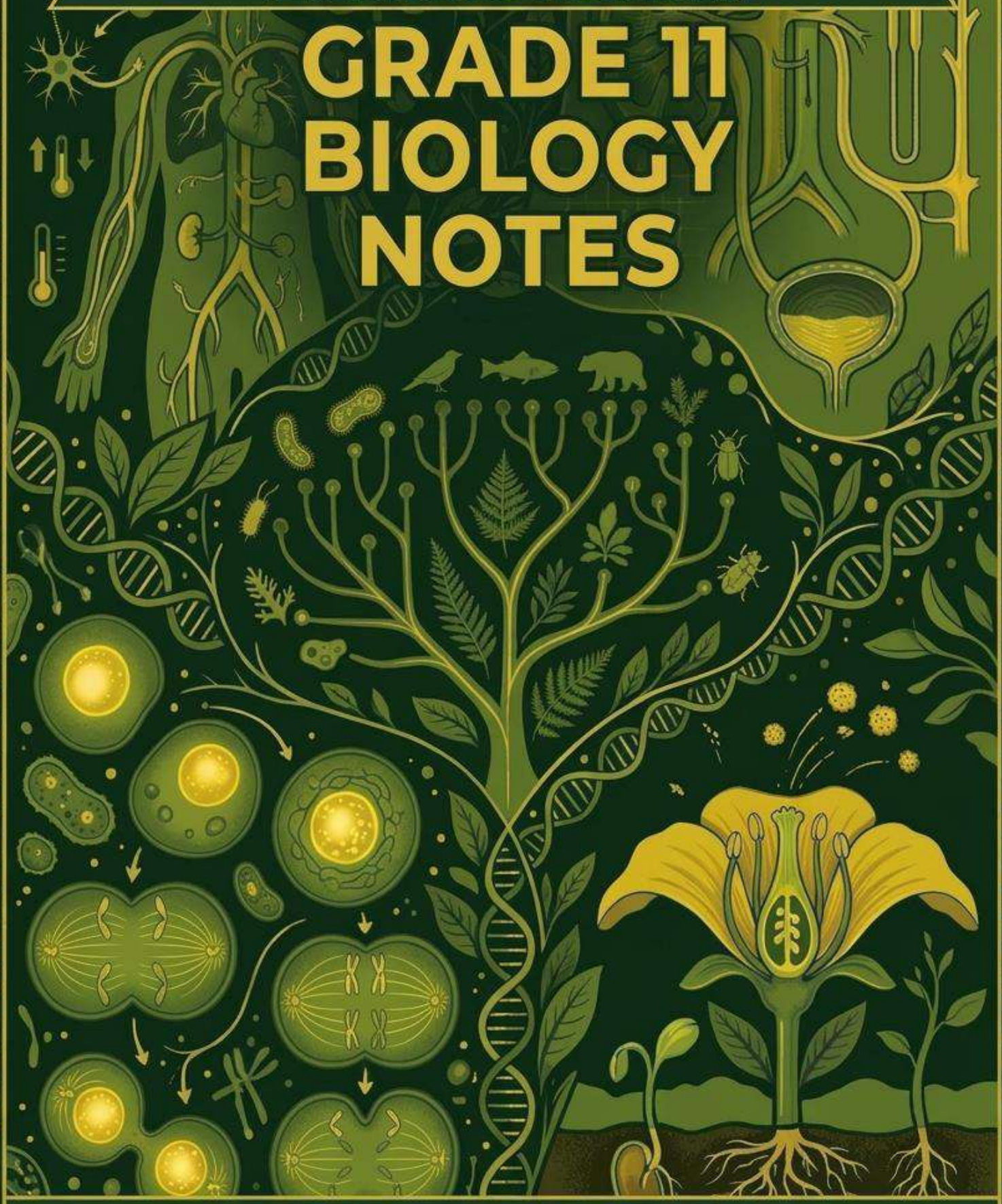
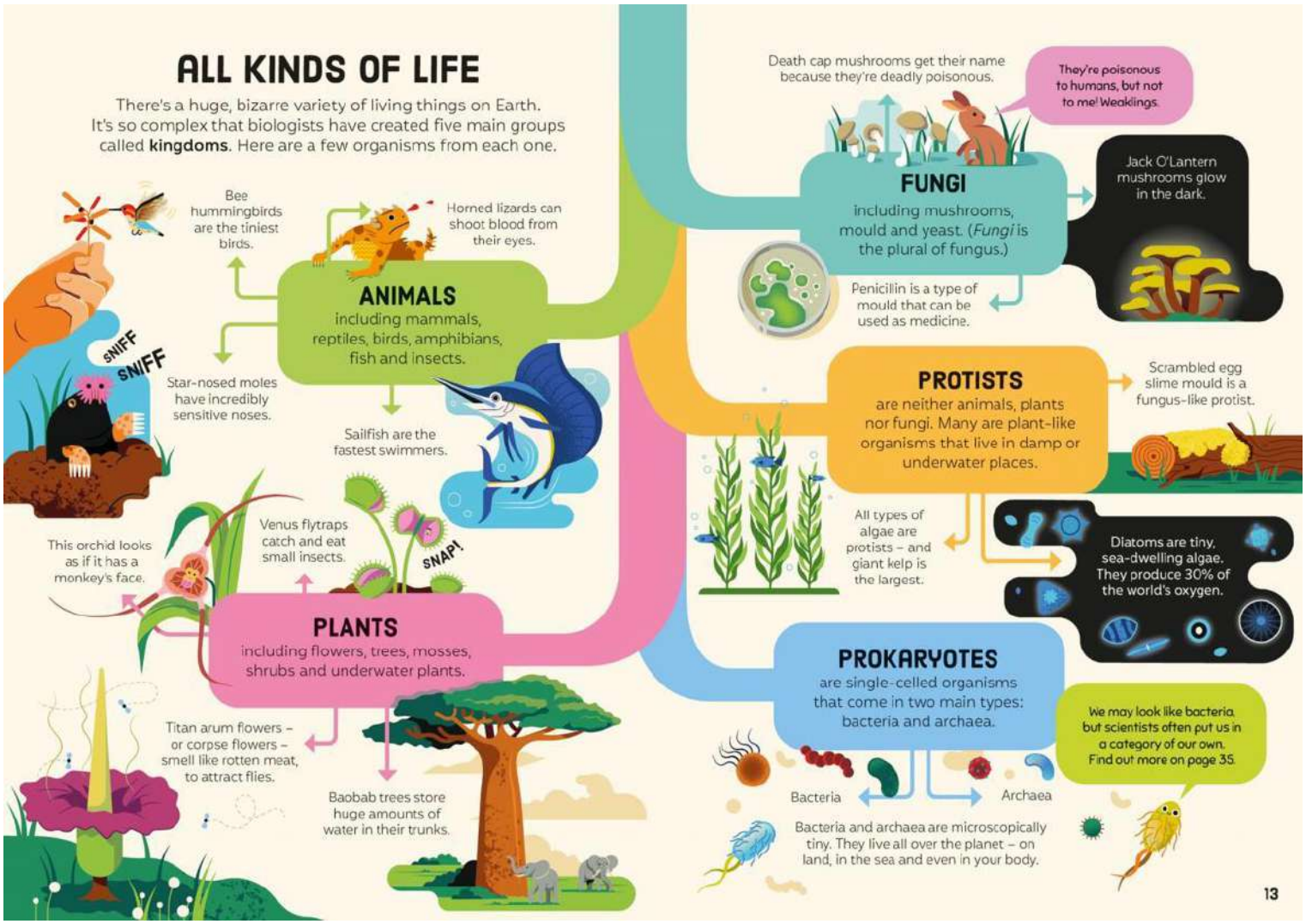
COMPETENCY BASED EDUCATION
KENYA CERTIFICATE OF BASIC EDUCATION

IT CONTAINS NOTES AND QUESTIONS AFTER EVERY SUBSTRAND
(PERFECT FOR STUDY AND REVISION)

GRADE 11 BIOLOGY NOTES



AUTHOR: COMPETENCE EDUCATION GROUP



1.0 Introduction to taxonomy

The natural world contains millions of different organisms. These organisms differ in size, shape, structure, habitat, mode of nutrition, reproduction and behaviour.

Examples include:

- Microscopic organisms such as bacteria and protozoa.
- Plants such as maize, beans, acacia and euphorbia.
- Fungi such as mushrooms, yeast and moulds.
- Animals such as cattle, goats, lions, elephants, birds and insects.

Biologists need a systematic way of identifying, naming, grouping and studying these organisms. This systematic approach is known as **taxonomy**.

Taxonomy helps scientists organise the enormous diversity of life into manageable groups based on similarities, differences and evolutionary relationships.

In Kenya, taxonomy is useful in studying organisms found in forests, grasslands, wetlands, lakes, rivers, farms, gardens, national parks and other ecosystems.

1.1.1 Meaning of taxonomy

Taxonomy is the branch of biology concerned with the identification, naming and classification of living organisms into groups based on their similarities, differences and relationships.

Taxonomy enables biologists to organise living organisms systematically for easy identification, study and communication.

Explanation of the main activities in taxonomy

Taxonomy involves three major activities:

1. Identification

Identification is the process of recognising an organism and determining the group to which it belongs.

- It involves observing the physical and biological characteristics of an organism.
- Scientists compare the organism with organisms that have already been described.
- Identification may involve examining leaves, flowers, roots, body structures, reproductive organs or microscopic features.
- Identification can be done using identification keys, field guides, photographs and laboratory equipment.

Example: A learner observes a plant with a tall stem, narrow leaves, fibrous roots and grains arranged on a cob. The learner identifies it as maize.

2. Nomenclature

Nomenclature is the scientific system of assigning names to organisms.

- It ensures that each recognised organism has a scientifically accepted name.
- Scientific names are internationally recognised.
- It eliminates confusion caused by different local and common names.
- It enables scientists from different countries to communicate accurately.

Example:

- Common name: Maize
- Scientific name: *Zea mays*

3. Classification

Classification is the process of arranging organisms into groups according to their shared characteristics and differences.

- Organisms with many similarities are placed in the same groups.
- Organisms with fewer similarities are placed in broader groups.
- Classification helps show relationships among organisms.
- Modern classification also considers evolutionary history and genetic similarities.

Example: Maize, wheat and rice are classified together in Kingdom Plantae because they share important plant characteristics.

1.1.2 Difference between identification, nomenclature and classification

Activity	Meaning	Example
Identification	Recognising an organism	Recognising a cow
Nomenclature	Giving an organism a scientific name	*Bos taurus*
Classification	Grouping organisms according to similarities	Placing a cow in Kingdom Animalia

Remember: Identification tells us what an organism is, nomenclature tells us what it is called scientifically, while classification tells us where it belongs in the biological grouping system.

1.1.3 Significance of taxonomy

Taxonomy is important in biology, agriculture, medicine, environmental conservation, wildlife management and other fields.

1. Makes identification of organisms easier

- Taxonomy provides an organised system for identifying organisms.
- It enables scientists and learners to recognise different species.
- It helps distinguish organisms that look alike.
- It is useful when identifying crops, weeds, pests, livestock and disease-causing organisms.

Example: A farmer can distinguish between beneficial insects and crop pests through correct identification.

2. Provides universal scientific names

- Different communities may use different common names for the same organism.
- Some organisms may share similar common names despite being different species.
- Scientific names provide a standard naming system recognised internationally.
- This promotes effective communication among scientists.

Example: The animal commonly known as a lion is scientifically named *Panthera leo*, regardless of the language spoken.

3. Helps in understanding relationships among organisms

- Classification reveals similarities and differences among organisms.
- It helps scientists understand how organisms are related.
- It assists in studying evolutionary relationships.
- It helps identify groups of organisms that may have common ancestors.

4. Supports biodiversity conservation

- Taxonomy helps identify rare, endangered and threatened species.
- It provides information about the variety of organisms in different ecosystems.
- It supports the preparation of conservation programmes.

- It helps conservationists monitor changes in species populations.

Example: Correct identification of elephants, black rhinoceroses, Grevy's zebras and other wildlife helps conservation organisations monitor and protect them.

5. Helps in agriculture

- Taxonomy enables farmers to identify crops, weeds, pests and beneficial organisms.
- It helps in identifying crop diseases and their causal organisms.
- It supports the selection of suitable crops for different environments.
- It helps agricultural researchers study crop varieties and their relationships.

Example: Correctly identifying fall armyworm helps farmers select appropriate control measures for maize crops.

6. Important in medicine and public health

- Taxonomy helps identify disease-causing organisms.
- It enables medical researchers to distinguish harmful microorganisms from harmless ones.
- It supports the development of appropriate diagnostic procedures and treatments.
- It assists in studying organisms responsible for malaria, cholera, tuberculosis and other diseases.

7. Supports scientific research

- It provides a common framework for organising biological information.
- It enables researchers to compare organisms from different geographical regions.
- It supports research in genetics, ecology, evolution and biotechnology.
- It makes scientific records more reliable and easier to retrieve.

8. Helps in environmental management

- Taxonomy assists in identifying organisms that indicate environmental pollution.
- It helps scientists monitor changes in ecosystems.
- It supports the management of invasive species.
- It enables the identification of organisms important in nutrient cycling.

9. Supports wildlife and fisheries management

- Taxonomy helps identify fish, birds, mammals and other wildlife.
- It assists in monitoring species populations.
- It helps prevent the exploitation of protected species.
- It supports sustainable management of natural resources.

10. Helps in discovering new organisms

- Taxonomy provides procedures for describing organisms that have not been scientifically documented.
- It helps scientists compare newly discovered organisms with known species.
- It allows new species to be given scientifically accepted names.

1.1.4 Taxonomic units

Taxonomic units are the different levels or categories used in the classification of living organisms.

Each level is known as a **taxon** (plural: taxa).

A taxon is a group of organisms recognised as a unit at any level of biological classification.

Taxonomic units are arranged hierarchically, from the broadest group to the most specific group.

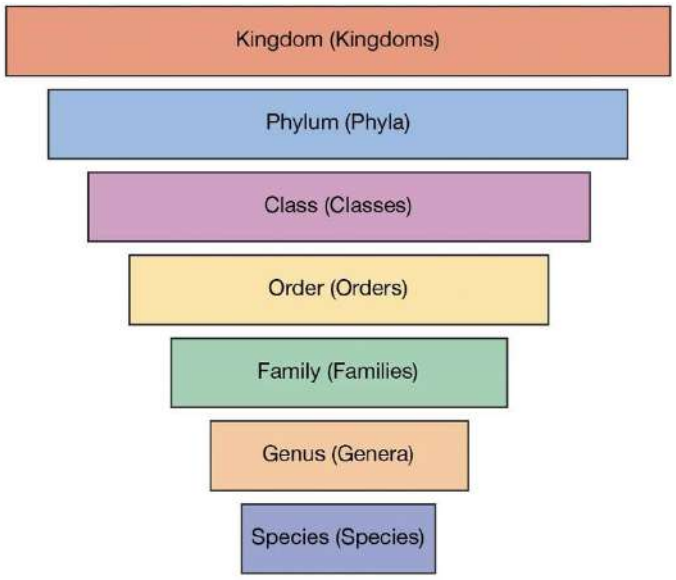
The major traditional taxonomic units are:

1. Kingdom
2. Phylum (for animals) or Division (traditionally used for plants)
3. Class
4. Order
5. Family
6. Genus
7. Species

Modern classification includes an additional and broader category called Domain, which is placed above Kingdom.

1.1.5 Hierarchy of the major taxonomic units

The taxonomic hierarchy is the arrangement of taxonomic groups in descending order, from the largest and most inclusive category to the smallest and most specific category.



Arrangement of taxonomic units

Broadest to most specific:

Kingdom → Phylum/Division → Class → Order → Family → Genus → Species.

Explanation of the major taxonomic units

1. Domain

- Domain is the highest and broadest taxonomic category in modern biological classification.

- It groups organisms according to fundamental cellular and genetic characteristics.
- There are three major domains:
    - Bacteria
    - Archaea
    - Eukarya
- Organisms in Domain Eukarya possess cells with a membrane-bound nucleus.
- Organisms in Domains Bacteria and Archaea are prokaryotic.

2. Kingdom

- A kingdom is a major taxonomic category below domain.
- It contains several related phyla or divisions.
- Organisms within a kingdom share broad characteristics.
- Examples of kingdoms in the traditional five-kingdom system include:
    - Monera
    - Protoctista
    - Fungi
    - Plantae
    - Animalia

3. Phylum or Division

- A phylum is a taxonomic category below kingdom and above class.
- It groups organisms with fundamental similarities in body organisation and structural features.
- The term phylum is commonly used for animals.
- The term division is traditionally used for plants and some other groups.

Examples:

- Phylum Chordata – animals possessing a notochord at some stage of development.
- Division Magnoliophyta – flowering plants in traditional plant classification.

4. Class

- A class is a taxonomic category below phylum or division.
- It contains related orders.
- Organisms in a class share more characteristics than organisms belonging to the same phylum.

Examples:

- Mammalia – mammals.
- Aves – birds.
- Insecta – insects.

5. Order

- An order is a taxonomic category below class and above family.
- It groups related families that share important characteristics.

Examples:

- Carnivora – cats, dogs, bears and other related carnivorous mammals.
- Primates – monkeys, apes and humans.
- Poales – grasses and related flowering plants.

6. Family

- A family is a taxonomic category below order and above genus.
- It groups closely related genera.
- Members of a family share several structural and biological characteristics.

Examples:

- Felidae – cats.
- Canidae – dogs, wolves and foxes.
- Poaceae – grasses, including maize and wheat.
- Fabaceae – legumes, including beans and peas.

7. Genus

- A genus is a taxonomic category below family and above species.
- It groups species that are closely related.
- Organisms in the same genus share many characteristics.
- The genus forms the first part of a scientific name in binomial nomenclature.

Examples:

- *Panthera* – lions, leopards, tigers and jaguars.
- *Canis* – domestic dogs, wolves and related species.
- *Zea* – maize and closely related species.

8. Species

- Species is the most specific basic taxonomic unit in traditional biological classification.
- It consists of organisms that share many characteristics.
- Under the biological species concept, members of a species can naturally interbreed and produce fertile offspring.
- This definition has limitations when applied to organisms that reproduce asexually, fossils and some hybridising organisms.

Examples:

- *Panthera leo* – lion.
- *Bos taurus* – domestic cattle.

- *Zea mays* – maize.

Example: Taxonomic classification of a lion

Taxonomic unit	Classification
Domain	Eukarya
Kingdom	Animalia
Phylum	Chordata
Class	Mammalia
Order	Carnivora
Family	Felidae
Genus	*Panthera*
Species	*Panthera leo*

Example: Taxonomic classification of maize

Taxonomic unit	Classification
Domain	Eukarya
Kingdom	Plantae
Division	Magnoliophyta
Class	Liliopsida
Order	Poales
Family	Poaceae
Genus	*Zea*
Species	*Zea mays*

Important observation about the hierarchy

- As one moves from Domain towards Species, the number of organisms in each group generally decreases.

- The similarities among organisms generally increase.
- The groups become more specific.
- Species members share more characteristics than organisms that only belong to the same kingdom.

1.1.6 The five kingdoms of classification

The five-kingdom classification system was proposed by **Robert H. Whittaker in 1969**.

He grouped living organisms into five kingdoms based on several characteristics, including:

1. Cell structure.
2. Number of cells.
3. Organisation of the body.
4. Mode of nutrition.
5. Method of reproduction.
6. Evolutionary relationships.

The five kingdoms are:

1. Kingdom Monera.
2. Kingdom Protoctista.
3. Kingdom Fungi.
4. Kingdom Plantae.
5. Kingdom Animalia.



A. KINGDOM MONERA

1. Meaning of Kingdom Monera

Kingdom Monera is the traditional kingdom consisting of simple, microscopic, prokaryotic organisms that generally possess a single cell.

These organisms lack a true nucleus and membrane-bound organelles.

The kingdom mainly includes:

- Bacteria.
- Cyanobacteria (traditionally called blue-green algae).
- Other prokaryotic microorganisms, including archaea in the traditional five-kingdom scheme.

2. General characteristics of Kingdom Monera

1. They are prokaryotic.

- Their cells lack a true, membrane-bound nucleus.
- Their genetic material is found in a region of the cytoplasm called the nucleoid.
- Their DNA is generally organised as a circular chromosome.
- Some bacteria also contain small circular DNA molecules called plasmids.

2. They are mostly unicellular.

- Most monerans consist of a single cell.
- Each cell carries out essential life processes.
- Some bacteria occur in colonies or groups.
- Some form chains or clusters.

3. They are microscopic.

- Most monerans are too small to be seen clearly with the naked eye.
- They are normally observed using a microscope.
- They occur in soil, water, air, food, living organisms and decaying materials.

4. They have different cell shapes.

Common bacterial shapes include:

- **Cocci:** Spherical or round-shaped bacteria.
- **Bacilli:** Rod-shaped bacteria.
- **Spirilla:** Spiral-shaped bacteria.
- **Vibrios:** Comma-shaped bacteria.

5. They have a cell wall.

- Most bacteria possess a cell wall outside the cell membrane.
- In many bacteria, the cell wall contains peptidoglycan.
- The cell wall provides protection and maintains cell shape.
- Some bacteria, such as Mycoplasma, lack a cell wall.

6. They lack membrane-bound organelles.

- They do not possess mitochondria.
- They do not have a membrane-bound nucleus.
- They lack membrane-bound chloroplasts.
- They possess ribosomes for protein synthesis.

7. They have different modes of nutrition.

Monerans may be autotrophic or heterotrophic.

Autotrophic nutrition:

- Some bacteria manufacture their own food.
- Photoautotrophic bacteria use light energy.
- Chemoautotrophic bacteria obtain energy by oxidising inorganic substances.

Heterotrophic nutrition:

- Some obtain nutrients from dead and decaying organic materials.
- Others obtain nutrients from living organisms.
- Some live in mutually beneficial associations with other organisms.

Examples:

- *Nitrosomonas* – involved in the conversion of ammonia into nitrite.
- *Nitrobacter* – involved in the conversion of nitrite into nitrate.
- *Rhizobium* – fixes atmospheric nitrogen in association with leguminous plants.
- *Lactobacillus* – used in the production of fermented foods.

8. They reproduce mainly asexually.

- Most bacteria reproduce through binary fission.
- During binary fission, the DNA is replicated.
- The cell elongates and divides into two daughter cells.
- Under favourable conditions, multiplication can occur rapidly.

9. Some are motile.

- Some bacteria move using structures called flagella.
- Others move by gliding or other mechanisms.
- Some bacteria are non-motile.

10. They occur in different environments.

- Soil.
- Freshwater.
- Seawater.
- Hot springs.

- The digestive systems of animals.
- On the surfaces of plants and animals.
- In decaying organic matter.

3. Examples of organisms in Kingdom Monera

Organism	Main characteristic or importance
Rhizobium	Fixes nitrogen in legume root nodules
Lactobacillus	Used in fermentation
Escherichia coli	Commonly inhabits the intestines of humans and other animals
Vibrio cholerae	Causes cholera
Salmonella enterica	Causes salmonellosis
Mycobacterium tuberculosis	Causes tuberculosis
Nitrosomonas	Converts ammonia into nitrite
Nitrobacter	Converts nitrite into nitrate
Azotobacter	Free-living nitrogen-fixing bacterium
Nostoc	Nitrogen-fixing cyanobacterium
Anabaena	Cyanobacterium capable of nitrogen fixation
Streptococcus	Includes species associated with human diseases
Staphylococcus aureus	Can cause skin and other infections
Bacillus subtilis	Common soil bacterium
Clostridium tetani	Causes tetanus

4. Importance of Kingdom Monera

Monerans are important in agriculture, medicine, food production, industry and environmental management.

A. Beneficial importance

1. Nitrogen fixation

- Some bacteria convert atmospheric nitrogen into compounds that plants can use.
- This increases the availability of nitrogen in agricultural soils.
- Nitrogen is important in the manufacture of proteins and chlorophyll.
- It improves soil fertility.

Example: Rhizobium lives in root nodules of leguminous plants such as beans, peas and groundnuts.

2. Decomposition of organic matter

- Some bacteria feed on dead plants and animals.
- They break down complex organic materials into simpler substances.
- They release nutrients back into the environment.
- This helps maintain nutrient cycles.

3. Improvement of soil fertility

- Some bacteria participate in nitrification.
- They convert ammonia and nitrite into other nitrogen compounds.
- This contributes to the formation of nitrates that can be absorbed by plants.

4. Food production

Some bacteria are used in the manufacture of fermented foods.

Examples:

- *Lactobacillus* is used in yoghurt production.
- Lactic acid bacteria are used in the preparation of fermented milk.
- Some bacteria are involved in the fermentation of traditional foods.

Example: Fermented milk products such as mursik depend on microbial fermentation.

5. Production of medicines

- Some bacteria produce antibiotics and other useful substances.
- These substances can be used to control harmful microorganisms.
- Bacterial products are also important in biotechnology.

Example: Streptomyces species are important sources of antibiotics.

6. Sewage treatment

- Bacteria break down organic waste in sewage treatment systems.
- They reduce the amount of organic pollution.
- They help improve the quality of treated wastewater.

7. Digestion in animals

- Some bacteria live in the digestive systems of animals.
- They assist in breaking down food materials.
- They may produce useful substances such as vitamins.
- Some microorganisms in ruminants assist in the digestion of plant fibre.

8. Industrial production

- Bacteria are used in the manufacture of enzymes, organic acids and other industrial products.
- Some are used in biotechnology to produce useful proteins.
- They are also used in the manufacture of certain chemicals.

9. Biological control

- Some bacteria produce substances that control insect pests.
- They can reduce dependence on certain chemical pesticides.

Example: Bacillus thuringiensis is used in biological control of particular insect larvae.

B. Harmful importance

1. Cause human diseases

Some bacteria cause diseases in humans.

Bacterium	**Disease**

Vibrio cholerae	Cholera
Mycobacterium tuberculosis	Tuberculosis
Salmonella enterica	Salmonellosis
Clostridium tetani	Tetanus
Mycobacterium leprae	Leprosy
Streptococcus pyogenes	Strep throat and other infections

2. Cause animal diseases

- Some bacteria cause diseases in domestic animals.
- These diseases may reduce livestock productivity.
- They may lead to animal deaths and economic losses.

Examples include:

- *Bacillus anthracis* – anthrax.
- *Brucella abortus* – brucellosis in cattle.
- *Mycobacterium bovis* – bovine tuberculosis.

3. Cause plant diseases

Some bacteria attack crops and cause reduced yields.

Examples:

- *Xanthomonas* species – cause various bacterial plant diseases.
- *Ralstonia solanacearum* – causes bacterial wilt in several crops.
- *Pectobacterium* species – cause soft rot in plants.

4. Cause food spoilage

- Some bacteria multiply in stored food.
- They cause unpleasant smells, tastes and changes in texture.
- Some produce toxins that can cause food poisoning.

5. Contaminate water

- Disease-causing bacteria may enter water sources through sewage and animal waste.
- Contaminated water can spread diseases such as cholera and typhoid fever.

B. KINGDOM PROTOCTISTA

1. Meaning of Kingdom Protoctista

Kingdom Protoctista is a traditional kingdom comprising mostly simple eukaryotic organisms that do not fit into the traditional kingdoms Plantae, Animalia or Fungi.

Most members are unicellular, although some are colonial or multicellular.

They possess a true nucleus and membrane-bound organelles.

The kingdom traditionally includes:

- Protozoa.
- Algae.
- Some slime moulds.

2. General characteristics of Kingdom Protoctista

1. They are eukaryotic.

- Their cells possess a true nucleus.
- The nucleus is surrounded by a nuclear membrane.
- They possess membrane-bound organelles such as mitochondria.
- Some photosynthetic members possess chloroplasts.

2. Most are unicellular.

- Most protoctists consist of a single cell.
- Some occur in colonies.
- Others, such as certain algae, have multicellular bodies.

3. They mostly live in aquatic or moist environments.

- Freshwater ponds.
- Rivers.
- Lakes.
- Damp soil.
- Wet organic matter.
- Marine environments.
- Inside the bodies of other organisms.

4. They have different modes of nutrition.

Some are autotrophic:

- They manufacture their own food through photosynthesis.
- They possess photosynthetic pigments.
- They contribute to oxygen production in aquatic environments.

Others are heterotrophic:

- They obtain nutrients by ingesting or absorbing food.
- Some feed on bacteria and other microorganisms.
- Some are parasites.

Some have mixed nutrition:

- They can manufacture food through photosynthesis.
- They can also obtain nutrients from external sources.

Example: Euglena can photosynthesise in the presence of light and obtain nutrients heterotrophically under certain conditions.

5. Some are motile.

Movement may occur through:

- **Cilia:** Short, hair-like structures used for movement.
- **Flagella:** Long, whip-like structures used for movement.
- **Pseudopodia:** Temporary extensions of the cytoplasm used for movement and feeding.

6. Some have a cell wall while others lack one.

- Many algae possess cell walls.
- Some have walls containing cellulose.
- Diatoms possess silica-rich cell walls.
- Protozoa such as Amoeba and Paramecium lack a rigid cell wall.

7. They reproduce through different methods.

Asexual reproduction:

- Binary fission.
- Multiple fission.
- Spore formation in some groups.

Sexual reproduction:

- Fusion of gametes in some algae.
- Conjugation in certain protozoans such as *Paramecium*.

8. Some cause diseases.

- Certain protoctists are parasitic.
- They live inside the bodies of humans and other animals.
- They may cause serious diseases.

3. Examples of organisms in Kingdom Protoctista

Organism	**Main feature or importance**
Amoeba proteus	Moves using pseudopodia
Paramecium caudatum	Moves using cilia
Euglena gracilis	Can photosynthesise and feed heterotrophically

Plasmodium falciparum	Causes severe malaria
Trypanosoma brucei	Causes African sleeping sickness
Giardia duodenalis	Causes giardiasis
Entamoeba histolytica	Causes amoebic dysentery
Chlamydomonas reinhardtii	Unicellular green alga
Spirogyra species	Filamentous freshwater algae
Volvox species	Colonial green algae
Chlorella vulgaris	Unicellular green alga
Diatoms	Important aquatic photosynthetic organisms
Sargassum species	Marine brown algae
Ulva species	Green marine algae

4. Importance of Kingdom Protoctista

A. Beneficial importance

1. Oxygen production

- Photosynthetic algae absorb carbon dioxide.
- They manufacture organic food through photosynthesis.
- They release oxygen into the environment.
- Aquatic algae and phytoplankton contribute significantly to global oxygen production.

2. Formation of aquatic food chains

- Many protoctists form phytoplankton.
- Phytoplankton are primary producers in aquatic ecosystems.
- They provide food for zooplankton and other aquatic organisms.
- They support fish populations and aquatic biodiversity.

3. Food production

- Some algae are used as human food.
- Certain seaweeds are consumed in different parts of the world.
- Algal products are used in food processing.

4. Industrial applications

- Agar obtained from certain red algae is used in laboratories and food industries.
- Alginates from brown algae are used as thickening and stabilising agents.
- Carrageenan from certain red algae is used in food processing.

5. Scientific research

- Some protoctists are used in studies of cell biology.
- They help scientists understand movement, reproduction and cellular processes.
- Some algae are used in research on photosynthesis.

6. Environmental monitoring

- Certain protoctists are used as indicators of water quality.
- Changes in their populations may indicate pollution or changes in water conditions.

7. Wastewater treatment

- Some algae absorb nutrients from wastewater.
- They can assist in the removal of excess nutrients under controlled treatment conditions.

B. Harmful importance

1. Cause malaria

- Malaria is caused by protozoan parasites of the genus *Plasmodium*.
- The parasites are transmitted by infected female *Anopheles* mosquitoes.
- They multiply in the liver and red blood cells of humans.

Important: The mosquito is the vector, while *Plasmodium* is the disease-causing organism.

2. Cause sleeping sickness

- African sleeping sickness is caused by *Trypanosoma brucei*.
- It is transmitted by infected tsetse flies.
- It affects humans and may cause serious nervous system complications.

3. Cause amoebic dysentery

- *Entamoeba histolytica* causes amoebiasis.
- Infection commonly occurs through contaminated food or water.
- It can cause diarrhoea and intestinal complications.

4. Cause giardiasis

- *Giardia duodenalis* causes an intestinal infection.

- It spreads through contaminated water and food.
- It may cause diarrhoea and abdominal discomfort.

5. Cause harmful algal blooms

- Some algae multiply excessively under favourable conditions.
- Such rapid growth may form algal blooms.
- Certain blooms release toxins.
- They may reduce water quality and harm aquatic organisms.

C. KINGDOM FUNGI

1. Meaning of Kingdom Fungi

Kingdom Fungi comprises eukaryotic organisms that obtain nutrients by absorbing dissolved organic substances from their surroundings.

Fungi include:

- Mushrooms.
- Moulds.
- Yeasts.
- Rusts.
- Smuts.

Fungi do not contain chlorophyll and therefore cannot manufacture their own food through photosynthesis.

2. General characteristics of Kingdom Fungi

1. They are eukaryotic.

- Their cells contain a well-defined nucleus.
- The nucleus is surrounded by a nuclear membrane.
- They possess membrane-bound organelles.
- Their cells contain mitochondria.

2. They may be unicellular or multicellular.

- Yeasts are mainly unicellular.
- Mushrooms and moulds are multicellular.
- Some fungi consist of long, branching filaments.

3. They possess cell walls made mainly of chitin.

- The cell wall surrounds the cell membrane.
- Chitin provides support and protection.
- It distinguishes fungal cell walls from the cellulose cell walls of plants.

4. They lack chlorophyll.

- Fungi do not contain chlorophyll.

- They cannot manufacture their own food through photosynthesis.
- They depend on organic substances obtained from other sources.

5. They are heterotrophic.

Fungi obtain food through absorption.

Their nutrition can be classified into three major types:

- **Saprophytic nutrition:** Fungi feed on dead and decaying organic matter.

Example: Mushrooms growing on dead tree trunks.

- **Parasitic nutrition:** Fungi obtain nutrients from living organisms, often causing diseases.

Example: Rust fungi attacking crop plants.

- **Symbiotic nutrition:** Fungi live in associations with other organisms where the partners benefit.

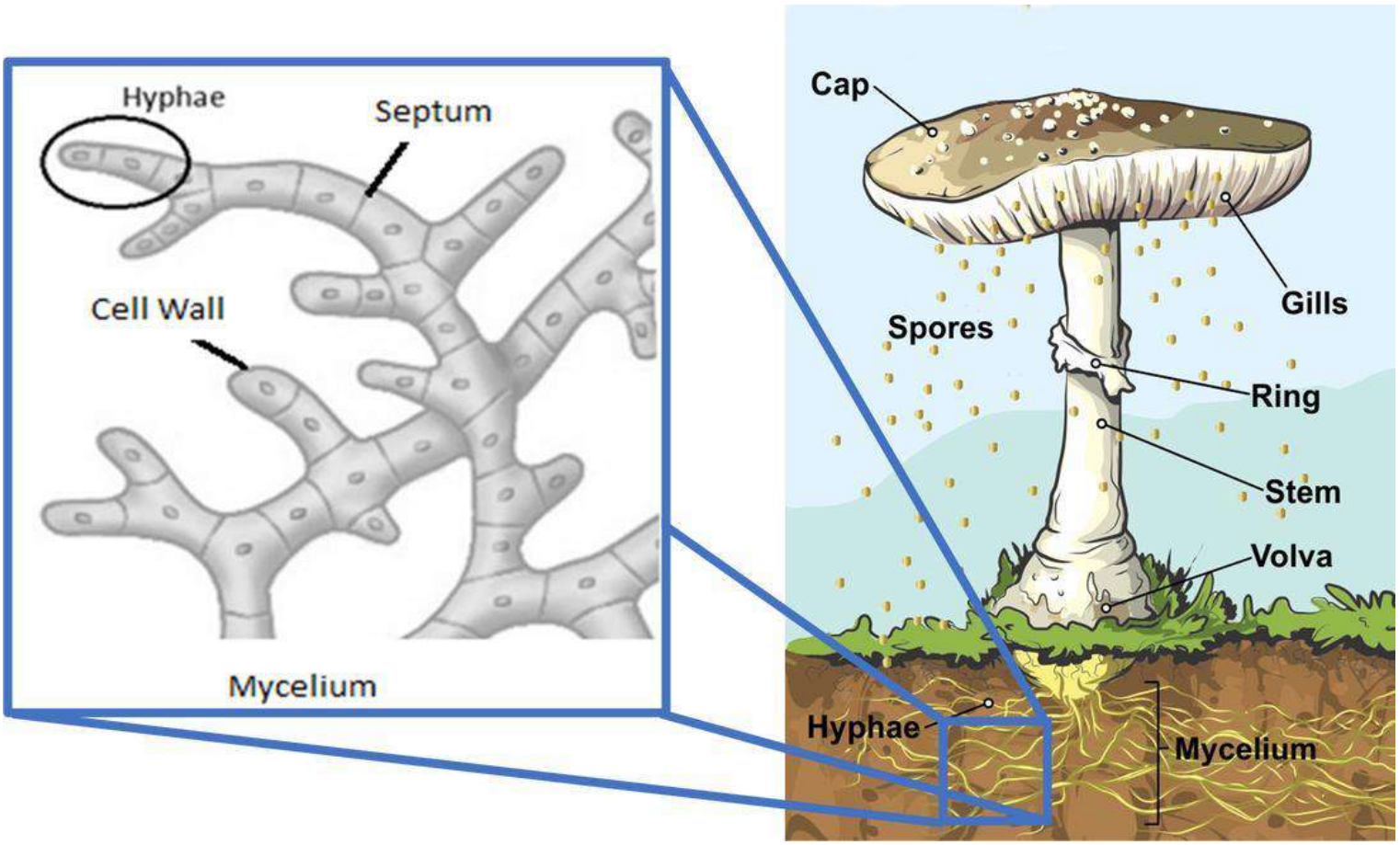
Example: Lichens, which consist of a fungus associated with an alga or cyanobacterium.

6. Most multicellular fungi consist of hyphae.

- A hypha is a thread-like fungal filament.
- Hyphae grow through the food source.
- They absorb nutrients from the surroundings.
- Some hyphae are divided by cross-walls called septa.
- Others lack regular septa.

7. Hyphae form a mycelium.

- A mycelium is a network of fungal hyphae.
- It forms the main vegetative body of many fungi.
- It increases the surface area available for nutrient absorption.



8. They reproduce through sexual and asexual methods.

Asexual reproduction:

- Budding in yeast.
- Fragmentation of hyphae.
- Formation of asexual spores.

Sexual reproduction:

- Fusion of compatible fungal cells or nuclei.
- Formation of sexual spores.
- Sexual reproduction contributes to genetic variation.

9. Most fungi are non-motile.

- They do not move from one place to another like animals.
- Their hyphae grow towards sources of nutrients.
- Some fungal spores may be dispersed by wind, water or animals.

10. They store carbohydrates mainly as glycogen.

- Fungi store food in the form of glycogen and oils.
- This is similar to animals.
- Plants mainly store carbohydrates as starch.

3. Examples of organisms in Kingdom Fungi

Organism	Main characteristic or importance
Saccharomyces cerevisiae	Baker's yeast
Rhizopus stolonifer	Common bread mould
Penicillium chrysogenum	Source of penicillin-related antibiotics
Aspergillus niger	Used in industrial production of citric acid
Agaricus bisporus	Edible mushroom
Puccinia graminis	Causes stem rust in wheat
Ustilago maydis	Causes corn smut
Candida albicans	Can cause candidiasis
Trichophyton rubrum	Causes certain fungal skin infections
Fusarium oxysporum	Causes vascular wilt in plants
Alternaria solani	Causes early blight in tomato and potato
Amanita muscaria	Poisonous mushroom
Mucor species	Common moulds
Pleurotus ostreatus	Oyster mushroom

4. Importance of Kingdom Fungi

A. Beneficial importance

1. Decomposition

- Fungi break down dead plants and animals.
- They decompose complex organic materials.
- They release nutrients into the soil.
- They help maintain nutrient cycles in ecosystems.

2. Food production

- Some mushrooms are edible.
- They provide nutrients such as proteins, fibre and minerals.
- They are commercially cultivated for human consumption.

Examples:

- Oyster mushrooms.
- Button mushrooms.
- Other edible cultivated mushrooms.

3. Baking industry

- Yeast is used in baking.
- It ferments sugars and produces carbon dioxide.
- Carbon dioxide causes dough to rise.
- This gives bread a soft and porous texture.

4. Brewing and fermentation

- Yeast converts sugars into alcohol and carbon dioxide during fermentation.
- It is used in various industrial fermentation processes.

5. Production of medicines

- Some fungi produce antibiotics and other pharmaceutical substances.
- *Penicillium* species are historically important in the discovery and production of penicillin.

6. Agriculture and soil fertility

- Fungi decompose organic materials in the soil.
- Some form mycorrhizal associations with plant roots.
- Mycorrhizal fungi improve the absorption of water and mineral nutrients, especially phosphorus.

7. Food processing

- Fungi are used in the production of certain cheeses.
- They are used in the manufacture of enzymes.
- They contribute to the development of flavour and texture in selected fermented foods.

8. Industrial production

- Fungi produce enzymes used in food processing and other industries.
- They are used in the manufacture of organic acids.
- Some are used in biotechnology.

B. Harmful importance

1. Cause plant diseases

Examples:

- *Puccinia graminis* causes stem rust.
- *Ustilago maydis* causes corn smut.
- *Fusarium oxysporum* causes vascular wilt.
- *Alternaria solani* causes early blight.

2. Cause human diseases

- Some fungi cause skin infections.
- Others cause infections of nails and mucous membranes.
- Some may cause serious infections in people with weakened immunity.

Examples:

- Athlete's foot.
- Ringworm.
- Candidiasis.

3. Cause food spoilage

- Fungi grow on stored food.
- They cause mould formation.
- They reduce food quality and may produce harmful toxins.

4. Cause livestock diseases

- Some fungi cause skin infections in domestic animals.
- These infections can affect animal health and productivity.

5. Produce poisonous substances

- Some mushrooms are poisonous.
- Consumption may cause severe illness or death.
- Some moulds produce mycotoxins that contaminate food and animal feeds.

Example: Certain strains of *Aspergillus flavus* produce aflatoxins, which can contaminate poorly stored maize and groundnuts.

D. KINGDOM PLANTAE

1. Meaning of Kingdom Plantae

Kingdom Plantae consists mainly of multicellular eukaryotic organisms whose cells generally possess cellulose cell walls and chloroplasts containing photosynthetic pigments.

Most plants manufacture their own food through photosynthesis.

Examples include:

- Mosses.
- Ferns.
- Grasses.

- Flowering plants.
- Conifers.

2. General characteristics of Kingdom Plantae

1. They are eukaryotic.

- Their cells have a true nucleus.
- The nucleus is surrounded by a nuclear membrane.
- They possess membrane-bound organelles.
- They have mitochondria and other specialised cell structures.

2. They are mostly multicellular.

- Most plants consist of many cells.
- Different cells perform specialised functions.
- Cells form tissues and organs.
- Major plant organs include roots, stems and leaves in vascular plants.

3. They possess cellulose cell walls.

- The cell wall surrounds the cell membrane.
- It provides structural support.
- It maintains cell shape.
- It protects plant cells from mechanical damage.

4. Most contain chlorophyll.

- Chlorophyll is the green pigment responsible for absorbing light energy.
- It is found in chloroplasts.
- It enables plants to carry out photosynthesis.

5. Most are autotrophic.

- Plants manufacture their own food.
- They use light energy to convert carbon dioxide and water into carbohydrates.
- Oxygen is released during photosynthesis.

6. They have large permanent vacuoles in many cells.

- Vacuoles store cell sap.
- They help maintain turgidity.
- They assist in the storage of water and dissolved substances.

