combining useful qualities; used for plum, almond and cherry trees.

What are the advantages and disadvantages?

Many plants with the same good qualities are produced quickly, but their genetic sameness means they are all equally sensitive to a disease or environmental change.

Describe the life cycle of a flowering plant.

How is the female gametophyte formed?

A megaspore mother cell in the ovule undergoes meiosis; one of the four megaspores survives and its nucleus divides by mitosis into eight. Two fuse as the fusion nucleus and one forms the egg, giving the embryo sac.

How is the male gametophyte formed?

Microspore mother cells in the anther undergo meiosis to form microspores; each divides by mitosis into a pollen grain with a tube cell and a generative cell, which forms two sperms.

How do pollination and fertilisation take place?

Pollen is transferred to the stigma by self- or cross-pollination. A pollen tube grows to the ovule; one sperm fuses with the egg (zygote, 2n) and the other with the fusion nucleus (endosperm nucleus, 3n): double fertilisation.

What happens after fertilisation?

The zygote becomes the embryo, the triploid nucleus becomes endosperm, the ovule becomes the seed and the ovary becomes the fruit; seeds germinate into new sporophytes.

Multiple Choice Questions (MCQs)

The usual method of reproduction in bacteria is: (A) Budding (B) Binary fission (C) Spore formation only (D) Grafting
Correct answer: (B) Binary fission. Bacteria divide into two.

Yeast commonly reproduces by: (A) Binary fission (B) Budding (C) Rhizome (D) Grafting
Correct answer: (B) Budding. A bud grows out of the parent cell.

Rhizopus produces spores in: (A) Anthers (B) Sporangia (C) Ovaries (D) Tubers
Correct answer: (B) Sporangia. Spores form in sporangia.

Strawberry spreads naturally by: (A) Tubers (B) Bulbs (C) Runners (stolons) (D) Suckers
Correct answer: (C) Runners (stolons). Runners form new plants at nodes.

The 'eyes' of a potato are: (A) Roots (B) Buds (C) Seeds (D) Spores
Correct answer: (B) Buds. They are buds on the stem tuber.

Onion is an example of a: (A) Corm (B) Bulb (C) Rhizome (D) Runner
Correct answer: (B) Bulb. Fleshy leaves around a short stem.

Banana plants commonly produce new plants by: (A) Suckers (B) Runners (C) Spores (D) Leaf buds
Correct answer: (A) Suckers. Suckers arise from the base.

Bryophyllum reproduces vegetatively by: (A) Root cuttings (B) Buds on leaf margins (C) Bulbs (D) Grafting
Correct answer: (B) Buds on leaf margins. Leaf-margin buds.

Sweet potato is propagated by: (A) Stem cuttings (B) Root cuttings (C) Grafting (D) Seeds only
Correct answer: (B) Root cuttings. Its swollen roots sprout.

In flowering plants the sporophyte is: (A) The pollen grain (B) The embryo sac (C) The main plant (D) The spore
Correct answer: (C) The main plant. The visible plant is the sporophyte.

Pollen is produced in the: (A) Ovary (B) Stigma (C) Anther (D) Sepal
Correct answer: (C) Anther. Anthers contain pollen sacs.

The part of a carpel that receives pollen is the: (A) Style (B) Stigma (C) Ovary (D) Filament
Correct answer: (B) Stigma. Stigma.

Endosperm nucleus is: (A) Haploid (B) Diploid (C) Triploid (D) Tetraploid
Correct answer: (C) Triploid. Sperm (n) + fusion nucleus (2n) = 3n.

After fertilisation the ovary becomes the: (A) Seed (B) Fruit (C) Embryo (D) Endosperm
Correct answer: (B) Fruit. Ovary → fruit.

Seedless grapes are produced by: (A) Double fertilisation (B) Parthenocarpy (C) Budding (D) Binary fission
Correct answer: (B) Parthenocarpy. Fruit forms without fertilisation.

Quick Revision Summary

- Asexual: no gametes, identical offspring. Sexual: gametes fuse, variation.
- Binary fission (bacteria, Amoeba), budding (yeast, Hydra), spores (Rhizopus; bacterial endospores), vegetative propagation.
- Natural vegetative: runner (strawberry), tuber (potato), rhizome (ginger), bulb (onion), corm (dasheen), sucker (banana), leaf buds (Bryophyllum).
- Artificial: cuttings (rose, grape; sweet potato root), grafting (fruit trees). + quick, identical; – no variation.
- Alternation of generations: sporophyte (2n) → spores (n, meiosis) → gametophyte (n) → gametes (mitosis) → zygote (2n).
- Flower: calyx, corolla, androecium (anther + filament), gynoecium (stigma + style + ovary).
- Double fertilisation: sperm + egg → zygote (2n); sperm + fusion nucleus → endosperm (3n). Ovule → seed, ovary → fruit.