7. They are generally non-motile.

- Plants are usually fixed in one place.
- They respond to environmental stimuli through growth movements.

- Examples include shoots growing towards light and roots growing towards gravity.

8. They store carbohydrates mainly as starch.

- Excess carbohydrates produced during photosynthesis may be converted into starch.
- Starch is stored in different plant tissues.
- It can be broken down when energy is required.

9. They reproduce sexually and asexually.

Sexual reproduction:

- Involves the fusion of male and female gametes.
- In flowering plants, fertilisation takes place after pollination.

Asexual reproduction:

- Occurs through vegetative propagation.
- Examples include reproduction by runners, bulbs, tubers, rhizomes and stem cuttings.

10. They respond to environmental stimuli.

- Shoots may grow towards light.
- Roots generally grow towards gravity.
- Some leaves fold when touched.
- Some flowers open or close in response to light conditions.

3. Major groups of Kingdom Plantae

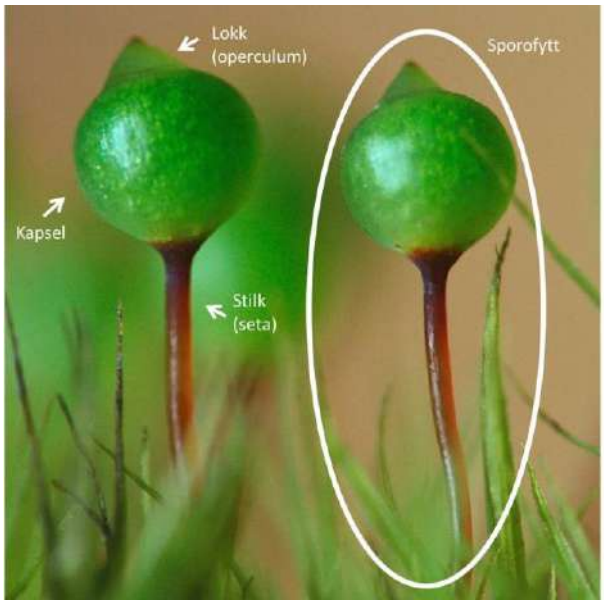
For introductory classification, plants may be studied under the following groups:

A. Bryophytes

- Small, non-vascular plants.
- Lack true roots, stems and leaves.
- Absorb water mainly through their surfaces.
- Commonly grow in moist environments.
- Reproduce through spores.

Examples:

- Mosses.
- Liverworts.

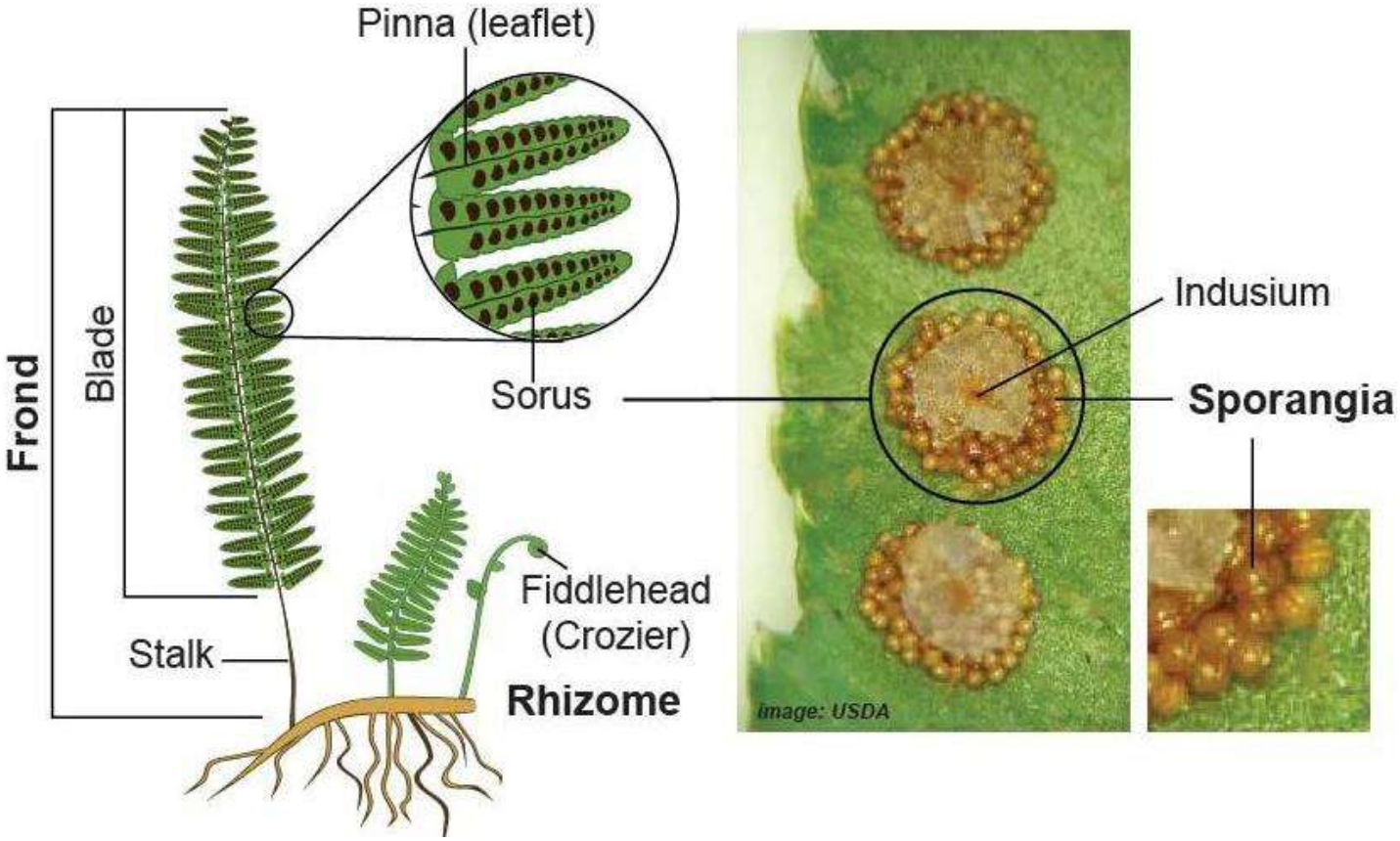


B. Pteridophytes

- Vascular plants.
- Possess true roots, stems and leaves.
- Reproduce through spores.
- Do not produce flowers or seeds.

Examples:

- Ferns.
- Horsetails.
- Club mosses.



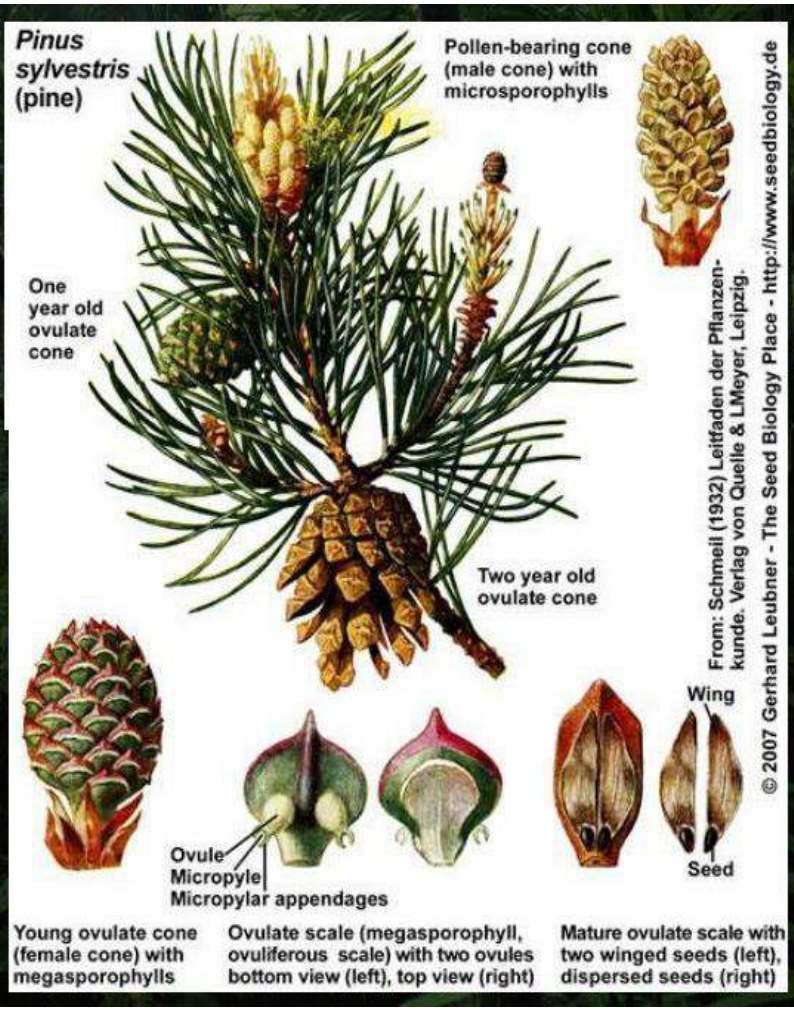
C. Gymnosperms

- Seed-producing plants.
- Their seeds are not enclosed in fruits.
- Many produce seeds in cones.
- Most are woody plants.

Examples:

- *Pinus* species.
- *Cupressus lusitanica*.
- *Podocarpus* species.

- **Seed→ plant embryo, energy supply, and protective coating (seed coat)**
  - **Allows spreading of plants away from water sources**
- **Gymnosperms→ "naked seed"; sporophyte release pollen grains (male-gametophyte) from Pollen Cones**
  - **travel by wind to fertilize ovules (eggs) in Seed Cones (pollination)**



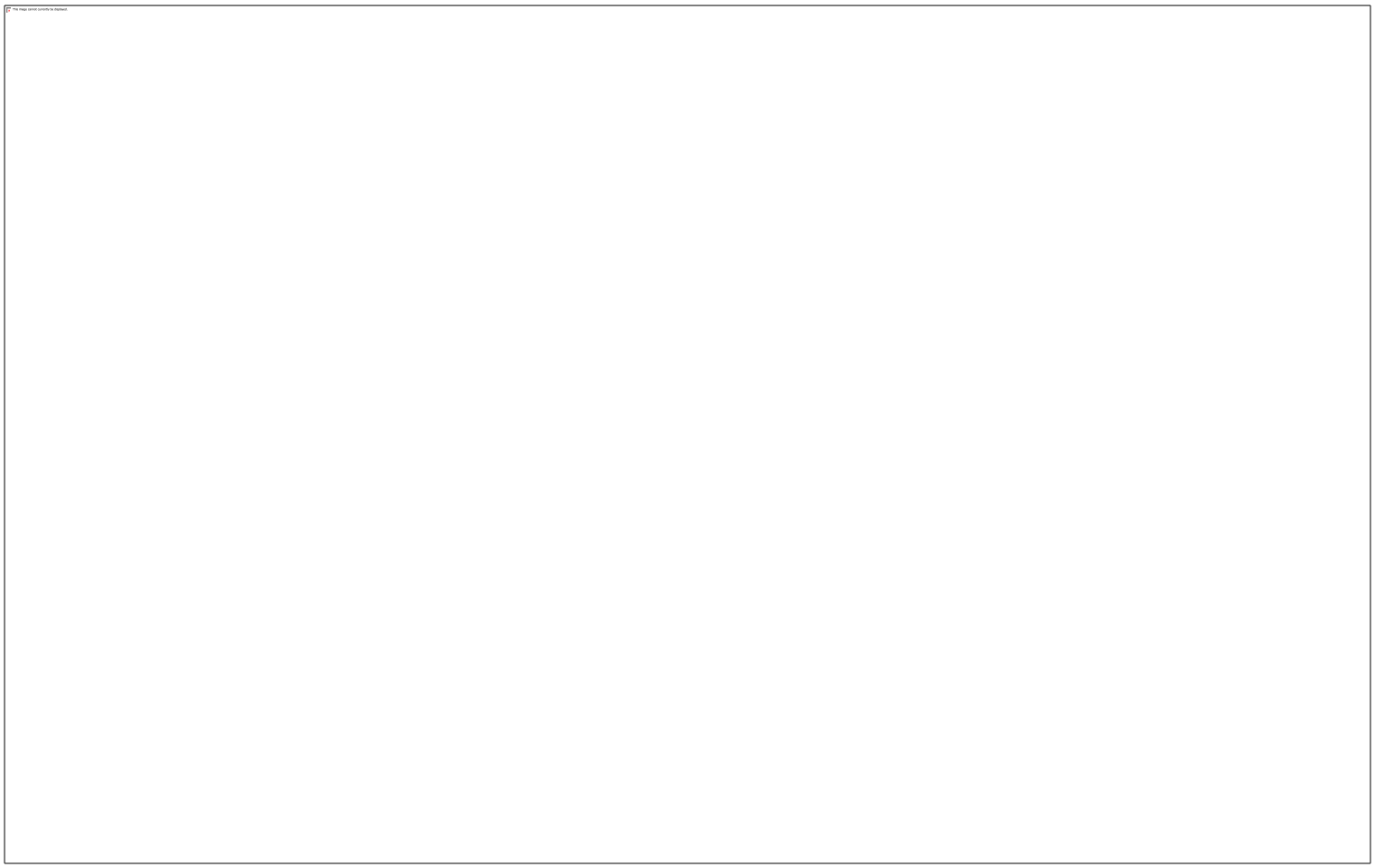
D. Angiosperms

- Flowering plants.
- Their seeds are enclosed within fruits.
- They produce flowers as reproductive structures.
- They include monocotyledonous and dicotyledonous plants in traditional school-level classification.

Examples:

- Maize.

- Beans.
- Mango.
- Avocado.
- Hibiscus.
- Sunflower.



4. Importance of Kingdom Plantae

A. Beneficial importance

1. Food production

- Plants provide food for humans.
- They provide carbohydrates, proteins, vitamins, minerals and oils.
- They form the foundation of most terrestrial food chains.

Examples in Kenya:

Plant	Food product
Maize	Grain
Beans	Seeds

Irish potato	Tuber
Sweet potato	Storage roots
Banana	Fruit
Cassava	Storage roots
Rice	Grain
Wheat	Grain
Sukuma wiki	Leaves
Cabbage	Leaves
Avocado	Fruit
Groundnuts	Seeds

2. Oxygen production

- Plants release oxygen during photosynthesis.
- Oxygen is essential for aerobic respiration.
- Vegetation contributes to maintaining atmospheric gas balance.

3. Source of medicines

- Many plants contain medicinal compounds.
- These compounds are used in traditional and modern medicine.
- Some plant products are used in the pharmaceutical industry.

Examples:

- Aloe plants.
- Neem.
- Cinchona, historically important as a source of quinine.

4. Source of timber

- Trees provide timber for construction.
- Timber is used in furniture making.
- It is used in carpentry and other industries.

Examples:

- *Eucalyptus* species.

- *Grevillea robusta*.
- *Pinus* species.
- *Juniperus procera*.

5. Soil conservation

- Roots bind soil particles together.
- Vegetation reduces soil erosion.
- Ground cover reduces the impact of raindrops.
- Trees help stabilise slopes and riverbanks.

6. Water conservation

- Vegetation reduces surface runoff.
- Forests contribute to the regulation of water cycles.
- Plant cover protects water catchment areas.

7. Provision of animal habitats

- Trees provide nesting sites for birds.
- Grasses provide food and shelter for herbivores.
- Forest vegetation supports insects, mammals, reptiles and birds.

8. Industrial raw materials

Plants provide:

- Cotton for textiles.
- Sisal for ropes and other products.
- Sugarcane for sugar.
- Oil palm for vegetable oil.
- Rubber for rubber products.
- Timber for furniture and construction.

9. Source of income and employment

- Crop production supports farmers.
- Horticulture provides employment.
- Forestry supports timber and wood industries.
- Flower production contributes to Kenya's export economy.

10. Climate regulation

- Plants absorb carbon dioxide during photosynthesis.
- Forests store carbon in biomass and soils.
- Trees provide shade and help regulate local temperatures.

B. Harmful importance

1. Some plants are poisonous.

- Some contain toxic chemicals.
- They may cause poisoning when eaten or handled improperly.

Examples:

- *Datura stramonium*.
- *Ricinus communis* (castor plant; seeds contain ricin).
- *Nerium oleander*.

2. Some plants are weeds.

- They compete with crops for water, light, nutrients and space.
- They may reduce agricultural productivity.
- Some interfere with harvesting and farm operations.

Examples:

- *Striga hermonthica* – parasitic weed affecting cereal crops.
- *Parthenium hysterophorus* – invasive weed.
- *Cyperus rotundus* – purple nutsedge.

3. Some plants are invasive.

- They spread rapidly outside their natural ranges.
- They may displace native plants.
- They may reduce biodiversity and alter ecosystems.

4. Some plants damage infrastructure.

- Certain roots may penetrate drainage systems.
- Large roots may damage paths, foundations and underground pipes.

E. KINGDOM ANIMALIA

1. Meaning of Kingdom Animalia

Kingdom Animalia consists of multicellular eukaryotic organisms that obtain nutrients by ingesting food or through other forms of heterotrophic nutrition.

Animals generally lack cell walls and are capable of movement at some stage of their life cycle.

Examples include:

- Mammals.
- Birds.
- Reptiles.
- Amphibians.

- Fish.
- Insects.
- Worms.
- Molluscs.

2. General characteristics of Kingdom Animalia

1. They are eukaryotic.

- Their cells have a true nucleus.
- Their cells contain membrane-bound organelles.
- They possess mitochondria.
- Their genetic material is enclosed within a nuclear membrane.

2. They are multicellular.

- Their bodies consist of many cells.
- Cells are organised into tissues.
- Tissues form organs.
- Organs work together in organ systems.

3. They lack cell walls.

- Animal cells are surrounded by cell membranes.
- They do not have rigid cellulose cell walls.
- This allows cells to take different shapes and perform specialised functions.

4. They are heterotrophic.

- Animals cannot manufacture their own food through photosynthesis.
- They obtain nutrients from other organisms.
- Most animals ingest food and digest it internally.

5. Most animals can move.

- Many animals move from one place to another.
- Movement helps them search for food.
- It assists in finding mates and escaping predators.
- Some animals, such as adult sponges, are sessile.

6. They have specialised sensory structures.

- Many animals possess sense organs.
- These detect light, sound, touch, taste and chemical signals.
- Sensory organs help animals respond to environmental changes.

7. They reproduce mainly sexually.

- Most animals reproduce through the fusion of male and female gametes.
- Fertilisation may be internal or external.
- Some animals also reproduce asexually.

8. They have specialised methods of respiration.

Animals may respire using:

- Lungs.
- Gills.
- Tracheal systems.
- Moist skin.
- Other specialised respiratory surfaces.

9. They have different feeding habits.

- Herbivores feed mainly on plants.
- Carnivores feed mainly on other animals.
- Omnivores feed on both plants and animals.
- Detritivores feed on dead organic material.

10. They have different body organisation levels.

- Some animals have relatively simple body structures.
- Others possess highly developed organ systems.
- Mammals and birds have complex systems for circulation, respiration, digestion and coordination.

3. Major groups of Kingdom Animalia

Animals can be broadly grouped into two categories:

A. Invertebrates

Invertebrates are animals that lack a vertebral column.

Examples include:

Group	Characteristics	Examples
Porifera	Simple aquatic animals with pores	Sponges
Cnidaria	Possess specialised stinging cells	Jellyfish, hydra
Platyhelminthes	Flat-bodied worms	Tapeworms, planaria
Nematoda	Cylindrical unsegmented worms	Roundworms
Annelida	Segmented worms	Earthworms
Mollusca	Soft-bodied animals, often with shells	Snails, octopus
Arthropoda	Jointed appendages and exoskeleton	Insects, spiders, crabs
Echinodermata	Spiny skin; mainly marine	Starfish, sea urchins

B. Vertebrates

Vertebrates are animals possessing a vertebral column or backbone.

The five major groups traditionally studied are:

1. Pisces (fish)

- Mostly aquatic vertebrates.
- Respire mainly through gills.
- Possess fins for movement.
- Most have scales.
- Most are cold-blooded (ectothermic).

Examples:

- Tilapia.
- Nile perch.
- Catfish.
- Trout.

2. Amphibia (amphibians)

- Many live both in water and on land during different stages of their life cycle.
- Their skin is generally moist and lacks scales.
- Many lay eggs in water.
- Many undergo metamorphosis.
- Adults commonly respire through lungs and skin.

Examples:

- Frogs.
- Toads.
- Salamanders.

3. Reptilia (reptiles)

- Mostly have dry skin covered with scales.
- They are ectothermic.
- Most lay eggs on land.
- They mainly respire through lungs.

Examples:

- Snakes.
- Lizards.
- Tortoises.
- Crocodiles.

4. Aves (birds)

- Their bodies are covered with feathers.
- They possess beaks.

- Their forelimbs are modified into wings.
- They are endothermic.
- They lay eggs with hard shells.
- They possess lungs and air sacs.

Examples:

- Chicken.
- Eagle.
- Ostrich.
- Weaver bird.
- Flamingo.

5. Mammalia (mammals)

- Possess mammary glands in females.
- Most give birth to live young.
- Their bodies generally have hair or fur.
- They are endothermic.
- They breathe using lungs.
- They have a well-developed nervous system.

Examples:

- Humans.
- Cattle.
- Goats.
- Sheep.
- Lions.
- Elephants.
- Zebras.
- Giraffes.

4. Importance of Kingdom Animalia

A. Beneficial importance

1. Food production

Animals provide:

- Meat.
- Milk.
- Eggs.
- Fish.

- Honey.

Examples:

- Cattle provide milk and beef.
- Goats provide milk and meat.
- Chickens provide eggs and meat.
- Bees produce honey.
- Fish provide animal protein.

2. Source of income

- Livestock farming generates income.
- Poultry farming provides employment.
- Fisheries support local communities.
- Wildlife tourism contributes to Kenya's economy.

3. Transport

- Donkeys are used to transport goods in some communities.
- Camels are used for transport in arid and semi-arid areas.
- Horses may be used for riding and transport.

4. Source of manure

- Animal waste is used as organic manure.
- It adds organic matter to the soil.
- It contributes to soil fertility.

5. Pollination

- Bees and other insects transfer pollen between flowers.
- This assists plant reproduction.
- It supports the production of fruits and seeds.

6. Seed dispersal

- Some animals eat fruits and disperse seeds through their droppings.
- Others carry seeds on their bodies.
- This assists plant distribution.

7. Scientific research

- Animals are used in biological and medical research under appropriate ethical regulations.
- They help scientists study physiology, genetics and disease processes.

8. Security and companionship

- Dogs may be trained for security and detection.

- Domestic animals such as cats and dogs provide companionship.

9. Ecological balance

- Predators regulate prey populations.
- Herbivores influence vegetation.
- Scavengers consume dead animals.
- Animals help maintain ecosystem stability.

10. Recreation and tourism

- Wildlife attracts tourists to national parks and reserves.
- Kenya's wildlife is an important tourism resource.

B. Harmful importance

1. Transmission of diseases

Some animals act as disease vectors.

Examples:

- Female *Anopheles* mosquitoes transmit malaria parasites.
- Tsetse flies transmit African trypanosomes.
- Some ticks transmit disease-causing organisms.
- Houseflies may mechanically transfer pathogens to food.

2. Crop destruction

- Elephants may destroy crops.
- Birds may feed on grains and fruits.
- Rodents may damage stored cereals.
- Some insects destroy leaves, stems and roots.

3. Livestock predation

- Lions, hyenas and leopards may attack livestock.
- This causes economic losses to farmers.

4. Competition with humans

- Some wild animals compete with people for water and grazing land.
- This may cause human-wildlife conflict.

5. Transmission of livestock diseases

- Some ticks transmit livestock pathogens.
- Some biting insects transmit parasites.
- This reduces animal productivity.

6. Destruction of property

- Rodents may damage buildings and stored food.

- Termites may destroy wooden structures.
- Some wild animals may damage fences and water infrastructure.

1.1.7 Comparative characteristics of the five kingdoms

The five kingdoms can be compared using their cellular organisation, cell walls, nutrition, reproduction and body organisation.

Characteristic	Monera	Protoctista	Fungi	Plantae	Animalia
Cell type	Prokaryotic	Eukaryotic	Eukaryotic	Eukaryotic	Eukaryotic
Number of cells	Mostly unicellular	Mostly unicellular	Unicellular or multicellular	Multicellular	Multicellular
True nucleus	Absent	Present	Present	Present	Present
Cell wall	Usually present	Present in some	Present	Present	Absent
Cell wall material	Usually peptidoglycan in bacteria	Variable	Mainly chitin	Mainly cellulose	No cell wall
Chlorophyll	Present in some	Present in some	Absent	Usually present	Absent
Nutrition	Autotrophic or heterotrophic	Autotrophic or heterotrophic	Heterotrophic	Mainly autotrophic	Heterotrophic
Movement	Some move	Some move	Generally non-motile	Generally non-motile	Most move
Reproduction	Mainly asexual	Sexual and asexual	Sexual and asexual	Sexual and asexual	Mainly sexual
Examples	Bacteria	Amoeba, algae	Yeast, mushrooms	Maize, beans	Cow, lion

Important distinctions

1. Fungi are not plants because they lack chlorophyll and obtain food through absorption.
2. Protoctists are eukaryotic, whereas monerans are prokaryotic.
3. Animal cells lack cell walls, whereas plant and fungal cells possess cell walls.
4. Not all protoctists are unicellular; some algae are multicellular.
5. Not all bacteria are harmful; many are beneficial to humans and the environment.

1.1.8 Nomenclature

Meaning of nomenclature

Nomenclature is the scientific system of assigning names to organisms according to internationally accepted naming rules.

Scientific nomenclature ensures that organisms are identified using standard names irrespective of geographical location or language.

Types of naming organisms

1. Common naming

Common names are the ordinary names given to organisms by people in different communities and languages.

Examples:

Organism	Common name
Zea mays	Maize

Oryza sativa	Rice
Mangifera indica	Mango
Bos taurus	Cattle
Panthera leo	Lion
Canis lupus familiaris	Domestic dog
Gallus gallus domesticus	Domestic chicken

Advantages of common names:

- They are easy to remember.
- They are familiar to local communities.
- They are useful in everyday communication.
- They are convenient when discussing familiar plants and animals.

Disadvantages of common names:

- One organism may have several common names.
- Different organisms may share the same common name.
- Common names vary between languages and communities.
- They may cause confusion in scientific communication.

2. Scientific naming

Scientific naming is the use of internationally accepted names to identify organisms.

Examples:

Common name	**Scientific name**
Human being	*Homo sapiens*
Lion	*Panthera leo*
Leopard	*Panthera pardus*
African elephant	*Loxodonta africana*
Giraffe	*Giraffa camelopardalis*
Zebra	*Equus quagga*
Domestic cattle	*Bos taurus*
Goat	*Capra hircus*
Sheep	*Ovis aries*
Maize	*Zea mays*

Importance of scientific nomenclature

1. **Universal identification:** Scientific names are recognised internationally.

2. **Avoidance of confusion:** They distinguish organisms that have similar common names.

3. **Scientific communication:** Researchers can communicate accurately regardless of their native languages.

4. **Organisation of biological information:** Scientific names make it easier to arrange organisms in biological records.

5. **Biodiversity research:** They assist in documenting and monitoring species.

6. **Conservation:** They enable conservationists to identify endangered and threatened species accurately.

7. **Agricultural research:** They help distinguish crops, weeds, pests and disease-causing organisms.

8. **Medical research:** They help identify microorganisms responsible for human and animal diseases.

1.1.9 Binomial nomenclature

Meaning of binomial nomenclature

Binomial nomenclature is the scientific system of naming an organism using two words.

The system was popularised and formalised by the Swedish scientist **Carolus Linnaeus**.

The two words are:

1. Genus name.
2. Specific epithet.

The combination of the genus name and specific epithet gives the scientific species name.

Structure of a scientific name

Zea mays

Zea **mays**

Genus name **Specific epithet**

Begins with a capital letter. Begins with a lowercase letter.

Together, the two words form the scientific name of maize.

Examples of binomial names

Common name	Scientific name	Genus
Human	*Homo sapiens*	*Homo*
Lion	*Panthera leo*	*Panthera*
Leopard	*Panthera pardus*	*Panthera*
Tiger	*Panthera tigris*	*Panthera*
Domestic cat	*Felis catus*	*Felis*
Domestic dog	*Canis lupus familiaris*	*Canis*
Maize	*Zea mays*	*Zea*
Rice	*Oryza sativa*	*Oryza*
Wheat	*Triticum aestivum*	*Triticum*
Common bean	*Phaseolus vulgaris*	*Phaseolus*
Mango	*Mangifera indica*	*Mangifera*

Rules and principles of binomial nomenclature

Rule 1: Every species has a two-word scientific name.

- The first word represents the genus.
- The second word represents the specific epithet.

Example: *Homo sapiens*.

Rule 2: The genus name begins with a capital letter.

- The first letter of the genus name must be uppercase.

Correct: *Panthera leo*.

Incorrect: *panthera leo*.

Rule 3: The specific epithet begins with a lowercase letter.

- The second word must begin with a small letter.

Correct: *Zea mays*.

Incorrect: *Zea Mays*.

Rule 4: Scientific names are written in italics when printed.

- Both words are italicised.
- This distinguishes scientific names from ordinary text.

Example: *Bos taurus*.

Rule 5: Scientific names are underlined separately when handwritten.

- The genus and specific epithet are underlined individually.
- They should not be joined by one continuous underline.

Example:

Zea mays.

Rule 6: Scientific names are Latin or Latinised.

- Scientific names are traditionally derived from Latin or Latinised words.
- This allows them to be used internationally.

Rule 7: The genus name is written before the specific epithet.

Correct: *Mangifera indica*.

Incorrect: *indica Mangifera*.

Rule 8: The genus name may be abbreviated after its first complete appearance.

- Once a scientific name has been written in full, the genus may be shortened to its initial letter.
- The abbreviated genus must retain its capital letter.

Example:

- First mention: *Homo sapiens*.
- Subsequent mention: *H. sapiens*.

Rule 9: Scientific names must follow internationally accepted nomenclature codes.

Different groups of organisms are governed by different naming codes, including:

- Animals – International Code of Zoological Nomenclature (ICZN).
- Plants, algae and fungi – International Code of Nomenclature (ICN).

- Bacteria – International Code of Nomenclature of Prokaryotes (ICNP).

Rule 10: The same genus may contain several species.

- Organisms in the same genus share many characteristics.
- They have different specific epithets.

Example:

Genus	Species
Panthera	*Panthera leo*
Panthera	*Panthera pardus*
Panthera	*Panthera tigris*

These rules follow the established principles of scientific naming.

Exercise: Correct the following scientific names

Rewrite each name correctly.

1. zea Mays
2. panthera Leo
3. homo Sapiens
4. bos Taurus
5. Mangifera Indica
6. canis Lupus
7. felis Catus
8. Oryza Sativa

Answers

1. *Zea mays*
2. *Panthera leo*
3. *Homo sapiens*
4. *Bos taurus*
5. *Mangifera indica*
6. *Canis lupus*
7. *Felis catus*
8. *Oryza sativa*

1.1.10 Examples of common organisms found in Kenya and their scientific names

Kenya has rich biological diversity. Organisms occur in forests, grasslands, wetlands, rivers, lakes, farms, gardens, homes, national parks and marine environments.

Correct identification of these organisms helps learners understand taxonomy using familiar examples.

The following examples are useful for field studies and classroom investigations.

A. Domestic animals and livestock

No.	Common name	Scientific name
1	Domestic cattle	*Bos taurus*
2	Zebu cattle	*Bos indicus*
3	Domestic goat	*Capra hircus*
4	Domestic sheep	*Ovis aries*
5	Domestic donkey	*Equus asinus*
6	Domestic horse	*Equus caballus*
7	Domestic pig	*Sus scrofa domesticus*
8	Domestic chicken	*Gallus gallus domesticus*
9	Domestic duck	*Anas platyrhynchos domesticus*
10	Domestic turkey	*Meleagris gallopavo*
11	Domestic rabbit	*Oryctolagus cuniculus*
12	Domestic cat	*Felis catus*
13	Domestic dog	*Canis lupus familiaris*
14	Domestic guinea pig	*Cavia porcellus*

15	Honey bee	*Apis mellifera*
16	Silkworm	*Bombyx mori*

Note: Scientific names of some domesticated animals have alternative taxonomic treatments. The names above are commonly used in biological references.

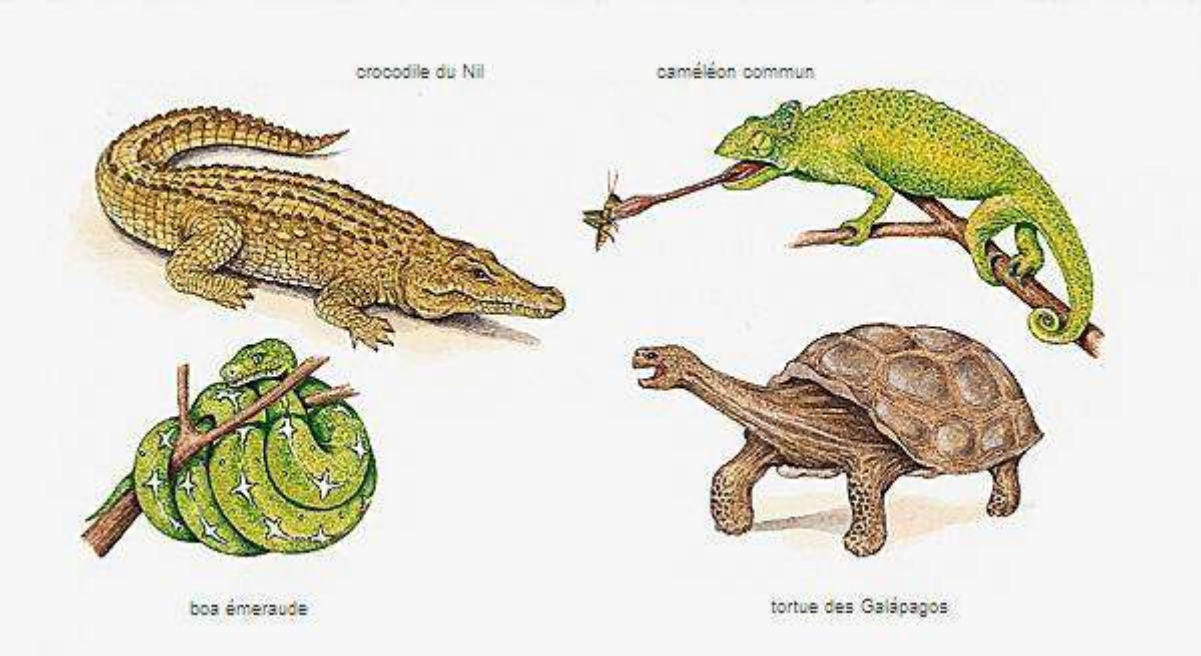
B. Wild mammals found in Kenya

No.	Common name	Scientific name
1	African lion	*Panthera leo*
2	African leopard	*Panthera pardus*
3	Cheetah	*Acinonyx jubatus*
4	African elephant	*Loxodonta africana*
5	Black rhinoceros	*Diceros bicornis*
6	White rhinoceros	*Ceratotherium simum*
7	Masai giraffe	*Giraffa tippelskirchi*
8	Plains zebra	*Equus quagga*
9	Grevy's zebra	*Equus grevyi*
10	African buffalo	*Syncerus caffer*
11	Spotted hyena	*Crocuta crocuta*
12	Striped hyena	*Hyaena hyaena*
13	African wild dog	*Lycaon pictus*
14	Common warthog	*Phacochoerus africanus*
15	Hippopotamus	*Hippopotamus amphibius*
16	Common eland	*Taurotragus oryx*
17	Impala	*Aepyceros melampus*
18	Thomson's gazelle	*Eudorcas thomsonii*
19	Grant's gazelle	*Nanger granti*
20	Wildebeest	*Connochaetes taurinus*
21	Waterbuck	*Kobus ellipsiprymnus*
22	Topi	*Damaliscus lunatus*
23	Banded mongoose	*Mungos mungo*
24	Meerkat	*Suricata suricatta*
25	Olive baboon	*Papio anubis*
26	Vervet monkey	*Chlorocebus pygerythrus*
27	Sykes' monkey	*Cercopithecus albogularis*
28	Black-and-white colobus	*Colobus guereza*
29	Aardvark	*Orycteropus afer*
30	Aardwolf	*Proteles cristata*
31	African civet	*Civettictis civetta*
32	Bat-eared fox	*Otocyon megalotis*
33	Cape hare	*Lepus capensis*
34	African porcupine	*Hystrix cristata*
35	Rock hyrax	*Procavia capensis*
36	African bush elephant	*Loxodonta africana*

C. Common birds found in Kenya

No.	Common name	Scientific name
1	Ostrich	*Struthio camelus*
2	African fish eagle	*Haliaeetus vocifer*
3	Lilac-breasted roller	*Coracias caudatus*
4	Marabou stork	*Leptoptilos crumenifer*
5	Grey crowned crane	*Balearica regulorum*
6	Secretary bird	*Sagittarius serpentarius*
7	Kori bustard	*Ardeotis kori*
8	African grey parrot	*Psittacus erithacus*
9	Helmeted guineafowl	*Numida meleagris*
10	House sparrow	*Passer domesticus*
11	Village weaver	*Ploceus cucullatus*
12	Superb starling	*Lamprotornis superbus*
13	Sacred ibis	*Threskiornis aethiopicus*
14	Hadada ibis	*Bostrychia hagedash*
15	Cattle egret	*Bubulcus ibis*
16	Great white pelican	*Pelecanus onocrotalus*
17	Greater flamingo	*Phoenicopterus roseus*
18	Lesser flamingo	*Phoeniconaias minor*
19	African hoopoe	*Upupa africana*
20	Pied crow	*Corvus albus*
21	African grey hornbill	*Lophoceros nasutus*
22	African jacana	*Actophilornis africanus*
23	Common ostrich	*Struthio camelus*
24	Helmeted vulture	*Necrosyrtes monachus*
25	African paradise flycatcher	*Terpsiphone viridis*

D. Common reptiles and amphibians



No.	Common name	Scientific name
1	Nile crocodile	*Crocodylus niloticus*
2	Leopard tortoise	*Stigmochelys pardalis*
3	African rock python	*Python sebae*
4	Black mamba	*Dendroaspis polylepis*
5	Puff adder	*Bitis arietans*

6	Egyptian cobra	*Naja haje*
7	Common agama	*Agama agama*
8	Nile monitor lizard	*Varanus niloticus*
9	Kenyan sand boa	*Eryx colubrinus*
10	Common chameleon	*Chamaeleo dilepis*
11	Green mamba	*Dendroaspis angusticeps*
12	African helmeted turtle	*Pelomedusa subrufa*
13	African bullfrog	*Pyxicephalus edulis*
14	African clawed frog	*Xenopus laevis*
15	Common toad	*Sclerophrys regularis*
16	Mascarene grass frog	*Ptychadena mascareniensis*

E. Common insects and other invertebrates

No.	Common name	Scientific name
1	Honey bee	*Apis mellifera*
2	Housefly	*Musca domestica*
3	Yellow fever mosquito	*Aedes aegypti*
4	Common house mosquito	*Culex quinquefasciatus*
5	African malaria mosquito	*Anopheles gambiae*
6	Desert locust	*Schistocerca gregaria*
7	Fall armyworm	*Spodoptera frugiperda*
8	Cotton bollworm	*Helicoverpa armigera*
9	African migratory locust	*Locusta migratoria*
10	African termite	*Macrotermes michaelseni*
11	Black garden ant	*Lasius niger*
12	Weaver ant	*Oecophylla longinoda*
13	Monarch butterfly	*Danaus plexippus*
14	African giant swallowtail	*Papilio antimachus*
15	African monarch	*Danaus chrysippus*
16	Ladybird beetle	*Coccinella septempunctata*
17	Dung beetle	*Scarabaeus sacer*
18	Tsetse fly	*Glossina morsitans*
19	Red spider mite	*Tetranychus urticae*
20	Scorpion	*Pandinus imperator*
21	Garden snail	*Cornu aspersum*
22	African giant snail	*Lissachatina fulica*
23	Earthworm	*Lumbricus terrestris*
24	Tick	*Rhipicephalus appendiculatus*
25	Dragonfly	*Anax imperator*

Some listed invertebrates are represented by particular species, while common names such as earthworm and dragonfly may refer to several species.

F. Common crops and food plants in Kenya



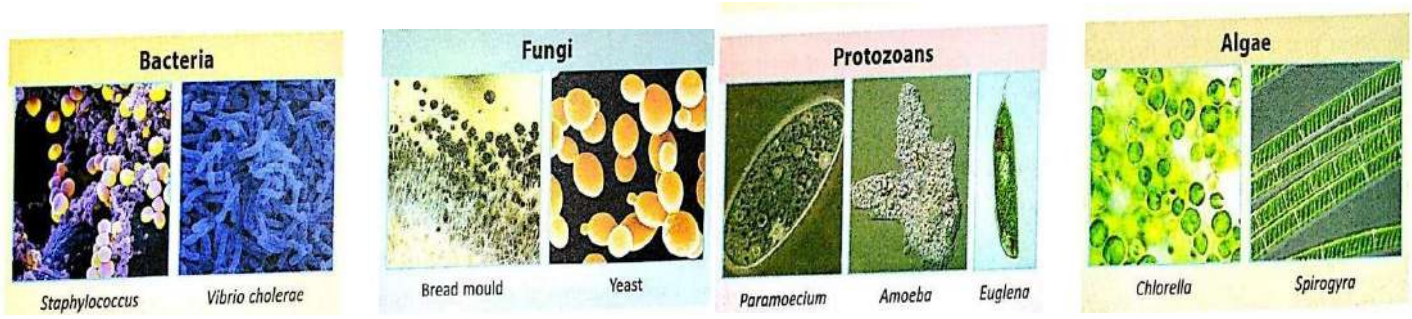
No.	Common name	Scientific name
1	Maize	*Zea mays*
2	Common bean	*Phaseolus vulgaris*
3	Rice	*Oryza sativa*
4	Wheat	*Triticum aestivum*
5	Sorghum	*Sorghum bicolor*
6	Finger millet	*Eleusine coracana*
7	Pearl millet	*Cenchrus americanus*
8	Cassava	*Manihot esculenta*
9	Sweet potato	*Ipomoea batatas*
10	Irish potato	*Solanum tuberosum*
11	Banana	*Musa* species
12	Sugarcane	*Saccharum officinarum*
13	Groundnut	*Arachis hypogaea*
14	Soybean	*Glycine max*
15	Cowpea	*Vigna unguiculata*
16	Pigeon pea	*Cajanus cajan*
17	Green gram	*Vigna radiata*
18	Tea	*Camellia sinensis*
19	Coffee	*Coffea arabica*
20	Cotton	*Gossypium hirsutum*
21	Sunflower	*Helianthus annuus*
22	Tomato	*Solanum lycopersicum*
23	Onion	*Allium cepa*
24	Cabbage	*Brassica oleracea*
25	Kale (sukuma wiki)	*Brassica oleracea*
26	Carrot	*Daucus carota*

27	Spinach	*Spinacia oleracea*
28	Pumpkin	*Cucurbita maxima*
29	Watermelon	*Citrullus lanatus*
30	Cucumber	*Cucumis sativus*
31	Avocado	*Persea americana*
32	Mango	*Mangifera indica*
33	Pawpaw	*Carica papaya*
34	Orange	*Citrus sinensis*
35	Lemon	*Citrus limon*
36	Passion fruit	*Passiflora edulis*
37	Pineapple	*Ananas comosus*
38	Guava	*Psidium guajava*
39	Coconut	*Cocos nucifera*
40	Macadamia	*Macadamia integrifolia*

G. Indigenous trees and other common plants in Kenya

No.	Common name	Scientific name
1	African olive	*Olea europaea* subsp. *cuspidata*
2	African pencil cedar	*Juniperus procera*
3	East African croton	*Croton megalocarpus*
4	African baobab	*Adansonia digitata*
5	Whistling thorn	*Vachellia drepanolobium*
6	Umbrella thorn	*Vachellia tortilis*
7	Fever tree	*Vachellia xanthophloea*
8	Mugumo (fig tree)	*Ficus thonningii*
9	Markhamia	*Markhamia lutea*
10	African mahogany	*Khaya anthotheca*
11	Meru oak	*Vitex keniensis*
12	African cherry	*Prunus africana*
13	Sausage tree	*Kigelia africana*
14	Flame tree	*Delonix regia*
15	Jacaranda	*Jacaranda mimosifolia*
16	Eucalyptus	*Eucalyptus* species
17	Grevillea	*Grevillea robusta*
18	Cypress	*Cupressus lusitanica*
19	Pine	*Pinus patula*
20	Neem	*Azadirachta indica*
21	Mango tree	*Mangifera indica*
22	Moringa	*Moringa oleifera*
23	Avocado tree	*Persea americana*
24	Kei apple	*Dovyalis caffra*
25	African tulip tree	*Spathodea campanulata*

H. Common fungi and microorganisms



No.	Common name	Scientific name

1	Baker's yeast	*Saccharomyces cerevisiae*
2	Bread mould	*Rhizopus stolonifer*
3	Button mushroom	*Agaricus bisporus*
4	Oyster mushroom	*Pleurotus ostreatus*
5	Penicillin mould	*Penicillium chrysogenum*
6	Black mould	*Aspergillus niger*
7	Corn smut	*Ustilago maydis*
8	Wheat stem rust	*Puccinia graminis*
9	Ringworm fungus	*Trichophyton rubrum*
10	Candida yeast	*Candida albicans*
11	Mucor mould	*Mucor mucedo*
12	Tomato early blight fungus	*Alternaria solani*

1.1.11 Practical activities in taxonomy

These activities enable learners to apply classification knowledge to organisms found in their surroundings.

Activity 1: Identifying organisms in the school environment

Materials required:

- Exercise book.
- Pen.
- Hand lens.
- Field guide.
- Camera or mobile device, where available.

Procedure:

1. Walk around the school compound under teacher supervision.
2. Observe different plants and animals.
3. Record the common names of the organisms.
4. Describe their observable characteristics.
5. Group the organisms into the five traditional kingdoms where applicable.
6. Use reference materials to identify their scientific names.
7. Present the findings to the class.

Expected observation table:

Organism	Observable features	Kingdom
Maize	Green leaves, roots and stem	Plantae
Grasshopper	Jointed legs, exoskeleton	Animalia
Mushroom	Cap, stalk and gills	Fungi
Pond Amoeba	Unicellular, pseudopodia	Protoctista
Soil bacterium	Microscopic prokaryotic cell	Monera

Activity 2: Comparing organisms from different kingdoms

Learners should compare a plant, animal, fungus and microscopic organism.

Record:

- Number of cells.
- Presence or absence of a true nucleus.
- Presence or absence of a cell wall.
- Mode of nutrition.
- Method of reproduction.
- Habitat.

Expected outcome: Learners should be able to distinguish organisms based on their characteristics.

Activity 3: Constructing a taxonomic hierarchy

Using a lion as an example, arrange the following taxonomic units in their correct order:

- Family Felidae.
- Kingdom Animalia.
- Genus *Panthera*.
- Class Mammalia.
- Species *Panthera leo*.
- Phylum Chordata.
- Order Carnivora.
- Domain Eukarya.

Expected answer:

Domain → Kingdom → Phylum → Class → Order → Family → Genus → Species.

Activity 4: Applying binomial nomenclature

Write the following common names alongside their scientific names:

1. Maize.
2. Mango.
3. Lion.
4. Human being.
5. Domestic cow.
6. Domestic goat.
7. Common bean.
8. African elephant.

Explain why the scientific names are written in italics.

Activity 5: Investigating fungi

1. Obtain a fresh mushroom specimen.
2. Observe its cap and stalk.
3. Examine the underside of the cap.
4. Draw and label the visible structures.
5. Discuss the role of fungi in decomposition.

Do not taste or handle unknown mushrooms. Wash hands after the activity.

1.1.12 Summary of key concepts

Concept	Main idea
Taxonomy	Identification, naming and classification of organisms
Identification	Recognising an organism
Classification	Grouping organisms according to similarities and differences
Nomenclature	Scientific naming of organisms
Taxon	A recognised classification group
Taxonomic hierarchy	Arrangement of classification units from broad to specific
Domain	Highest modern taxonomic category
Kingdom	Major taxonomic category below domain
Genus	Group of closely related species
Species	Basic taxonomic unit in traditional classification
Binomial nomenclature	Naming a species using two words
Monera	Traditional kingdom of prokaryotic organisms
Protoctista	Traditional kingdom of mostly simple eukaryotes
Fungi	Eukaryotic absorptive heterotrophs
Plantae	Mainly photosynthetic multicellular organisms
Animalia	Multicellular heterotrophic organisms

1.1.13 Revision questions

Instructions: Attempt all questions. Use the knowledge and skills acquired from the notes.

Section A: Multiple-choice questions

Choose the correct answer from the alternatives A, B, C and D.

1. The branch of biology concerned with the identification, naming and classification of organisms is known as:

A. Ecology

B. Taxonomy

C. Physiology

D. Anatomy

2. Which one of the following is the most specific taxonomic unit?

A. Kingdom

B. Class

C. Genus

D. Species

3. Which scientist proposed the five-kingdom classification system in 1969?

A. Charles Darwin

B. Carolus Linnaeus

C. Robert H. Whittaker

D. Gregor Mendel

4. Which one of the following organisms belongs to Kingdom Monera in the traditional five-kingdom system?

A. Amoeba

B. Rhizobium

C. Mushroom

D. Fern

5. An organism whose cells lack a true nucleus is classified as:

A. Eukaryotic

B. Multicellular

C. Prokaryotic

D. Photosynthetic

6. Which one of the following structures is used by Amoeba for movement?

A. Cilia B. Flagella

C. Pseudopodia D. Hyphae

7. Which one of the following organisms belongs to Kingdom Fungi?

A. Euglena

B. Rhizopus

C. Paramecium

D. Chlamydomonas

8. The cell wall of most fungi is mainly made of:

A. Cellulose

B. Peptidoglycan

C. Chitin

D. Starch

9. Which one of the following is a characteristic of Kingdom Animalia?

A. Presence of cellulose cell walls

B. Presence of chlorophyll

C. Absence of cell walls

D. Manufacture of food through photosynthesis

10. Which one of the following organisms is a cyanobacterium?

A. Nostoc

B. Amoeba

C. Mushroom

D. Spirogyra

11. The scientific name of maize is:

A. *Mangifera indica*

B. *Zea mays*

C. *Oryza sativa*

D. *Phaseolus vulgaris*

12. Which taxonomic unit comes immediately after family?

A. Order

B. Class

C. Genus

D. Phylum

13. Which one of the following organisms reproduces commonly through budding?

A. Yeast B. Lion

C. Maize D. Amoeba

14. Which one of the following bacteria is involved in nitrogen fixation in leguminous plants?

A. *Vibrio cholerae*

B. *Rhizobium*

C. *Salmonella enterica*

D. *Mycobacterium tuberculosis*

15. Which one of the following organisms belongs to Kingdom Protoctista?

A. Paramecium

B. Mushroom

C. Earthworm

D. Maize

16. Which one of the following scientific names is correctly written?

A. *panthera Leo*

B. *Panthera Leo*

C. *panthera leo*

D. *Panthera leo*

17. Which one of the following is an example of a gymnosperm?

A. Maize

B. Bean

C. Pine

D. Mango

18. Which one of the following fungi is commonly used in bread making?

A. *Puccinia graminis*

B. *Saccharomyces cerevisiae*

C. *Ustilago maydis*

D. *Fusarium oxysporum*

19. Which organism causes malaria?

A. *Trypanosoma brucei*

B. *Plasmodium falciparum*

C. *Entamoeba histolytica*

D. *Giardia duodenalis*

20. Which one of the following taxonomic units contains several related genera?

A. Species B. Family

C. Class D. Kingdom

21. The scientific name of the African elephant is:

A. *Equus grevyi*

B. *Loxodonta africana*

C. *Panthera leo*

D. *Giraffa tippelskirchi*

22. Which one of the following organisms obtains nutrients mainly through absorption?

A. Lion

B. Goat

C. Mushroom

D. Grasshopper

23. The kingdom that contains organisms with cellulose cell walls and chlorophyll is:

A. Fungi

B. Plantae

C. Animalia

D. Monera

24. Which one of the following is a beneficial role of bacteria in agriculture?

A. Causing cholera

B. Causing tuberculosis

C. Fixing atmospheric nitrogen

D. Causing food poisoning

25. Which taxonomic category is immediately above order?

A. Family

B. Genus

C. Class

D. Species

Section B: Structured questions

26. (a) Define the term taxonomy. (2 marks)

(b) Distinguish between the following terms:

(i) Identification. (2 marks)

(ii) Classification. (2 marks)

(iii) Nomenclature. (2 marks)

(c) State four reasons why taxonomy is important in biology. (4 marks)

27. (a) List the five kingdoms in the traditional five-kingdom classification system. (5 marks)

(b) State four characteristics of organisms belonging to Kingdom Monera. (4 marks)

(c) Give three examples of organisms belonging to Kingdom Monera. (3 marks)

28. (a) State four characteristics of Kingdom Protoctista. (4 marks)

(b) Name three structures used by protoctists for movement. (3 marks)

(c) State three ways in which protoctists are economically important. (3 marks)

29. (a) Describe five general characteristics of Kingdom Fungi. (5 marks)

(b) Explain three beneficial uses of fungi. (3 marks)

(c) Name two diseases caused by fungi. (2 marks)

30. (a) State five general characteristics of Kingdom Plantae. (5 marks)

(b) Name the four major groups of plants traditionally studied under Kingdom Plantae. (4 marks)

(c) State one distinguishing characteristic of gymnosperms. (1 mark)

31. (a) State five characteristics of organisms belonging to Kingdom Animalia. (5 marks)

(b) Distinguish between vertebrates and invertebrates. (2 marks)

(c) Name the five major groups of vertebrates. (5 marks)

32. (a) Arrange the following taxonomic units in descending order, starting with the broadest:

Genus, Family, Kingdom, Species, Order, Class, Phylum. (4 marks)

(b) State the taxonomic classification of a lion from kingdom to species. (4 marks)

(c) Explain why species is considered the basic taxonomic unit. (2 marks)

33. (a) Define binomial nomenclature. (2 marks)

(b) State five rules governing binomial nomenclature. (5 marks)

(c) Identify the genus and specific epithet in the scientific name *Mangifera indica*. (2 marks)

(d) Write the scientific name of maize correctly. (1 mark)

34. (a) Give the scientific names of the following organisms:

(i) Human being. (1 mark)

(ii) African lion. (1 mark)

(iii) Maize. (1 mark)

(iv) Mango. (1 mark)

(v) Domestic cattle. (1 mark)

(b) Explain three disadvantages of using common names when identifying organisms. (3 marks)

(c) State two advantages of using scientific names. (2 marks)

35. (a) Explain five ways in which organisms belonging to Kingdom Monera are important to humans and the environment. (5 marks)

(b) State five harmful effects of bacteria. (5 marks)

36. (a) Differentiate between autotrophic and heterotrophic nutrition. (2 marks)

(b) Explain how the following organisms obtain their nutrition:

(i) Mushroom. (2 marks)

(ii) Green plant. (2 marks)

(iii) Amoeba. (2 marks)

(iv) Parasitic bacterium. (2 marks)

37. A learner collected the following organisms during a field investigation:

- Mushroom.
- Maize plant.
- Grasshopper.
- Amoeba.
- Bacterium.

(a) Classify each organism into its appropriate traditional kingdom. (5 marks)

(b) State one characteristic that justifies the classification of each organism. (5 marks)

38. Explain five ways in which taxonomy contributes to biodiversity conservation in Kenya. (10 marks)

1.1.14 practical assessment and project

Project title: Investigating biodiversity within the local environment

Learners should work in groups to prepare a biodiversity catalogue of organisms found within their school or local community.

Project requirements:

1. Identify at least 20 organisms.
2. Include plants, animals, fungi and microorganisms where specimens or reliable images are available.
3. Record their common names.
4. Provide their scientific names.
5. Classify each organism into its traditional kingdom.
6. Record at least two observable characteristics.
7. Take photographs or make labelled drawings.
8. Explain the importance of selected organisms to the local community.
9. Identify organisms that require conservation.
10. Present the findings to the class.

Suggested project record

No.	Common name	Scientific name	Kingdom	Habitat
1	Maize	*Zea mays*	Plantae	Farm
2	Cow	*Bos taurus*	Animalia	Farm
3	Mushroom	*Agaricus* species	Fungi	Moist ground
4	Earthworm	*Lumbricus terrestris*	Animalia	Soil
5	Bean	*Phaseolus vulgaris*	Plantae	Farm

Competency assessment indicators

The teacher should assess whether the learner can:

- Correctly identify organisms.
- Distinguish between the five traditional kingdoms.
- Apply scientific naming rules.
- Arrange taxonomic units in the correct hierarchy.
- Use scientific vocabulary accurately.
- Appreciate the importance of biodiversity.
- Demonstrate responsible environmental conservation practices.

STRAND 1: CELL BIOLOGY AND BIODIVERSITY

SUB-STRAND 1.2: ECOLOGY

1.2.1 Introduction to ecology

Meaning of ecology

Ecology is the branch of biology that deals with the scientific study of interactions between living organisms and their physical environment.

It examines how organisms interact with:

- Other organisms of the same species.
- Organisms belonging to different species.
- Non-living components of the environment.
- Their habitats and available resources.

Ecology helps explain how organisms survive, reproduce, compete for resources and maintain populations within different environments.

Examples of ecological studies in Kenya

1. Studying the relationship between zebras, wildebeests and grass in the Maasai Mara ecosystem.
2. Investigating how elephants influence vegetation in Amboseli National Park.
3. Studying the relationship between fish, algae and aquatic plants in Lake Victoria.
4. Investigating how soil moisture affects maize growth in agricultural ecosystems.
5. Studying the effects of drought on livestock and vegetation in Kajiado, Turkana and Marsabit counties.
6. Investigating how deforestation affects biodiversity in the Mau Forest Complex.
7. Studying how mangrove forests support marine organisms along the Kenyan coast.

Importance of studying ecology

Ecology is important because it:

1. **Promotes environmental conservation:** It helps people understand the importance of protecting forests, wildlife, wetlands and other natural habitats.

2. **Supports sustainable agriculture:** Farmers use ecological knowledge to manage soil fertility, water, pests and beneficial organisms.

3. **Promotes wildlife management:** It helps conservationists understand the feeding habits, breeding patterns and habitats of wild animals.

4. **Helps control environmental pollution:** Ecological studies reveal how pollutants affect organisms and ecosystems.

5. **Supports disease control:** It helps explain how disease-causing organisms interact with vectors, hosts and environmental conditions.

6. **Promotes sustainable utilisation of resources:** It guides the responsible use of water, forests, fisheries and other natural resources.

7. **Helps predict environmental changes:** Ecological knowledge helps scientists understand the effects of drought, floods, global warming and climate change.

8. **Supports urban planning:** It helps planners understand the effects of human settlements, industries and infrastructure on natural ecosystems.

9. **Promotes biodiversity conservation:** It helps identify endangered organisms and the environmental conditions necessary for their survival.

10. **Supports climate change mitigation:** It explains the role of forests, soils, oceans and other ecosystems in storing carbon.

1.2.2 Basic ecological terminology

Ecology involves several important terms used to describe organisms and their environment.

1. Habitat

A habitat is the natural place or environment where an organism lives and obtains the resources necessary for survival.

A habitat provides organisms with:

- Food.
- Water.
- Shelter.
- Space.
- Suitable breeding sites.
- Appropriate environmental conditions.

Examples of habitats:

Organism	Habitat
Lion	Grassland and savanna
Tilapia	Freshwater
Camel	Arid and semi-arid environments
Earthworm	Moist soil
Frog	Moist terrestrial and aquatic environments
Mangrove tree	Saline coastal wetlands
Cactus	Arid environments
Trout	Cold, well-oxygenated freshwater

Importance of habitats to organisms

1. They provide food and water.
2. They offer protection against predators.
3. They provide suitable conditions for reproduction.
4. They provide shelter against unfavourable weather.
5. They provide space for movement and growth.
6. They support interactions between organisms.

2. Ecological niche

An ecological niche is the functional role and position occupied by an organism in an ecosystem, including how it obtains resources, interacts with other organisms and responds to environmental conditions.

A niche describes what an organism does in its environment rather than simply where it lives.

Examples:

- Bees occupy a pollination niche because they transfer pollen between flowers while collecting nectar and pollen.
- Earthworms occupy a decomposer-related niche because they break down organic matter and improve soil structure.
- Lions occupy a predator niche because they hunt and feed on other animals.
- Vultures occupy a scavenger niche because they feed on dead animals.
- Green plants occupy a producer niche because they manufacture food through photosynthesis.

Difference between habitat and niche

Habitat	Ecological niche
Refers to where an organism lives.	Refers to the role of an organism in an ecosystem.
Describes the physical environment.	Describes how an organism lives and interacts.
Several organisms may share one habitat.	Different species may have different niches within the same habitat.
Example: A lake.	Example: A fish feeding on aquatic insects.

3. Population

A population is a group of organisms belonging to the same species, living in a particular geographical area at a particular time and capable of interbreeding.

Examples:

- All zebras living in a particular section of Maasai Mara.
- All tilapia of the same species in a particular lake.
- All maize plants growing in one farm.
- All acacia trees of a particular species in a woodland.
- All frogs of the same species in a particular pond.

Characteristics of a population

A population can be described using several characteristics:

1. Population size.
2. Population density.
3. Population distribution or dispersion.
4. Population growth.
5. Birth rate (natality).
6. Death rate (mortality).

7. Immigration.
8. Emigration.
9. Age structure.
10. Sex ratio.

These characteristics help ecologists understand changes in population numbers over time.

4. Community

A community is a group of populations of different species living and interacting in the same geographical area at a particular time.

A community consists of different populations of plants, animals, fungi and microorganisms.

Example: A forest community

A forest community may contain:

- Trees.
- Shrubs.
- Grasses.
- Birds.
- Insects.
- Mammals.
- Reptiles.
- Fungi.
- Bacteria.

The organisms interact through feeding relationships, competition, pollination, parasitism, predation and decomposition.

5. Ecosystem

An ecosystem is a functional unit consisting of a community of living organisms and the non-living components of their environment interacting with one another.

An ecosystem includes:

- Living organisms (biotic components).
- Non-living environmental factors (abiotic components).
- Interactions between living organisms and their physical environment.

Examples of ecosystems in Kenya:

- Maasai Mara grassland ecosystem.
- Mau Forest ecosystem.
- Lake Victoria aquatic ecosystem.
- Amboseli ecosystem.
- Tana River ecosystem.

- Arabuko-Sokoke Forest ecosystem.
- Coastal mangrove ecosystem.

6. Biome

A biome is a large geographical region characterised by particular climatic conditions and dominant types of vegetation, together with the animals adapted to those conditions.

Examples include:

- Tropical rainforest biome.
- Savanna grassland biome.
- Desert biome.
- Temperate forest biome.
- Tundra biome.
- Aquatic biome.

A biome contains several ecosystems with related environmental characteristics.

7. Biomass

Biomass is the total mass of living organic matter in a given area, habitat or trophic level at a particular time.

Biomass may be expressed as:

- Grams per square metre (g/m^2).
- Kilograms per hectare (kg/ha).
- Tonnes per hectare (t/ha).

Examples:

- The total mass of maize plants growing in one hectare.
- The total mass of grass in a particular grassland.
- The total mass of fish in a lake.
- The total mass of trees in a forest.

Importance of biomass measurement

1. Helps determine the productivity of ecosystems.
2. Helps estimate the amount of organic matter available as food.
3. Helps monitor changes in vegetation.
4. Helps assess carbon storage in forests.
5. Helps evaluate the effects of grazing on grasslands.

8. Carrying capacity

Carrying capacity is the maximum population size of a particular species that an environment can support sustainably over a long period under prevailing environmental conditions.

Carrying capacity depends on the availability of:

- Food.
- Water.
- Shelter.
- Breeding sites.
- Space.
- Other essential resources.

Example:

A grassland may support a certain number of cattle depending on the amount of available pasture and water. If the number of cattle exceeds the carrying capacity, overgrazing may occur.

Factors affecting carrying capacity

1. Availability of food.
2. Availability of water.
3. Size of habitat.
4. Climate.
5. Soil fertility.
6. Predation.
7. Disease outbreaks.
8. Competition.
9. Human activities.
10. Availability of breeding and shelter sites.

9. Ecological succession

Ecological succession is the gradual and orderly change in the composition and structure of a biological community in an area over time.

During succession, some organisms establish themselves, modify environmental conditions and are gradually replaced by other organisms.

Types of ecological succession

A. Primary succession

Primary succession is the development of a biological community in an area where no established soil or previous biological community exists.

It may begin on:

- Bare rocks.
- Newly exposed volcanic surfaces.
- Newly formed land.
- Freshly exposed mineral surfaces.

Stages of primary succession

1. **Nudation:** A bare area is formed where an established community is absent.
2. **Invasion:** Pioneer organisms arrive and establish themselves.
3. **Ecesis:** The pioneer organisms become established and begin growing.
4. **Aggregation:** The organisms increase in number and spread.
5. **Competition and co-action:** Organisms compete for available resources.
6. **Reaction:** Organisms modify environmental conditions.
7. **Stabilisation:** A relatively stable community develops.

Examples of primary succession:

- Colonisation of bare volcanic rock.
- Development of vegetation on newly exposed rock surfaces.
- Colonisation of newly formed land.

B. Secondary succession

Secondary succession is the gradual development of a biological community in an area where a previous community existed but was disturbed or destroyed, while the soil remains.

It may occur following:

- Forest fires.
- Abandoned agricultural land.
- Flood damage.
- Overgrazing.
- Deforestation.
- Human land clearance.

Examples of secondary succession:

- Regrowth of vegetation after a forest fire.
- Regeneration of vegetation on abandoned farmland.
- Recovery of grassland after controlled disturbance.

Differences between primary and secondary succession

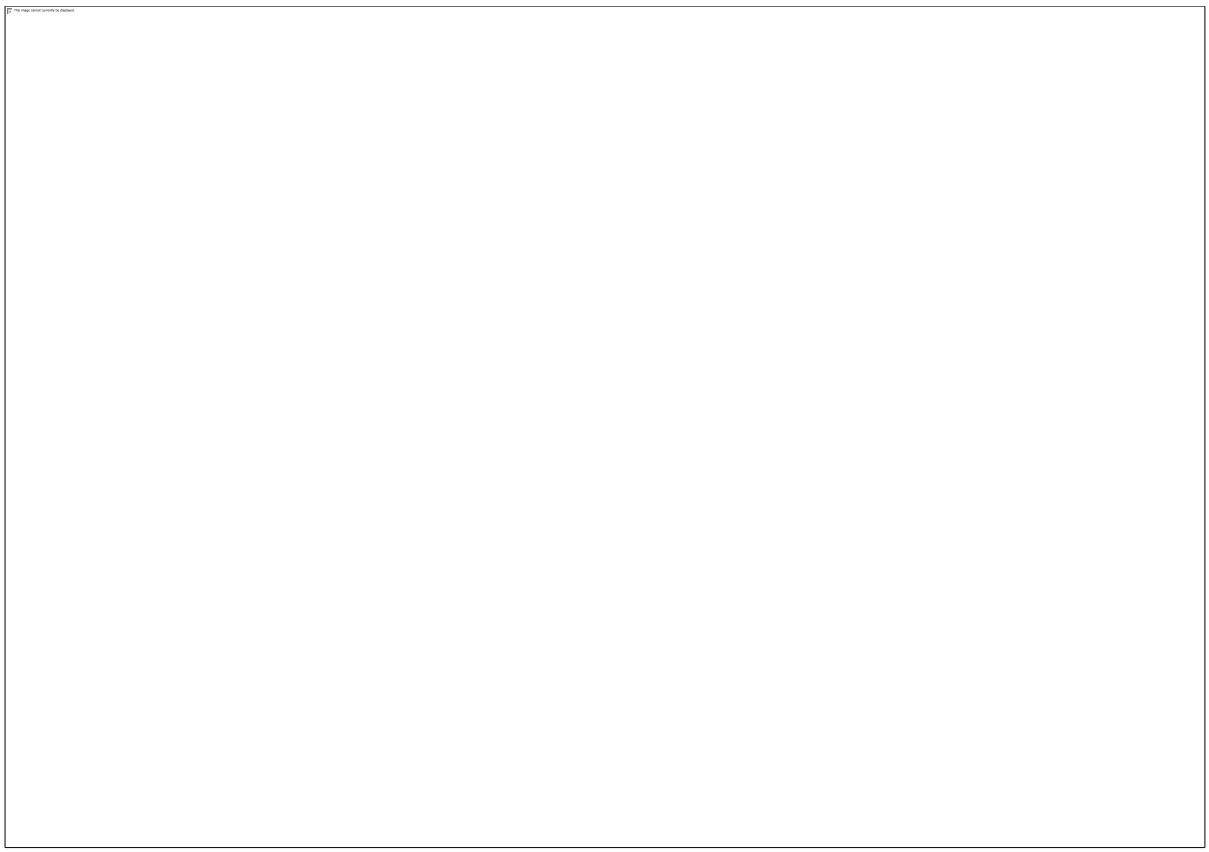
Primary succession	**Secondary succession**
Begins in an area without established soil.	Begins where soil remains.

Starts on bare surfaces.	Starts in a previously occupied habitat.
Usually takes a longer time.	Usually occurs faster.
Pioneer species may include lichens and mosses.	Pioneer species may include grasses and herbs.
Soil formation is an important early process.	Soil is already present.

1.2.3 Components of an ecosystem

An ecosystem consists of two major components:

1. Biotic components.
2. Abiotic components.



A. Biotic components

Biotic components are all the living organisms found in an ecosystem.

They include:

- Plants.
- Animals.
- Fungi.
- Bacteria.
- Algae.
- Other microorganisms.

Biotic components are grouped according to their roles in the ecosystem.

1. Producers

Producers are organisms that manufacture their own organic food from simple inorganic substances, usually through photosynthesis.

Most producers contain chlorophyll, which absorbs light energy for photosynthesis.

Examples:

- Green grasses.
- Maize plants.
- Trees.
- Algae.
- Aquatic plants.
- Phytoplankton.

Importance of producers

1. They manufacture food for other organisms.
2. They form the first trophic level in most food chains.
3. They release oxygen during photosynthesis.
4. They absorb carbon dioxide from the atmosphere or water.
5. They provide habitats and shelter for other organisms.
6. They support energy flow through ecosystems.

2. Consumers

Consumers are organisms that obtain organic food by feeding on other organisms.

They cannot manufacture sufficient organic food from inorganic substances.

Consumers are classified according to their feeding habits.

A. Primary consumers

These are organisms that feed directly on producers.

They are mainly herbivores.

Examples:

- Cattle.
- Goats.
- Sheep.
- Zebras.
- Grasshoppers.
- Rabbits.
- Giraffes.

B. Secondary consumers

These are organisms that feed mainly on primary consumers.

They are commonly carnivores or omnivores.

Examples:

- Frogs feeding on grasshoppers.
- Lizards feeding on insects.
- Small fish feeding on zooplankton.
- Spiders feeding on insects.

C. Tertiary consumers

These are organisms that feed on secondary consumers.

Examples:

- Large predatory fish.
- Snakes feeding on insect-eating frogs.
- Larger carnivorous birds feeding on smaller predators.

D. Quaternary consumers

These are organisms that feed on tertiary consumers and may occupy high trophic levels in some food chains.

Examples depend on the particular ecosystem and food chain.

3. Decomposers

Decomposers are organisms that break down dead organic matter and organic wastes into simpler substances.

The main decomposers include:

- Bacteria.
- Fungi.

Process of decomposition

1. Organisms die or produce organic wastes.
2. Decomposers colonise the dead organic matter.
3. They release enzymes onto the organic material.
4. Complex organic substances are broken down into simpler substances.
5. Nutrients are released into the environment.
6. Plants absorb the released mineral nutrients through their roots.

Importance of decomposers

1. They recycle nutrients in ecosystems.
2. They prevent excessive accumulation of dead organic matter.

3. They contribute to soil formation.
4. They improve soil fertility.
5. They support nutrient cycles.
6. They help maintain ecosystem balance.

4. Detritivores

Detritivores are organisms that feed by ingesting dead organic matter called detritus.

Examples include:

- Earthworms.
- Millipedes.
- Woodlice.
- Some beetles.

Difference between decomposers and detritivores

Decomposers	**Detritivores**
Break down organic matter externally using enzymes.	Ingest dead organic matter.
Mainly include bacteria and fungi.	Include earthworms and millipedes.
Absorb soluble breakdown products.	Digest ingested organic material internally.

B. Abiotic components

Abiotic components are the non-living physical and chemical factors that influence organisms in an ecosystem.

They determine the conditions under which organisms survive, grow, reproduce and distribute themselves.

Abiotic factors can be grouped into:

1. Climatic factors.
2. Physiographic factors.
3. Edaphic factors.
4. Chemical factors.

1. Climatic factors

Climatic factors are atmospheric conditions that influence organisms in an ecosystem.

They include:

A. Temperature

Temperature is the degree of hotness or coldness of the environment.

Effects of temperature:

1. Influences the rate of enzyme-controlled metabolic reactions.
2. Affects growth and development of organisms.

3. Influences the distribution of plants and animals.
4. Affects the rate of evaporation and transpiration.
5. Influences breeding and reproductive activities.
6. Determines the activity of many organisms.

Example: High temperatures and low rainfall in northern Kenya favour organisms adapted to arid conditions.

B. Rainfall

Rainfall is the amount of water received by an area through precipitation over a given period.

Effects of rainfall:

1. Determines the availability of water.
2. Influences plant growth.
3. Determines the type of vegetation.
4. Affects soil moisture.
5. Influences breeding patterns of some animals.
6. Affects the distribution of terrestrial organisms.

Example: Areas with high rainfall such as parts of Kakamega support dense vegetation, while arid areas such as Turkana have sparse vegetation.

C. Light intensity

Light intensity refers to the amount of light energy reaching a particular area.

Effects of light intensity:

1. Influences the rate of photosynthesis.
2. Affects flowering in some plants.
3. Influences plant distribution.
4. Affects the activity of diurnal and nocturnal animals.
5. Influences the growth of aquatic plants and algae.

D. Relative humidity

Relative humidity is the amount of water vapour present in the air expressed as a percentage of the maximum amount the air can hold at the same temperature.

Effects:

1. Influences the rate of transpiration.
2. Affects water loss from animals.
3. Influences the growth of fungi.
4. Affects the survival of organisms sensitive to drying.
5. Influences the spread of some diseases.

E. Wind

Wind is the movement of air from one region to another.

Effects of wind:

1. Increases the rate of transpiration.
2. Helps in the dispersal of seeds and fruits.
3. Assists in pollination of wind-pollinated plants.
4. Influences the movement of flying organisms.
5. May cause mechanical damage to plants.
6. Influences evaporation.

F. Atmospheric gases

Important atmospheric gases include:

- Oxygen.
- Carbon dioxide.
- Nitrogen.

Their importance:

- Oxygen is required for aerobic respiration.
- Carbon dioxide is used by green plants during photosynthesis.
- Nitrogen is required for the formation of proteins and nucleic acids after biological fixation and assimilation.

2. Physiographic factors

Physiographic factors are physical features of the land that influence the distribution and survival of organisms.

They include:

A. Altitude

Altitude refers to the height of a place above sea level.

Effects:

1. Influences temperature.
2. Affects atmospheric pressure.
3. Influences vegetation distribution.
4. Affects the distribution of animals.
5. Influences the availability of oxygen.

Example: Vegetation on Mount Kenya changes with altitude.

B. Slope

Slope refers to the degree of steepness or inclination of land.

Effects:

1. Influences the rate of surface runoff.

2. Affects soil erosion.
3. Influences soil moisture.
4. Determines the depth of soil.
5. Affects plant establishment.

C. Aspect

Aspect refers to the direction a slope faces in relation to the sun.

Effects:

1. Influences the amount of sunlight received.
2. Affects soil temperature.
3. Influences evaporation.
4. Affects soil moisture.
5. Influences vegetation distribution.

D. Drainage

Drainage refers to the ability of soil or land to remove excess water.

Effects:

1. Influences soil aeration.
2. Affects root respiration.
3. Influences the growth of plants.
4. Determines the distribution of water-tolerant plants.
5. Affects soil microbial activities.

3. Edaphic factors

Edaphic factors are soil-related physical, chemical and biological conditions that influence the distribution and growth of organisms.

They include:

- Soil pH.
- Soil texture.
- Soil structure.
- Soil moisture.
- Soil depth.
- Soil aeration.
- Mineral nutrient content.
- Soil organic matter.

Effects of soil factors

1. Soil pH affects the availability of mineral nutrients.

2. Soil texture influences water-holding capacity.
3. Soil structure influences root penetration.
4. Soil aeration influences root respiration.
5. Soil depth determines the space available for root growth.
6. Soil organic matter improves fertility and water retention.

4. Chemical factors

These are chemical substances and conditions in the environment that influence living organisms.

Examples:

- Salinity.
- Dissolved oxygen.
- Mineral salts.
- Water pH.
- Nutrient concentration.
- Toxic substances.

Example: High salt concentration in coastal soils limits the growth of many ordinary terrestrial plants but favours halophytes.

1.2.4 Types of ecosystems

An ecosystem may be natural or artificial.

A. Natural ecosystems

Natural ecosystems develop mainly through natural processes without being deliberately created by humans.

Examples:

- Forest ecosystems.
- Grassland ecosystems.
- Desert ecosystems.
- Freshwater ecosystems.
- Marine ecosystems.

B. Artificial ecosystems

Artificial ecosystems are ecosystems established or significantly modified by humans for particular purposes.

Examples:

- Agricultural farms.
- Fish ponds.
- Aquariums.
- Irrigated gardens.

- Greenhouses.
- Reservoirs.

Characteristics of artificial ecosystems

1. They are established or managed by humans.
2. They may have fewer species than natural ecosystems.
3. They often require human inputs.
4. Their nutrient cycles may depend on external fertilisers and feeding.
5. Their populations may be controlled through management practices.

1.2.5 Forest ecosystems

Meaning of a forest ecosystem

A forest ecosystem is a terrestrial ecosystem dominated by trees and other woody vegetation, together with animals, microorganisms and non-living environmental components.

Forests contain several layers of vegetation and support diverse communities of organisms.

Types of forests

1. Tropical rainforests.
2. Tropical seasonal forests.
3. Montane forests.
4. Temperate forests.
5. Coniferous forests.
6. Mangrove forests.
7. Dry forests.

Examples of forest ecosystems in Kenya

- Mau Forest Complex.
- Kakamega Forest.
- Arabuko-Sokoke Forest.
- Mount Kenya forests.
- Aberdare Forest.
- Cherangani Hills forests.
- Coastal mangrove forests.

Characteristics of forest ecosystems

A. Climatic characteristics

1. Many forests receive moderate to high rainfall, although dry forests receive less.
2. Tropical rainforests experience high rainfall throughout much of the year.

3. Temperature and humidity vary according to altitude and geographical location.
4. Forest interiors often have higher humidity than exposed areas.
5. The forest canopy reduces the amount of sunlight reaching the forest floor.
6. Wind movement is often reduced beneath dense vegetation.
7. Evapotranspiration contributes to local atmospheric moisture.

B. Physiographic characteristics

1. Forests occur on plains, hills, mountains and coastal regions.
2. Montane forests occur at relatively high altitudes.
3. Forest vegetation may grow on slopes and valleys.
4. Drainage conditions influence forest distribution.
5. Soil depth and slope influence tree establishment.

C. Biotic characteristics

1. Forests contain many tree species.
2. They support shrubs, herbs, climbers and epiphytes.
3. They contain insects, birds, reptiles and mammals.
4. Fungi and bacteria are important decomposers.
5. Forest organisms occupy different feeding levels.
6. Competition for light, water, nutrients and space is common.

Vertical stratification of forests

Vertical stratification refers to the arrangement of vegetation into different layers according to height.

1. Emergent layer

- It is the uppermost layer of tall trees.
- Trees receive direct sunlight.
- Trees are exposed to strong winds.
- Some birds and insects occupy this layer.

2. Canopy layer

- It consists of the crowns of many trees.
- It forms a continuous or nearly continuous cover.
- It receives a large amount of sunlight.
- It supports birds, monkeys, insects and climbing plants.
- It intercepts rainfall and reduces light penetration.

3. Understorey layer

- It occurs below the canopy.
- It consists of young trees and shade-tolerant plants.

- Light intensity is relatively low.
- Humidity is often high.
- It provides shelter for many organisms.

4. Shrub layer

- It consists of shrubs and small woody plants.
- It receives limited sunlight.
- It provides food and shelter for insects and small animals.

5. Herb layer

- It consists of small non-woody plants.
- Examples include ferns, herbs and seedlings.
- It is affected by the availability of light and soil moisture.

6. Forest floor

- It is the lowest layer.
- It contains fallen leaves, dead plants and animal remains.
- Decomposition occurs actively in suitable moist conditions.
- Fungi, bacteria, earthworms and other detritivores are common.

Importance of forest ecosystems

1. **Carbon storage:** Trees absorb carbon dioxide during photosynthesis and store carbon in their tissues.
2. **Oxygen production:** Green forest plants release oxygen during photosynthesis.
3. **Water catchment protection:** Forests help regulate water flow into rivers and streams.
4. **Soil conservation:** Tree roots hold soil particles together and reduce erosion.
5. **Habitat provision:** Forests provide habitats for many plant and animal species.
6. **Climate regulation:** Forests influence temperature, humidity and local rainfall patterns.
7. **Economic benefits:** Forests provide timber, fuelwood, medicinal plants and other forest products.
8. **Employment:** Forestry, tourism and forest-related industries create employment.
9. **Recreation and tourism:** Forests attract tourists and support ecotourism.
10. **Nutrient cycling:** Decomposition of forest litter returns nutrients to the soil.
11. **Cultural importance:** Some forests are important traditional and cultural sites.
12. **Genetic resources:** Forests contain plants and animals that may be useful in agriculture, medicine and scientific research.

Threats to forest ecosystems in Kenya

- Deforestation.
- Illegal logging.
- Forest fires.

- Charcoal production.
- Agricultural encroachment.
- Overgrazing.
- Infrastructure development.
- Invasive species.
- Climate change.
- Unsustainable harvesting of forest products.

Conservation of forest ecosystems

1. Afforestation – planting trees in areas that previously had little or no forest cover.
2. Reforestation – replanting trees in areas where forests have been cleared or degraded.
3. Agroforestry – integrating trees with crops and/or livestock.
4. Establishing forest reserves.
5. Controlling illegal logging.
6. Preventing forest fires.
7. Promoting community forest management.
8. Controlling overgrazing.
9. Protecting indigenous tree species.
10. Environmental education and awareness.

1.2.6 Grassland ecosystems

Meaning of a grassland ecosystem

A grassland ecosystem is a terrestrial ecosystem dominated by grasses and herbaceous vegetation, with relatively few trees and shrubs.

Trees may occur individually or in scattered groups.

Examples in Kenya include:

- Maasai Mara grasslands.
- Amboseli grasslands.
- Tsavo grassland and savanna habitats.
- Laikipia grasslands.
- Other natural grazing areas in the Rift Valley.

Characteristics of grassland ecosystems

A. Climatic characteristics

1. Rainfall is generally lower or more seasonal than in tropical rainforests.
2. Many grasslands experience distinct wet and dry seasons.
3. Temperatures vary according to altitude and geographical location.

4. Dry periods may result in water shortages.
5. Grass growth increases during favourable rainy seasons.
6. Some areas experience seasonal fires.
7. Strong winds may occur in open grasslands.

B. Physiographic characteristics

1. Grasslands commonly occur on plains and gently rolling landscapes.
2. They may also occur on plateaus and valleys.
3. Soil conditions vary from fertile to relatively poor soils.
4. Drainage influences grass distribution.
5. Some grasslands occur on shallow or rocky soils.

C. Biotic characteristics

1. Grasses are the dominant plants.
2. Trees and shrubs may be scattered.
3. Herbivores are often abundant.
4. Predators feed on herbivorous animals.
5. Insects are common.
6. Soil organisms and decomposers are important.
7. Many organisms show adaptations to drought and fire.

Common organisms in grassland ecosystems

Plants

- Red oat grass.
- Star grass.
- Rhodes grass.
- Acacia trees.
- Shrubs.
- Herbaceous plants.

Animals

- Zebras.
- Wildebeests.
- Gazelles.
- Giraffes.
- Buffaloes.
- Elephants.
- Lions.

- Cheetahs.
- Hyenas.
- Ostriches.
- Grasshoppers.
- Termites.

Adaptations of grassland organisms

Adaptations of grasses

1. Narrow leaves reduce water loss.
2. Extensive root systems enable absorption of water from the soil.
3. Growth points are often near the ground, allowing regrowth after grazing.
4. Flexible stems allow grasses to bend without breaking easily.
5. Many grasses produce numerous seeds.
6. Some grasses survive unfavourable seasons through underground structures.

Adaptations of grazing animals

1. Strong teeth enable them to cut and grind grasses.
2. Long legs assist movement across open areas.
3. Eyes positioned on the sides of the head provide a wide field of vision in many prey species.
4. Camouflage helps some animals avoid detection.
5. Herd behaviour improves protection against predators.
6. Some animals migrate in search of fresh pasture and water.

Importance of grassland ecosystems

1. Provide grazing land for livestock.
2. Support wildlife and biodiversity.
3. Provide habitats for insects, birds and mammals.
4. Store carbon in plant tissues and soils.
5. Reduce soil erosion when vegetation is maintained.
6. Support tourism and wildlife conservation.
7. Provide pasture and hay for livestock.
8. Support nutrient cycling.
9. Provide suitable environments for pollinators.
10. Support livelihoods of pastoral and agro-pastoral communities.

Threats to grassland ecosystems

- Overgrazing.
- Frequent uncontrolled fires.

- Conversion into agricultural land.
- Invasive plant species.
- Soil erosion.
- Habitat fragmentation.
- Drought.
- Climate change.
- Human settlement and infrastructure development.

Conservation measures

1. Controlled grazing.
2. Rotational grazing.
3. Reseeding degraded grasslands.
4. Controlled burning where ecologically appropriate.
5. Controlling invasive species.
6. Preventing soil erosion.
7. Conserving wildlife corridors.
8. Maintaining appropriate livestock numbers.
9. Protecting water sources.
10. Restoring degraded rangelands.

1.2.7 Desert and semi-arid ecosystems

Meaning of a desert ecosystem

A desert ecosystem is an ecosystem found in regions receiving very low and/or highly unreliable rainfall, resulting in limited water availability and sparse vegetation.

Desert ecosystems may be hot or cold.

In Kenya, learners mainly study hot arid and semi-arid environments.