Exam Tips

- Learn one example for each asexual method; most MCQs test examples.
- Remember which structures are stems: runner, tuber, rhizome, bulb and corm are all stems, even if underground.
- Draw and label a flower; examiners often ask for the four whorls and the parts of stamen and carpel.
- In double fertilisation questions, always state the ploidy: zygote 2n, endosperm 3n.
- Keep the order: pollination → pollen tube → fertilisation → seed and fruit.

Note on Facts

The textbook gives garlic as an example of a corm. A garlic head is actually a compound bulb made of cloves. Well-known corms are dasheen (taro/arvi), crocus and gladiolus.

The textbook describes the embryo sac as seven cells: one egg, one fusion nucleus and five non-functional cells. In standard terms these are the egg cell, two synergids, three antipodal cells and a large central cell containing the two polar nuclei (which fuse to form the fusion nucleus).

The textbook's chapter pages carry the running header 'Plant Physiology' in places; the chapter is Reproduction in Plants.

Chapter 11: Biostatistics

Biologists collect numbers all the time: heights, pulse rates, crop yields, numbers of infected people. Biostatistics is the branch of statistics that turns such data into reliable conclusions. Chapter 11 explains why it is needed and teaches three basic tools: the mean, the median and the mode, plus how to show data in a bar chart.

The worked examples in these notes use fresh data sets, so you can practise the method rather than memorise the textbook's numbers.

Learning Objectives

- Define biostatistics and describe its main uses with examples.
- Define and calculate the mean of a data set.
- Define and find the median for an odd and an even number of values.
- Define and find the mode, including bimodal data and data with no mode.
- Draw and label a bar chart from biological data.

Key Concepts

11.1 What Is Biostatistics?

Biostatistics is the application of statistical methods to biology, medicine and agriculture. It is essential for planning experiments, clinical trials and studies of disease in populations.

Designing experiments: it decides how many subjects or samples are needed and how to group them, for example the sample size of a drug trial. Analysing data: it reveals trends, patterns and relationships, for example how light and water affect plant growth. Interpreting results: it tells whether a difference is real or could be due to chance.

Predicting outcomes: models built from current data forecast things such as the spread of an infectious disease, so vaccines and hospital beds can be planned. Public health and policy: governments base decisions such as vaccination campaigns on statistical evidence.

11.1 Fields That Use Biostatistics

Epidemiology: studying how diseases are distributed in populations, infection and recovery rates, and how well vaccines work. Genetics: studying how traits are inherited and finding genetic markers linked to diseases such as diabetes. Agriculture: comparing crop varieties, fertilisers and pest resistance. Clinical trials: testing whether a new medicine works better than a placebo.

11.2 Mean

The mean (average) is the sum of all values divided by the number of values: Mean = (sum of values) ÷ (number of values). It gives an overall central value.

Example: resting pulse rates (beats per minute) of five students are 72, 68, 80, 75 and 70. Sum =

365; number of values = 5; mean = 365 ÷ 5 = 73 beats per minute.

The mean uses every value, but one very large or very small value (an outlier) can pull it away from the typical value.

11.2 Median

The median is the middle value when data are arranged in order. First arrange the values in ascending (or descending) order. If the number of values n is odd, the median is the value at position (n + 1) ÷ 2. If n is even, the median is the average of the values at positions n ÷ 2 and (n ÷ 2) + 1.

Odd example: the pulse rates above in order are 68, 70, 72, 75, 80. n = 5, position (5 + 1) ÷ 2 = 3, so the median is 72.

Even example: add a sixth student with 78: 68, 70, 72, 75, 78, 80. n = 6, so take positions 3 and 4: (72 + 75) ÷ 2 = 73.5.

The median is not affected much by outliers, so it is useful for skewed data such as incomes or hospital stay lengths.

11.2 Mode

The mode is the value that occurs most often. Count how often each value appears; the value with the highest frequency is the mode.

Example: lengths of seven leaves (cm) are 6, 7, 7, 8, 9, 7, 6. The value 7 occurs three times, more than any other, so the mode is 7 cm.