Examples of Kenyan arid and semi-arid areas:

- Turkana.
- Marsabit.
- Wajir.
- Mandera.
- Garissa.
- Isiolo.
- Samburu.
- Parts of Kajiado and Tana River counties.

Characteristics of desert ecosystems

A. Climatic characteristics

1. Rainfall is very low or highly irregular.
2. Evaporation rates are often high.
3. Temperatures may be very high during the day.
4. Night temperatures may be considerably lower than daytime temperatures.
5. Relative humidity is often low.
6. Water shortages are common.
7. Strong winds may occur.
8. Droughts may persist for long periods.

B. Physiographic characteristics

1. Some deserts have sandy surfaces.
2. Others contain rocky surfaces and gravel plains.
3. Sand dunes may occur.
4. Drainage is often limited or seasonal.
5. Vegetation cover is generally sparse.
6. Some areas contain seasonal rivers and dry riverbeds.
7. Soil organic matter is often low in sparsely vegetated areas.

C. Biotic characteristics

1. Vegetation is generally sparse.
2. Plants show adaptations that reduce water loss.
3. Many animals are nocturnal.
4. Some animals obtain water from food.
5. Some organisms survive long periods without drinking.
6. Burrowing is common among certain animals.
7. Organisms may have behavioural and physiological adaptations to heat and water scarcity.

Examples of desert organisms

Plants

- Acacia species.
- Aloe species.
- Euphorbia species.
- Thorny shrubs.
- Desert grasses.

- Succulent plants.

Animals

- Camel.
- Fennec fox in North African deserts.
- Desert lizards.
- Snakes.
- Scorpions.
- Jerboas.
- Desert beetles.
- Some rodents.

Importance of desert ecosystems

1. They support specially adapted biodiversity.
2. They provide grazing resources for pastoral communities during favourable seasons.
3. They support tourism and wildlife conservation.
4. They provide habitats for unique plants and animals.
5. They contain valuable mineral resources.
6. They provide opportunities for solar energy production.
7. They support scientific research on drought resistance and adaptation.
8. They contribute to regional ecological processes.

Threats to desert ecosystems

1. Desertification.
2. Overgrazing.
3. Deforestation.
4. Unsustainable extraction of resources.
5. Climate change.
6. Soil erosion.
7. Water scarcity.
8. Habitat destruction.

1.2.8 Aquatic ecosystems

Meaning of an aquatic ecosystem

An aquatic ecosystem is an ecosystem found in water, consisting of living organisms interacting with the physical and chemical conditions of their aquatic environment.

Aquatic ecosystems are broadly classified into:

1. Freshwater ecosystems.

2. Marine ecosystems.
3. Brackish-water ecosystems.

A. Freshwater ecosystems

Freshwater ecosystems contain water with relatively low concentrations of dissolved salts.

Examples:

- Lakes.
- Rivers.
- Streams.
- Ponds.
- Freshwater wetlands.
- Reservoirs.

Examples in Kenya

- Lake Victoria.
- Lake Naivasha.
- Lake Baringo.
- Lake Jipe.
- River Tana.
- River Athi.
- River Nzoia.
- River Mara.

Characteristics of freshwater ecosystems

A. Climatic characteristics

1. Water temperature varies with season and depth.
2. Light intensity decreases with increasing water depth.
3. Water temperature influences the metabolic activities of aquatic organisms.
4. Rainfall influences water levels.
5. Evaporation may increase salt concentration in some water bodies.
6. Seasonal changes influence breeding and feeding patterns.

B. Physiographic characteristics

1. Water bodies vary in depth.
2. Lakes may have shallow and deep zones.
3. Rivers have flowing water.
4. Ponds generally have relatively small surface areas.
5. Bottom surfaces may consist of mud, sand, gravel or rock.

6. Water movement influences the distribution of organisms.

C. Biotic characteristics

1. They contain aquatic plants and algae.
2. They support fish and other aquatic animals.
3. Plankton are important components.
4. Amphibians may occur in freshwater habitats.
5. Bacteria and fungi decompose organic matter.
6. Aquatic insects may occur in different water zones.

B. Marine ecosystems

Marine ecosystems occur in seas and oceans and contain water with relatively high salt concentrations.

Examples:

- Indian Ocean.
- Coral reefs.
- Seagrass beds.
- Open ocean habitats.
- Coastal marine environments.

Characteristics of marine ecosystems

A. Climatic characteristics

1. Water temperature varies according to latitude, depth and ocean currents.
2. Light intensity decreases with depth.
3. Salinity is generally high.
4. Waves and currents influence water movement.
5. Dissolved oxygen varies with temperature, mixing and biological activity.

B. Physiographic characteristics

1. Marine environments include shallow coastal waters and deep ocean regions.
2. They contain sandy beaches, rocky shores and coral reefs.
3. Seafloor depth varies.
4. Ocean currents transport nutrients and organisms.
5. Coastal environments may contain mangrove forests and seagrass beds.

C. Biotic characteristics

1. They contain phytoplankton and marine algae.
2. They support fish, molluscs and crustaceans.
3. Marine mammals such as dolphins occur.
4. Sea turtles inhabit marine environments.

5. Corals support diverse reef communities.
6. Marine bacteria and fungi contribute to decomposition.

C. Brackish-water ecosystems

Brackish-water ecosystems occur where freshwater mixes with seawater.

Examples:

- Estuaries.
- Mangrove swamps.
- Coastal lagoons.



Characteristics

1. Salinity varies according to freshwater and seawater input.
2. Organisms must tolerate changing salt concentrations.
3. They support mangrove trees and salt-tolerant organisms.
4. They provide breeding and nursery grounds for fish.
5. They support crabs, molluscs, fish and aquatic birds.

Importance of aquatic ecosystems

1. Provide habitats for aquatic organisms.
2. Supply water for domestic and agricultural use.
3. Support fisheries and aquaculture.
4. Provide food and employment.
5. Support tourism and recreation.
6. Regulate climate and store carbon.
7. Support nutrient cycling.

8. Provide breeding grounds for fish.
9. Support transport and trade.
10. Provide opportunities for scientific research.
11. Wetlands help filter pollutants and trap sediments.
12. Mangroves and coral reefs help protect coastlines.

Threats to aquatic ecosystems

- Water pollution.
- Agricultural runoff.
- Industrial effluent.
- Oil spills.
- Plastic waste.
- Overfishing.
- Destruction of wetlands.
- Destructive fishing methods.
- Invasive species.
- Climate change.
- Ocean acidification.
- Eutrophication.

Conservation of aquatic ecosystems

1. Treating sewage before discharge.
2. Preventing dumping of plastics and other wastes.
3. Protecting wetlands.
4. Conserving mangrove forests.
5. Controlling agricultural chemical runoff.
6. Promoting sustainable fishing.
7. Establishing marine protected areas.
8. Restoring degraded coral reefs.
9. Protecting riverbank vegetation.
10. Promoting community participation in water conservation.

1.2.9 Adaptations of organisms to different habitats

Meaning of adaptation

An adaptation is an inherited structural, physiological or behavioural characteristic that increases an organism's ability to survive and reproduce in a particular environment.

Adaptations develop over many generations through evolutionary processes, particularly natural selection.

Organisms living in different habitats possess different adaptations depending on the environmental challenges they face.

Types of adaptations

There are three main types:

1. Structural adaptations.
2. Physiological adaptations.
3. Behavioural adaptations.

A. Structural adaptations

Structural adaptations are physical features of an organism's body that improve its chances of survival in a particular habitat.

Examples:

- Thick waxy cuticle in desert plants.
- Webbed feet in aquatic birds.
- Long roots in desert plants.
- Streamlined bodies in fish.
- Thick fur in animals living in cold environments.

B. Physiological adaptations

Physiological adaptations are internal functional processes that enable organisms to survive in their habitats.

Examples:

- Production of concentrated urine by desert mammals.
- Salt excretion by some marine birds.
- Opening of stomata at night in many CAM plants.
- Production of antifreeze proteins in some cold-water organisms.

C. Behavioural adaptations

Behavioural adaptations are activities or patterns of behaviour that help organisms survive and reproduce.

Examples:

- Nocturnal activity in desert animals.
- Burrowing to escape high temperatures.
- Migration in search of food and water.
- Basking by reptiles to regulate body temperature.

- Huddling together to conserve heat.

1.2.10 Adaptations of plants to different habitats

Plants are classified according to the water conditions of the habitats in which they naturally grow.

The major groups include:

1. Xerophytes.
2. Mesophytes.
3. Hydrophytes.
4. Halophytes.

A. Xerophytes

Meaning of xerophytes

Xerophytes are plants adapted to live in habitats where water is scarce or unavailable for long periods.

They are commonly found in:

- Deserts.
- Semi-arid regions.
- Dry grasslands.
- Rocky areas.
- Dry and exposed environments.

Examples of xerophytes

- Cactus species.
- Aloe species.
- Euphorbia species.
- Some Acacia species.
- Desert grasses.

Adaptations of xerophytes

1. Reduced leaf surface area

- Many xerophytes have small leaves or leaves modified into spines.
- This reduces the surface area exposed to the atmosphere.
- It therefore reduces water loss through transpiration.

Example: Cactus.

2. Thick waxy cuticle

- The leaves or stems have a thick waxy covering.

- The cuticle reduces evaporation of water from the plant surface.
- It protects plant tissues from drying.

3. Sunken stomata

- Some xerophytes have stomata located in pits or depressions.
- These depressions trap moist air.
- They reduce the diffusion gradient for water vapour.
- This reduces transpiration.

4. Reduced number of stomata

- Some xerophytes have relatively few stomata.
- This reduces the number of openings through which water vapour can escape.

5. Extensive root systems

- Some xerophytes develop deep taproots.
- These roots reach underground water.
- Others develop widely spreading shallow roots that absorb water rapidly after rainfall.

6. Succulent stems or leaves

- Some xerophytes have thick, fleshy stems or leaves.
- These structures store water for use during dry periods.

Example: Aloe and cactus.

7. Leaf modification into spines

- Leaves may be reduced to sharp spines.
- Spines reduce water loss.
- They also protect the plant against herbivores.

8. Photosynthetic stems

- In some xerophytes, leaves are reduced while green stems carry out photosynthesis.
- This reduces the surface area exposed to water loss.

9. Leaf folding or rolling

- Some grasses roll or fold their leaves during dry conditions.
- This reduces exposure of the leaf surface to dry air.
- It reduces transpiration.

10. CAM photosynthesis

- Many succulent plants use Crassulacean Acid Metabolism (CAM).
- Their stomata open mainly at night when temperatures are lower.
- Carbon dioxide is absorbed and temporarily stored in organic acids.

- During the day, stomata remain mostly closed while stored carbon dioxide is used in photosynthesis.
- This reduces water loss.

11. Leaf shedding

- Some dryland plants shed leaves during prolonged dry periods.
- This reduces the surface area available for transpiration.

12. Dormancy

- Some xerophytic plants survive unfavourable dry seasons as dormant seeds or underground structures.
- They resume growth when water becomes available.

B. Mesophytes

Meaning of mesophytes

Mesophytes are plants adapted to grow in habitats with moderate water availability.

They are neither specially adapted to extremely dry conditions nor to permanently waterlogged conditions.

Examples:

- Maize.
- Beans.
- Mango.
- Sunflower.
- Tomato.
- Most ordinary garden plants.

Adaptations of mesophytes

1. Broad leaves

- Many mesophytes have broad leaves.
- Broad leaves provide a large surface area for absorbing sunlight.
- This supports photosynthesis.

2. Moderately developed cuticle

- Their leaves have a cuticle that reduces excessive water loss.
- It is generally not as thick as that of many xerophytes.

3. Well-developed root systems

- Roots absorb water and mineral salts from the soil.
- They also anchor the plant firmly.

4. Normally distributed stomata

- Stomata are present mainly on the lower leaf surface in many terrestrial dicotyledonous mesophytes.
- They regulate gaseous exchange and transpiration.

5. Well-developed vascular tissues

- Xylem transports water and mineral salts.
- Phloem transports manufactured food.

6. Flexible water regulation

- Mesophytes regulate stomatal opening according to water availability and environmental conditions.

7. Well-developed leaves

- Leaves contain chlorophyll for photosynthesis.
- Their structures are suitable for ordinary terrestrial conditions.

8. Support tissues

- Mechanical tissues help support stems and leaves.
- This enables plants to remain upright.

C. Hydrophytes

Meaning of hydrophytes

Hydrophytes are plants adapted to grow in aquatic environments or waterlogged habitats.

They may be:

- Completely submerged.
- Partly submerged.
- Floating on water.
- Rooted in waterlogged soil.

Examples:

- Water lily.
- Water hyacinth.
- Duckweed.
- Hydrilla.
- Water lettuce.
- Papyrus.
- Reeds.

Types of hydrophytes

1. Free-floating hydrophytes

These plants float freely on the water surface without being permanently rooted in the bottom soil.

Examples:

- Duckweed.
- Water hyacinth.
- Water lettuce.

2. Rooted floating-leaved hydrophytes

These plants are rooted in the bottom soil, while their leaves float on the water surface.

Examples:

- Water lily.

3. Submerged hydrophytes

These plants grow completely or almost completely underwater.

Examples:

- Hydrilla.
- Vallisneria.

4. Emergent hydrophytes

These plants are rooted in waterlogged soil, but their stems and leaves extend above the water surface.

Examples:

- Papyrus.
- Reeds.

Adaptations of hydrophytes

1. Large air spaces (aerenchyma)

- Many hydrophytes have large air-filled spaces in their tissues.
- These spaces assist gaseous exchange.
- They help transport oxygen to submerged tissues.
- They also provide buoyancy.

2. Reduced root systems

- Many floating hydrophytes have reduced roots.
- They obtain water and dissolved mineral nutrients directly from the surrounding water.
- Roots may mainly provide anchorage.

3. Thin or absent cuticle

- Submerged leaves often have a very thin cuticle or lack a prominent one.
- Water loss is not a major challenge underwater.
- This allows exchange of dissolved substances with the surrounding water.

4. Reduced supporting tissues

- Water provides buoyancy and support.
- Therefore, many hydrophytes have less developed mechanical tissues.

5. Flexible stems

- Flexible stems bend with water currents.
- This reduces the likelihood of mechanical damage.

6. Broad floating leaves

- Floating plants may have broad leaves.
- This increases the surface area available for absorbing sunlight.
- It also helps the leaves remain on the water surface.

7. Stomatal distribution

- Floating leaves commonly have stomata on their upper surfaces.
- This allows gaseous exchange with the atmosphere.
- Fully submerged leaves generally lack functional stomata.

8. Reduced vascular tissues

- Some submerged hydrophytes have reduced xylem.
- Water is readily available around their tissues.
- Therefore, extensive water-conducting tissues may not be necessary.

9. Finely divided leaves

- Some submerged plants have narrow or finely divided leaves.
- This reduces resistance to water currents.
- It increases the surface area exposed to dissolved gases and nutrients.

10. Reduced root anchorage in floating plants

- Free-floating plants do not need extensive roots for anchorage.
- They remain suspended through buoyancy and water movement.

D. Halophytes

Meaning of halophytes

Halophytes are plants adapted to grow in habitats with high salt concentrations.

They are commonly found in:

- Mangrove swamps.
- Salt marshes.
- Saline coastal soils.
- Salt lakes.
- Saline inland wetlands.

Examples:

- Mangroves.
- Glasswort (Salicornia).

- Saltbush (Atriplex).
- Some salt-tolerant grasses.

Adaptations of halophytes

1. Salt exclusion

- Some halophytes prevent excessive salt from entering their roots.
- Specialised root membranes regulate the movement of ions.
- This protects internal tissues from excessive salt accumulation.

2. Salt secretion

- Some halophytes possess specialised salt glands.
- These glands remove excess salt from the plant.
- Salt may be deposited on the leaf surface and later washed away by rain.

3. Succulent leaves

- Some halophytes have thick, fleshy leaves.
- Water is stored in these leaves.
- This dilutes the concentration of salts within the plant tissues.

4. Osmotic adjustment

- Halophytes accumulate compatible organic solutes in their cells.
- These substances help maintain water uptake from saline surroundings.
- They also protect cellular structures.

5. Specialised roots

- Mangroves may develop aerial roots.
- These roots help with gaseous exchange in waterlogged, oxygen-poor soils.

6. Pneumatophores

- Some mangrove species develop upward-growing breathing roots.
- These roots project above the muddy soil.
- They contain structures that allow gaseous exchange.

7. Prop roots

- Some mangroves develop supporting roots that extend from the trunk and branches into the mud.
- These roots provide mechanical support in soft, unstable soils.

8. Vivipary

- Some mangroves produce seeds that germinate while still attached to the parent plant.
- The developing propagules may later detach and establish themselves in suitable muddy habitats.

9. Thick cuticle

- A thick cuticle helps reduce water loss from plant surfaces.

10. Leaf shedding

- Some salt-tolerant plants remove leaves containing accumulated salts.

Comparison of the four groups of plants

Feature	Xerophytes	Mesophytes	Hydrophytes	Halophytes
Habitat	Dry areas	Moderately moist areas	Aquatic/waterlogged areas	Saline areas
Water availability	Low	Moderate	Abundant	Available but saline
Cuticle	Usually thick	Moderate	Often thin in submerged leaves	Often thick
Roots	Often extensive	Well developed	Often reduced in floating forms	Specialised in some species
Leaves	Often small or reduced	Usually broad and well developed	Floating or finely divided	Often succulent in some species
Stomata	Often reduced or sunken	Normally distributed	Upper surface in floating leaves	Variable
Main challenge	Water shortage	Ordinary water balance	Excess water and oxygen supply	High salt concentration

1.2.11 Adaptations of animals to different habitats

Animals possess structural, physiological and behavioural adaptations that enable them to survive in their habitats.

These adaptations help animals:

- Obtain food.
- Obtain water.
- Escape from predators.
- Regulate body temperature.
- Reproduce successfully.
- Move efficiently.
- Survive unfavourable environmental conditions.

A. Adaptations of desert animals

Desert animals live in environments characterised by limited water, high daytime temperatures, intense sunlight and sometimes large differences between daytime and night temperatures.

Examples include:

- Camel.
- Desert fox.
- Desert lizard.

- Snakes.
- Scorpions.
- Desert rodents.
- Desert beetles.

Adaptations of a camel

The camel is an important example of an animal adapted to arid environments.

Structural adaptations

1. **Hump for fat storage**
   - A camel has one or two humps depending on the species.
   - The humps store fat rather than water.
   - Fat can be metabolised to provide energy and metabolic water.
2. **Long legs**
   - Long legs raise the body away from the hot ground.
   - They reduce the transfer of heat from the ground to the body.
   - They also enable efficient movement over long distances.
3. **Broad, padded feet**
   - The feet spread the animal's weight over a large surface area.
   - This prevents it from sinking deeply into loose sand.
   - Thick pads protect the feet from hot ground.
4. **Long eyelashes**
   - Long eyelashes protect the eyes from blowing sand and dust.
5. **Closable nostrils**
   - The nostrils can close partially or completely.
   - This prevents sand from entering the respiratory system.
6. **Thick lips**
   - The tough lips allow the camel to feed on thorny desert plants.
7. **Coat insulation**
   - The coat helps protect the body against intense solar radiation.
   - It also reduces heat exchange with the surroundings.

Physiological adaptations

8. **Tolerance to dehydration**
   - Camels can tolerate considerable body water loss compared with many other mammals.
   - They can recover water balance after drinking.
9. **Concentrated urine**

- Their kidneys conserve water by producing highly concentrated urine.

10. **Dry faeces**

- Their digestive system absorbs much of the available water, producing relatively dry faeces.

11. **Variable body temperature**

- Camels allow their body temperature to fluctuate within a wider range than many other mammals.
- This reduces the need for evaporative cooling.

12. **Water recovery from breathing**

- The nasal passages help recover some moisture from exhaled air.

Behavioural adaptations

13. Camels may reduce activity during the hottest parts of the day.
14. They may feed during cooler periods.
15. They may seek shade when available.
16. They can travel long distances in search of pasture and water.

B. Adaptations of desert rodents

1. **Nocturnal behaviour:** Many desert rodents are active at night when temperatures are lower.
2. **Burrowing:** They dig underground burrows to escape high temperatures and predators.
3. **Concentrated urine:** Their kidneys conserve water.
4. **Dry faeces:** Their digestive systems minimise water loss.
5. **Water from food:** Some obtain much of their water from seeds, plants and other food materials.
6. **Reduced sweating:** Many small desert mammals have limited evaporative water loss.
7. **Large ears in some species:** Large ears increase heat loss by radiation and convection.

C. Adaptations of desert reptiles

1. **Scaly skin:** The dry, keratinised skin reduces water loss through the body surface.
2. **Behavioural thermoregulation:** They move between sunlight and shade to regulate body temperature.
3. **Burrowing:** Some reptiles hide underground during extreme temperatures.
4. **Nocturnal activity:** Some become active at night to avoid daytime heat.
5. **Concentrated nitrogenous waste:** Many reptiles excrete nitrogenous waste mainly as uric acid, reducing water loss.
6. **Camouflage:** Their body colour may resemble the surrounding soil and rocks, helping them avoid predators.
7. **Low metabolic requirements:** Some can survive for long periods with relatively little food.

D. Adaptations of aquatic animals

Aquatic animals live in freshwater, marine or brackish-water habitats.

Examples include:

- Fish.
- Whales.
- Dolphins.
- Tilapia.
- Crabs.
- Octopuses.
- Turtles.
- Aquatic insects.
- Frogs.

Adaptations of fish

Structural adaptations

1. **Streamlined body**
   - The body is tapered at both ends.
   - This reduces resistance as the fish moves through water.
   - It enables efficient swimming.
2. **Fins**
   - Pectoral and pelvic fins assist steering and balance.
   - Dorsal and anal fins provide stability.
   - The caudal fin provides propulsion in many fish.
3. **Gills**
   - Gills extract dissolved oxygen from water.
   - They provide a large surface area for gaseous exchange.
   - They are richly supplied with blood vessels.

4. **Scales**
   - Scales protect the body from injury.
   - They reduce friction in some fish.
5. **Mucus covering**
   - The mucus reduces friction during swimming.
   - It also provides protection against pathogens and physical damage.
6. **Lateral line system**
   - The lateral line detects water movements and vibrations.
   - It helps fish locate food, avoid predators and maintain position in schools.

7. **Swim bladder**

- Many bony fish possess a swim bladder.
- It helps regulate buoyancy and maintain position at different depths.

Physiological adaptations

8. Gills are adapted to extract oxygen from water.
9. Freshwater fish regulate water and salt balance by producing large amounts of dilute urine and actively absorbing ions.
10. Marine bony fish conserve water by drinking seawater and excreting excess salts through specialised gill cells and kidneys.
11. Some fish can tolerate changes in salinity.
12. Some fish have antifreeze proteins that help prevent ice crystal formation in very cold waters.

Behavioural adaptations

13. Some fish form schools for protection.
14. Some migrate to suitable breeding grounds.
15. Some hide among aquatic vegetation to avoid predators.
16. Some occupy different depths according to food availability and environmental conditions.

Adaptations of whales and dolphins

Whales and dolphins are mammals that live in water.

1. **Streamlined body:** Reduces resistance during swimming.
2. **Flippers:** Help in steering and maintaining balance.
3. **Tail flukes:** Provide propulsion through powerful up-and-down movements.
4. **Blowhole:** Allows breathing atmospheric air at the water surface.
5. **Blubber:** A thick layer of fat beneath the skin provides insulation and energy storage.
6. **Large oxygen stores:** Their blood and muscles contain oxygen-binding pigments that allow prolonged diving.
7. **Diving reflex:** Heart rate and blood flow are adjusted during diving to conserve oxygen.
8. **Echolocation:** Dolphins use reflected sound waves to detect objects and locate prey.
9. **Body flexibility:** Their muscular bodies and flexible spines facilitate swimming.
10. **Reproductive adaptations:** They give birth to live young and feed them with milk.

Adaptations of aquatic birds

Examples include ducks, flamingos and pelicans.

1. Webbed feet assist swimming.
2. Waterproof feathers provide insulation and reduce water penetration.
3. Streamlined bodies reduce resistance in water.
4. Long legs in wading birds enable movement through shallow water.

5. Long beaks assist in capturing aquatic organisms.
6. Some birds have specialised bills for filtering food from water.
7. Preening helps maintain feather condition and waterproofing.

Adaptations of amphibians

Examples include frogs and toads.

1. Moist skin enables cutaneous respiration.
2. Webbed hind feet assist swimming in many aquatic frogs.
3. Powerful hind limbs facilitate jumping and swimming.
4. Nostrils and eyes positioned near the top of the head enable some frogs to remain mostly submerged while breathing and observing their surroundings.
5. Eggs are commonly laid in water or moist environments.
6. Many species undergo metamorphosis from aquatic larvae to adults.
7. Some species can exchange gases through their skin.

1.2.12 Characteristics of populations

Meaning of population characteristics

Population characteristics are measurable features that describe the size, distribution, structure and changes in a population within a particular habitat.

Ecologists study population characteristics to understand how organisms survive, reproduce and respond to environmental changes.

The major population characteristics include:

1. Population size.
2. Population density.
3. Population dispersion.
4. Population growth.
5. Natality.
6. Mortality.
7. Immigration.
8. Emigration.
9. Age structure.
10. Sex ratio.

A. Population size

Population size is the total number of individuals of a particular species living in a defined geographical area at a given time.

Examples:

- 250 zebras in a particular grassland.

- 500 tilapia in a fish pond.
- 120 maize plants in a demonstration plot.
- 60 acacia trees in a woodland study area.

Population size may change due to:

- Births.
- Deaths.
- Immigration.
- Emigration.

Population size equation

$N=N0+B+I-D-E$

Where:

- N = Final population size.
- N0 = Initial population size.
- B = Number of births.
- I = Number of immigrants.
- *D* = Number of deaths.
- *E* = Number of emigrants.

Worked example

A wildlife reserve has an initial population of 500 antelopes. During the year:

- 80 are born.
- 30 immigrate.
- 50 die.
- 20 emigrate.

Calculate the final population size.

Solution

$N=500+80+30-50-20$

$N=540$

Answer: 540 antelopes

B. Population density

Population density is the number of individuals of a particular species per unit area or volume of habitat at a given time.

Formula for population density

Population density=Total number of individualsArea occupiedPopulation density=Area occupiedTotal num ber of individuals

For aquatic organisms, density may be expressed per unit volume.

Density=Number of organismsVolume of waterDensity=Volume of waterNumber of organisms

Worked example 1

A grassland covering 4 hectares contains 200 zebras.

Calculate the population density.

$$Density = \frac{200}{4}$$

=50 zebras per hectare

Worked example 2

A fish pond has a volume of 500 cubic metres and contains 1,000 fish.

$$Density = \frac{1000}{500}$$

=2 fish per m^3

Factors affecting population density

1. Availability of food.
2. Availability of water.
3. Breeding success.
4. Predation.
5. Disease.
6. Competition.
7. Immigration.
8. Emigration.
9. Habitat size.
10. Environmental conditions.

Importance of population density

- Helps determine the abundance of organisms.
- Assists in wildlife management.
- Helps estimate livestock stocking rates.
- Helps monitor endangered species.
- Helps assess the effects of environmental changes.
- Supports sustainable fisheries management.

C. Population dispersion

Population dispersion refers to the pattern in which individuals of a population are distributed within a particular habitat.

There are three main types of population dispersion.

1. Clumped dispersion

Clumped dispersion occurs when individuals of a population are grouped together in particular areas of a habitat.

It is common where resources are unevenly distributed.

Characteristics:

1. Organisms occur in groups or clusters.
2. Individuals are concentrated in favourable areas.
3. Food and water may be available in patches.
4. Social behaviour may encourage grouping.
5. Individuals may gather for protection.

Examples:

- Elephants around water points.
- Zebras in herds.
- Fish in schools.
- Maize plants growing in patches.
- Colonies of termites.

Advantages:

- Protection against predators.
- Easier access to concentrated resources.
- Improved chances of finding mates.
- Cooperative activities such as hunting and defence.

Disadvantages:

- Increased competition for food.
- Rapid spread of diseases.
- Competition for breeding sites.

2. Uniform dispersion

Uniform dispersion occurs when individuals are distributed at approximately equal distances from one another.

Characteristics:

1. Individuals are regularly spaced.
2. Competition may cause separation.
3. Territorial behaviour may maintain spacing.
4. Resources may be evenly distributed.

Examples:

- Some territorial bird populations.

- Nesting seabirds that maintain minimum spacing.
- Trees planted at regular intervals in a plantation.
- Agricultural crops established using uniform spacing.

Causes:

- Territorial behaviour.
- Competition for resources.
- Chemical inhibition between plants (allelopathy).
- Deliberate human planting.

3. Random dispersion

Random dispersion occurs when individuals are distributed irregularly, with the position of one individual largely independent of the positions of others.

It is more likely where:

- Resources are widely available.
- Competition is limited.
- Environmental conditions are relatively uniform.

Examples:

- Some wind-dispersed plants under suitable conditions.
- Some insects in relatively uniform habitats.

Comparison of dispersion patterns

Clumped	Uniform	Random
Individuals occur in groups.	Individuals are regularly spaced.	Individuals occur irregularly.
Resources are often patchy.	Competition or territoriality may be strong.	Resources may be relatively uniform.
Most commonly observed in nature.	Less common in natural populations.	Occurs under certain environmental conditions.

D. Population growth

Population growth is the change in the number of individuals in a population over a given period.

Population growth may be positive, negative or zero.

Positive population growth

Occurs when births and immigration exceed deaths and emigration.

Negative population growth

Occurs when deaths and emigration exceed births and immigration.

Zero population growth

Occurs when population gains equal population losses over a given period.

Types of population growth

1. Exponential growth

Exponential growth occurs when a population increases rapidly under favourable conditions with abundant resources and limited environmental resistance.

It produces a J-shaped growth curve.

Characteristics:

1. Population increases rapidly.
2. Resources are initially abundant.
3. Birth rates exceed death rates.
4. Competition is initially low.
5. Growth may continue rapidly until limiting factors become important.

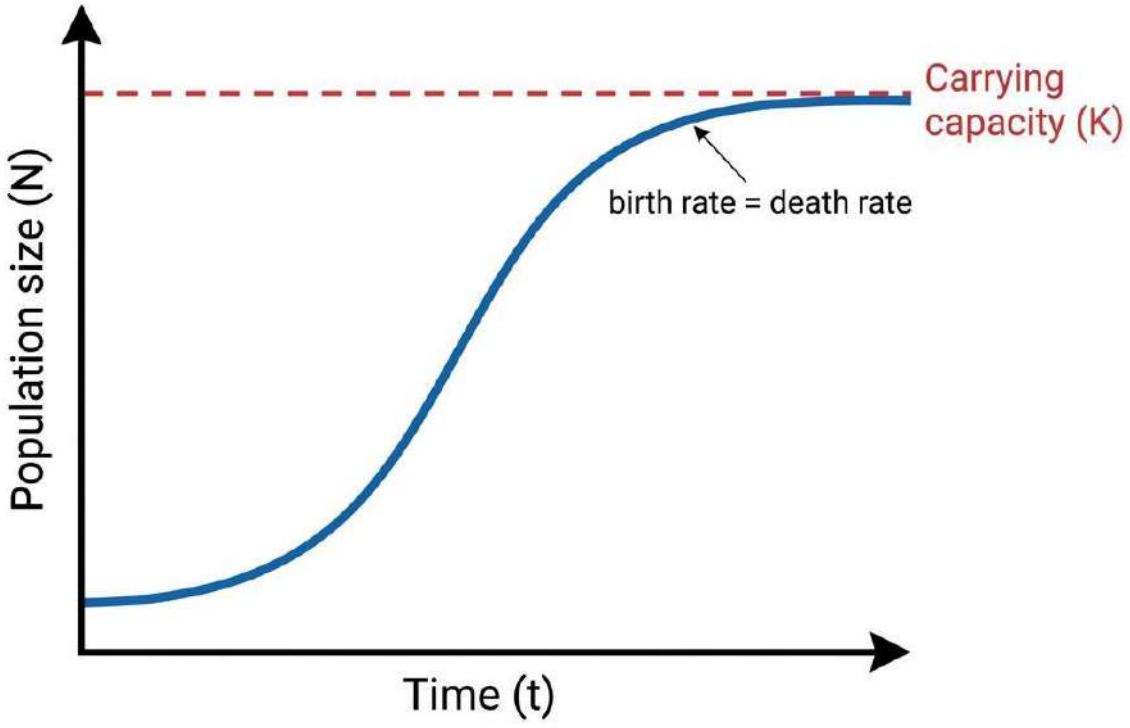
Examples:

- Bacteria multiplying in a suitable nutrient medium.
- Invasive organisms establishing in a new favourable habitat.

2. Logistic growth

Logistic growth occurs when population growth slows as environmental resistance increases and the population approaches the carrying capacity.

It produces an S-shaped or sigmoid curve.



Characteristics:

1. Growth begins slowly.
2. The population then increases rapidly.

3. Growth rate gradually decreases.
4. Competition for resources increases.
5. Population approaches carrying capacity.
6. Population size may fluctuate around carrying capacity.

Stages of logistic growth

1. **Lag phase:** Population increases slowly as organisms establish themselves and begin reproducing.
2. **Exponential phase:** Population increases rapidly because resources are still relatively abundant.
3. **Decelerating phase:** Growth slows as competition and other limiting factors increase.
4. **Stationary phase:** Population size becomes relatively stable around carrying capacity.

Factors influencing population growth

- Birth rate.
- Death rate.
- Immigration.
- Emigration.
- Food availability.
- Water availability.
- Predation.
- Disease.
- Competition.
- Climate.

E. Natality (birth rate)

Natality is the rate at which new individuals are added to a population through reproduction during a given period.

It may be expressed as births per 1,000 individuals per year.

Formula

$$Natality\ rate = \frac{Number\ of\ births}{Initial\ population} \times 1000$$

Example

A population of 500 rabbits produces 100 young in one year.

$$Natality\ rate = \frac{100}{500} \times 1000$$

=200 births per 1000 rabbits per year

F. Mortality (death rate)

Mortality is the rate at which individuals die in a population during a given period.

Formula

$$Mortality\ rate = \frac{Number\ of\ deaths}{Initial\ population} \times 1000$$

Example

A population of 400 fish experiences 40 deaths in one year.

$$Mortality\ rate = \frac{40}{400} \times 1000$$

=100 deaths per 1000 fish per year

G. Immigration

Immigration is the movement of individuals into an existing population from another area.

Examples:

- Zebras moving into a grassland.
- Fish entering a newly connected water body.
- Birds arriving in Kenya during seasonal migration.

Effects of immigration:

1. Increases population size.
2. May increase genetic variation.
3. May increase competition for resources.
4. May introduce new diseases or parasites.

H. Emigration

Emigration is the movement of individuals out of a population to another area.

Examples:

- Animals leaving an area due to drought.
- Birds moving to another habitat in search of food.
- Wildlife moving away from an area experiencing habitat disturbance.

Effects of emigration:

1. Reduces population size.
2. Reduces competition for available resources.
3. May reduce breeding opportunities.
4. May change the genetic composition of the population.

I. Age structure

Age structure refers to the distribution of individuals in a population according to their age groups.

The three major age groups are:

1. Pre-reproductive.
2. Reproductive.
3. Post-reproductive.

Importance of age structure

- Helps predict future population growth.
- Indicates reproductive potential.
- Helps wildlife managers plan conservation measures.
- Assists in understanding population stability.

J. Sex ratio

Sex ratio is the proportion of males to females in a population.

For example, a population with 40 males and 60 females has a male-to-female ratio of 2:3.

Importance of sex ratio

1. Influences reproductive potential.
2. Helps assess population structure.
3. Supports wildlife breeding programmes.
4. Helps monitor changes in populations.

1.2.13 Methods of estimating population size

Meaning of population estimation

Population estimation is the process of determining or approximating the number of individuals of a particular species in a defined area.

Ecologists use different methods depending on:

- Type of organism.
- Size of the habitat.
- Mobility of organisms.
- Density of the population.
- Availability of equipment.
- Time and resources available.

The main methods include:

1. Direct counting.
2. Sampling methods.
3. Quadrat method.
4. Line transect method.
5. Belt transect method.
6. Capture-mark-recapture method.

A. Direct counting method

Direct counting is a method of estimating population size by physically counting all individuals in a defined area.

It is suitable where organisms are:

- Large.
- Easily visible.
- Few in number.
- Relatively stationary or concentrated in a manageable area.

Examples:

- Counting cattle in a fenced pasture.
- Counting trees in a small school compound.
- Counting flamingos in a clearly visible section of a lake.
- Counting plants in a small experimental plot.

Procedure

1. Identify and define the study area.
2. Determine the species to be studied.
3. Establish clear boundaries.
4. Move systematically through the area.
5. Count all visible individuals.
6. Record the results.
7. Repeat the count if necessary to improve reliability.

Advantages

1. Simple to understand.
2. Provides an actual count when every individual can be observed.
3. Does not require complicated equipment.
4. Suitable for small populations.
5. Useful for monitoring visible organisms.

Disadvantages

1. Time-consuming in large areas.
2. Difficult where organisms are hidden.
3. Mobile organisms may move during counting.
4. Organisms may be counted more than once.
5. Not suitable for very large or inaccessible habitats.
6. Dense vegetation makes counting difficult.

B. Sampling method

Sampling is a method of estimating population characteristics by studying a representative portion of the entire population rather than counting every individual.

The results obtained from the sample are used to estimate the characteristics of the whole population.

Example:

A learner wants to estimate the number of grass plants in a large grassland. Instead of counting every grass plant, the learner selects several representative sample plots and counts the plants within them.

Types of sampling

1. Random sampling

Individuals or sampling locations are selected randomly so that each eligible sampling unit has a known chance of selection.

Methods include:

- Random number tables.
- Random number generators.
- Grid coordinates.

2. Systematic sampling

Samples are selected at regular intervals along a predetermined route or grid.

Example: Selecting a sampling point every 10 metres.

3. Stratified sampling

A habitat is divided into relatively uniform sections called strata, and samples are selected from each section.

Example: Sampling grass populations separately in wet, dry and rocky sections of a grassland.

Advantages of sampling

1. Saves time.
2. Reduces the cost of investigation.
3. Suitable for large habitats.
4. Provides estimates of population density.
5. Allows comparisons between habitats.
6. Useful where direct counting is difficult.

Disadvantages of sampling

1. Results may contain sampling errors.
2. Poorly selected samples may be unrepresentative.
3. Rare species may be missed.
4. A large sample may require considerable time.
5. Different observers may obtain slightly different results.

C. Quadrat method

A quadrat is a square or rectangular frame of known area used to sample organisms within a defined section of a habitat.

The quadrat method is mainly used for:

- Plants.
- Sessile organisms.
- Slow-moving organisms.
- Organisms that are distributed over a particular area.

Examples:

- Grass.
- Small herbs.
- Seedlings.
- Seaweeds.
- Barnacles.



Materials required

- Quadrat frame.
- Measuring tape.
- String.
- Pegs.
- Recording sheet.
- Pen.
- Identification guide.

Procedure

1. Select the habitat to be investigated.
2. Identify the organism being studied.
3. Determine the size of the quadrat.
4. Mark the boundaries of the study area.
5. Select sampling points randomly or systematically.
6. Place the quadrat on the ground.
7. Count all individuals of the selected species within the quadrat.
8. Record the results.
9. Repeat the procedure at several sampling points.
10. Calculate the mean number of individuals per quadrat.
11. Use the mean to estimate population density.

Calculating population density using quadrats

Mean number per quadrat=Total individuals countedNumber of quadratsMean number per quadrat=Numb er of quadratsTotal individuals counted

$$Density = \frac{Mean\ number\ per\ quadrat}{Area\ of\ one\ quadrat}$$

Worked example

A learner places five quadrats, each measuring 1 m^2, in a grassland and records the following numbers of grass plants:

Quadrat	Number of grass plants
1	20
2	25
3	15
4	30
5	10
Total	100

Step 1: Calculate the mean number of grass plants per quadrat.

$$Mean = \frac{100}{5} = 20$$

Step 2: Calculate population density.

$$Density = \frac{20}{1}$$

=20 plants/m^2

Step 3: If the grassland covers 500 m^2, estimate the total population.

Estimated population=20×500

=10,000 plants=10,000 plants

Estimated population = 10,000 grass plants

Advantages of the quadrat method

1. Simple to use.
2. Relatively inexpensive.
3. Suitable for stationary organisms.
4. Allows estimation of population density.
5. Enables comparisons between habitats.
6. Can be used to investigate plant distribution.

Disadvantages of the quadrat method

1. Not suitable for highly mobile animals.
2. Results may be inaccurate if sampling points are not representative.
3. Organisms near the quadrat boundary may be difficult to count.
4. It may be difficult to identify some species.
5. Large areas require many samples.

Precautions when using quadrats

- Use an appropriate quadrat size.
- Select sampling points fairly.
- Avoid deliberately selecting areas with many or few organisms.
- Use the same counting rules throughout.
- Take sufficient samples.
- Record observations immediately.

D. Line transect method

A line transect is a sampling method in which a measuring tape or line is stretched across a habitat and organisms touching or occurring along the line are recorded.

It is useful for studying changes in the distribution of organisms across an environmental gradient.

Examples:

- Vegetation changes from a riverbank towards dry land.
- Plant distribution along a forest edge.
- Changes in organisms from the shoreline towards the sea.

Procedure

1. Select the habitat.
2. Identify the environmental gradient to be investigated.
3. Stretch a measuring tape across the habitat.
4. Record organisms that touch the line or occur directly beneath it, according to the chosen sampling rule.
5. Record the position and species of each organism.
6. Repeat the investigation where necessary.

7. Compare the distribution of organisms along the transect.

Advantages

1. Simple to establish.
2. Useful for studying distribution along environmental gradients.
3. Helps show changes in vegetation.
4. Requires relatively little equipment.
5. Allows comparison between different habitat zones.

Disadvantages

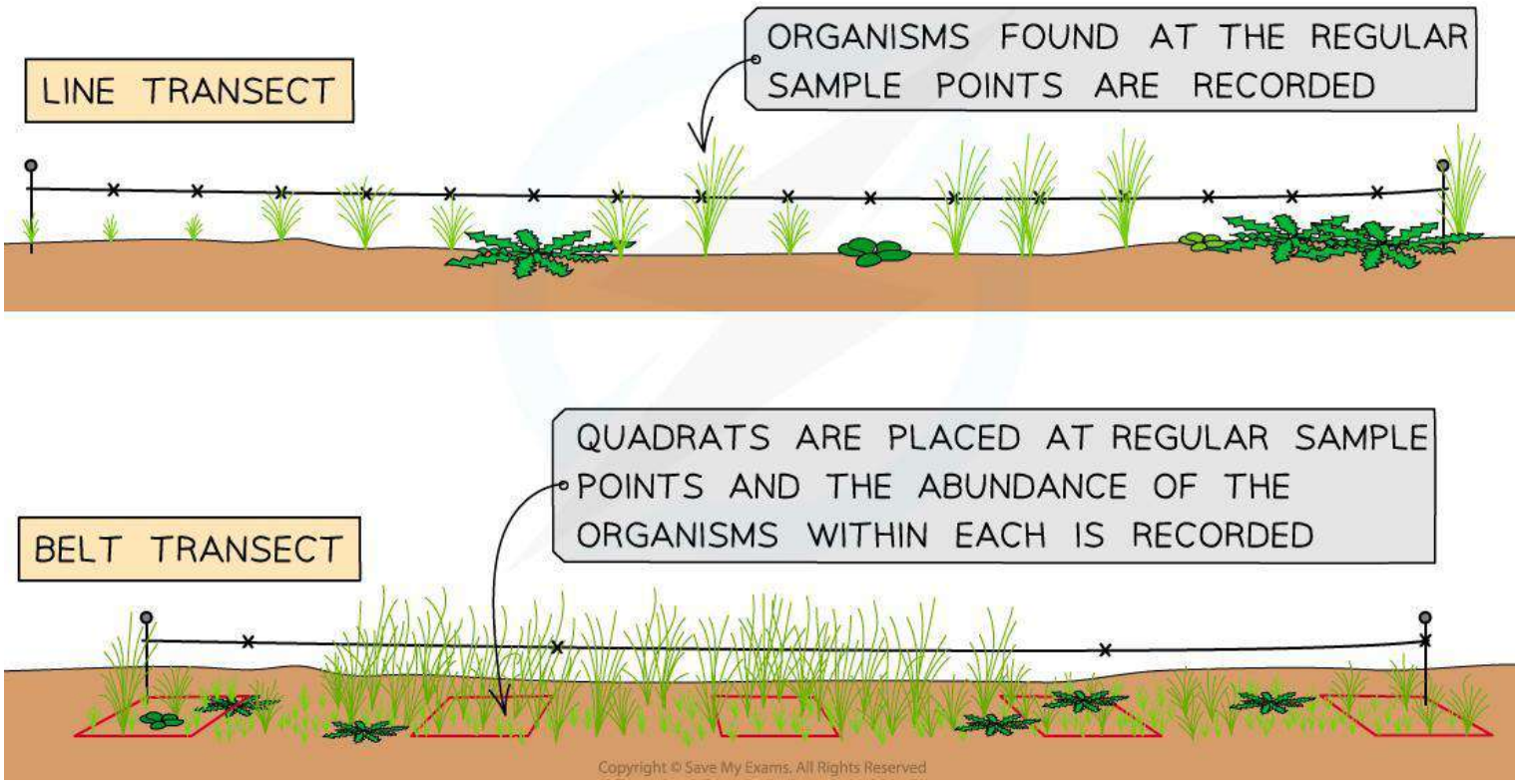
1. May miss organisms that do not occur along the line.
2. Results may not represent the entire habitat.
3. Mobile organisms may move during sampling.
4. It provides limited information about organisms away from the line.

E. Belt transect method

A belt transect is a sampling method in which organisms are studied within a strip of habitat of a known width and length.

It may be established by placing quadrats continuously or at regular intervals along a line.

It provides information about the distribution and abundance of organisms across a wider area than a line transect.



Types of belt transects

3. **Continuous belt transect**

- Quadrats are placed next to one another along the transect.
- Organisms in every quadrat are recorded.
- It provides detailed information about distribution.

4. **Interrupted belt transect**

- Quadrats are placed at regular intervals along the transect.
- Gaps are left between quadrats.
- It reduces the time required for sampling.

Procedure

1. Select the habitat.
2. Identify the environmental gradient.
3. Stretch a measuring tape across the area.
4. Place quadrats along the measuring tape.
5. Record the number and types of organisms in each quadrat.
6. Repeat the procedure if necessary.
7. Compare abundance and distribution across the transect.

Advantages

1. Provides information on abundance and distribution.
2. Suitable for studying plant communities.
3. Shows changes in species composition.
4. Useful in ecological succession studies.
5. Can be used to compare different habitat zones.

Disadvantages

1. Time-consuming when many quadrats are used.
2. Requires more equipment than a simple line transect.
3. Mobile organisms may move during sampling.
4. Incorrect quadrat placement may produce biased results.

Differences between line and belt transects

Line transect	**Belt transect**
Uses a line across the habitat.	Uses a strip of known width and length.
Records organisms touching or occurring along the line.	Records organisms within the strip or quadrats.
Covers a relatively narrow sampling path.	Covers a wider sampling area.

Useful for showing changes along a gradient.	Useful for studying abundance and distribution across a gradient.

F. Capture-mark-recapture method

The capture-mark-recapture method is a technique used to estimate the population size of mobile animals.

It involves:

1. Capturing a sample of animals.
2. Marking the captured animals harmlessly.
3. Releasing them back into the habitat.
4. Allowing time for them to mix with the population.
5. Capturing a second sample.
6. Counting the number of marked and unmarked animals in the second sample.

It is suitable for organisms such as:

- Fish.
- Grasshoppers.
- Beetles.
- Small mammals.
- Some amphibians.

Procedure

First capture

1. Capture a sample of animals from the habitat.
2. Count the captured animals.
3. Mark them using a safe method.
4. Record the number marked.
5. Release them carefully into the habitat.

Mixing period

6. Allow the marked animals to mix randomly with the rest of the population.
7. Allow sufficient time for them to return to their normal activities.

Second capture

8. Capture a second sample from the same habitat.
9. Count the total number captured.
10. Identify how many of the captured animals are marked.
11. Record the results.
12. Calculate the estimated population size.

Lincoln-Petersen formula

$N=M\times CR$

Where:

- N = Estimated population size.
- M = Number of animals captured and marked during the first capture.
- C = Total number of animals captured during the second capture.
- R = Number of marked animals recaptured during the second capture.

Worked example

A learner captures 40 grasshoppers and marks them safely. They are released into the grassland.

After allowing time for mixing, the learner captures another 50 grasshoppers. Of these, 10 are marked.

Calculate the estimated population size.

Given:

- M=40
- C=50
- R=10

Formula:

$N=M\times CR$ Estimated population = 200 grasshoppers

Assumptions of the capture-mark-recapture method

For the method to give reliable estimates:

1. The population should remain relatively closed during the study period.
2. There should be no significant births, deaths, immigration or emigration between captures.
3. Marks should remain visible until the second capture.
4. Marking should not harm the organisms.
5. Marking should not significantly affect their behaviour.
6. Marked individuals should mix randomly with unmarked individuals.
7. All individuals should have approximately equal chances of being captured.
8. Marks should not be lost or overlooked.

Advantages

1. Suitable for mobile animals.
2. Does not require counting every individual.
3. Can be used in large habitats.
4. Useful in wildlife population studies.
5. Helps monitor changes in animal populations.

Disadvantages

1. Marked organisms may lose their marks.

2. Some organisms may avoid traps after first capture.
3. Predators may identify marked organisms more easily.
4. Organisms may migrate between captures.
5. The method may be unsuitable for very small or sensitive organisms.
6. It depends on assumptions that may not always hold.

Precautions

- Use harmless marking materials.
- Avoid injuring animals.
- Handle organisms carefully.
- Release captured organisms at the original site.
- Allow sufficient time for mixing.
- Obtain appropriate permission before handling wildlife.
- Follow ethical wildlife research guidelines.

Comparison of population estimation methods

Method	Organisms suitable	Main application
Direct counting	Visible and manageable organisms	Actual counting
Sampling	Organisms in large habitats	Estimating population characteristics
Quadrat	Plants and stationary organisms	Density and abundance
Line transect	Organisms along a line	Distribution along a gradient
Belt transect	Organisms in a strip	Distribution and abundance
Capture-mark-recapture	Mobile animals	Estimating population size

1.2.14 Factors affecting populations in ecosystems

Population size and distribution are influenced by interactions between biotic and abiotic factors.

These factors determine whether organisms can survive, reproduce and increase in number.

A. Biotic factors

Biotic factors are living organisms and their interactions that influence the survival, reproduction and distribution of other organisms.

The major biotic factors include:

1. Competition

Competition is an interaction in which organisms require the same limited resources in an environment.

Resources may include:

- Food.
- Water.
- Light.

- Space.
- Mineral nutrients.
- Mating partners.
- Breeding sites.

Types of competition

A. Intraspecific competition

Competition between individuals belonging to the same species.

Examples:

- Two male lions competing for mates.
- Maize plants competing for light and nutrients.
- Zebras competing for grazing resources.

B. Interspecific competition

Competition between individuals belonging to different species.

Examples:

- Cattle and goats competing for pasture.
- Weeds and maize competing for nutrients, water and sunlight.
- Lions and hyenas competing for prey.

Effects of competition

1. Reduces access to resources.
2. May reduce growth rates.
3. May reduce reproductive success.
4. May cause migration.
5. May limit population size.
6. May lead to territorial behaviour.
7. May result in competitive exclusion under certain conditions.

2. Predation

Predation is an interaction in which one organism, called the predator, captures, kills and feeds on another organism, called the prey.

Examples:

- Lions feeding on zebras.
- Cheetahs feeding on gazelles.
- Snakes feeding on rodents.
- Frogs feeding on insects.

- Spiders feeding on flies.

Effects of predation

1. Reduces the population of prey organisms.
2. Controls population sizes.
3. Prevents excessive increase of some populations.
4. Influences the distribution of prey.
5. Promotes natural selection.
6. Helps maintain ecological balance.

3. Parasitism

Parasitism is an interaction in which one organism, the parasite, lives in or on another organism, the host, obtaining nutrients or other benefits at the host's expense.

Examples:

- Ticks feeding on cattle.
- Tapeworms living in the intestines of humans and other animals.
- Mistletoe obtaining water and mineral nutrients from host trees.
- *Plasmodium* living in humans and mosquitoes during its life cycle.

Effects of parasitism

1. Weakens host organisms.
2. May reduce reproductive success.
3. May cause diseases.
4. May increase host mortality.
5. May reduce population growth.

4. Disease

Diseases are conditions that interfere with the normal functioning of organisms.

They may be caused by:

- Bacteria.
- Viruses.
- Fungi.
- Protozoan parasites.
- Other pathogens.

Effects of disease on populations

1. Increases mortality.
2. Reduces reproduction.

3. Reduces population size.
4. May cause population decline.
5. May alter the distribution of organisms.

5. Mutualism

Mutualism is an interaction between organisms of different species in which both organisms benefit.

Examples:

Bees and flowering plants

- Bees obtain nectar and pollen.
- Flowers receive assistance in pollination.

Rhizobium and leguminous plants

- Bacteria obtain carbohydrates and a suitable environment.
- Plants benefit from biologically fixed nitrogen.

Mycorrhizae and plant roots

- Fungi receive carbohydrates.
- Plants benefit from improved absorption of water and mineral nutrients.

Effects of mutualism

1. Improves access to resources.
2. Supports reproduction.
3. Enhances survival.
4. May increase population growth.
5. Strengthens ecosystem interactions.

6. Commensalism

Commensalism is an interaction in which one organism benefits while the other is neither significantly helped nor harmed.

Example:

- Some birds use trees for nesting sites without significantly affecting the trees.
- Epiphytic plants use trees for physical support while obtaining their own nutrients and water.

7. Food availability

Food availability affects the number of organisms that an ecosystem can support.

- Abundant food encourages survival and reproduction.
- Food shortages increase competition.
- Prolonged food shortages may cause starvation and death.
- Organisms may migrate in search of food.

8. Human activities

Human activities may influence populations positively or negatively.

Negative activities

- Deforestation.
- Overhunting.
- Overfishing.
- Pollution.
- Habitat destruction.
- Uncontrolled burning.
- Overgrazing.

Positive activities

- Afforestation.
- Wildlife conservation.
- Habitat restoration.
- Sustainable farming.
- Establishment of protected areas.
- Pollution control.

B. Abiotic factors affecting populations

Abiotic factors are non-living physical and chemical conditions that influence population survival, distribution and growth.

Abiotic factor	Effect on populations
Temperature	Influences metabolism, growth and survival.
Rainfall	Determines water availability and vegetation growth.
Light intensity	Influences photosynthesis and plant distribution.
Soil pH	Affects nutrient availability and plant growth.
Soil moisture	Influences seed germination and plant survival.
Salinity	Determines which organisms can survive in aquatic and coastal environments.
Oxygen concentration	Affects respiration of aquatic and terrestrial organisms.
Wind	Influences transpiration, dispersal and movement.
Altitude	Influences temperature and atmospheric pressure.
Soil nutrients	Affect plant growth and productivity.
Water depth	Influences light penetration and aquatic organism distribution.
Water current	Influences movement and distribution of aquatic organisms.

How abiotic factors limit population growth

1. Temperature extremes

- Very high temperatures may cause dehydration and death.
- Very low temperatures may slow metabolism.
- Some organisms cannot reproduce outside their suitable temperature range.

2. Water shortage

- Reduces plant growth.
- Reduces food availability for herbivores.
- May cause migration.
- May increase mortality.

3. Light limitation

- Reduces photosynthesis.
- Reduces primary productivity.
- May limit the distribution of plants.

4. Oxygen deficiency

- Reduces aerobic respiration.
- May cause death of aquatic organisms.
- Often occurs in polluted or stagnant water bodies.

5. Salinity changes

- Affect osmotic balance.
- May cause water loss or excessive water entry into cells.
- Limit the distribution of organisms that cannot tolerate changing salt concentrations.

6. Soil nutrient deficiency

- Reduces plant growth.
- Reduces food available to herbivores.
- May reduce population carrying capacity.

1.2.15 Nutrient cycles in ecosystems

Meaning of nutrient cycling

Nutrient cycling is the continuous movement and recycling of essential chemical elements between living organisms and the non-living components of the environment.

Nutrients move through:

- The atmosphere.
- Soil.
- Water.
- Living organisms.

- Dead organic matter.

Nutrient cycles ensure that essential elements are reused instead of being permanently lost from biological systems.

Important nutrient cycles include:

1. Nitrogen cycle.
2. Carbon cycle.
3. Water cycle.
4. Phosphorus cycle.
5. Sulphur cycle.

The nitrogen and carbon cycles are particularly important in understanding the relationship between ecosystems and environmental change.

A. Nitrogen cycle

Meaning of nitrogen cycle

The nitrogen cycle is the continuous movement of nitrogen between the atmosphere, soil, water and living organisms through biological, chemical and physical processes.

Nitrogen is an essential element because it is needed for the manufacture of:

- Amino acids.
- Proteins.
- Nucleic acids (DNA and RNA).
- Chlorophyll.
- Other nitrogen-containing compounds.

Although atmospheric nitrogen makes up approximately 78% of the atmosphere, most organisms cannot use nitrogen gas directly.

Nitrogen must first be converted into usable forms.

Processes involved in the nitrogen cycle

1. Nitrogen fixation

Nitrogen fixation is the conversion of atmospheric nitrogen gas into ammonia or other biologically available nitrogen compounds.

It occurs through:

A. Biological nitrogen fixation

- Certain bacteria convert atmospheric nitrogen into ammonia.
- Some nitrogen-fixing bacteria live freely in the soil.
- Others live in association with plant roots.

Examples:

- *Rhizobium* in the root nodules of leguminous plants.
- *Azotobacter* in soil.
- Some cyanobacteria such as *Nostoc*.

B. Atmospheric nitrogen fixation

- Lightning provides sufficient energy for atmospheric nitrogen to react with oxygen.
- Nitrogen oxides are formed.
- These compounds may dissolve in rainwater and enter the soil.

C. Industrial nitrogen fixation

- Industries use the Haber-Bosch process to manufacture ammonia from nitrogen and hydrogen.
- The ammonia is used in the production of nitrogen fertilisers.

2. Nitrification

Nitrification is the biological conversion of ammonia or ammonium ions into nitrites and then nitrates by nitrifying microorganisms under suitable oxygen conditions.

It occurs in two main stages:

First stage: Ammonium to nitrite

- Ammonium ions are oxidised to nitrite.
- This is carried out by ammonia-oxidising microorganisms.

Second stage: Nitrite to nitrate

- Nitrite is oxidised to nitrate.
- This is carried out by nitrite-oxidising microorganisms.

Nitrates are readily absorbed by many plants.

3. Assimilation

Assimilation is the absorption and incorporation of inorganic nitrogen compounds into organic substances by living organisms.

In plants:

1. Roots absorb nitrates or ammonium ions from the soil.
2. The nitrogen is converted into organic compounds.
3. Amino acids are formed.
4. Amino acids are used to manufacture proteins and other nitrogen-containing substances.

In animals:

1. Animals consume plants or other animals.
2. Nitrogen-containing organic substances enter the digestive system.
3. Amino acids are absorbed.
4. The amino acids are used to manufacture proteins and other body substances.

4. Ammonification

Ammonification is the conversion of organic nitrogen in dead organisms and animal wastes into ammonia or ammonium compounds by decomposers.

Process:

1. Plants and animals die or produce nitrogen-containing wastes.
2. Bacteria and fungi decompose the organic matter.
3. Organic nitrogen compounds are broken down.
4. Ammonia or ammonium ions are released into the soil or water.

5. Denitrification

Denitrification is the conversion of nitrates into gaseous nitrogen compounds, mainly nitrogen gas, by denitrifying microorganisms under oxygen-deficient conditions.

Process:

1. Nitrates are present in soil or water.
2. Denitrifying bacteria use nitrate during respiration under low-oxygen conditions.
3. Nitrate is reduced through intermediate nitrogen compounds.
4. Nitrogen gas is released into the atmosphere.

Examples of denitrifying bacteria include species of *Pseudomonas*.

Importance of the nitrogen cycle

1. Maintains nitrogen availability in ecosystems.
2. Supports the manufacture of proteins.
3. Supports plant growth.
4. Helps maintain soil fertility.
5. Supports the formation of DNA and RNA.
6. Promotes agricultural productivity.
7. Prevents permanent depletion of available nitrogen.
8. Maintains ecosystem productivity.

Human activities that interfere with the nitrogen cycle

- Excessive use of nitrogen fertilisers.
- Burning of fossil fuels.
- Deforestation.
- Poor agricultural practices.
- Improper disposal of sewage.
- Industrial emissions.
- Excessive livestock manure accumulation.

Effects of interference

1. Water eutrophication.
2. Nitrate contamination of groundwater.
3. Increased emissions of nitrous oxide.
4. Soil acidification in some environments.
5. Changes in ecosystem species composition.
6. Loss of biodiversity.

B. Carbon cycle

Meaning of carbon cycle

The carbon cycle is the continuous movement of carbon between the atmosphere, oceans, soil, rocks and living organisms.

Carbon is important because it forms the structural basis of organic molecules, including:

- Carbohydrates.
- Proteins.
- Lipids.
- Nucleic acids.

The main carbon reservoirs include:

- Atmosphere.
- Oceans.
- Living organisms.
- Soil organic matter.
- Sedimentary rocks.
- Fossil fuel deposits.

Processes involved in the carbon cycle

1. Photosynthesis

- Green plants absorb carbon dioxide from the atmosphere or water.
- Light energy is used to convert carbon dioxide and water into organic substances.
- Carbon becomes incorporated into plant tissues.

Simplified equation:

$6CO2+6H2O \rightarrow lightC6H12O6+6O26CO2+6H2OlightC6H12O6+6O2$

2. Feeding

- Herbivores obtain carbon by feeding on plants.
- Carnivores obtain carbon by feeding on other animals.

- Carbon moves through food chains and food webs.

3. Respiration

- Plants, animals and microorganisms respire.
- Organic substances are broken down to release energy.
- Carbon dioxide is released into the environment.

4. Decomposition

- Decomposers break down dead plants, animals and organic wastes.
- Carbon is released through microbial respiration.
- Some carbon remains stored in soil organic matter.

5. Combustion

Combustion is the burning of organic materials and fossil fuels.

Examples:

- Burning firewood.
- Burning charcoal.
- Burning petrol and diesel.
- Forest fires.
- Industrial fuel combustion.

Carbon dioxide is released into the atmosphere.

6. Ocean-atmosphere exchange

- Carbon dioxide moves between the atmosphere and ocean water.
- Oceans absorb some atmospheric carbon dioxide.
- Dissolved carbon may be used by marine organisms.
- Some carbon becomes stored in marine sediments.

7. Sedimentation and fossilisation

- Some dead organisms and organic materials become buried.
- Over geological time, some carbon becomes stored in sedimentary rocks and fossil fuels.
- This removes carbon from rapid biological cycling for long periods.

Importance of the carbon cycle

1. Maintains carbon availability in ecosystems.
2. Provides carbon for photosynthesis.
3. Supports the formation of organic compounds.
4. Helps regulate atmospheric carbon dioxide.
5. Supports food chains and food webs.
6. Maintains the balance between photosynthesis and respiration.

7. Influences global climate.
8. Supports long-term carbon storage in soils, forests and oceans.

Human activities that interfere with the carbon cycle

1. Deforestation.
2. Burning fossil fuels.
3. Industrial activities.
4. Cement production.
5. Forest fires.
6. Destruction of wetlands.
7. Unsustainable land-use practices.

Effects

- Increased atmospheric carbon dioxide.
- Enhanced greenhouse effect.
- Global warming.
- Ocean acidification.
- Changes in rainfall patterns.
- Loss of biodiversity.

1.2.16 Environmental pollution

Meaning of environmental pollution

Environmental pollution is the introduction of harmful substances or forms of energy into the environment at levels that cause adverse changes to the physical, chemical or biological characteristics of air, water or land.

The substances or agents that cause pollution are called pollutants.

Examples of pollutants include:

- Plastic waste.
- Industrial chemicals.
- Sewage.
- Smoke.
- Pesticides.
- Fertilisers.
- Oil.
- Heavy metals.
- Radioactive substances.
- Excessive heat.
- Noise.

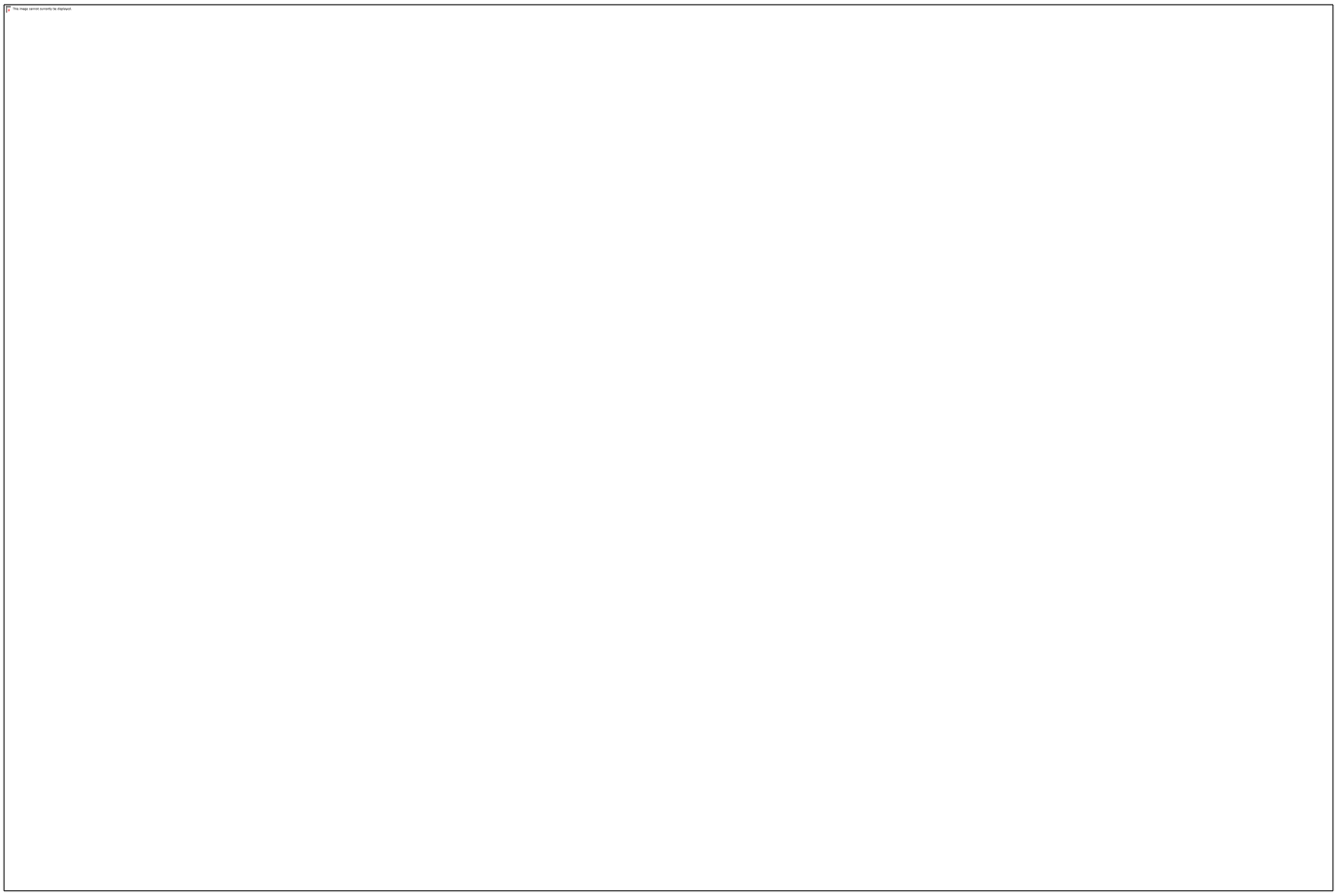
Sources of environmental pollution

1. Industrial activities.
2. Agricultural activities.
3. Domestic waste disposal.
4. Transport systems.
5. Mining activities.
6. Construction.
7. Burning of fossil fuels.
8. Deforestation.
9. Improper sewage disposal.
10. Urbanisation.

Types of environmental pollution

A. Air pollution

Air pollution is the contamination of the atmosphere by harmful gases, particles or biological substances at concentrations that may affect human health, other organisms or environmental processes.



Sources of air pollution

1. Motor vehicle exhaust emissions.
2. Industrial emissions.
3. Burning of charcoal and firewood.

4. Open burning of waste.
5. Forest fires.
6. Dust from construction sites.
7. Mining and quarrying.
8. Agricultural burning.
9. Fossil fuel power generation.

Common air pollutants

Pollutant	Main source
Carbon monoxide	Incomplete combustion
Carbon dioxide	Fossil fuel combustion and respiration
Sulphur dioxide	Burning sulphur-containing fuels
Nitrogen oxides	Vehicles and industries
Particulate matter	Dust, smoke and combustion
Ground-level ozone	Chemical reactions involving pollutants in sunlight
Volatile organic compounds	Fuels, solvents and industrial processes

Effects of air pollution

1. Causes respiratory illnesses.
2. Irritates the eyes, nose and throat.
3. Reduces visibility.
4. Damages plant tissues.
5. May cause acid deposition.
6. Contributes to global warming through greenhouse gases.
7. May reduce crop productivity.
8. Affects wildlife.
9. Can damage buildings and infrastructure.
10. May alter ecosystem functioning.

Control and prevention of air pollution

1. Use cleaner sources of energy.
2. Maintain motor vehicles regularly.
3. Promote public transport.
4. Avoid open burning of waste.
5. Install industrial emission-control equipment.
6. Promote tree planting.

7. Enforce environmental regulations.
8. Use energy-efficient appliances.
9. Control dust at construction sites.
10. Promote clean cooking technologies.

B. Water pollution

Water pollution is the contamination of water bodies by harmful substances or microorganisms, making water unsuitable or unsafe for aquatic organisms and other uses.

Sources of water pollution

1. Untreated sewage.
2. Industrial effluent.
3. Agricultural runoff.
4. Oil spills.
5. Plastic waste.
6. Mining waste.
7. Household detergents.
8. Animal waste.
9. Soil erosion and sedimentation.
10. Improper disposal of chemicals.

Types of water pollutants

1. Biological pollutants

Examples:

- Bacteria.
- Viruses.
- Protozoan parasites.
- Disease-causing fungi.

2. Chemical pollutants

Examples:

- Pesticides.
- Fertilisers.
- Heavy metals.
- Industrial chemicals.
- Detergents.

3. Physical pollutants

Examples:

- Plastic waste.
- Sediments.
- Suspended particles.
- Excessive heat.

Effects of water pollution

1. Causes death of aquatic organisms.
2. Reduces dissolved oxygen.
3. Makes water unsafe for drinking.
4. Causes waterborne diseases.
5. Disrupts aquatic food chains.
6. Reduces fish production.
7. Causes eutrophication.
8. Contaminates aquatic plants and animals.
9. Reduces biodiversity.
10. Affects fishing and tourism activities.

Eutrophication

Eutrophication is the excessive enrichment of a water body with nutrients, especially nitrogen and phosphorus compounds, leading to excessive growth of algae and aquatic plants.

Stages of eutrophication

1. Fertilisers and sewage containing nitrates and phosphates enter a water body.
2. Nutrient concentration increases.
3. Algae multiply rapidly, forming an algal bloom.
4. Algal blooms reduce light penetration into deeper water.
5. Submerged plants may die due to reduced light.
6. Algae and plants eventually die.
7. Decomposers break down the dead organic matter.
8. Decomposition increases oxygen consumption.
9. Dissolved oxygen levels decrease.
10. Fish and other aquatic organisms may die due to oxygen deficiency.

Effects of eutrophication

- Fish deaths.
- Reduced biodiversity.

- Unpleasant odours.
- Poor water quality.
- Reduced recreational value.
- Increased water treatment costs.
- Possible development of harmful algal blooms.

Control of eutrophication

1. Treat sewage before discharge.
2. Control fertiliser application.
3. Establish vegetation buffer strips near rivers.
4. Prevent livestock waste from entering water bodies.
5. Control soil erosion.
6. Improve wastewater management.
7. Monitor nutrient levels in water bodies.

C. Soil or land pollution

Soil pollution is the contamination of soil by harmful substances that alter its natural characteristics and reduce its ability to support healthy ecosystems.



Sources of soil pollution

1. Improper disposal of solid waste.
2. Excessive use of pesticides.
3. Excessive application of fertilisers.
4. Industrial chemical waste.
5. Oil spills.
6. Mining activities.
7. Electronic waste.
8. Sewage sludge.
9. Improper disposal of batteries.
10. Plastic waste.

Effects of soil pollution

1. Reduces soil fertility.
2. Kills beneficial soil organisms.
3. Contaminates crops.
4. Pollutes groundwater.
5. Interferes with plant growth.
6. Causes loss of biodiversity.
7. May introduce toxic substances into food chains.
8. Makes land unsuitable for certain uses.
9. Affects human and animal health.
10. May cause long-term ecosystem damage.

Control of soil pollution

1. Proper waste disposal.
2. Recycling of materials.
3. Use of organic farming methods where appropriate.
4. Controlled application of pesticides.
5. Proper storage of chemicals.
6. Treatment of industrial waste.
7. Prevention of illegal dumping.
8. Restoration of contaminated land.
9. Public environmental education.
10. Enforcement of environmental laws.

D. Noise pollution

Noise pollution is the presence of excessive or unwanted sound that interferes with normal activities and may cause adverse effects on humans and other organisms.



Sources of noise pollution

- Motor vehicles.

- Aircraft.
- Construction equipment.
- Industrial machinery.
- Loud music.
- Generators.
- Mining operations.
- Public address systems.

Effects of noise pollution

1. Hearing impairment.
2. Sleep disturbance.
3. Stress and irritation.
4. Reduced concentration.
5. Interference with communication.
6. Disruption of animal communication.
7. Interference with breeding and feeding behaviour in wildlife.
8. Disturbance of migration and movement patterns in some animals.

Control measures

1. Use noise-reducing equipment.
2. Maintain machinery.
3. Establish appropriate industrial zones.
4. Use sound barriers.
5. Regulate loudspeakers.
6. Plant vegetation barriers where appropriate.
7. Enforce noise control regulations.
8. Use hearing protection in noisy workplaces.

E. Thermal pollution

Thermal pollution is the undesirable change in the temperature of a water body due to human activities.

It commonly occurs when industries and power stations discharge heated water into rivers, lakes or other water bodies.

Effects of thermal pollution

1. Raises water temperature.
2. Reduces the solubility of oxygen in water.
3. May increase the metabolic rate of aquatic organisms.
4. Can cause thermal stress.

5. May interfere with fish breeding.
6. Alters aquatic species composition.
7. May increase the growth of certain microorganisms.
8. Can cause death of temperature-sensitive organisms.

Control measures

1. Use cooling towers.
2. Use cooling ponds.
3. Recycle heated water.
4. Allow industrial water to cool before discharge.
5. Monitor water temperatures.
6. Enforce environmental discharge standards.

1.2.17 Global warming

Meaning of global warming

Global warming is the long-term increase in the average temperature of the Earth's surface and lower atmosphere, mainly caused by the increasing concentration of human-generated greenhouse gases.

It is largely associated with the enhanced greenhouse effect.

The greenhouse effect

The greenhouse effect is a natural process through which certain atmospheric gases absorb and re-emit infrared radiation, helping to keep the Earth's surface warm enough to support life.

The natural greenhouse effect is essential for life. However, human activities have increased the concentration of greenhouse gases, strengthening this effect and causing additional warming.

Greenhouse gases

Greenhouse gases are atmospheric gases that absorb and emit infrared radiation.

The main greenhouse gases include:

1. Carbon dioxide (CO_2)

Sources:

- Burning fossil fuels.
- Deforestation.
- Cement production.
- Some industrial processes.

2. Methane (CH_4)

Sources:

- Livestock digestion.
- Rice cultivation.
- Landfills.

- Wetlands.
- Fossil fuel extraction and distribution.

3. Nitrous oxide (N_2O)

Sources:

- Agricultural soils.
- Nitrogen fertilisers.
- Biomass burning.
- Some industrial processes.

4. Water vapour

- Water vapour is a naturally occurring greenhouse gas.
- Its atmospheric concentration increases as warmer air supports more moisture.
- It acts mainly as a feedback that amplifies warming.

5. Fluorinated gases

Examples:

- Hydrofluorocarbons.
- Perfluorocarbons.
- Sulphur hexafluoride.
- Nitrogen trifluoride.

They are used in certain industrial, refrigeration and electrical applications.

Causes of global warming

1. Burning coal, petroleum and natural gas.
2. Deforestation.
3. Industrial emissions.
4. Cement manufacturing.
5. Agricultural methane emissions.
6. Livestock production.
7. Waste decomposition in landfills.
8. Burning of biomass.
9. Changes in land use.
10. Emissions from transport systems.

Effects of global warming

A. Effects on temperature

1. Increased average global temperatures.
2. More frequent or intense heat extremes in many regions.

3. Increased heat stress in humans and animals.

B. Effects on rainfall

1. Changes in rainfall patterns.
2. Increased risk of drought in some regions.
3. Increased risk of heavy rainfall in many regions.
4. Changes in seasonal rainfall patterns.

C. Effects on ecosystems

1. Shifts in the distribution of plant and animal species.
2. Changes in breeding seasons.
3. Increased stress on sensitive organisms.
4. Increased risk of extinction for vulnerable species.
5. Changes in species interactions.
6. Increased risk of wildfires in some regions.

D. Effects on aquatic ecosystems

1. Warming of oceans and lakes.
2. Coral bleaching.
3. Changes in aquatic species distribution.
4. Increased ocean stratification in some areas.
5. Changes in dissolved oxygen conditions.
6. Increased sea-level rise due to ocean warming and melting land ice.

E. Effects on agriculture

1. Reduced crop productivity in some areas.
2. Increased water demand.
3. Increased heat stress in livestock.
4. Changes in pest and disease distribution.
5. Greater risk of crop failure during extreme droughts.
6. Changes in suitable crop-growing areas.

F. Effects on human communities

1. Increased heat-related illnesses.
2. Water insecurity.
3. Food insecurity.
4. Damage to infrastructure from extreme weather.
5. Displacement of communities.
6. Increased economic losses.

1.2.18 Climate change

Meaning of climate change

Climate change refers to long-term changes in the average weather conditions and variability of the Earth's climate over extended periods, usually decades or longer.

It includes changes in:

- Temperature.
- Rainfall.
- Wind patterns.
- Humidity.
- Frequency and intensity of extreme weather.
- Sea level.
- Seasonal weather patterns.

Climate change may result from natural processes and human activities. The rapid climate change observed in recent decades is primarily driven by human-generated greenhouse gas emissions.

Difference between global warming and climate change

Global warming	Climate change
Refers specifically to the long-term rise in average global temperature.	Refers to wider long-term changes in the climate system.
It is a major component of modern climate change.	Includes temperature, rainfall, wind and extreme weather changes.
Mainly associated with the enhanced greenhouse effect in the current period.	May be caused by natural and human influences.
Example: Increase in global average temperature.	Example: Changes in rainfall patterns and sea levels.

Causes of climate change

A. Human causes

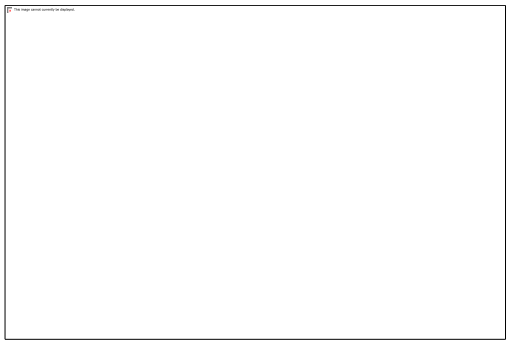
1. Burning fossil fuels.
2. Deforestation.
3. Industrialisation.
4. Agricultural emissions.
5. Land-use changes.
6. Waste disposal.
7. Increased greenhouse gas emissions.

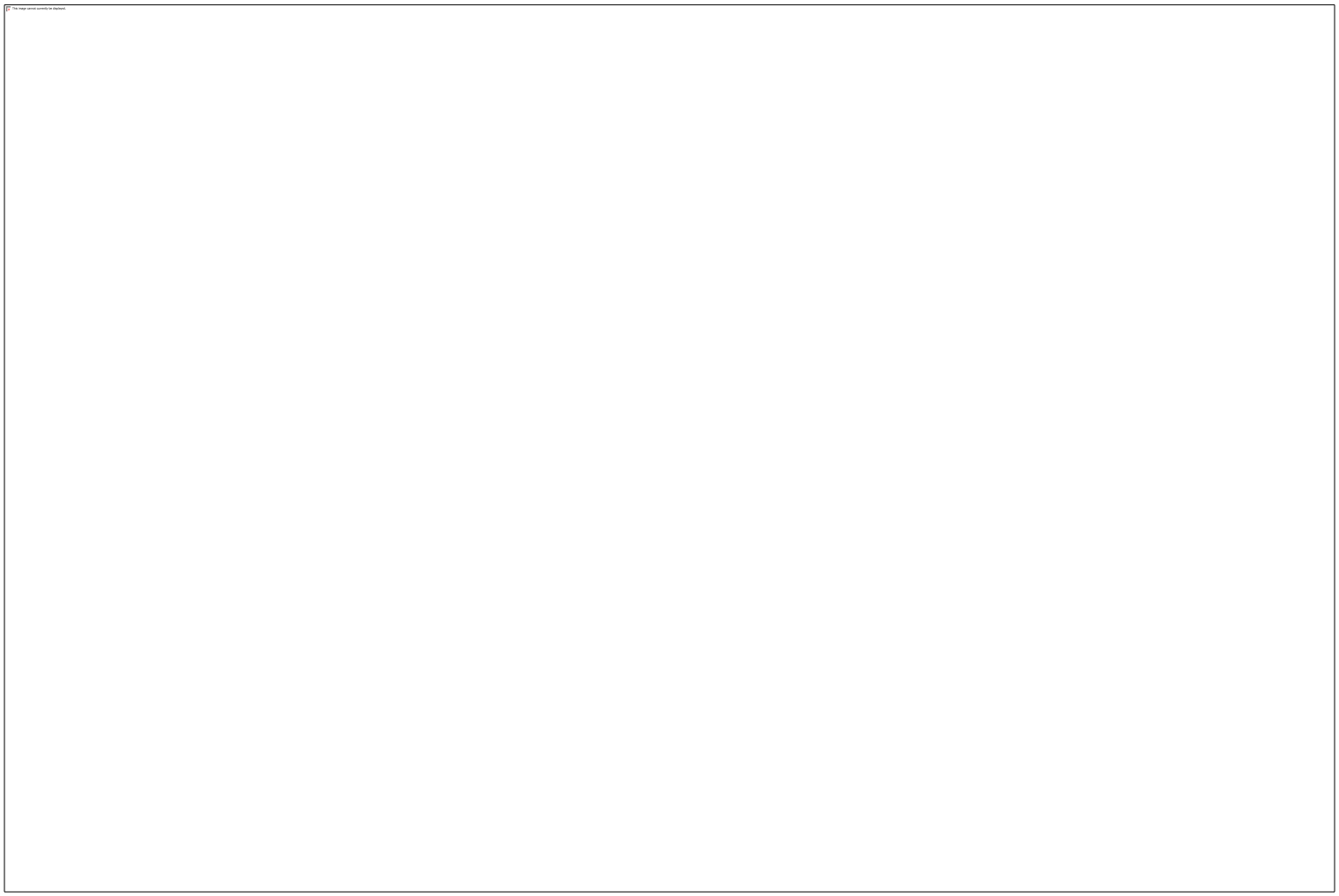
B. Natural causes

1. Volcanic eruptions.
2. Variations in solar energy.
3. Natural ocean circulation changes.
4. Long-term changes in the Earth's orbit and axial orientation.

Natural factors influence climate, but they do not explain the dominant warming trend observed since the mid-twentieth century.

Effects of climate change in Kenya





1. Increased drought frequency and severity in vulnerable areas

- Arid and semi-arid regions may experience prolonged water shortages.
- Pasture and water resources become scarce.

- Livestock may die due to inadequate food and water.

2. Changes in rainfall patterns

- Rainfall seasons may become less predictable.
- Some regions may experience prolonged dry spells.
- Other regions may experience more intense rainfall.

3. Flooding

- Heavy rainfall may cause rivers to overflow.
- Floods may destroy crops, homes and infrastructure.
- Flooding may increase soil erosion.

4. Reduced agricultural productivity

- High temperatures may reduce crop yields.
- Water shortages affect irrigation.
- Unpredictable rainfall interferes with planting and harvesting.
- Crop pests and diseases may change their distribution.

5. Livestock losses

- Heat stress affects livestock productivity.
- Pasture shortages reduce animal body condition.
- Water shortages affect livestock survival.
- Some vector-borne diseases may expand into new areas.

6. Biodiversity loss

- Some organisms may lose suitable habitats.
- Species may migrate to more favourable environments.
- Sensitive species may face increased extinction risks.
- Ecosystem interactions may change.

7. Changes in aquatic ecosystems

- Rising water temperatures affect aquatic organisms.
- Changes in rainfall influence lake and river water levels.
- Coral reefs are threatened by warming and ocean acidification.

8. Coastal impacts

- Sea-level rise increases the risk of coastal flooding and erosion.
- Saltwater may enter freshwater systems and agricultural land.
- Coastal infrastructure and settlements may be threatened.

9. Human health effects

- Heat-related illness may increase.
- Flooding may increase exposure to waterborne diseases.
- Changes in temperature and rainfall may affect disease-vector distribution.
- Food insecurity may increase health risks.

10. Economic impacts

- Damage to roads, bridges and buildings.
- Losses in agriculture and livestock production.
- Increased expenditure on disaster response.
- Reduced tourism income in affected areas.

1.2.19 Relationship between environmental pollution, global warming and climate change

Environmental pollution, global warming and climate change are closely related, but they do not mean the same thing.

How they are connected

Step 1: Human activities produce pollutants and greenhouse gases

- Industries release gases and particles.
- Vehicles release exhaust emissions.
- Deforestation reduces carbon absorption by vegetation.
- Burning fossil fuels releases carbon dioxide.
- Agriculture releases methane and nitrous oxide.

Step 2: Greenhouse gas concentrations increase

- Carbon dioxide, methane and nitrous oxide accumulate in the atmosphere.
- These gases absorb and emit infrared radiation.

Step 3: The enhanced greenhouse effect occurs

- More outgoing infrared radiation is absorbed and re-emitted by greenhouse gases.
- This results in additional warming of the Earth's surface and lower atmosphere.

Step 4: Global warming develops

- Average global temperatures increase over time.
- Heat extremes become more likely or intense in many regions.

Step 5: Climate systems change

- Rainfall patterns change.
- Ice melts.
- Sea levels rise.
- Ecosystems respond to changing temperatures and moisture conditions.
- Extreme weather risks change.