A data set can have two modes (bimodal): 4, 5, 5, 6, 6, 7 has modes 5 and 6. If every value occurs equally often, as in 3, 4, 5, 6, there is no mode. The mode is the only one of the three measures that also works for categories, such as the most common blood group in a class.

11.3 Bar Chart

A bar chart shows data for separate categories using bars whose heights (or lengths) are proportional to the values. It makes comparison between categories quick and clear.

Steps: (1) collect the data; (2) arrange it as categories with their values; (3) draw the x-axis and y-axis; (4) label the x-axis with the categories and the y-axis with the quantity and its unit; (5) choose a suitable scale with equal intervals that covers the largest value; (6) draw bars of equal width with equal gaps, each reaching its value; (7) give the chart a title and label the bars.

Example: number of seeds (out of 20) that germinated at different temperatures: 10°C – 4, 20°C – 12, 30°C – 18, 40°C – 7. The largest value is 18, so a y-axis from 0 to 20 in steps of 5 works well. The chart shows germination is highest at 30°C.

Important Definitions

Statistics
The science of collecting, organising, analysing and interpreting numerical data.

Biostatistics
The application of statistical methods to biological and medical sciences.

Data
Facts or measurements collected for study.

Epidemiology
The study of the distribution and causes of diseases in populations.

Clinical trial
A planned study that tests a new medicine or treatment on people.

Placebo
A dummy treatment with no active substance, used for comparison in trials.

Mean
The sum of all values divided by the number of values.

Median
The middle value of data arranged in order.

Mode
The value that occurs most frequently in a data set.

Bimodal
A data set with two modes.

Outlier
A value much larger or smaller than the rest of the data.

Bar chart
A graph that uses bars of equal width to compare values of different categories.

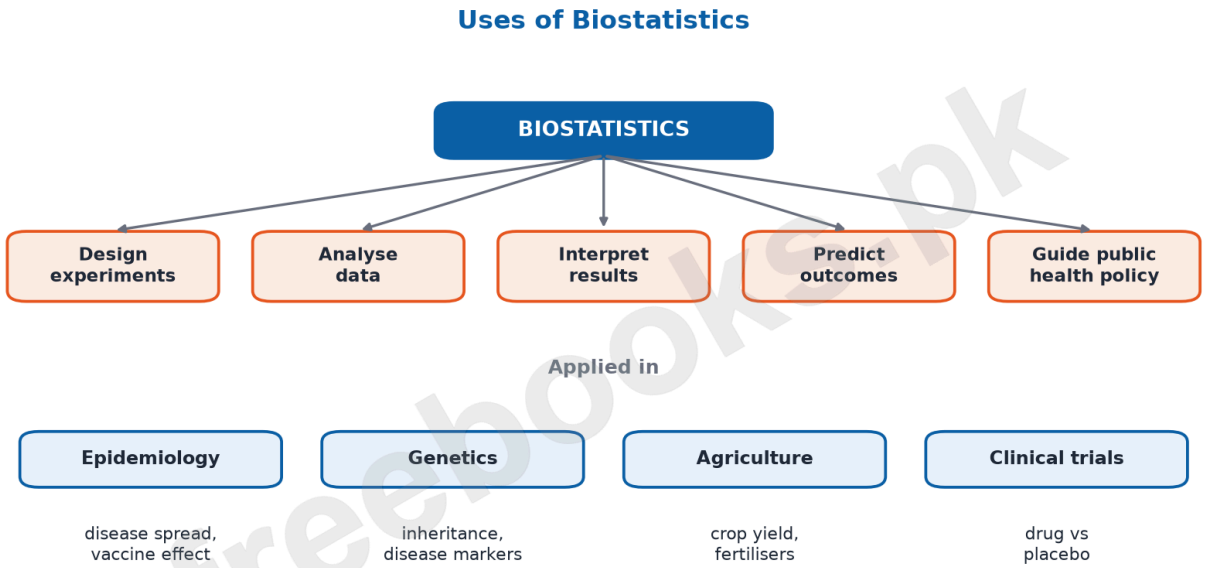
Key Facts at a Glance

Measure	How to find it / best use
Mean	Sum ÷ number of values · overall average
Median (n odd)	Value at position (n + 1) ÷ 2
Median (n even)	Average of values at n ÷ 2 and n ÷ 2 + 1
Median	Best for skewed data / outliers