Step 6: Ecosystems and human communities are affected

- Biodiversity is threatened.
- Agricultural productivity may decline in vulnerable areas.
- Water availability changes.
- Human health and livelihoods are affected.

Important distinction

Not every pollutant directly causes global warming.

For example:

- Carbon dioxide is both an air pollutant in some regulatory contexts and a major greenhouse gas.
- Methane is a greenhouse gas.
- Particulate matter causes serious air pollution, but its effects on climate vary according to its composition.
- Plastic waste causes environmental pollution but does not directly produce the main greenhouse effect in the same way as carbon dioxide.

Examples of how pollution contributes to climate change

Human activity	Environmental effect	Climate connection
Deforestation	Habitat destruction and soil degradation	Reduces carbon storage and may release carbon
Burning coal	Air pollution	Releases carbon dioxide
Burning petrol	Air pollution	Releases carbon dioxide
Livestock farming	Methane emissions	Strengthens greenhouse effect
Excessive fertiliser use	Soil and water pollution	May increase nitrous oxide emissions
Waste decomposition in landfills	Waste pollution	Releases methane
Industrial processes	Air and water pollution	May release greenhouse gases

1.2.20 Mitigation and adaptation to climate change

Meaning of climate change mitigation

Climate change mitigation refers to actions taken to reduce greenhouse gas emissions or increase the removal and storage of greenhouse gases from the atmosphere.

Mitigation addresses the causes of climate change.

Ways of mitigating climate change

1. Afforestation and reforestation

- Planting trees increases carbon absorption.
- Trees store carbon in trunks, branches, leaves and roots.
- Forest restoration improves biodiversity.

2. Renewable energy

- Solar energy reduces dependence on fossil fuels.
- Wind energy provides electricity without direct fossil fuel combustion during operation.
- Geothermal energy provides a relatively low-emission energy source.
- Sustainable hydropower can contribute to cleaner electricity generation.

3. Energy efficiency

- Using efficient appliances reduces energy demand.
- Improving building design reduces unnecessary energy use.
- Efficient industrial machinery reduces fuel consumption.

4. Sustainable transport

- Promoting public transport reduces emissions per passenger.
- Walking and cycling reduce fossil fuel use.
- Electric vehicles can reduce transport emissions when powered by low-emission electricity.

5. Sustainable agriculture

- Agroforestry increases tree cover.
- Improved livestock feeding and manure management can reduce methane emissions.
- Efficient fertiliser application reduces nitrous oxide emissions.
- Conservation agriculture can improve soil carbon storage.

6. Proper waste management

- Recycling reduces the need for some energy-intensive production processes.
- Composting suitable organic waste reduces landfill disposal.
- Capturing landfill methane reduces greenhouse gas emissions.
- Avoiding open waste burning reduces air pollution.

7. Forest conservation

- Protecting existing forests prevents the release of stored carbon.
- Conserving wetlands protects important carbon stores.
- Preventing forest degradation protects biodiversity.

8. Cleaner industrial processes

- Industries can adopt energy-efficient machinery.
- Cleaner production technologies can reduce emissions.

- Appropriate pollution-control systems can minimise harmful releases.

Meaning of climate change adaptation

Climate change adaptation refers to adjustments made by human communities and natural systems in response to actual or expected climate conditions in order to reduce harm or take advantage of possible opportunities.

Adaptation addresses the effects of climate change.

Adaptation measures in Kenya



1. Growing drought-resistant crops

- Farmers can grow crops such as sorghum, millet and drought-tolerant varieties of maize.
- These crops may perform better than sensitive varieties under water-limited conditions.

2. Irrigation

- Drip irrigation delivers water close to plant roots.
- Sprinkler irrigation distributes water over crops.
- Proper irrigation planning reduces the effects of unreliable rainfall.

3. Rainwater harvesting

- Water can be collected from rooftops.
- Storage tanks and reservoirs can be used.
- Harvested water can support domestic and agricultural activities.

4. Agroforestry

- Farmers integrate trees with crops and livestock.
- Trees provide shade, reduce wind speed and help protect soil.
- Some trees provide fodder, fruits and fuelwood.

5. Soil and water conservation

- Terracing reduces surface runoff.
- Mulching reduces evaporation.
- Contour farming reduces soil erosion.
- Cover crops protect the soil.

6. Livestock management

- Farmers can keep livestock breeds suited to local environmental conditions.
- Rotational grazing reduces pasture degradation.
- Fodder conservation provides feed during drought.
- Livestock numbers can be adjusted to available pasture.

7. Early warning systems

- Weather forecasts help farmers plan planting and harvesting.
- Drought alerts support preparedness.
- Flood warnings reduce loss of life and property.

8. Water resource conservation

- Protecting wetlands maintains water storage and ecological functions.
- Protecting catchment forests supports water regulation.
- Repairing leaking water systems reduces wastage.

9. Disaster preparedness

- Communities can develop drought and flood response plans.
- Schools can educate learners about environmental risks.
- Emergency response systems can reduce damage.

10. Coastal protection

- Mangrove restoration reduces wave energy.
- Protecting coastal wetlands helps buffer against flooding.
- Sustainable coastal planning reduces exposure to sea-level rise.

Differences between mitigation and adaptation

Mitigation	**Adaptation**
Addresses the causes of climate change.	Addresses the effects of climate change.
Reduces greenhouse gas emissions.	Reduces vulnerability to climate impacts.
Increases carbon removal and storage.	Improves resilience to environmental changes.
Example: Planting trees to absorb carbon dioxide.	Example: Planting drought-tolerant crops.
Example: Using solar energy.	Example: Harvesting rainwater.
Benefits may occur over long periods and across regions.	Benefits often address specific local risks.

Important: Some activities provide both mitigation and adaptation benefits. For example, agroforestry can store carbon while providing shade and improving soil protection.

1.2.21 Ecological balance and conservation

Meaning of ecological balance

Ecological balance refers to a relatively stable condition in an ecosystem in which populations, communities and environmental processes interact without persistent disruption of essential ecological functions.

Ecological balance does not mean that populations never change. Natural ecosystems experience seasonal and long-term changes.

Factors that maintain ecological balance

1. Balanced predator-prey relationships.
2. Adequate food availability.
3. Nutrient cycling.
4. Decomposition.
5. Appropriate population sizes.
6. Biodiversity.
7. Suitable climatic conditions.
8. Habitat availability.
9. Natural competition.
10. Sustainable use of natural resources.

Meaning of biodiversity conservation

Biodiversity conservation refers to the protection, management and sustainable use of genetic diversity, species diversity and ecosystem diversity.

Methods of biodiversity conservation

A. In-situ conservation

In-situ conservation is the protection of organisms within their natural habitats.

Examples in Kenya:

- Maasai Mara National Reserve.
- Amboseli National Park.
- Tsavo National Parks.
- Nairobi National Park.
- Kakamega Forest.
- Arabuko-Sokoke Forest.
- Marine protected areas.

Advantages:

1. Protects organisms in their natural habitats.
2. Maintains ecological interactions.

3. Conserves several species together.
4. Supports natural reproduction.
5. Maintains ecosystem processes.

B. Ex-situ conservation

Ex-situ conservation is the protection of organisms outside their natural habitats.

Examples:

- Botanical gardens.
- Seed banks.
- Gene banks.
- Zoos.
- Captive breeding programmes.
- Tissue culture collections.

Advantages:

1. Protects threatened species.
2. Supports breeding programmes.
3. Preserves genetic material.
4. Allows scientific research.
5. Supports reintroduction programmes.

Role of learners and schools in environmental conservation

1. Planting indigenous trees.
2. Maintaining school gardens.
3. Proper waste disposal.
4. Separating recyclable waste.
5. Conserving water.
6. Protecting nearby wetlands.
7. Avoiding unnecessary destruction of habitats.
8. Participating in environmental clean-up activities.
9. Establishing environmental clubs.
10. Educating the local community about conservation.

1.2.22 Practical activities and field investigations

Ecology is best understood through observation, experimentation and investigation of organisms in their natural environments.

The following activities are suitable for Grade 11 Biology learners in Kenyan schools.

Practical activity 1: Investigating an ecosystem



Objective: To identify the biotic and abiotic components of a local ecosystem.

Materials

- Exercise books.
- Pens.
- Thermometer.
- Quadrat.
- Measuring tape.
- Hand lens.
- Soil thermometer, where available.

Procedure

1. Visit a school garden, grassland, pond or nearby forest under teacher supervision.
2. Observe the different organisms present.
3. Identify producers, consumers and decomposers.
4. Record the non-living environmental factors.
5. Describe interactions between organisms.
6. Identify possible food chains.
7. Present the findings to the class.

Expected results

Biotic components	Abiotic components
Grasses	Temperature
Trees	Sunlight
Insects	Water
Birds	Soil
Earthworms	Air
Fungi	Humidity
Bacteria	Mineral nutrients

Conclusion: An ecosystem consists of interacting living organisms and non-living environmental components.

Practical activity 2: Investigating plant distribution using quadrats

Objective: To estimate the population density of grass plants in a school compound.

Materials

- Quadrat.
- Measuring tape.
- Recording sheet.
- Pegs.
- Pen.

Procedure

1. Select a grassland area.
2. Determine the size of the quadrat.
3. Place the quadrat randomly at different locations.
4. Count the grass plants in each quadrat.
5. Record the number of plants.
6. Calculate the mean number of plants per quadrat.
7. Calculate the population density.

Expected observation table

Quadrat	Number of plants
1	12
2	18
3	15
4	20
5	10
Total	75

Mean population:

755=15575=15

If each quadrat measures 1 m^2:

Density=15 plants/m2Density=15 plants/m2

Practical activity 3: Investigating ecological succession

Objective: To observe changes in plant communities over time.

Procedure

1. Identify an area where vegetation is recovering after disturbance.
2. Observe the types of plants present.
3. Record the abundance of grasses, herbs, shrubs and trees.
4. Identify possible pioneer species.

5. Observe changes in vegetation over several weeks or months.
6. Explain how environmental conditions influence succession.

Expected outcome: Learners should understand that ecological communities change over time.

Practical activity 4: Investigating water pollution

Objective: To investigate physical indicators of water quality.

Materials

- Clean sample bottles.
- Thermometer.
- pH paper or pH meter.
- Transparent container.
- Recording sheet.

Procedure

1. Collect water samples from two approved sampling locations under teacher supervision.
2. Record the temperature.
3. Observe the colour.
4. Compare water clarity.
5. Measure pH.
6. Record visible suspended particles.
7. Compare the results.
8. Discuss possible sources of pollution.

Important safety precaution: Do not taste or directly handle potentially contaminated water. Use appropriate protective equipment.

Practical activity 5: Investigating plant adaptations

Objective: To identify structural adaptations in plants from different habitats.

Materials

- Cactus or aloe specimen.
- Maize plant.
- Water lily photograph or specimen.
- Mangrove photograph.
- Hand lens.

Procedure

1. Observe the leaves, stems and roots.
2. Record the characteristics of each plant.
3. Identify the habitat of each plant.

4. Explain how each feature assists survival.
5. Classify the plants as xerophytes, mesophytes, hydrophytes or halophytes.

1.2.24 Summary of key ecological concepts

Term	Definition
Ecology	Study of interactions between organisms and their environment.
Habitat	Natural place where an organism lives.
Niche	Functional role of an organism in an ecosystem.
Population	Individuals of the same species living in a defined area at a particular time.
Community	Populations of different species interacting in an area.
Ecosystem	Living organisms interacting with their non-living environment.
Biome	Large geographical region characterised by particular climatic and vegetation features.
Biomass	Total mass of living organic matter in a given area or trophic level.
Carrying capacity	Maximum population an environment can sustainably support.
Ecological succession	Gradual change in the composition of a biological community over time.
Biotic factors	Living components of an ecosystem.
Abiotic factors	Non-living components of an ecosystem.
Producers	Organisms that manufacture organic food.
Consumers	Organisms that obtain food by feeding on other organisms.
Decomposers	Organisms that break down dead organic matter externally.
Detritivores	Organisms that ingest dead organic matter.
Xerophytes	Plants adapted to dry habitats.
Mesophytes	Plants adapted to moderately moist habitats.
Hydrophytes	Plants adapted to aquatic habitats.
Halophytes	Plants adapted to saline habitats.
Population density	Number of individuals per unit area or volume.
Population dispersion	Pattern of distribution of individuals within a habitat.
Natality	Addition of new individuals through reproduction.
Mortality	Death rate within a population.
Immigration	Movement of individuals into a population.
Emigration	Movement of individuals out of a population.
Population growth	Change in population size over time.
Quadrat	Frame of known area used in ecological sampling.

Transect	A line or strip used to study organism distribution across a habitat.
Capture-mark-recapture	Method of estimating mobile animal population size.
Nitrogen cycle	Movement and recycling of nitrogen in the environment.
Carbon cycle	Movement of carbon between the atmosphere, organisms and other reservoirs.
Water cycle	Continuous movement of water through the environment.
Eutrophication	Excessive nutrient enrichment of water resulting in excessive algal growth.
Pollution	Introduction of harmful substances or energy into the environment.
Global warming	Long-term increase in Earth's average temperature.
Climate change	Long-term changes in climate patterns and variability.
Mitigation	Actions that reduce greenhouse gas emissions or increase their removal.
Adaptation	Adjustments that reduce vulnerability to climate impacts.
Conservation	Protection and sustainable management of biodiversity and natural resources.

1.2.25 Revision exercises

Instructions: Answer all questions. Draw labelled diagrams where necessary. Show all working in numerical questions.

SECTION A: Multiple-choice questions

Choose the correct answer from the alternatives A, B, C and D.

1. The branch of biology concerned with the study of interactions between organisms and their environment is called:

A. Taxonomy

B. Ecology

C. Genetics

D. Anatomy

2. The natural place where an organism lives is referred to as its:

A. Niche

B. Community

C. Habitat

D. Population

3. Which one of the following correctly describes an ecological niche?

A. The physical place occupied by an organism.

B. The functional role of an organism in an ecosystem.

C. The total number of organisms in a habitat.

D. The geographical distribution of a biome.

4. A group of zebras of the same species living in the Maasai Mara at a particular time constitutes a:

A. Community

B. Biome

C. Population

D. Ecosystem

5. Which one of the following is an abiotic component of an ecosystem?

A. Fungi

B. Grass

C. Temperature

D. Bacteria

6. Which one of the following organisms acts as a primary producer?

A. Lion

B. Maize plant

C. Grasshopper

D. Mushroom

7. Which one of the following organisms is a decomposer?

A. Goat

B. Grass

C. Mushroom

D. Zebra

8. Which one of the following is a characteristic of a tropical rainforest ecosystem?

A. Very low rainfall throughout the year.

B. Sparse vegetation and limited biodiversity.

C. Dense vegetation and generally high humidity.

D. Absence of decomposers.

9. The dominant vegetation in a grassland ecosystem consists of:

A. Grasses

B. Mangroves

C. Mosses

D. Aquatic algae

10. Which one of the following plants is adapted to dry environmental conditions?

A. Water lily

B. Hydrilla

C. Cactus

D. Duckweed

11. Plants adapted to saline environments are called:

A. Mesophytes

B. Xerophytes

C. Hydrophytes

D. Halophytes

12. Which one of the following features helps xerophytes reduce water loss?

A. Thin cuticle

B. Sunken stomata

C. Large exposed leaves

D. Numerous exposed stomata

13. A water lily is classified as a hydrophyte because it:

A. Grows in dry habitats.

B. Is adapted to aquatic environments.

C. Grows in highly saline soils.

D. Requires extremely low water availability.

14. Which one of the following adaptations enables mangrove trees to obtain oxygen in waterlogged soil?

A. Extensive flowers

B. Pneumatophores

C. Broad fruits

D. Thin stems

15. The hump of a camel mainly stores:

A. Water

B. Protein

C. Fat

D. Mineral salts

16. Which one of the following features helps fish maintain buoyancy?

A. Lateral line

B. Swim bladder

C. Gills

D. Scales

17. The arrangement of individuals in groups within a habitat is referred to as:

A. Uniform dispersion

B. Random dispersion

C. Clumped dispersion

D. Linear dispersion

18. Which one of the following is a characteristic of uniform population dispersion?

A. Individuals occur in groups.

B. Individuals are regularly spaced.

C. Individuals occur without any pattern.

D. Individuals occupy different ecosystems.

19. The maximum population size that an environment can support sustainably is known as:

A. Population density

B. Carrying capacity

C. Biomass

D. Natality

20. Which one of the following processes increases the population size through the movement of individuals into an area?

A. Mortality

B. Emigration

C. Immigration

D. Predation

21. A quadrat is mainly used to estimate the population density of:

A. Lions.

B. Migrating birds.

C. Grass plants.

D. Swimming fish.

22. Which method is most appropriate for estimating the population size of mobile grasshoppers?

A. Direct counting of the entire habitat.

B. Capture-mark-recapture.

C. Quadrat sampling only.

D. Soil sampling.

23. In a capture-mark-recapture investigation, the number of marked organisms recaptured is represented by:

A. M

B. C

C. R

D. N

24. A population has 50 individuals. During one year, 20 are born and 10 die. There is no immigration or emigration. What is the new population size?

A. 30

B. 40

C. 60

D. 80

25. Which one of the following processes converts atmospheric nitrogen into biologically available nitrogen compounds?

A. Denitrification

B. Nitrogen fixation

C. Respiration

D. Transpiration

26. Which microorganisms are commonly associated with nitrogen fixation in the root nodules of leguminous plants?

A. Rhizobium

B. Plasmodium

C. Amoeba

D. Penicillium

27. The conversion of ammonia or ammonium into nitrites and then nitrates is called:

A. Assimilation

B. Ammonification

C. Nitrification

D. Denitrification

28. Which one of the following processes releases carbon dioxide into the atmosphere?

A. Photosynthesis

B. Respiration

C. Nitrogen fixation

D. Nitrification

29. Excessive enrichment of a water body with nutrients, resulting in rapid algal growth, is called:

A. Desertification

B. Eutrophication

C. Transpiration

D. Succession

30. Which one of the following gases is a major greenhouse gas produced by burning fossil fuels?

A. Oxygen

B. Nitrogen

C. Carbon dioxide

D. Hydrogen

31. Which one of the following is an example of climate change mitigation?

A. Constructing flood barriers.

B. Growing drought-resistant crops.

C. Using solar energy instead of fossil fuels.

D. Constructing emergency water storage tanks.

32. Which one of the following is an example of climate change adaptation?

A. Reducing fossil fuel consumption.

B. Harvesting rainwater for use during dry periods.

C. Reducing industrial greenhouse gas emissions.

D. Replacing coal power with solar energy.

33. Which one of the following is an effect of global warming on aquatic ecosystems?

A. Permanent increase in dissolved oxygen.

B. Coral bleaching.

C. Complete elimination of ocean currents.

D. Permanent increase in fish populations.

34. Which one of the following is an example of primary ecological succession?

A. Regrowth of grass after grazing.

B. Vegetation recovery after a forest fire.

C. Colonisation of bare volcanic rock.

D. Regrowth of plants on abandoned farmland.

35. The conversion of nitrates into gaseous nitrogen compounds is called:

A. Nitrification

B. Assimilation

C. Denitrification

D. Ammonification

SECTION B: Structured questions

Question 36: Introduction to ecology (10 marks)

(a) Define the following terms:

(i) Ecology. (2 marks)

(ii) Habitat. (1 mark)

(iii) Ecological niche. (1 mark)

(iv) Ecosystem. (1 mark)

(b) Distinguish between a population and a community. (2 marks)

(c) State three reasons why the study of ecology is important in Kenya. (3 marks)

Question 37: Components of ecosystems (10 marks)

(a) Distinguish between biotic and abiotic components of an ecosystem. (2 marks)

(b) Describe the following groups of biotic components:

(i) Producers. (2 marks)

(ii) Consumers. (2 marks)

(iii) Decomposers. (2 marks)

(c) State two examples of abiotic factors in an aquatic ecosystem. (2 marks)

Question 38: Forest, grassland and desert ecosystems (10 marks)

(a) State four characteristics of a forest ecosystem. (4 marks)

(b) Explain three characteristics of a grassland ecosystem. (3 marks)

(c) State three characteristics of a desert ecosystem. (3 marks)

Question 39: Aquatic ecosystems (10 marks)

(a) Name three types of aquatic ecosystems. (3 marks)

(b) Distinguish between freshwater and marine ecosystems. (2 marks)

(c) State three characteristics of freshwater ecosystems. (3 marks)

(d) Give two examples of aquatic ecosystems found in Kenya. (2 marks)

Question 40: Adaptations of plants (10 marks)

(a) Define the term adaptation. (2 marks)

(b) Distinguish between xerophytes and hydrophytes. (2 marks)

(c) Explain three adaptations of xerophytes to dry conditions. (3 marks)

(d) State three adaptations of hydrophytes to aquatic environments. (3 marks)

Question 41: Adaptations of animals (10 marks)

(a) State four structural adaptations of a camel to desert conditions. (4 marks)

(b) Explain three physiological adaptations of desert animals. (3 marks)

(c) State three adaptations of fish to aquatic environments. (3 marks)

Question 42: Population characteristics (10 marks)

(a) Define population density. (2 marks)

(b) Explain the following types of population dispersion:

(i) Clumped dispersion. (2 marks)

(ii) Uniform dispersion. (2 marks)

(iii) Random dispersion. (2 marks)

(c) State two factors that influence population growth. (2 marks)

Question 43: Population growth calculations (10 marks)

A wildlife reserve had an initial population of 800 gazelles. During one year, 120 were born, 60 died, 40 immigrated and 100 emigrated.

(a) Calculate the population size at the end of the year. (4 marks)

(b) State the meaning of:

(i) Natality. (2 marks)

(ii) Mortality. (2 marks)

(c) Explain one way immigration affects population size. (2 marks)

Question 44: Population estimation methods (10 marks)

(a) Explain the quadrat method of estimating population density. (3 marks)

(b) State three advantages of using quadrats in ecological investigations. (3 marks)

(c) Distinguish between a line transect and a belt transect. (2 marks)

(d) State two organisms for which the capture-mark-recapture method is suitable. (2 marks)

Question 45: Capture-mark-recapture calculations (10 marks)

A learner captured 60 grasshoppers from a grassland, marked them and released them. Later, the learner captured 80 grasshoppers. Of these, 20 were marked.

(a) State the formula used to estimate population size using the capture-mark-recapture method. (2 marks)

(b) Calculate the estimated population size. (3 marks)

(c) State three assumptions of the capture-mark-recapture method. (3 marks)

(d) Give two precautions taken when marking organisms. (2 marks)

Question 46: Factors affecting populations (10 marks)

(a) Distinguish between biotic and abiotic factors. (2 marks)

(b) Explain four biotic factors that influence population size. (4 marks)

(c) State four abiotic factors that influence the distribution of organisms. (4 marks)

Question 47: Nitrogen cycle (10 marks)

(a) Define the nitrogen cycle. (2 marks)

(b) Explain the following processes:

(i) Nitrogen fixation. (2 marks)

(ii) Nitrification. (2 marks)

(iii) Denitrification. (2 marks)

(c) State two reasons why nitrogen is important to living organisms. (2 marks)

Question 48: Carbon cycle (10 marks)

(a) Define the carbon cycle. (2 marks)

(b) Explain four processes involved in the carbon cycle. (4 marks)

(c) State four ways in which human activities interfere with the carbon cycle. (4 marks)

Question 49: Environmental pollution (10 marks)

(a) Define environmental pollution. (2 marks)

(b) State four sources of water pollution. (4 marks)

(c) Explain two effects of water pollution on aquatic ecosystems. (2 marks)

(d) State two methods of controlling water pollution. (2 marks)

Question 50: Eutrophication (10 marks)

(a) Define eutrophication. (2 marks)

(b) Explain the stages involved in eutrophication. (6 marks)

(c) State two measures that can be used to control eutrophication. (2 marks)

Question 51: Global warming and climate change (10 marks)

(a) Distinguish between global warming and climate change. (2 marks)

(b) Name four greenhouse gases. (4 marks)

(c) Explain two human activities that contribute to global warming. (2 marks)

(d) State two effects of global warming on the Kenyan environment. (2 marks)

Question 52: Climate change mitigation and adaptation (10 marks)

(a) Define climate change mitigation. (2 marks)

(b) Define climate change adaptation. (2 marks)

(c) Explain three ways of mitigating climate change in Kenya. (3 marks)

(d) State three ways in which farmers can adapt to climate change. (3 marks)

Question 53: Ecological succession (10 marks)

(a) Define ecological succession. (2 marks)

(b) Distinguish between primary and secondary succession. (4 marks)

(c) Explain four stages involved in ecological succession. (4 marks)

Question 54: Integrated ecological investigation (10 marks)

A group of Grade 11 learners visited a grassland ecosystem near their school. They observed grasses, shrubs, insects, birds, earthworms and grazing animals. They also recorded temperature, soil moisture and light intensity.

(a) Identify three biotic components in the ecosystem. (3 marks)

(b) Identify three abiotic components in the ecosystem. (3 marks)

(c) Name two methods that the learners could use to estimate the population of grass plants. (2 marks)

(d) State two reasons why the investigation is important in understanding ecosystems. (2 marks)

1.2.26 Application and competency-based questions

These questions require learners to apply ecological knowledge to real-life situations.

1. Case study: Drought in a Kenyan pastoral community

A prolonged drought occurs in a semi-arid area of Kajiado County. Grass becomes scarce, water sources dry up and livestock begin losing body condition.

Answer the following:

(a) Identify three abiotic factors responsible for the changes in the ecosystem.

(b) Explain how drought affects the population of grazing animals.

(c) Suggest four measures the community can use to manage the effects of drought.

(d) Explain how rotational grazing can support the recovery of grassland vegetation.

2. Case study: Pollution of a freshwater lake

A lake receives untreated sewage and agricultural runoff containing fertilisers. After some weeks, the water becomes green and many fish begin dying.

(a) Identify the environmental problem.

(b) Explain how fertilisers contribute to the problem.

(c) Explain why fish may die.

(d) Suggest four measures that can prevent the problem.

3. Case study: Conservation of a forest ecosystem

A community living near the Mau Forest depends on forest resources for fuelwood, water and other products. However, excessive tree cutting has reduced vegetation cover.

(a) Identify three ecological effects of deforestation.

(b) Explain how deforestation affects the carbon cycle.

(c) Suggest five measures for restoring the forest.

(d) Explain the importance of community participation in forest conservation.

4. Case study: Population estimation

A learner wishes to estimate the number of grasshoppers in a large school grassland.

(a) Identify the most appropriate population estimation method.

(b) Describe how the learner should conduct the investigation.

(c) Explain three assumptions of the method.

(d) State two possible sources of error.

5. Case study: Climate-smart agriculture

A farmer in Turkana experiences unreliable rainfall and frequent crop failure.

(a) Suggest three drought-tolerant crops suitable for investigation in the area.

(b) Explain three ways the farmer can conserve soil moisture.

(c) Explain how agroforestry can support climate change mitigation and adaptation.

(d) Suggest two methods of harvesting and storing rainwater.

1.2.27 Further learner research and projects

Project	Expected output
Investigating biodiversity in the school compound	A catalogue of local organisms and their habitats.
Population density of grasses	A field report containing quadrat calculations.
Comparing plant adaptations	A labelled illustrated comparison of xerophytes, mesophytes, hydrophytes and halophytes.
Investigating pollution in a local water source	A water-quality investigation report.
Studying ecological succession	A photographic record of vegetation changes.
Constructing nutrient cycle models	Labelled nitrogen and carbon cycle models.
Investigating climate change effects	A report on climate-related challenges in the local community.
Environmental conservation campaign	A school or community conservation activity.

Assessment rubric for ecological field investigation

Assessment area	Expected performance
Identification	Correctly identifies organisms and environmental factors.
Data collection	Records accurate and relevant observations.
Scientific procedures	Uses appropriate ecological sampling methods.
Calculations	Correctly calculates density and estimated population size.
Interpretation	Explains ecological relationships using scientific concepts.
Communication	Presents findings clearly using tables, diagrams and explanations.
Environmental responsibility	Demonstrates safe and ethical investigation practices.

STRAND 1: CELL BIOLOGY AND BIODIVERSITY

SUB-STRAND 1.3: TAXONOMY II

1.0 Introduction to Taxonomy

1.1 Meaning of taxonomy

Taxonomy is the branch of biology concerned with the identification, naming, description and classification of organisms into groups based on their similarities, differences and evolutionary relationships.

Taxonomy helps biologists to organise the enormous diversity of living organisms into manageable groups for study.

1.2 Importance of taxonomy

Taxonomy is important because it:

1. **Makes identification easier:** Organisms can be identified using their observable characteristics.
2. **Provides universal names:** Scientific names reduce confusion caused by different local names.
3. **Shows relationships:** Classification helps scientists understand similarities and differences among organisms.
4. **Supports conservation:** Correct identification helps in protecting endangered species and managing biodiversity.
5. **Promotes scientific communication:** Scientists from different countries can communicate about organisms using agreed scientific names.
6. **Supports agriculture:** Identification of crop plants, weeds, pests and beneficial organisms assists agricultural production.
7. **Supports medicine:** Identification of disease-causing organisms and medicinal plants is important in healthcare.
8. **Supports ecological studies:** Classification helps in studying food chains, food webs and ecosystem relationships.

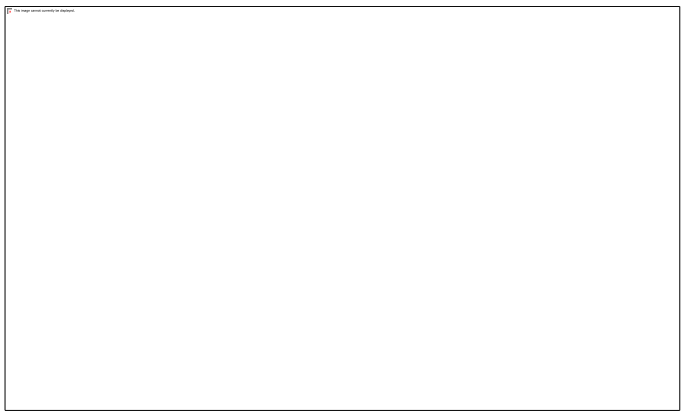


Figure 1: The hierarchical arrangement of organisms in biological classification.

1.3 Taxonomic hierarchy

Organisms are classified into groups arranged from the largest, broadest group to the smallest, most specific group.

The main taxonomic ranks are:

1. Kingdom
2. Phylum (or Division in plants)
3. Class
4. Order

5. Family
6. Genus
7. Species

Explanation of the taxonomic ranks

- **Kingdom:** A large group containing organisms with broad similarities.
- **Phylum:** A subdivision of a kingdom consisting of organisms sharing important structural features. In plant classification, the term *division* is commonly used.
- **Class:** A subdivision of a phylum or division.
- **Order:** A group of related families.
- **Family:** A group of related genera.
- **Genus:** A group of closely related species.
- **Species:** The basic unit of classification. It generally consists of organisms that can naturally interbreed and produce fertile offspring.

Example: Classification of human beings

Taxonomic rank	Classification
Kingdom	Animalia
Phylum	Chordata
Class	Mammalia
Order	Primates
Family	Hominidae
Genus	Homo
Species	Homo sapiens

Remember

As one moves from kingdom towards species, the number of organisms in each group decreases while the similarities among the organisms increase.

1.4 Scientific naming (binomial nomenclature)

Binomial nomenclature is the system of naming organisms using two names: the genus name and the specific epithet.

It was popularised by the Swedish scientist Carl Linnaeus.

Rules of writing scientific names

1. Each scientific name has two parts.
2. The first part is the genus name.
3. The second part is the specific epithet.

4. The genus name begins with a capital letter.
5. The specific epithet begins with a small letter.
6. Both names are italicised when typed.
7. When handwritten, the two names are underlined separately.
8. Scientific names are usually derived from Latin or Latinised words.
9. After the first full mention, the genus name may be abbreviated where the meaning remains clear.

Examples

- *Homo sapiens* – human being.
- *Zea mays* – maize.
- *Mangifera indica* – mango.
- *Canis familiaris* – domestic dog (a commonly used traditional name; classification and accepted naming may vary).
- *Felis catus* – domestic cat.

2.0 KINGDOM PLANTAE

2.1 General characteristics of Kingdom Plantae

Kingdom Plantae consists of multicellular, eukaryotic organisms that generally manufacture their own food through photosynthesis.

Plants are important components of terrestrial and aquatic ecosystems. They provide food, oxygen, shelter, medicine, fuel and raw materials.

General characteristics of plants

1. **Eukaryotic cells:** Plant cells have a true nucleus surrounded by a nuclear membrane.
2. **Multicellular organisation:** Most plants consist of many cells organised into tissues and organs.
3. **Cellulose cell walls:** Their cells have cell walls mainly made of cellulose, which provide support and protection.
4. **Chloroplasts:** Most green plants contain chloroplasts with chlorophyll for photosynthesis.
5. **Autotrophic nutrition:** Most plants manufacture carbohydrates from carbon dioxide and water using light energy.
6. **Food storage:** Many plants store carbohydrates in the form of starch.
7. **Large permanent vacuoles:** Most plant cells contain large vacuoles containing cell sap.
8. **Limited movement:** Plants are generally fixed to a surface or substrate, although some plant parts show movement in response to stimuli.
9. **Growth:** Plants usually show growth throughout their lives in regions containing meristematic tissues.
10. **Reproduction:** Plants reproduce sexually and/or asexually.
11. **Alternation of generations:** Many plant groups have a life cycle involving alternating gametophyte and sporophyte generations.

12. **Adaptation:** Plants possess structural and physiological features that enable them to survive in different habitats.

Examples of plants found in Kenya: Maize, beans, tea, coffee, acacia, bamboo, ferns, mosses, cypress, podo and water lilies.

2.2 Major divisions of Kingdom Plantae

For this Grade 11 classification, the major plant divisions are:

1. Division Bryophyta
2. Division Pteridophyta
3. Division Spermatophyta

The first two divisions consist of plants that reproduce by spores. Spermatophyta consists of seed-producing plants.



Figure 2: Representative plants from the major plant divisions.

3.0 DIVISION BRYOPHYTA

3.1 Meaning of Bryophyta

Bryophyta is a division of simple, non-vascular plants that reproduce by spores and usually grow in moist, shaded environments.

They are commonly referred to as bryophytes. They do not possess true roots, stems and leaves.

Examples: Mosses, liverworts and hornworts.



3.2 General characteristics of organisms in Division Bryophyta

1. **They are non-vascular plants.**
   - They lack well-developed xylem and phloem tissues.
   - Water and dissolved mineral salts move mainly by diffusion and osmosis from cell to cell.
   - This limits their size and restricts many species to moist habitats.
2. **They lack true roots, stems and leaves.**
   - They possess simple structures that perform similar functions.
   - Mosses have root-like structures called rhizoids.
   - Rhizoids anchor the plant and may assist in water absorption.
3. **They are generally small in size.**
   - Most bryophytes are short because they lack well-developed supporting and conducting tissues.
4. **They commonly grow in moist and shaded habitats.**
   - Moisture is important for their survival and reproduction.
   - They may grow on rocks, soil, tree trunks and damp walls.
5. **They reproduce by spores.**
   - They do not produce flowers, fruits or seeds.
   - Spores are produced in structures called capsules or sporangia.
6. **The gametophyte is the dominant generation.**
   - The green, visible plant body is usually the gametophyte.
   - It produces male and female reproductive structures.
7. **They require water for fertilisation.**
   - The male gametes are motile and swim through a film of water to reach the female gamete.
   - This explains why many bryophytes thrive in moist environments.
8. **They show alternation of generations.**
   - Their life cycle alternates between a gametophyte and a sporophyte.
   - The sporophyte remains attached to and depends partly or entirely on the gametophyte.
9. **They are photosynthetic.**
   - Most possess chlorophyll and manufacture their own food.
10. **They may reproduce vegetatively.**
   - Some reproduce through fragmentation or specialised structures.

3.3 Distinguishing features of Bryophyta

- Absence of true vascular tissues.
- Absence of true roots, stems and leaves.
- Presence of rhizoids.
- Reproduction by spores rather than seeds.

- Dominant gametophyte generation.
- Fertilisation requires water.

3.4 Classes and common groups of bryophytes

In traditional school-level classification, bryophytes are commonly studied under three major groups:

A. Mosses (Bryopsida)

Characteristics

1. Have small, leafy shoots.
2. Possess rhizoids for anchorage.
3. Commonly grow in damp and shaded places.
4. Produce spores in capsules borne on stalk-like structures.
5. Have a dominant gametophyte generation.

Examples: *Funaria*, *Sphagnum* and *Polytrichum*.

B. Liverworts (Marchantiopsida)

Characteristics

1. Many have a flat, lobed body called a thallus.
2. Some have simple leaf-like structures.
3. They commonly grow on moist soil, rocks and tree trunks.
4. They possess rhizoids.
5. Some reproduce vegetatively using gemmae contained in gemma cups.

Example: *Marchantia*.

C. Hornworts (Anthocerotopsida)

Characteristics

1. Have a flat, thallus-like gametophyte.
2. Produce long, narrow, horn-like sporophytes.
3. Usually grow in damp soil.
4. Their sporophytes develop from the gametophyte.
5. Their cells commonly contain a large chloroplast, often with a pyrenoid.

Example: *Anthoceros*.

3.5 Economic and ecological importance of Bryophyta

1. **Soil formation:** They colonise bare surfaces and contribute to the formation of soil as they grow and decompose.
2. **Soil conservation:** Mosses form mats that reduce the impact of raindrops and help reduce soil erosion.
3. **Water retention:** Mosses absorb and retain water, helping maintain moisture in their habitats.
4. **Habitat provision:** They provide shelter for small invertebrates and microorganisms.

5. **Peat formation:** Some species of *Sphagnum* accumulate to form peat in wetlands.
6. **Horticulture:** Peat and moss materials have been used in horticultural growing media, although sustainable alternatives are encouraged because peatland extraction damages ecosystems.
7. **Environmental monitoring:** Some bryophytes are useful indicators of environmental conditions, including air pollution.
8. **Nutrient cycling:** Their growth and decomposition contribute to nutrient movement in ecosystems.

Kenyan context: Mosses may be observed in damp forest environments, including parts of the Aberdare Range and Mount Kenya.

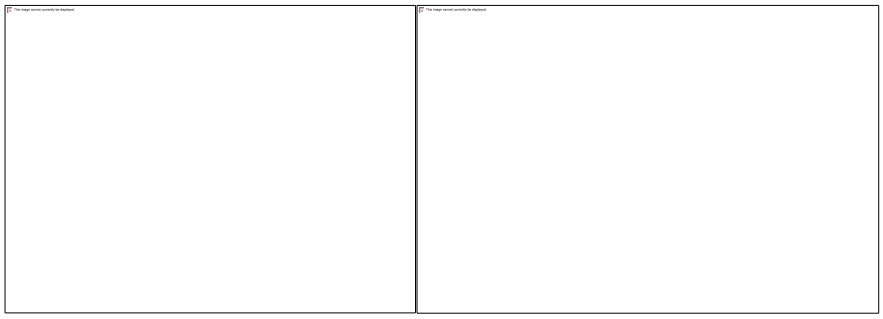
4.0 DIVISION PTERIDOPHYTA

4.1 Meaning of Pteridophyta

Pteridophyta is a traditional division of seedless vascular plants that reproduce using spores rather than seeds.

They possess true roots, stems and leaves, as well as vascular tissues for transporting water, mineral salts and manufactured food.

Examples: Ferns, horsetails and club mosses.



4.2 General characteristics of Pteridophyta

1. **They are vascular plants.**
   - They possess xylem and phloem.
   - Xylem transports water and mineral salts from the roots.
   - Phloem transports manufactured food from photosynthetic tissues.
2. **They have true roots, stems and leaves.**
   - Roots anchor the plant and absorb water and mineral salts.
   - Stems support the plant and conduct substances.
   - Leaves carry out photosynthesis.
3. **They do not produce seeds.**
   - Reproduction occurs through spores.
   - Spores are usually produced in sporangia.
4. **They do not produce flowers or fruits.**
   - They lack the reproductive structures associated with flowering plants.

5. **The sporophyte is the dominant generation.**
   - The familiar fern plant is the diploid sporophyte.
   - It produces spores by meiosis.
6. **They show alternation of generations.**
   - The gametophyte is usually small and independent in many ferns.
   - It is commonly called a prothallus.
7. **They generally require water for fertilisation.**
   - Their male gametes are motile and swim towards the female gamete.
8. **They commonly grow in moist environments.**
   - Many species are found in forests, riverbanks and damp shaded areas.
   - Some species are adapted to drier habitats.
9. **They have well-developed conducting tissues.**
   - Their vascular tissues allow them to grow taller than most bryophytes.
10. **They may reproduce vegetatively.**
    - Some spread through underground stems called rhizomes.

4.3 Distinguishing features of Pteridophyta

- Presence of vascular tissues.
- Presence of true roots, stems and leaves.
- Reproduction by spores.
- Absence of flowers, fruits and seeds.
- Dominant sporophyte generation.
- Fertilisation generally requires water.

4.4 Major groups commonly studied under Pteridophyta

A. Ferns

Characteristics

1. Have large leaves called fronds.
2. Young fronds are often coiled, a condition called circinate vernation.
3. Sporangia are commonly grouped into clusters called sori.
4. Sori are often found on the underside of mature fronds.
5. They may possess underground rhizomes.
6. They reproduce through spores.

Examples: *Pteris*, *Adiantum* and *Dryopteris*.

B. Horsetails

Characteristics

1. Have jointed and ribbed stems.
2. Leaves are small and arranged in whorls.
3. Some species have silica deposits in their stems.
4. Spores are produced in cone-like structures called strobili.
5. They are commonly found in moist habitats.

Example: *Equisetum*.

C. Club mosses

Characteristics

1. Have small leaves called microphylls.
2. Their stems may creep along the ground.
3. Some produce spores in terminal cone-like structures called strobili.
4. They resemble mosses but possess vascular tissues and true organs.

Example: *Lycopodium*.

4.5 Economic and ecological importance of Pteridophyta

1. **Ornamental plants:** Ferns are grown in gardens, homes and landscaped environments.
2. **Soil conservation:** Their roots and rhizomes help bind soil particles and reduce erosion.
3. **Soil formation:** They colonise suitable habitats and contribute organic matter when they decompose.
4. **Habitat provision:** Their leaves and stems provide shelter for small organisms.
5. **Medicinal uses:** Some fern species have been used in traditional medicine, although medicinal use requires scientific safety assessment.
6. **Historical coal formation:** Ancient vascular plants, including relatives of some modern groups, contributed to coal deposits over geological time.
7. **Ecological restoration:** Suitable fern species can be used in restoring degraded moist habitats.
8. **Aquatic nitrogen fixation:** The water fern *Azolla* hosts nitrogen-fixing cyanobacteria and can be used as a biofertiliser in rice cultivation.

Kenyan agricultural example: *Azolla* can be incorporated into rice-growing systems to improve nitrogen availability and reduce dependence on some manufactured fertilisers.

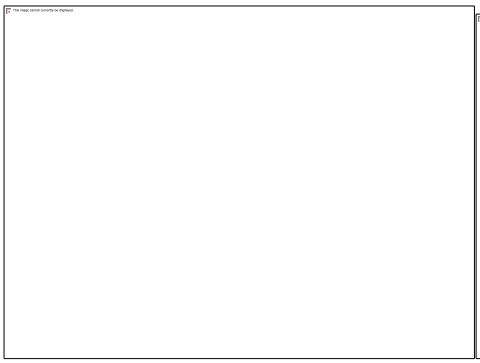
5.0 DIVISION SPERMATOPHYTA

5.1 Meaning of Spermatophyta

Spermatophyta is a division of vascular plants that produce seeds. They are commonly referred to as seed plants.

They possess well-developed roots, stems, leaves and vascular tissues. Their reproductive structures produce pollen and ovules.

Examples: Maize, beans, mango, pine, cypress, coconut and avocado.




5.2 General characteristics of Spermatophyta

1. **They are vascular plants.**
    - They possess xylem and phloem for transport of materials.
    - This enables efficient movement of water, mineral salts and manufactured food.
2. **They have true roots, stems and leaves.**
    - These organs perform specialised functions such as anchorage, absorption, support, transport and photosynthesis.
3. **They reproduce by seeds.**
    - A seed contains an embryo, stored food (in many species) and a protective seed coat.
    - The embryo develops into a new plant under suitable conditions.
4. **They produce pollen grains.**
    - Pollen grains contain the male reproductive cells or cells that give rise to male gametes.
    - Pollen transfer allows fertilisation without the need for free-standing water.
5. **They produce ovules.**
    - The ovule contains the female reproductive structures.
    - After fertilisation, the ovule develops into a seed.
6. **The sporophyte is the dominant generation.**
    - The visible plant is the sporophyte.
    - The gametophytes are highly reduced.
7. **They are well adapted to terrestrial habitats.**
    - Pollen and seeds help them reproduce successfully on land.
8. **They show alternation of generations.**
    - The sporophyte produces spores through meiosis.
    - These develop into highly reduced gametophytes.
9. **They have specialised reproductive structures.**
    - Gymnosperms commonly produce cones.
    - Angiosperms produce flowers.
10. **They show a wide range of growth forms.**

- They include herbs, shrubs, climbers and trees.

5.3 Major subdivisions of Spermatophyta

Spermatophyta is commonly divided into:

1. Gymnospermae
2. Angiospermae

Figure 3: Comparison of gymnosperm and angiosperm reproductive structures.

6.0 SUBDIVISION GYMNOSPERMAE

6.1 Meaning of Gymnospermae

Gymnospermae is a group of seed-producing vascular plants whose seeds are not enclosed within an ovary or fruit. Their seeds are described as naked seeds.

Most gymnosperms produce reproductive structures called cones.

Examples: Pine, cypress, cedar, fir and cycads.

6.2 General characteristics of Gymnospermae

1. **They produce naked seeds.**
   - Their seeds are not enclosed in fruits.
   - Seeds are usually borne on the scales of female cones.
2. **They do not produce true flowers.**
   - Their reproductive structures are usually cones or strobili.
3. **They are vascular plants.**
   - They possess conducting tissues for transporting water and food.
4. **They are mostly woody plants.**
   - Many are trees and shrubs.
   - They have well-developed supporting tissues.
5. **They have true roots, stems and leaves.**
   - These organs are adapted to their different functions.
6. **Many have needle-like or scale-like leaves.**
   - These reduce surface area and may reduce water loss.
   - This feature is common in many conifers.
7. **They are mostly evergreen.**
   - Many retain their leaves throughout the year, although some gymnosperms are deciduous.
8. **They produce pollen grains.**
   - Pollen carries the male reproductive cells or gives rise to them.
   - Pollination commonly takes place through wind.
9. **Fertilisation does not require external water.**

- The pollen grain produces a pollen tube that transports the male gametes towards the egg.

10. **The sporophyte is dominant.**
    - The visible tree or shrub is the sporophyte generation.
11. **They are mostly wind-pollinated.**
    - Their pollen grains are often light and produced in large quantities.
12. **They show alternation of generations.**
    - The gametophytes are highly reduced and dependent on the sporophyte.

6.3 Distinguishing features of Gymnospermae

- Naked seeds.
- Seeds not enclosed in fruits.
- Cones are common reproductive structures.
- No true flowers.
- Mostly woody trees and shrubs.
- Many possess needle-like or scale-like leaves.
- Pollination is commonly by wind.

6.4 Classes of Gymnospermae commonly studied

Traditional classifications recognise several major groups. The following are useful for school-level study.

A. Coniferopsida (conifers)

Characteristics

1. Mostly trees and shrubs.
2. Many possess needle-like or scale-like leaves.
3. Commonly produce male and female cones.
4. Seeds are borne on the scales of female cones.
5. Most are wind-pollinated.
6. Many have resin canals.

Examples: *Pinus*, *Cupressus* and *Juniperus*.

B. Cycadopsida (cycads)

Characteristics

1. Usually have stout, unbranched stems.
2. Possess large, stiff, compound leaves arranged in a crown.
3. Produce cones.
4. Many species have separate male and female plants.
5. They resemble palm trees but are not true palms.

Example: *Cycas*.

C. Ginkgoopsida

Characteristics

1. Represented today by a single living species.
2. Have distinctive fan-shaped leaves.
3. Are deciduous.
4. Male and female reproductive structures occur on separate trees.
5. They produce seeds that are not enclosed in fruits.

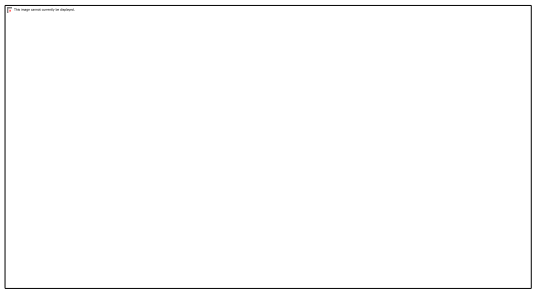
Example: *Ginkgo biloba*.

D. Gnetopsida

Characteristics

1. Possess some features that resemble those of flowering plants.
2. Have specialised conducting tissues.
3. Produce reproductive structures in compound strobili.
4. They are mostly adapted to particular terrestrial habitats.

Examples: *Gnetum*, *Ephedra* and *Welwitschia*.



6.5 Economic importance of Gymnospermae

1. **Timber:** Pine and cypress provide timber for construction, furniture and joinery.
2. **Paper production:** Wood pulp from conifers is used in the manufacture of paper and cardboard.
3. **Resins:** Some conifers produce resins used in industrial products.
4. **Medicines:** Certain gymnosperms provide compounds used in pharmaceutical research and medicine.
5. **Ornamental value:** Cypress, cycads and other gymnosperms are planted in gardens and landscapes.
6. **Windbreaks:** Trees such as cypress can be planted as windbreaks on farms.
7. **Carbon storage:** Forests of gymnosperms absorb and store carbon dioxide.
8. **Soil conservation:** Their roots help hold soil together and reduce erosion.
9. **Habitat provision:** They provide food and shelter for various organisms.
10. **Recreation and tourism:** Forests containing conifers provide scenic and recreational value.

Kenyan examples: Cypress and pine plantations are important sources of timber and wood products in parts of Kenya.

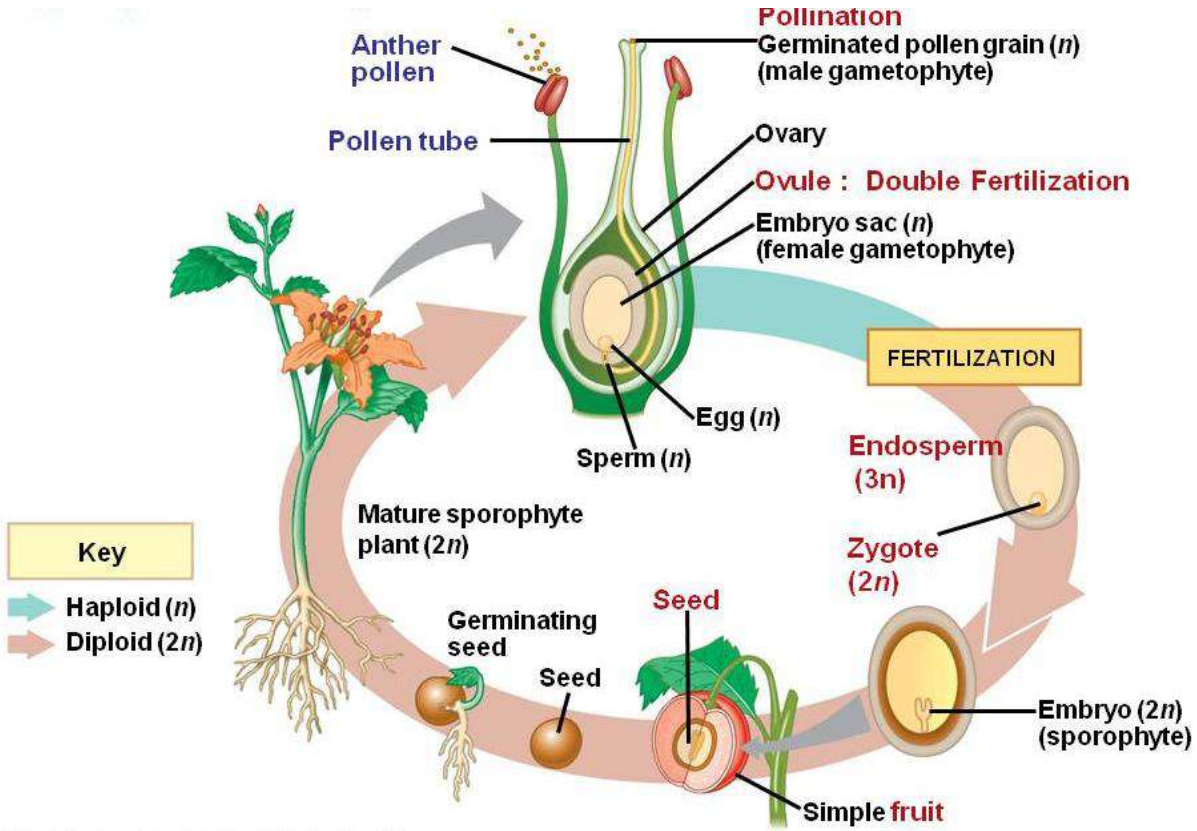
7.0 SUBDIVISION ANGIOSPERMAE

7.1 Meaning of Angiospermae

Angiospermae is a group of seed-producing vascular plants that produce flowers and have seeds enclosed within fruits.

They are commonly referred to as flowering plants.

Examples: Maize, beans, mango, avocado, sunflower, tea, coffee, grass and banana.



7.2 General characteristics of Angiospermae

1. **They produce flowers.**
   - Flowers are specialised reproductive structures.
   - They may contain male reproductive organs, female reproductive organs or both.
2. **They produce enclosed seeds.**
   - Their ovules are enclosed within an ovary.
   - After fertilisation, the ovules develop into seeds.
3. **They produce fruits.**
   - The ovary usually develops into a fruit after fertilisation.
   - The fruit protects seeds and may assist in seed dispersal.
4. **They possess vascular tissues.**
   - Xylem transports water and mineral salts.

- Phloem transports manufactured food.

5. **They have true roots, stems and leaves.**
   - These organs perform specialised functions.
6. **They show double fertilisation.**
   - One male nucleus fuses with the egg nucleus to form a diploid zygote.
   - Another male nucleus fuses with the two polar nuclei to form the primary endosperm nucleus, usually triploid.
7. **The sporophyte generation is dominant.**
   - The familiar flowering plant is the sporophyte.
   - The gametophytes are highly reduced.
8. **They show a wide range of habitats.**
   - They occur in forests, grasslands, wetlands, deserts, farms and freshwater environments.
9. **They have varied pollination mechanisms.**
   - Pollination may occur through wind, insects, birds, bats, water and other agents.
10. **They have diverse growth forms.**
    - They include herbs, shrubs, trees and climbers.

7.3 Distinguishing features of Angiospermae

- Presence of flowers.
- Seeds enclosed within fruits.
- Ovules enclosed in ovaries before fertilisation.
- Double fertilisation.
- Wide range of pollination mechanisms.
- Fruits help in seed protection and dispersal.

7.4 Classes of Angiospermae

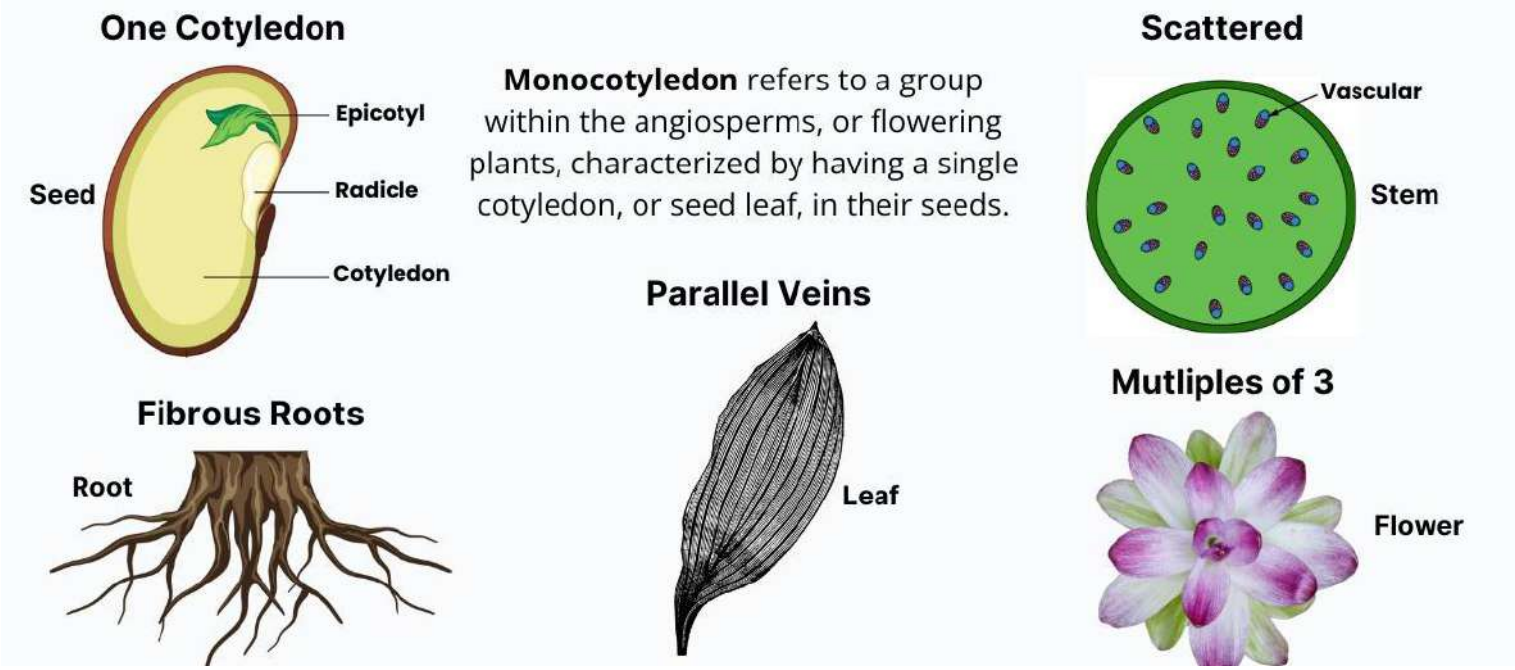
In traditional school-level classification, angiosperms are commonly divided into two major classes:

1. Monocotyledonae (monocotyledons)
2. Dicotyledonae (dicotyledons)

Modern plant systematics recognises monocots and several other evolutionary groups, including eudicots, rather than treating all traditional dicots as one natural group. The comparison below follows the familiar school-level monocot–dicot approach.

A. Class Monocotyledonae

Meaning: Monocotyledons are flowering plants whose seeds typically contain one cotyledon or seed leaf.



General characteristics of monocotyledons

1. **One cotyledon**
   - The seed embryo has one cotyledon.
   - In maize, the cotyledon is called the scutellum.
2. **Fibrous root system**
   - They usually have many thin roots of similar size.
   - The roots arise from the base of the stem or other stem regions.
3. **Parallel leaf venation**
   - Leaf veins generally run parallel to one another.
   - This is a useful feature for identifying many monocot plants.
4. **Floral parts in threes or multiples of three**
   - Their flowers commonly have three petals or floral structures arranged in multiples of three.
5. **Scattered vascular bundles**
   - Vascular bundles are scattered within the stem ground tissue.
   - They are not normally arranged in a complete ring.
6. **Usually lack vascular cambium in the stem**
   - Most monocots do not undergo typical secondary thickening through a vascular cambium.
7. **Leaves often have a sheathing leaf base**
   - The leaf base may partly or completely surround the stem.
8. **Pollen commonly has one aperture or furrow**
   - This is a microscopic feature used in plant classification.

Examples of monocotyledons

- Maize
- Wheat
- Rice
- Sugarcane
- Banana
- Onion
- Lilies
- Grasses
- Coconut
- Napier grass

B. Class Dicotyledonae

Meaning: Dicotyledons are flowering plants whose seeds typically contain two cotyledons or seed leaves.



General characteristics of dicotyledons

1. **Two cotyledons**
   - The embryo has two seed leaves.
   - These may store food or transfer stored food to the developing embryo.
2. **Taproot system**
   - The primary root develops into a main root.
   - Smaller lateral roots branch from the main root.

3. **Net-like leaf venation**

- The veins branch and form a network.
- This is also called reticulate venation.

4. **Floral parts in fours or fives**
   - Floral structures commonly occur in multiples of four or five.
5. **Vascular bundles arranged in a ring**
   - In many dicot stems, vascular bundles are arranged in a ring.
   - This arrangement is associated with secondary growth in many species.
6. **Secondary growth is common in many species**
   - Vascular cambium may produce additional xylem and phloem.
   - This contributes to an increase in stem thickness.
7. **Leaves usually have a distinct petiole**
   - Many dicot leaves possess a stalk connecting the leaf blade to the stem.
8. **Pollen commonly has three apertures or furrows in eudicots**
   - This is a useful microscopic feature of the eudicot group.

Examples of dicotyledons

- Beans
- Peas
- Mango
- Avocado
- Sunflower
- Groundnuts
- Tomato
- Hibiscus
- Cotton
- Eucalyptus

7.5 Differences between monocotyledons and dicotyledons

Feature	Monocotyledons	Dicotyledons
Cotyledons	One	Two
Root system	Usually fibrous	Usually taproot
Leaf venation	Usually parallel	Usually net-like

Floral parts	Usually in threes	Usually in fours or fives
Stem vascular bundles	Usually scattered	Usually arranged in a ring
Secondary growth	Generally absent	Common in many species
Leaf base	Often sheathing	Often distinct petiole
Examples	Maize, rice, banana	Bean, mango, sunflower

Important examination point

Root type, leaf venation, number of cotyledons and arrangement of vascular bundles are useful identifying features. However, no single visible feature should be treated as an absolute rule for every flowering plant.

7.6 Economic importance of Angiospermae

1. **Food production:** Maize, beans, rice, potatoes, bananas and vegetables provide food.
2. **Fodder:** Napier grass, Rhodes grass and other grasses provide livestock feed.
3. **Timber:** Eucalyptus, mahogany and other flowering trees provide timber.
4. **Medicine:** Some flowering plants are sources of medicinal compounds.
5. **Beverages:** Tea and coffee are important commercial crops in Kenya.
6. **Fibre:** Cotton and sisal are used in textile and rope production.
7. **Oils:** Sunflower, groundnuts and sesame provide edible oils.
8. **Ornamental value:** Roses, hibiscus and other flowering plants beautify homes and public spaces.
9. **Soil conservation:** Grasses and other plants protect soil from erosion.
10. **Environmental protection:** Plants absorb carbon dioxide, release oxygen and provide habitats.
11. **Income generation:** Flower farming, horticulture and crop production create employment and income.
12. **Pollinator support:** Flowers provide nectar and pollen for bees, butterflies and other pollinators.

7.7 Summary: distinguishing the three plant divisions

Feature	Bryophyta	Pteridophyta	Spermatophyta
Vascular tissues	Absent	Present	Present
True roots	Absent	Present	Present
True stems and leaves	Absent	Present	Present
Reproduction	Spores	Spores	Seeds
Flowers	Absent	Absent	Present only in angiosperms
Fruits	Absent	Absent	Present only in angiosperms
Dominant generation	Gametophyte	Sporophyte	Sporophyte
Water needed for fertilisation	Yes	Generally yes	No external water required
Examples	Mosses	Ferns	Pine, maize, beans

8.0 KINGDOM ANIMALIA

8.1 Meaning of Kingdom Animalia

Kingdom Animalia consists of multicellular, eukaryotic organisms that obtain nutrients by feeding on other organisms or organic matter. They are commonly called animals.

Animals occur in almost every habitat, including forests, grasslands, deserts, freshwater, marine environments and soil.

8.2 General characteristics of Kingdom Animalia

1. **They are eukaryotic.**
   - Their cells possess a true nucleus enclosed by a nuclear membrane.
   - They also contain membrane-bound organelles.
2. **They are multicellular.**
   - Their bodies consist of many cells.
   - Cells are organised into tissues, organs and organ systems in most animals.
3. **They lack cell walls.**
   - Animal cells have a cell membrane but no cellulose cell wall.
   - This allows cells to take different shapes and perform specialised functions.
4. **They are heterotrophic.**
   - Animals cannot manufacture their own food through photosynthesis.
   - They obtain nutrients by consuming plants, other animals or organic matter.
5. **They show different modes of nutrition.**
   - Herbivores feed mainly on plants.
   - Carnivores feed mainly on other animals.
   - Omnivores feed on both plants and animals.
   - Parasites obtain nutrients from living hosts.
6. **Most animals can move from one place to another.**
   - Movement helps them search for food, escape predators, find mates and locate suitable habitats.
   - Some animals, such as adult sponges, are sessile.
7. **They respond to stimuli.**
   - Animals respond to changes in their surroundings.
   - They commonly possess nervous and sensory systems.
8. **They have specialised tissues.**
   - Most animals possess muscle and nervous tissues.
   - These tissues help in movement, coordination and response to stimuli.

9. **They reproduce mainly sexually.**

- Most produce male and female gametes.
- Fertilisation may be internal or external.
- Some animals can also reproduce asexually.

10. **They have different body plans.**

- Animals may show radial or bilateral symmetry.
- Their bodies may be segmented or unsegmented.

11. **They have different methods of respiration.**

- Respiration may occur through lungs, gills, tracheal systems or the body surface.

12. **They have different methods of excretion.**

- Waste products are removed through specialised organs or body surfaces, depending on the animal group.

13. **They store carbohydrates as glycogen.**

- Excess carbohydrates may be stored in the liver and muscles in vertebrates.

14. **They show different developmental patterns.**

- Some develop directly into adults.
- Others undergo metamorphosis, as in butterflies and frogs.

8.3 Major groups of Kingdom Animalia

Animals are broadly classified into two groups:

1. **Invertebrates:** Animals without a vertebral column.
2. **Vertebrates:** Animals with a vertebral column.

The two phyla studied in this sub-strand are:

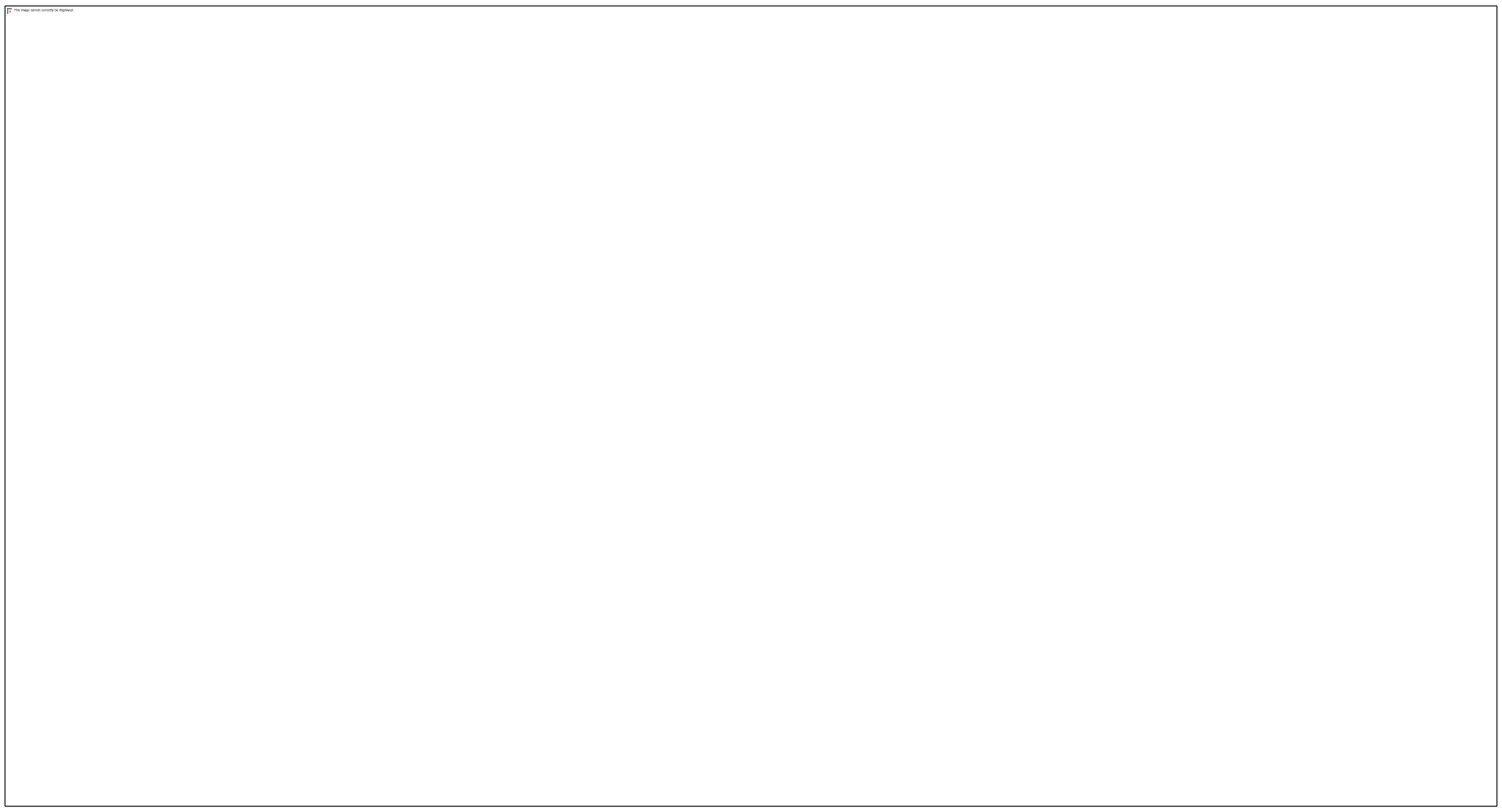
- Phylum Chordata.
- Phylum Arthropoda.

9.0 PHYLUM CHORDATA

9.1 Meaning of Chordata

Chordata is a phylum of animals that possess, at least at some stage in their development, a notochord, a dorsal hollow nerve cord, pharyngeal slits or pouches, and a post-anal tail.

Chordates include fish, amphibians, reptiles, birds, mammals and some marine animals.



9.2 General characteristics of Phylum Chordata

1. **Presence of a notochord**
   - A notochord is a flexible supporting rod found along the dorsal side of the body.
   - It is present at least during some stage of development.
   - In most vertebrates, it is largely replaced by the vertebral column during development.
2. **Dorsal hollow nerve cord**
   - A nerve cord is located above the notochord.
   - In vertebrates, it develops into the brain and spinal cord.
3. **Pharyngeal slits or pouches**
   - These occur in the pharynx at some stage of development.
   - In fish, they are associated with gill structures.
   - In other chordates, they may be modified into different structures.
4. **Post-anal tail**
   - A tail extends beyond the anus at some stage of development.
   - It may be reduced or absent in the adult of some species.
5. **Bilateral symmetry**
   - The body can be divided into approximately equal right and left halves along one plane.
6. **Triploblastic organisation**
   - The embryo develops from three primary germ layers: ectoderm, mesoderm and endoderm.
7. **Coelom**

- Most chordates possess a true body cavity called a coelom.

8. **Closed circulatory system in vertebrates**
   - Blood is transported through blood vessels.
   - The heart pumps blood around the body.

9. **Well-developed organ systems**
   - Most have specialised digestive, respiratory, circulatory, excretory and nervous systems.

10. **Sexual reproduction is common**
   - Most reproduce sexually, although reproductive patterns differ among groups.

11. **Internal or external fertilisation**
   - Fertilisation may occur inside or outside the female's body, depending on the species.

12. **Endoskeleton in vertebrates**
   - Vertebrates possess an internal skeleton made of bone, cartilage or both.
   - It supports the body and protects internal organs.

9.3 Distinguishing characteristics of Chordata

- Notochord at some developmental stage.
- Dorsal hollow nerve cord.
- Pharyngeal slits or pouches at some developmental stage.
- Post-anal tail at some developmental stage.
- Bilateral symmetry.
- Well-developed organ systems in vertebrates.

9.4 Main subdivisions of Chordata

For school-level study, Chordata is commonly divided into:

1. Urochordata (Tunicata).
2. Cephalochordata.
3. Vertebrata (Craniata).

The main vertebrate classes are discussed below.

10.0 CLASSIFICATION OF VERTEBRATES UP TO CLASS LEVEL

10.1 Meaning of Vertebrata

Vertebrata is a major group of chordates whose members possess a vertebral column or backbone.

Vertebrates have a skull that protects the brain and a well-developed internal skeleton.

The main vertebrate groups studied at this level are:

1. Pisces – traditional grouping for fish.
2. Amphibia.
3. Reptilia.
4. Aves.
5. Mammalia.

Note: Modern classification recognises that traditional Pisces is not a single natural evolutionary group. For school-level identification, fish are often studied under the classes Chondrichthyes and Osteichthyes.

10.2 Class Chondrichthyes (cartilaginous fish)

Meaning: Chondrichthyes is a class of fish whose skeletons are mainly made of cartilage rather than bone.

General characteristics

1. Have a skeleton made mainly of cartilage.
2. Have streamlined bodies that reduce water resistance.
3. Possess paired pectoral and pelvic fins.
4. Have gill slits that are usually not covered by an operculum.
5. Lack a swim bladder.
6. Have placoid scales, also called dermal denticles.
7. Have a well-developed sense of smell and other sensory systems.
8. Fertilisation is usually internal.
9. Many have several rows of replaceable teeth.
10. Most are marine, although some species can enter freshwater.

Distinguishing features

- Cartilaginous skeleton.
- Exposed gill slits in most species.
- Placoid scales.
- No swim bladder.
- Internal fertilisation is common.

Examples: Sharks, rays and skates.

Economic and ecological importance

- Help maintain balance in marine food webs.
- Some species support fisheries and tourism.
- Their presence can indicate the condition of marine ecosystems.
- Overfishing threatens many species.

10.3 Class Osteichthyes (bony fish)

Meaning: Osteichthyes is a class of fish whose skeleton is mainly made of bone.

General characteristics

1. Have a skeleton mainly made of bone.
2. Possess gills covered by an operculum.
3. Usually have a swim bladder for controlling buoyancy.
4. Have fins for swimming, balance and steering.
5. Have scales covering most of the body.
6. Respire using gills.
7. Are ectothermic; their body temperature changes with the surrounding environment.
8. Most reproduce through external fertilisation, although exceptions occur.
9. Have a streamlined body in many species.
10. Have a lateral line system that detects vibrations and movements in water.

Distinguishing features

- Bony skeleton.
- Gill covers called opercula.
- Swim bladder in most species.
- Scales and fins.
- Lateral line sensory system.

Examples: Tilapia, Nile perch, catfish, salmon and goldfish.

Kenyan examples

- Nile tilapia in Lake Victoria and fish farms.
- Nile perch in Lake Victoria.
- Catfish in freshwater systems and aquaculture.

Economic importance

1. Provide protein for human consumption.
2. Support fishing and aquaculture industries.
3. Provide employment and income to fishing communities.
4. Support tourism and recreation.
5. Fish products can be processed, preserved and sold in markets.

10.4 Class Amphibia

Meaning: Amphibia is a class of vertebrates that generally have an aquatic larval stage and a terrestrial or semi-aquatic adult stage.

General characteristics

1. **Moist skin**

- Their skin is thin, moist and lacks scales.
- It assists in gaseous exchange in many species.

2. **Ectothermic**
   - Their body temperature changes with environmental temperature.
3. **Respiration**
   - Larvae commonly use gills.
   - Adults commonly use lungs and their moist skin.
   - Some species rely heavily on skin respiration.
4. **Reproduction**
   - Many lay eggs in water or moist environments.
   - Fertilisation is often external in frogs and toads.
   - Some species show internal fertilisation or other reproductive variations.

5. **Metamorphosis**
   - Many undergo a change from larval to adult form.
   - A tadpole develops into an adult frog through metamorphosis.
6. **Two pairs of limbs in many adults**
   - Frogs and toads usually have four limbs.
   - Limbs assist in walking, jumping or swimming.
7. **Three-chambered heart**
   - Most adult amphibians have two atria and one ventricle.
8. **No scales**
   - Their skin is generally naked and moist.
9. **Eggs lack a hard shell**
   - Eggs are usually protected by a jelly-like covering.
10. **Dependence on moisture**
    - Their skin and eggs are vulnerable to drying.

Distinguishing features

- Moist, glandular skin.
- Ectothermic body temperature.
- Eggs usually laid in water or moist places.
- Metamorphosis in many species.
- Larvae commonly possess gills.
- Adults generally respire through lungs and skin.

Examples: Frogs, toads, salamanders and caecilians.

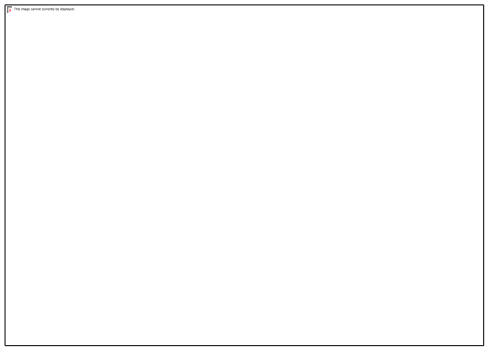
Kenyan examples: Frogs and toads found around wetlands, farms, forests and water bodies.

Economic and ecological importance

1. Feed on insects, including some agricultural pests.
2. Form part of food chains as prey for birds, snakes and other predators.
3. Help scientists monitor environmental health because many are sensitive to pollution and habitat changes.
4. Support ecological balance by controlling some invertebrate populations.
5. Some species are used in scientific research.

10.5 Class Reptilia

Meaning: Reptilia is a class of ectothermic vertebrates that generally have dry skin covered with scales or scutes made of keratin.



General characteristics

1. **Dry, scaly skin**
   - Their skin is covered with keratinised scales or scutes.
   - This reduces water loss.
2. **Ectothermic**
   - Their body temperature depends largely on environmental conditions.
   - They may bask in the sun to warm up.
3. **Respiration through lungs**
   - Reptiles breathe using well-developed lungs.
   - They do not use skin respiration as their main respiratory method.
4. **Internal fertilisation**
   - Fertilisation occurs inside the female reproductive tract.
5. **Amniotic eggs**
   - Many lay eggs with protective coverings.
   - The embryo develops within membranes that protect it and support its development.
6. **Mostly terrestrial**
   - Many live on land, while others are aquatic or semi-aquatic.

7. **Usually have claws**

- Many possess claws that assist in movement, digging and capturing prey.
- Snakes lack limbs.

8. **Heart structure**

- Most have a three-chambered heart with an incompletely divided ventricle.
- Crocodilians have a four-chambered heart.

9. **Direct development**

- Young reptiles generally resemble smaller versions of adults.
- They do not normally undergo a tadpole-like larval stage.

10. **Varied feeding habits**

- They include carnivores, herbivores and omnivores.

Distinguishing features

- Dry skin with scales or scutes.
- Ectothermic.
- Respire using lungs.
- Internal fertilisation.
- Amniotic eggs or other amniotic reproductive adaptations.
- Direct development.

Examples: Snakes, lizards, tortoises, turtles and crocodiles.

Kenyan examples: Nile crocodile, agama lizards, tortoises and various snake species.

Economic and ecological importance

1. Control populations of rodents and other pests.
2. Form important links in food chains.
3. Some species attract tourists to national parks and reserves.
4. Their presence contributes to ecosystem balance.
5. Some may pose risks to humans and livestock, requiring safe coexistence and professional wildlife management.

10.6 Class Aves (birds)

Meaning: Aves is a class of warm-blooded vertebrates characterised by feathers, wings and beaks.



General characteristics

1. **Body covered with feathers**
    - Feathers provide insulation.
    - They assist in flight, display and protection.
2. **Forelimbs modified into wings**
    - Wings are used for flight in most birds.
    - Some birds are flightless.
3. **Beak present**
    - Birds have a beak without teeth.
    - Beak shape varies depending on feeding habits.
4. **Endothermic**
    - They maintain a relatively constant internal body temperature.
5. **Respiration through lungs**
    - Birds possess lungs and air sacs.
    - Air sacs improve the efficiency of ventilation.
6. **Four-chambered heart**
    - The heart has two atria and two ventricles.
    - This supports efficient separation of oxygenated and deoxygenated blood.
7. **Lay hard-shelled eggs**
    - Fertilisation is internal.
    - Eggs are generally laid outside the body and incubated.
8. **Light but strong skeleton**
    - Many bones are hollow or pneumatic.
    - This helps reduce body weight in flying birds.
9. **Hind limbs adapted for movement**
    - Feet may be adapted for perching, walking, swimming, running or catching prey.
10. **Well-developed vision**
    - Many birds have excellent eyesight.
11. **Cloaca**
    - Digestive, urinary and reproductive systems open into a common chamber called the cloaca.

Distinguishing features

- Feathers.
- Wings.
- Beak without teeth.

- Endothermic body temperature.
- Hard-shelled eggs.
- Four-chambered heart.
- Lungs with air sacs.

Examples: Eagles, chickens, ostriches, ducks, flamingos, weaver birds and cranes.

Kenyan examples: Ostriches in arid and semi-arid areas, flamingos in suitable Rift Valley lakes, and crowned cranes in grassland and wetland habitats.

Economic and ecological importance

1. **Pest control:** Insect-eating birds reduce populations of crop pests.
2. **Pollination:** Some birds feed on nectar and transfer pollen between flowers.
3. **Seed dispersal:** Fruit-eating birds disperse seeds through their droppings.
4. **Food:** Poultry provides meat and eggs.
5. **Income generation:** Poultry farming and bird-related tourism create employment.
6. **Scavenging:** Vultures remove animal carcasses and help reduce the spread of some diseases.
7. **Environmental monitoring:** Changes in bird populations can indicate habitat disturbance and environmental changes.

10.7 Class Mammalia

Meaning: Mammalia is a class of vertebrates characterised by mammary glands that produce milk for feeding their young. They generally possess hair or fur.

General characteristics

1. **Mammary glands**
   - Females possess mammary glands that produce milk.
   - Milk provides nourishment to the young.
2. **Hair or fur**
   - Most mammals have hair at some stage of life.
   - Hair provides insulation, protection and sensory functions.
3. **Endothermic**
   - They maintain a relatively constant internal body temperature.
4. **Respiration through lungs**
   - All mammals breathe using lungs.
   - A muscular diaphragm assists breathing.
5. **Four-chambered heart**
   - Blood circulation is efficient because oxygenated and deoxygenated blood are separated.
6. **External ears in many species**
   - Many mammals have external ear structures called pinnae.

- These help collect sound.

7. **Different types of teeth**
   - Mammals may have incisors, canines, premolars and molars.
   - Teeth are adapted to different feeding habits.
8. **Internal fertilisation**
   - Fertilisation occurs inside the female reproductive system.
9. **Mostly give birth to live young**
   - Most mammals are viviparous.
   - Monotremes, such as the platypus, lay eggs.
10. **Well-developed brain**
    - Mammals generally have a highly developed nervous system and complex behaviour.
11. **Parental care**
    - Most mammals provide considerable care to their young.
    - This increases the chances of survival.
12. **Different types of limbs**
    - Limbs are adapted for walking, running, swimming, climbing, digging or flying.

Distinguishing features

- Mammary glands that produce milk.
- Hair or fur.
- Endothermic.
- Three middle-ear bones.
- A muscular diaphragm.
- Mostly viviparous, with exceptions.
- Four-chambered heart.

Examples: Humans, elephants, lions, zebras, cattle, goats, bats, whales and dogs.

Kenyan examples: African elephants, lions, zebras, giraffes, cattle, goats, sheep and humans.

Economic and ecological importance

1. **Food:** Cattle, goats and sheep provide milk and meat.
2. **Transport:** Donkeys and camels are used for transport in some areas.
3. **Farm work:** Oxen may be used for ploughing and other agricultural activities.
4. **Tourism:** Wildlife such as elephants, lions and giraffes attracts tourists.
5. **Pollination:** Bats pollinate some plants.
6. **Seed dispersal:** Some mammals disperse seeds through their droppings.
7. **Pest control:** Insect-eating bats reduce populations of some insects.

8. **Manure:** Livestock manure is used to improve soil fertility.
9. **Companionship:** Dogs and cats are kept as companion animals.
10. **Ecological balance:** Mammals occupy different positions in food chains and food webs.

10.8 Comparison of the five commonly studied vertebrate groups

Feature	Fish	Amphibia	Reptilia	Aves	Mammalia
Habitat	Mainly aquatic	Aquatic and terrestrial	Mainly terrestrial; some aquatic	Terrestrial and aquatic	Terrestrial and aquatic
Body covering	Scales	Moist skin	Dry scales/scutes	Feathers	Hair/fur
Respiration	Gills	Gills in larvae; lungs and skin in many adults	Lungs	Lungs and air sacs	Lungs
Temperature	Ectothermic	Ectothermic	Ectothermic	Endothermic	Endothermic
Heart	Usually two chambers in fish	Usually three	Usually three; crocodilians four	Four	Four
Fertilisation	Usually external in bony fish	Often external	Internal	Internal	Internal
Reproduction	Mostly eggs	Mostly eggs	Mostly eggs; exceptions	Eggs	Mostly live birth
Example	Tilapia	Frog	Lizard	Chicken	Cow

11.0 PHYLUM ARTHROPODA

11.1 Meaning of Arthropoda

Arthropoda is a phylum of invertebrate animals characterised by jointed appendages, segmented bodies and a hard external skeleton called an exoskeleton.

It is the largest animal phylum in terms of the number of described species.

Arthropods are found in almost all habitats, including soil, freshwater, marine environments, forests, grasslands, farms and human settlements.

11.2 General characteristics of Phylum Arthropoda

1. **Jointed appendages**
   - Their legs and other appendages have joints.
   - Joints allow flexible movement.
2. **Segmented body**
   - Their bodies consist of segments.
   - In some groups, segments are organised into specialised regions.
3. **Chitinous exoskeleton**
   - Their bodies are covered by a hard external skeleton mainly made of chitin.
   - It protects internal organs and provides support.
4. **Moulting**
   - The exoskeleton does not grow continuously with the animal.
   - Arthropods periodically shed the old exoskeleton and form a larger one.
   - This process is called ecdysis or moulting.
5. **Bilateral symmetry**
   - Their bodies can be divided into approximately equal right and left halves.
6. **Open circulatory system**
   - Most have an open circulatory system.
   - A fluid called haemolymph circulates through body spaces.
7. **Well-developed sensory organs**
   - Many possess compound eyes, simple eyes, antennae and sensory hairs.
   - These detect light, chemicals, movement and touch.
8. **Different respiratory structures**
   - Insects mainly use tracheal systems.
   - Many crustaceans use gills.
   - Arachnids may possess book lungs, tracheae or both.

9. **Excretion**
   - Insects commonly use Malpighian tubules.
   - Crustaceans commonly possess specialised excretory glands.
10. **Sexual reproduction is common**
    - Most reproduce sexually.
    - Fertilisation may be internal or external, depending on the group.
11. **Varied development**

- Some undergo incomplete metamorphosis.
- Others undergo complete metamorphosis.