Mode	Most frequent value · works for categories
Possible modes	One, two (bimodal), more, or none
Bar chart	Categories on x-axis, values on y-axis, equal widths and gaps

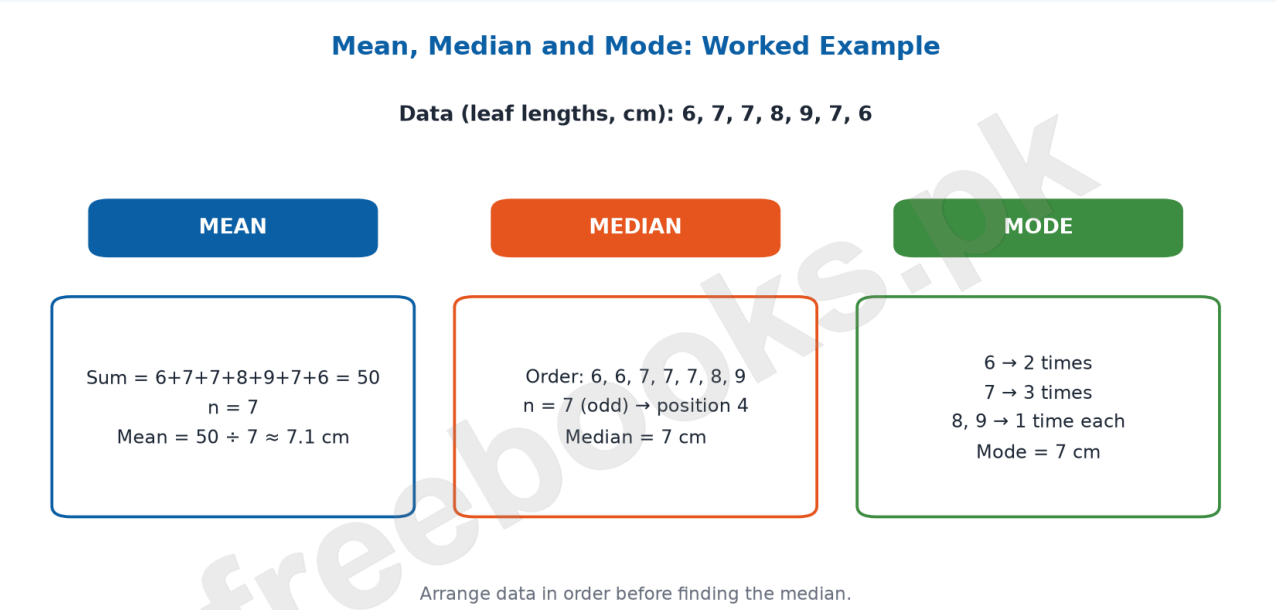
Diagrams

Uses of biostatistics: A chart of the five main uses of biostatistics and four fields where it is applied.

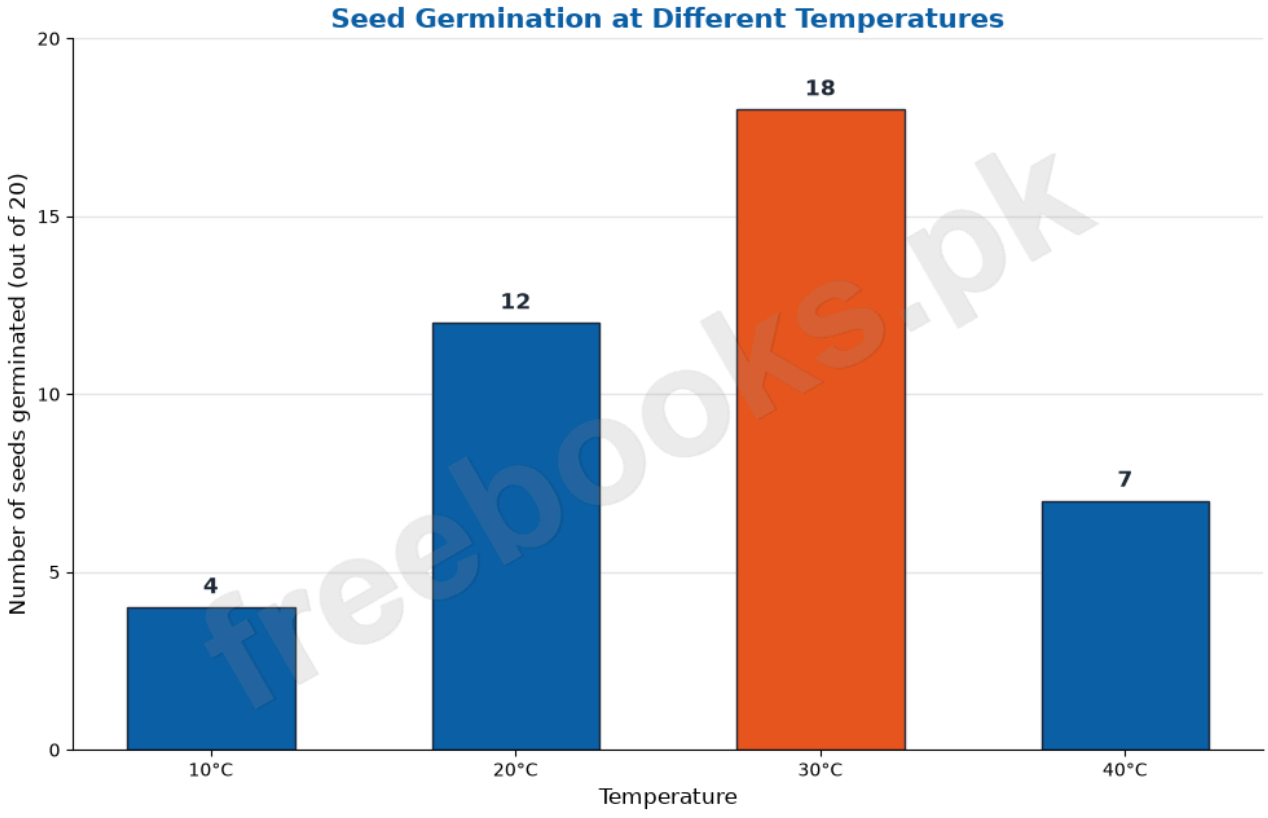


Mean, median and mode worked out: A step-by-step worked example finding the mean, median and mode of a small data set.

freebooks.pk



Example bar chart: A bar chart of the number of seeds germinating at four temperatures, with labelled axes and scale.



Short Questions and Answers

Define biostatistics.
Biostatistics is the use of statistical methods to collect, analyse and interpret data in biology,

medicine and agriculture.

Why is biostatistics needed when planning a drug trial?
It decides how many patients are needed and how to divide them into groups, so that a real effect of the drug can be detected reliably.

Give one example of biostatistics in agriculture.
Comparing the yield of several wheat varieties grown with different fertilisers to find the best combination.

How can biostatistics help during an epidemic?
By analysing infection and recovery rates it can predict how the disease will spread, so vaccination and hospital resources can be planned.

Find the mean of 12, 15, 9, 14.
Sum = 50; number of values = 4; mean = 50 ÷ 4 = 12.5.

Find the median of 21, 18, 25, 19, 23.
In order: 18, 19, 21, 23, 25. n = 5, position 3, so the median is 21.

Find the median of 8, 3, 6, 10.
In order: 3, 6, 8, 10. n = 4, so median = (6 + 8) ÷ 2 = 7.

Find the mode of 2, 4, 4, 5, 4, 2, 6.
4 occurs three times, more than any other value, so the mode is 4.

When does a data set have no mode?
When every value occurs the same number of times, so no value is more frequent than the others.

Why is the median sometimes better than the mean?
Because one extreme value (outlier) changes the mean a lot but hardly changes the median.

What should be kept the same for all bars in a bar chart?
The width of the bars and the gaps between them; only the height should change with the value.

Long Questions and Answers

Describe the uses of biostatistics with examples.

How does it help in designing studies?

It plans the number of samples and the grouping in an experiment or clinical trial so the data collected can answer the question.

How does it help in analysing and interpreting data?

It reveals trends and relationships, such as the effect of light on plant growth, and tells whether differences are real or due to chance.

How does it help in prediction and policy?

Models made from data predict outcomes such as disease spread, and the evidence guides health policies such as vaccination campaigns.

Which fields depend on biostatistics?

Epidemiology, genetics, agriculture and clinical trials all use it to draw reliable conclusions from data.

Explain mean, median and mode with worked examples.

How is the mean calculated?

Add all values and divide by their number. For 72, 68, 80, 75, 70: 365 ÷ 5 = 73.

How is the median found for an odd number of values?

Arrange in order and take the value at position (n + 1) ÷ 2. For 68, 70, 72, 75, 80 the median is the 3rd value, 72.

How is the median found for an even number of values?

Take the average of the two middle values. For 68, 70, 72, 75, 78, 80 the median is (72 + 75) ÷ 2 = 73.5.

How is the mode found?

Count the frequency of each value; the most frequent is the mode. In 6, 7, 7, 8, 9, 7, 6 the mode is 7. Data can be bimodal or have no mode.

Describe how to draw a bar chart from biological data.

How is the data prepared?

Collect the data and arrange it in a table of categories and their values, such as temperature and number of seeds germinated.

How are the axes drawn and labelled?

Draw the x-axis for categories and the y-axis for values; label both, including the unit of the values.

How is the scale chosen?

Look at the largest value and choose equal intervals that cover it, for example 0 to 20 in steps of 5 for a largest value of 18.

How are the bars drawn?

Draw a bar for each category up to its value, keeping all bars the same width with equal gaps, then add a title and labels.

Multiple Choice Questions (MCQs)

Biostatistics applies statistics to: (A) Physics (B) Biological sciences (C) Literature (D) Economics only
Correct answer: (B) Biological sciences. Bio + statistics.

The mean of 4, 6, 8, 10 is: (A) 6 (B) 7 (C) 8 (D) 28
Correct answer: (B) 7. 28 ÷ 4 = 7.

The median of 3, 9, 5, 7, 1 is: (A) 5 (B) 7 (C) 3 (D) 25
Correct answer: (A) 5. In order 1, 3, 5, 7, 9; middle = 5.

The median of 2, 4, 6, 8 is: (A) 4 (B) 5 (C) 6 (D) 20
Correct answer: (B) 5. (4 + 6) ÷ 2 = 5.

The mode of 1, 3, 3, 3, 5, 5 is: (A) 1 (B) 3 (C) 5 (D) No mode
Correct answer: (B) 3. 3 occurs most often.

The data set 2, 2, 4, 4, 6 is: (A) Unimodal (B) Bimodal (C) Without a mode (D) Has median 2
Correct answer: (B) Bimodal. 2 and 4 each occur twice.

For n = 7 values, the median is at position: (A) 3 (B) 3.5 (C) 4 (D) 7
Correct answer: (C) 4. (7 + 1) ÷ 2 = 4.

Which measure is least affected by an outlier? (A) Mean (B) Median (C) Sum (D) Range
Correct answer: (B) Median. The median depends only on the middle position.

Which measure can be used for blood groups (A, B, AB, O)? (A) Mean (B) Median (C) Mode (D) None
Correct answer: (C) Mode. Mode works for categories.

In a bar chart, all bars must have equal: (A) Height (B) Width (C) Colour value (D) Label
Correct answer: (B) Width. Only height varies with value.

Comparing a new drug with a placebo is an example of: (A) Epidemiology (B) A clinical trial (C) Genetics (D) Agriculture
Correct answer: (B) A clinical trial. Clinical trials test treatments.

Predicting the spread of an infection helps in: (A) Designing bar charts (B) Planning vaccination campaigns (C) Finding the mode (D) Grafting
Correct answer: (B) Planning vaccination campaigns. Prediction guides resource planning.

Quick Revision Summary

- Biostatistics = statistics applied to biology; uses: design, analyse, interpret, predict, guide policy.

- Fields: epidemiology, genetics, agriculture, clinical trials.
- Mean = sum ÷ number of values.
- Median: arrange in order; n odd → position (n + 1) ÷ 2; n even → average of positions n ÷ 2 and n ÷ 2 + 1.
- Mode = most frequent value; data may be bimodal or have no mode.
- Bar chart: categories on x-axis, values on y-axis, equal scale intervals, equal bar width and gaps, title and labels.

Exam Tips

- Always arrange data in order before finding the median; this is the most common mistake.
- Show your working (sum, number of values, position) to get full marks even if you slip in arithmetic.
- Check for bimodal data and 'no mode' cases in MCQs.
- In bar charts, label both axes with units and choose a scale that uses most of the graph paper.
- Learn one real example for each use of biostatistics (drug trial, disease spread, crop yield).

Note on Facts

In the textbook's odd-number median example, the position is written as (4/2) = 3. The correct calculation is (n + 1) ÷ 2 = (5 + 1) ÷ 2 = 3; the answer (160 cm) is right.

The textbook's chapter pages carry the running header 'Plant Physiology'; the chapter is Biostatistics.