12. **Different habitats**

- They occur on land, in freshwater and in marine environments.

11.3 Distinguishing features of Arthropoda

- Jointed appendages.
- Segmented body.
- Chitinous exoskeleton.
- Moulting.
- Open circulatory system in most groups.
- Well-developed sensory organs.
- Body regions and appendages differ among classes.

11.4 Classes of Arthropoda

The main classes commonly studied are:

1. Insecta.
2. Arachnida.
3. Crustacea.
4. Chilopoda.
5. Diplopoda.

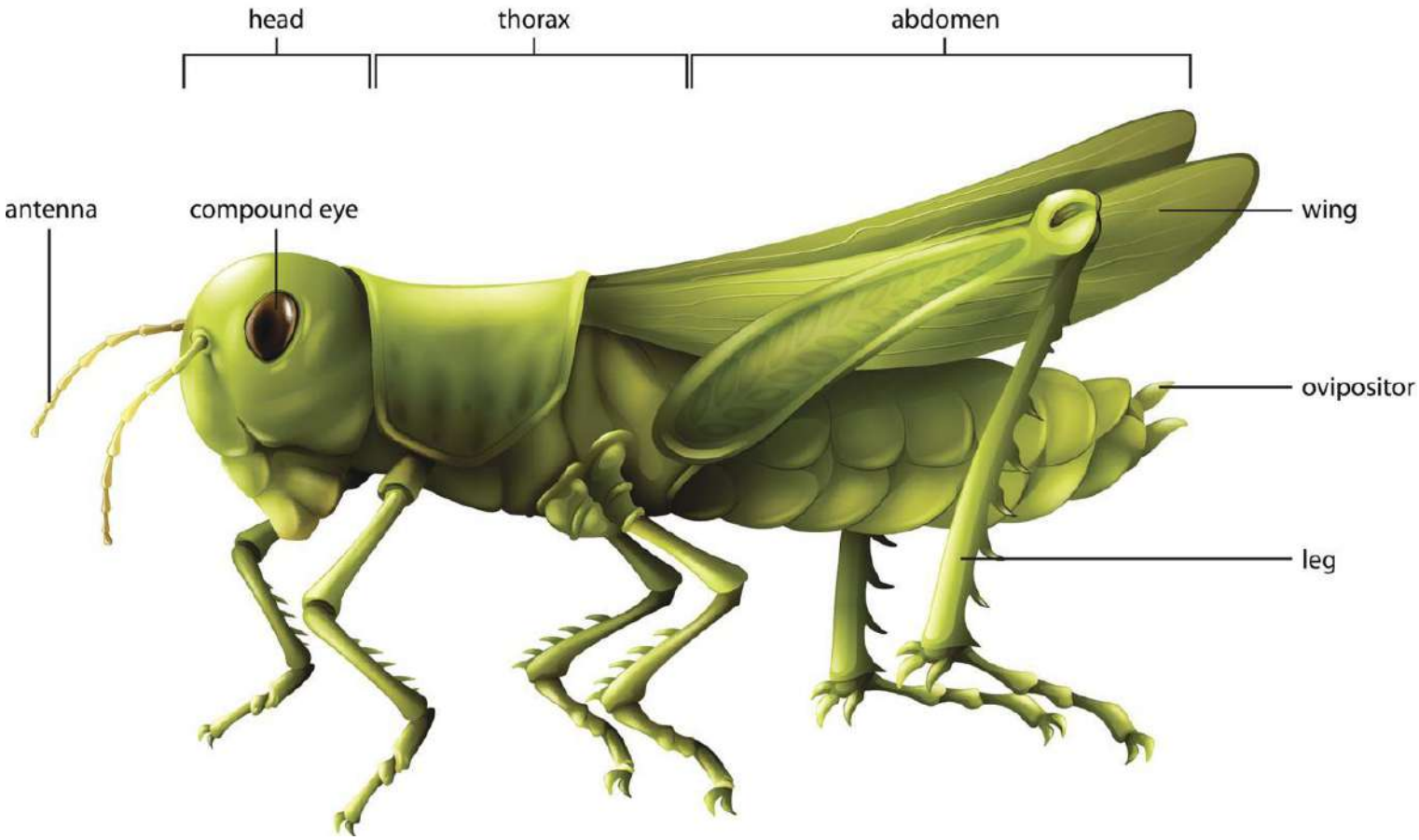
12.0 CLASS INSECTA

12.1 Meaning of Insecta

Insecta is a class of arthropods whose members generally have three body regions, three pairs of jointed legs and one pair of antennae.

Insects are the most diverse group of arthropods.

Examples: Bees, butterflies, mosquitoes, houseflies, grasshoppers, beetles, ants, termites and cockroaches.



12.2 General characteristics of Insecta

1. **Body divided into three regions**
   - Head.
   - Thorax.
   - Abdomen.
2. **Three pairs of legs**
   - Six jointed legs are attached to the thorax.
   - Legs may be adapted for jumping, digging, swimming, running or grasping.
3. **One pair of antennae**
   - Antennae are sensory structures.
   - They detect touch, smell, movement and other environmental information.
4. **Compound eyes**
   - Many insects possess a pair of compound eyes.
   - Some also have simple eyes called ocelli.
5. **Usually two pairs of wings**
   - Many insects possess two pairs of wings.
   - Some have one pair or lack wings entirely.
   - Wings are attached to the thorax.

6. **Chitinous exoskeleton**

- It protects the body and provides support.
- It reduces water loss to some extent.

7. **Respiration through tracheal systems**

- Air enters through openings called spiracles.
- Tracheae distribute air to body tissues.

8. **Open circulatory system**

- Haemolymph circulates within the body cavity.
- It does not normally transport oxygen because gaseous exchange is mainly through the tracheal system.

9. **Excretion through Malpighian tubules**

- These remove nitrogenous waste from the haemolymph.
- They assist in conserving water.

10. **Reproduction**

- Most insects reproduce sexually.
- Many lay eggs.

11. **Metamorphosis**

- Many insects undergo complete or incomplete metamorphosis.
- Their young may differ greatly from adults.

12. **Varied mouthparts**

- Mouthparts are adapted to different feeding methods.
- They may be adapted for biting, chewing, piercing, sucking, siphoning or sponging.

12.3 Distinguishing features of Insecta

- Three body regions: head, thorax and abdomen.
- Three pairs of legs.
- One pair of antennae.
- Usually one or two pairs of wings.
- Compound eyes common.
- Respiration through a tracheal system.

12.4 Mouthparts of insects and their adaptations

Different insects possess mouthparts adapted to the type of food they obtain.

A. Biting and chewing mouthparts

Characteristics

- Strong mandibles are present.

- The mandibles cut, crush and grind food.
- Maxillae and other mouthparts assist in handling food.

Examples: Grasshopper, cockroach and beetle.

Adaptation: Suitable for feeding on solid food such as leaves, seeds and other organic materials.

B. Piercing and sucking mouthparts

Characteristics

- Possess slender piercing structures.
- These penetrate plant or animal tissues.
- Food fluids are sucked through a feeding tube.

Examples: Mosquito and aphid.

Adaptation: Suitable for obtaining blood or plant sap.

C. Siphoning mouthparts

Characteristics

- Possess a long, coiled proboscis.
- The proboscis acts as a tube for sucking liquids.

Example: Adult butterfly.

Adaptation: Enables the insect to obtain nectar from flowers.

D. Sponging mouthparts

Characteristics

- Possess soft, sponge-like structures at the tip of the proboscis.
- The structures absorb liquid food.

Example: Housefly.

Adaptation: Suitable for feeding on liquid or dissolved food materials.

12.5 Metamorphosis in insects

Metamorphosis is the series of changes in body form and structure that an insect undergoes during development from egg to adult.

There are two major patterns:

A. Complete metamorphosis

Complete metamorphosis involves four distinct stages:

1. Egg.
2. Larva.
3. Pupa.
4. Adult.



Explanation of the stages

- **Egg:** The female lays eggs in a suitable environment.
- **Larva:** The egg hatches into a larva that feeds actively and grows.
- **Pupa:** The larva changes into an adult form within a protective stage.
- **Adult:** The mature insect emerges and reproduces.

Examples: Butterfly, housefly, mosquito, bee and beetle.

B. Incomplete metamorphosis

Incomplete metamorphosis involves three main stages:

1. Egg.
2. Nymph.
3. Adult.

Explanation

- **Egg:** The female lays eggs.
- **Nymph:** A young insect hatches and resembles a small adult but lacks fully developed wings and reproductive organs.
- **Adult:** The insect becomes sexually mature after a series of moults.

Examples: Grasshopper, cockroach and termite.

12.6 Economic importance of insects

Insects have both beneficial and harmful effects on human activities, agriculture, health and the environment.

A. Beneficial economic importance

1. **Pollination**

- Bees, butterflies and some beetles transfer pollen between flowers.

- Pollination increases fruit and seed formation.
- It supports production of crops such as sunflower, avocado and passion fruit.

2. **Production of honey**
   - Honeybees produce honey.
   - Honey is used as food and in various products.
   - Beekeeping provides income to households and communities.
3. **Production of beeswax**
   - Beeswax is used in candles, cosmetics, polishes and other products.
4. **Silk production**
   - Silkworm larvae produce silk fibres.
   - Silk is used in textile manufacture.
5. **Biological pest control**
   - Ladybird beetles feed on aphids.
   - Some wasps parasitise crop pests.
   - Predatory insects help reduce the need for chemical pesticides.
6. **Decomposition**
   - Some insects feed on dead plants and animals.
   - They contribute to decomposition and nutrient recycling.
7. **Food for other organisms**
   - Insects provide food for birds, reptiles, fish, amphibians and mammals.
   - They support food chains and food webs.
8. **Food for humans and livestock**
   - Some edible insects provide protein.
   - Insect larvae may be used in animal-feed production.
9. **Research and education**
   - Insects such as fruit flies are used in genetics and biological research.
10. **Income generation**
    - Beekeeping, silk production and insect farming can provide employment and income.

B. Harmful economic importance

1. **Crop destruction**
   - Locusts, caterpillars and grasshoppers feed on crops.
   - They may cause serious yield losses.
2. **Transmission of diseases**
   - Mosquitoes transmit malaria and other diseases.

- Tsetse flies transmit trypanosomes that cause sleeping sickness in humans and nagana in livestock.
- Some other insects transmit disease-causing organisms.

3. **Destruction of stored products**
   - Weevils and grain borers attack stored maize, beans and other cereals.
   - They reduce food quality and quantity.
4. **Damage to buildings**
   - Termites feed on wood and may damage houses, furniture, fences and other wooden structures.
5. **Damage to livestock**
   - Ticks are arachnids rather than insects, but some insect pests such as biting flies can irritate livestock and reduce productivity.
   - Certain insects also damage animal hides and stored animal products.
6. **Destruction of clothes and materials**
   - Clothes moth larvae may damage wool and other natural fibres.
7. **Food contamination**
   - Houseflies may carry disease-causing microorganisms from waste to food.
8. **Stinging and biting**
   - Bees, wasps, mosquitoes and other insects may cause pain, irritation or allergic reactions.

C. Examples of insects of agricultural importance in Kenya

Insect	Economic effect
Honeybee	Pollination, honey and beeswax
Desert locust	Destruction of crops and pasture
Fall armyworm	Damage to maize and other cereal crops
Maize weevil	Damage to stored maize
Aphid	Sucks plant sap and may transmit plant viruses
Ladybird beetle	Feeds on aphids and helps control pests
Termite	Decomposes dead wood but can damage buildings and crops
Tsetse fly	Transmits trypanosomes
Mosquito	Transmits malaria parasites and other pathogens
Silkworm	Produces silk

CBE application: Integrated pest management

A farmer in Trans Nzoia notices aphids attacking bean plants. Instead of immediately applying a broad-spectrum insecticide, the farmer can monitor the infestation, conserve ladybird beetles, remove heavily infested plant parts and use an appropriate control method when necessary.

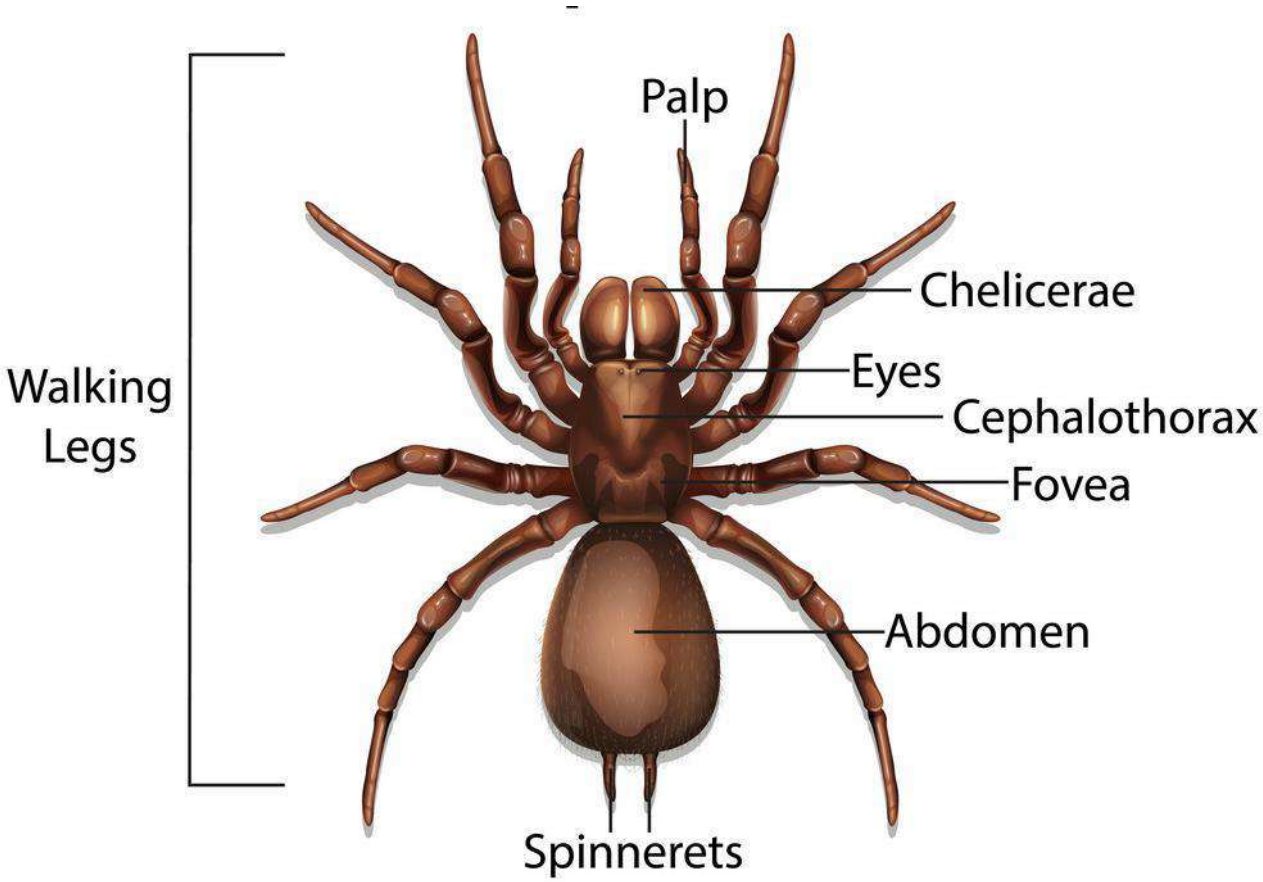
This demonstrates problem-solving, environmental responsibility and sustainable agricultural practice.

13.0 CLASS ARACHNIDA

13.1 Meaning of Arachnida

Arachnida is a class of arthropods that includes spiders, scorpions, ticks and mites.

They are mainly terrestrial animals.



13.2 General characteristics

1. Their bodies are usually divided into two main regions:
    - Cephalothorax.
    - Abdomen.
2. They have four pairs of walking legs, making eight legs in total.
3. They lack antennae.
4. They do not have wings.
5. They possess simple eyes in many species.
6. Their bodies are covered by a chitinous exoskeleton.
7. They have specialised mouthparts called chelicerae.
8. They possess another pair of appendages called pedipalps.
9. Respiration may occur through book lungs, tracheae or both.
10. They have an open circulatory system.
11. Most are predators or parasites.
12. Many reproduce sexually.

13.3 Distinguishing features of Arachnida

- Four pairs of legs.
- Two main body regions in typical forms.
- No antennae.
- No wings.
- Chelicerae and pedipalps present.

Examples: Spiders, scorpions, ticks and mites.

13.4 Economic importance of Arachnida

Beneficial importance

1. Spiders feed on mosquitoes, flies and other insects.
2. They help control populations of crop pests.
3. They form part of food chains.
4. Some mites are useful in biological pest control.
5. Some arachnids are used in scientific research.

Harmful importance

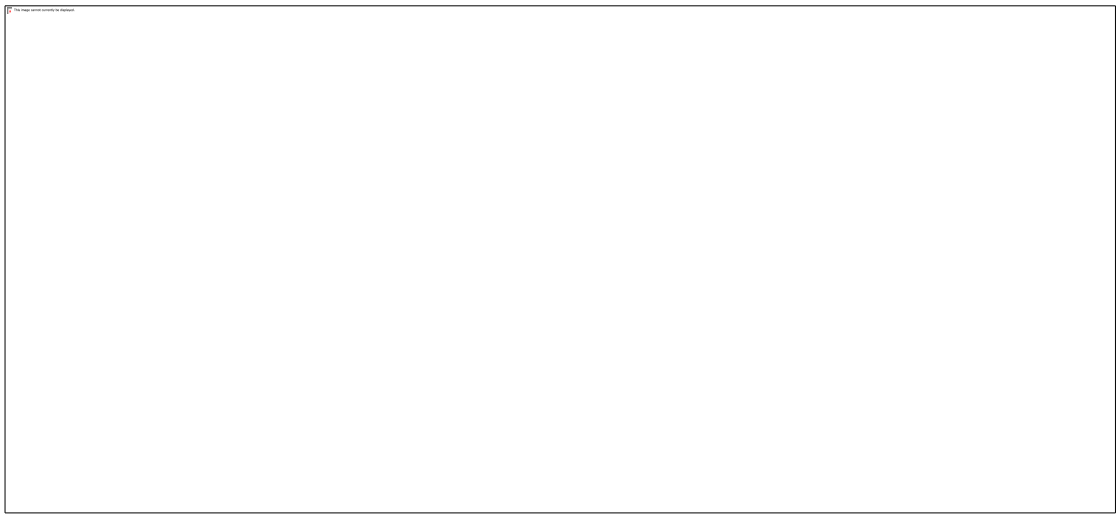
1. Some ticks transmit diseases to livestock and humans.
2. Some mites damage crops and stored products.
3. Certain spiders and scorpions possess venom that can harm humans.
4. Parasitic mites may cause skin irritation and diseases in animals.

14.0 CLASS CRUSTACEA

14.1 Meaning of Crustacea

Crustacea is a group of arthropods that are mostly aquatic and generally possess two pairs of antennae, jointed appendages and gills.

Examples: Crabs, prawns, shrimps, lobsters and freshwater crayfish.



14.2 General characteristics

1. Most are aquatic, although some live in moist terrestrial environments.
2. The body is commonly divided into cephalothorax and abdomen.
3. They possess two pairs of antennae.
4. They have several pairs of jointed appendages.
5. Their bodies are covered by a hard exoskeleton.
6. Many have a carapace covering the cephalothorax.
7. Most breathe through gills.
8. They possess compound eyes in many species.
9. They have an open circulatory system.
10. They generally reproduce sexually.
11. Some undergo larval stages during development.
12. Their appendages are adapted for walking, swimming, feeding and defence.

14.3 Distinguishing features of Crustacea

- Two pairs of antennae.
- Mostly aquatic.
- Gills are common respiratory structures.
- Several pairs of jointed appendages.
- Often have a carapace.
- Body commonly divided into cephalothorax and abdomen.

Examples: Crabs, prawns, shrimps and lobsters.

14.4 Economic importance of Crustacea

1. **Food:** Crabs, prawns and shrimps are consumed by humans.
2. **Employment:** Fishing, processing and marketing provide jobs.
3. **Income generation:** Crustacean fisheries support coastal communities.
4. **Food chains:** They are food for fish, birds and marine mammals.
5. **Decomposition:** Some feed on dead organic matter and contribute to nutrient recycling.
6. **Aquaculture:** Some crustaceans are farmed for commercial purposes.
7. **Tourism:** Some support recreational fishing and seafood-related tourism.

Harmful effects

- Some crabs damage young crops in particular habitats.
- Certain crustaceans may act as intermediate hosts for parasites.
- Some species may damage fishing nets or compete with desirable aquatic species.

15.0 CLASS CHILOPODA

15.1 Meaning of Chilopoda

Chilopoda is a class of arthropods commonly known as centipedes. They have elongated, segmented bodies with one pair of legs on most body segments.

15.2 General characteristics

1. Have long, flattened bodies.
2. Body consists of many segments.
3. Most body segments have one pair of legs.
4. Possess one pair of antennae.
5. Have a pair of poison claws called forcipules near the head.
6. Respire through tracheal systems.
7. Have a chitinous exoskeleton.
8. Are mainly terrestrial.
9. Usually hide in damp, dark places.
10. Are mainly carnivorous and feed on insects, spiders and other small animals.

15.3 Distinguishing features

- One pair of legs per body segment in most segments.
- Flattened body.
- Poison claws near the head.
- Carnivorous feeding habits.

Examples: Soil centipedes and large tropical centipedes.

15.4 Economic importance

Beneficial

1. Feed on insects and other small invertebrates.
2. Help regulate populations of some soil pests.
3. Form part of food chains.

Harmful

1. Some can inflict painful bites.
2. Certain species may cause swelling and irritation.
3. They may enter houses in search of damp hiding places.

16.0 CLASS DIPLOPODA

16.1 Meaning of Diplopoda

Diplopoda is a class of arthropods commonly known as millipedes. They generally have elongated, cylindrical bodies with most apparent body segments bearing two pairs of legs.

16.2 General characteristics

1. Have long, cylindrical or slightly flattened bodies.

2. Possess many body segments.
3. Most apparent segments have two pairs of legs.
4. Have one pair of antennae.
5. Have a hard chitinous exoskeleton.
6. Respire through tracheal systems.
7. Are mainly terrestrial.
8. Prefer damp and dark habitats.
9. Feed mainly on decaying plant material.
10. Often coil into a spiral when disturbed.
11. Some release irritating or unpleasant-smelling defensive chemicals.

16.3 Distinguishing features

- Two pairs of legs on most apparent body segments.
- Cylindrical body in many species.
- Slow movement.
- Mostly feed on decaying organic matter.
- Coil into a spiral when disturbed.

Examples: Garden millipedes and other soil millipedes.

16.4 Economic importance

Beneficial

1. Decompose dead plant materials.
2. Help recycle nutrients.
3. Contribute to soil formation.
4. Improve organic matter incorporation into soil.
5. Form part of soil food webs.

Harmful

1. Some species may feed on young seedlings.
2. Large numbers may damage emerging crops.
3. Some release defensive chemicals that irritate skin.

16.5 Comparison of the five main arthropod classes

Feature	Insecta	Arachnida	Crustacea	Chilopoda	Diplopoda
Body regions	Head, thorax, abdomen	Usually cephalothorax and abdomen	Usually cephalothorax and abdomen	Head and long trunk	Head and long trunk
Legs	3 pairs	4 pairs	Variable; usually many	1 pair per segment	2 pairs on most apparent segments
Antennae	1 pair	None	2 pairs	1 pair	1 pair
Wings	Often present	Absent	Absent	Absent	Absent
Respiration	Tracheae	Book lungs/tracheae	Mainly gills	Tracheae	Tracheae
Habitat	Land and water	Mainly land	Mainly aquatic	Mainly land	Mainly land
Examples	Bee, grasshopper	Spider, tick	Crab, prawn	Centipede	Millipede

17.0 DICHOTOMOUS KEYS

17.1 Meaning of a dichotomous key

A **dichotomous key** is a scientific tool used to identify unknown organisms by following a sequence of paired, contrasting statements based on observable characteristics.

The word *dichotomous* means divided into two parts. At every step, the user chooses one of two alternatives that best describes the organism.

Dichotomous keys are widely used in biology, ecology, agriculture, forestry, biodiversity studies and wildlife identification.

17.2 Importance of dichotomous keys

1. **Identification of organisms:** They help identify unknown plants and animals.
2. **Classification:** They help group organisms according to observable features.
3. **Biodiversity surveys:** They assist researchers in recording species in a particular habitat.
4. **Agriculture:** They help identify crop pests, weeds and beneficial organisms.
5. **Forestry:** They assist in identifying trees and other forest plants.
6. **Conservation:** They help identify endangered and protected species.
7. **Environmental monitoring:** They support the identification of organisms used as indicators of environmental conditions.
8. **Scientific research:** They provide a systematic approach to identifying specimens.
9. **Education:** They develop observation, comparison, reasoning and problem-solving skills.

17.3 Principles of constructing a dichotomous key

A good dichotomous key should follow these principles:

1. **Use paired statements.**
    - Each step must have two alternatives.
    - The alternatives are called a couplet.
2. **Use contrasting features.**
    - The two statements should describe opposite or clearly different characteristics.
    - For example, leaves present versus leaves absent.
3. **Use observable characteristics.**
    - Select features that can be seen or examined.
    - Avoid statements based on assumptions.
4. **Use clear and simple language.**
    - Statements should be short and precise.
    - Avoid vague words such as "large", "small" or "normal" unless a clear comparison is provided.
5. **Use reliable distinguishing features.**
    - Choose features that consistently separate the organisms being studied.
6. **Begin with broad differences.**
    - Start with obvious features that divide the organisms into large groups.
    - Proceed to more specific features.
7. **Avoid overlapping alternatives.**
    - The two choices should not both describe the same specimen.
8. **Number each couplet clearly.**
    - Each pair of statements should have a number or letter.
9. **Provide directions to the next step.**
    - Each alternative should lead to another numbered couplet or to the organism's name.
10. **Use the same feature type where possible.**
    - For example, compare leaf arrangement with leaf arrangement rather than mixing unrelated characteristics.
11. **Ensure all organisms can be identified.**
    - Test the key using every specimen included.
12. **Arrange statements logically.**
    - The key should lead from general features to specific identification.

17.4 Important terms used in dichotomous keys

- **Couplet:** A pair of contrasting statements in a dichotomous key.

- **Lead:** One of the two statements in a couplet.
- **Diagnostic feature:** A characteristic used to distinguish one organism from another.
- **Identification:** The process of determining the identity of an organism.
- **Specimen:** An organism or part of an organism used for examination.

17.5 Types of dichotomous keys

A. Indented key

In an indented key, each choice is arranged below the preceding choice, with further choices indented progressively.

B. Bracketed key

In a bracketed key, each alternative is numbered and directs the user to another numbered couplet or to the name of the organism.

Both types use paired alternatives and follow the same basic identification principles.

17.6 Example 1: Constructing a simple dichotomous key for plants

Consider the following plants:

- Moss
- Fern
- Pine
- Maize
- Bean

Observable characteristics

- Moss lacks true vascular tissues.
- Fern has vascular tissues but does not produce seeds.
- Pine produces naked seeds in cones.
- Maize produces flowers and has one cotyledon.
- Bean produces flowers and has two cotyledons.

Bracketed dichotomous key

1a. Plant lacks well-developed vascular tissues ..... Moss

1b. Plant has well-developed vascular tissues ..... Go to 2

2a. Plant reproduces by spores and does not produce seeds ..... Fern

2b. Plant produces seeds ..... Go to 3

3a. Seeds are not enclosed in fruits ..... Pine

3b. Seeds are enclosed in fruits ..... Go to 4

4a. Seed has one cotyledon ..... Maize

4b. Seed has two cotyledons ..... Bean

17.7 Example 2: Constructing a dichotomous key for arthropods

Consider these five arthropods:

- Grasshopper
- Spider

- Crab
- Centipede
- Millipede

Bracketed key

1a. Animal has three pairs of legs ..... Go to 2

1b. Animal does not have three pairs of legs ..... Go to 3

2a. Body has three main regions and one pair of antennae ..... Grasshopper

2b. Body does not have three main regions ..... Check specimen characteristics

3a. Animal has four pairs of legs and no antennae ..... Spider

3b. Animal has many pairs of legs ..... Go to 4

4a. Most body segments have one pair of legs ..... Centipede

4b. Most apparent body segments have two pairs of legs ..... Millipede

Additional identification of crab: A crab has two pairs of antennae and several pairs of jointed appendages. It can be separated from the other specimens using those features.

A complete key for this set should include a first couplet that separates the crab by its two pairs of antennae or aquatic crustacean features, then directs the remaining specimens to the appropriate couplets. For example:

1a. Animal has two pairs of antennae ..... Crab

1b. Animal does not have two pairs of antennae ..... Go to 2

2a. Animal has three pairs of legs ..... Grasshopper

2b. Animal has more than three pairs of legs ..... Go to 3

3a. Animal has four pairs of legs and no antennae ..... Spider

3b. Animal has many pairs of legs ..... Go to 4

4a. Most body segments have one pair of legs ..... Centipede

4b. Most apparent body segments have two pairs of legs ..... Millipede

17.8 How to use a dichotomous key

1. Obtain the unknown specimen.
2. Observe its external characteristics carefully.
3. Read the first pair of statements.
4. Select the statement that best describes the specimen.
5. Follow the direction given by the selected statement.
6. Continue selecting between paired statements.
7. Stop when the organism's identity is reached.
8. Confirm the identification by checking other distinguishing features.

17.9 Practical applications of dichotomous keys in Kenya

1. Identifying weeds in maize, wheat and bean farms.
2. Identifying insects that attack crops.
3. Identifying tree species in forests and school compounds.
4. Identifying aquatic organisms in rivers and lakes.
5. Identifying grass species in grazing fields.
6. Identifying medicinal and poisonous plants.
7. Supporting biodiversity surveys in national parks and conservancies.
8. Identifying organisms during environmental impact assessments.
9. Supporting biological research in universities and research institutions.
10. Helping learners organise and classify specimens collected during fieldwork.

17.10 Precautions when using dichotomous keys

- Handle specimens carefully.
- Do not guess when a characteristic is unclear.
- Use a hand lens where necessary.
- Observe the same features described in the key.
- Avoid damaging rare or protected organisms.
- Use photographs or field guides where collecting specimens is not permitted.
- Record the identification process for future reference.

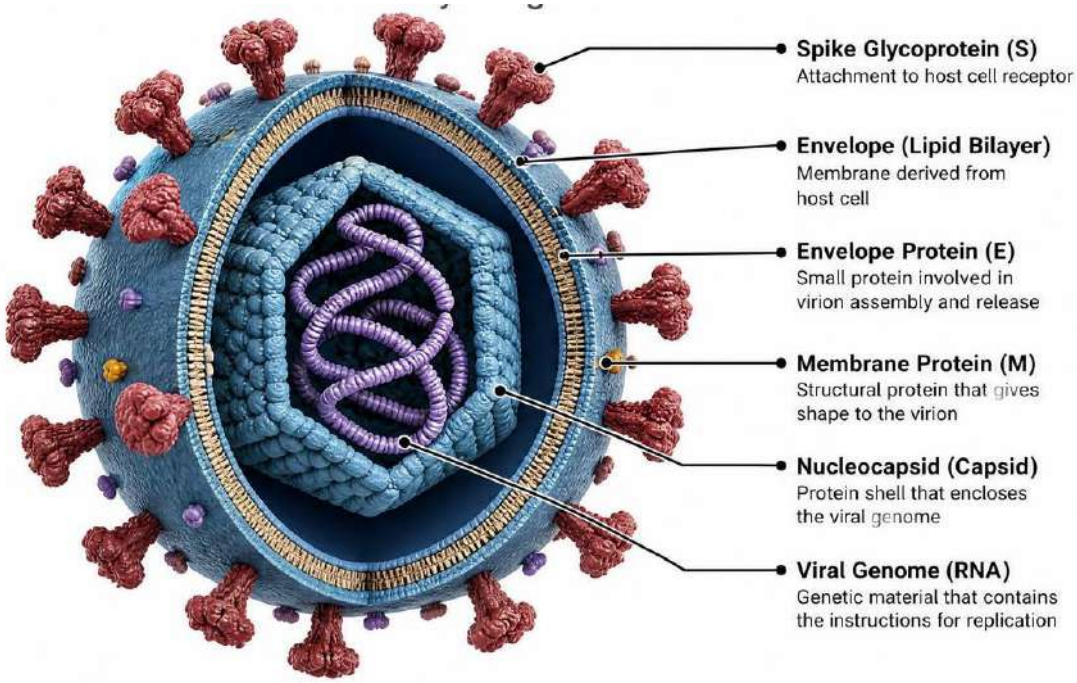
18.0 VIRUSES

18.1 Meaning of viruses

Viruses are extremely small, acellular infectious agents consisting of genetic material, either DNA or RNA, enclosed in a protein coat. Some viruses also possess an outer lipid envelope.

Viruses can reproduce only inside suitable living host cells. Outside a host cell, they cannot carry out independent reproduction or normal metabolic activities.

They infect animals, plants, fungi, bacteria and other organisms.



18.2 General characteristics of viruses

1. **They are acellular.**
   - They do not have a cellular structure.
   - They lack cytoplasm, a nucleus and membrane-bound organelles.

2. **They contain genetic material.**
   - A virus contains either DNA or RNA as its genetic material.
   - It does not normally contain both types as its genome.
3. **They have a protein coat.**
   - The protein coat is called a capsid.
   - It protects the genetic material.
4. **Some have an envelope.**
   - The envelope is usually derived from host cell membranes.
   - It may contain viral proteins that assist in attaching to host cells.
5. **They are extremely small.**
   - Most viruses are too small to be seen using an ordinary light microscope.
   - They are commonly studied using electron microscopes.
6. **They are obligate intracellular parasites.**
   - They can reproduce only inside suitable living host cells.
   - They depend on host cell machinery to make viral components.
7. **They lack independent metabolism.**
   - They do not carry out respiration, feeding or protein synthesis independently.

- They use the host cell's resources to produce new virus particles.

8. **They show host specificity.**
   - Many viruses infect only certain types of hosts or particular cell types.
   - Some infect a wide range of hosts.
9. **They reproduce through replication and assembly.**
   - Viral genetic material directs the host cell to produce viral components.
   - These components are assembled into new virus particles.
10. **They may be crystallised.**
   - Some viruses can be crystallised outside host cells and retain their infectivity under suitable conditions.
11. **They may cause diseases.**
   - Viral infections affect humans, animals and plants.
12. **They can mutate.**
   - Changes in viral genetic material may produce new variants.
   - Mutation can affect transmissibility, host range and other characteristics.

18.3 Structure of a typical virus

A virus may contain the following structures:

A. Genetic material

- It is the nucleic acid found inside the virus.
- It may be DNA or RNA.
- It contains instructions for producing new virus particles.

B. Capsid

- The capsid is the protein coat surrounding the genetic material.
- It protects the nucleic acid.
- It is made up of smaller protein units called capsomeres.

C. Envelope

- Some viruses possess an outer lipid membrane.
- The envelope is usually acquired from the host cell membrane during release.
- It helps the virus enter suitable host cells.

D. Surface spikes

- Some enveloped viruses possess glycoprotein spikes.
- They help the virus attach to receptors on host cells.

- They may influence which cells the virus can infect.

E. Enzymes

- Some viruses carry enzymes required for replication.
- These enzymes assist in copying or processing viral genetic material.

18.4 Examples of viruses

1. **Tobacco mosaic virus (TMV)**
   - Infects tobacco and some other plants.
   - May cause mosaic patterns on leaves and reduce plant growth.
2. **Influenza virus**
   - Causes influenza, commonly known as flu.
   - Infects the respiratory system.
3. **Human immunodeficiency virus (HIV)**
   - Attacks cells of the immune system.
   - Can lead to acquired immunodeficiency syndrome (AIDS) if untreated.
4. **Bacteriophages**
   - Viruses that infect bacteria.
   - Some are used in scientific research and biotechnology.
5. **Rabies virus**
   - Causes rabies in mammals.
   - It can be transmitted through the saliva of infected animals, commonly through bites.
6. **Coronavirus**
   - A group of viruses that can infect humans and animals.
   - Some cause respiratory illnesses.
7. **African cassava mosaic virus**
   - Infects cassava plants.
   - Can cause leaf distortion and mosaic symptoms, reducing yields.
8. **Maize streak virus**
   - Causes maize streak disease.
   - It is transmitted by leafhoppers and may cause significant yield losses.

18.5 Conditions necessary for viral replication

Viruses do not grow independently like bacteria or plants. They multiply only when they enter suitable living host cells.

The following conditions are important:

1. **A suitable living host**

- A virus must enter a compatible host cell.
- Different viruses infect different host species and cell types.

2. **Suitable host-cell receptors**
   - Viral surface proteins must interact with suitable receptors on the host cell.
   - This allows attachment and entry.
3. **Suitable cellular machinery**
   - The host cell provides ribosomes, enzymes and other materials needed to make viral components.
   - Some viruses also carry their own enzymes.
4. **Availability of raw materials**
   - Host cells supply amino acids, nucleotides, lipids and energy.
   - These are used to produce new virus particles.
5. **Suitable intracellular environment**
   - Temperature, pH and chemical conditions within the host cell must allow viral processes to occur.
   - Different viruses are adapted to different host-cell environments.
6. **Ability to evade or overcome host defences**
   - The virus must avoid or counter the host's antiviral defence mechanisms sufficiently to replicate.
7. **Successful assembly and release**
   - Newly produced viral components must be assembled into complete virus particles.
   - These particles may leave the cell by budding, exocytosis or cell lysis, depending on the virus.

Important scientific clarification

Viruses do not multiply in ordinary nutrient solutions in the way bacteria do. They require suitable living cells. Temperature, moisture and nutrients outside the host may affect virus survival, but they do not provide the conditions for independent viral reproduction.

18.6 General stages of viral replication

1. **Attachment**
   - The virus binds to specific receptors on a suitable host cell.
2. **Entry or penetration**
   - The virus or its genetic material enters the host cell.
3. **Uncoating**
   - The viral genetic material is released from its protective coat where necessary.
4. **Replication and synthesis**
   - The viral genome is copied.
   - The host cell's machinery produces viral proteins and other components.

5. **Assembly**

- Viral genetic material and protein coats are assembled into new virus particles.

6. **Release**

- New virus particles leave the host cell.
- Some viruses cause the host cell to burst, while others leave through budding.

18.7 Economic importance of viruses

Viruses have both harmful and useful effects.

A. Harmful economic importance

1. **Human diseases**

- Some viruses cause influenza, measles, hepatitis, HIV infection and other diseases.
- Illness can reduce productivity and increase healthcare costs.

2. **Livestock diseases**

- Foot-and-mouth disease virus affects cattle and other cloven-hoofed animals.
- Newcastle disease virus affects poultry.
- Rabies virus affects mammals.

3. **Crop diseases**

- Maize streak virus affects maize.
- Cassava mosaic viruses affect cassava.
- Tomato yellow leaf curl virus affects tomato plants.

4. **Reduced agricultural production**

- Viral infections may reduce crop yields and livestock productivity.
- Farmers may incur additional costs in controlling vectors and managing infected plants or animals.

5. **Food security challenges**

- Crop and livestock diseases can reduce the availability of food.
- Severe outbreaks may affect household incomes and national food supplies.

6. **Trade restrictions**

- Outbreaks of certain viral diseases may lead to restrictions on the movement or sale of animals and animal products.

7. **Public health costs**

- Viral outbreaks may require vaccination programmes, surveillance, treatment and public health education.

B. Beneficial economic importance

1. **Scientific research**

- Viruses are used in research on genetics, molecular biology and cell processes.

2. **Vaccine development**

- Some viruses or modified viral components are used in vaccine production.
- Viral vectors may be used to deliver genetic instructions in certain vaccines.

3. **Gene therapy**
   - Modified viruses can act as vectors for transferring genetic material into target cells in some gene therapy approaches.
4. **Biological control**
   - Certain viruses infect insect pests and may be used as biological control agents.
   - Baculoviruses are used in some pest management programmes.
5. **Bacteriophage applications**
   - Bacteriophages infect bacteria.
   - They are being investigated and used in some settings to control bacterial infections and contamination.
6. **Biotechnology**
   - Viral systems are used in molecular biology, genetic engineering and the study of gene expression.
7. **Cancer research and treatment**
   - Certain modified viruses are being developed for oncolytic therapy, where they selectively infect and destroy some cancer cells.

18.8 Prevention and control of viral diseases

1. Vaccination where an effective vaccine is available.
2. Washing hands with soap and clean water.
3. Practising safe food handling and proper sanitation.
4. Controlling disease vectors such as mosquitoes.
5. Avoiding contact with infected animals.
6. Seeking prompt medical attention after suspected exposure to serious infections such as rabies.
7. Using certified disease-free seeds and planting materials.
8. Removing and safely managing infected crop plants where recommended.
9. Practising quarantine and biosecurity in livestock and poultry production.
10. Using disease-resistant crop varieties where available.
11. Following public health guidance during outbreaks.
12. Avoiding unnecessary use of antibiotics because antibiotics do not treat viral infections.

18.9 Differences between viruses and bacteria

Feature	Viruses	Bacteria
Organisation	Acellular	Cellular
Cell structure	No true cell structure	Prokaryotic cells
Genetic material	DNA or RNA	DNA and RNA
Cytoplasm	Absent	Present
Ribosomes	Absent	Present
Metabolism	No independent metabolism	Carry out metabolism
Reproduction	Replicate inside host cells	Usually divide by binary fission
Growth on ordinary nutrient media	Cannot multiply independently	Many can grow on suitable media
Size	Generally much smaller	Generally larger
Antibiotics	Not effective against viruses	Some bacteria are susceptible to antibiotics

19.0 PREPARATION OF A HERBARIUM

19.1 Meaning of a herbarium

A **herbarium** is an organised collection of preserved plant specimens that are mounted, labelled, classified and stored for scientific study and future reference.

A herbarium provides a permanent record of plant diversity in a particular area. It is used in taxonomy, plant identification, ecology, conservation, agriculture and botanical research.

Herbaria may be maintained by schools, universities, botanical gardens, museums and research institutions.

19.2 Importance of preparing a herbarium

1. **Plant identification:** Preserved specimens can be used to identify unknown plants.
2. **Taxonomic studies:** They provide material for studying similarities and differences among plant species.
3. **Biodiversity records:** They document plant species found in a particular locality.
4. **Research:** Scientists can use herbarium specimens in botanical and ecological investigations.
5. **Conservation:** Herbarium records can help monitor changes in plant distribution over time.
6. **Education:** Learners can use specimens to study plant structures and classification.
7. **Agriculture:** Herbarium collections may help identify weeds, forage plants and useful crop relatives.
8. **Historical records:** Old specimens provide information about the plants that existed in a locality in the past.
9. **Reference material:** Specimens can be compared with newly collected plants during identification.

10. **Environmental studies:** They can provide information about vegetation changes and habitat conditions.

19.3 Materials and equipment required

The following materials may be used:

- Plant specimens.
- Secateurs or pruning shears.
- Gloves.
- Newspaper sheets or blotting paper.
- Plant press or two flat boards.
- Cardboard sheets.
- Strong straps or rope.
- Herbarium mounting sheets.
- Glue or adhesive strips.
- Labels.
- Pencil or permanent archival pen.
- Ruler.
- Hand lens.
- Field notebook.
- Plant identification guide.

19.4 Procedure for preparing herbarium specimens

Step 1: Selecting the plant specimen

1. Select a healthy, representative plant specimen.
2. Where possible, collect a specimen that shows important identifying features.
3. For flowering plants, select a specimen with leaves, flowers and, if available, fruits.
4. For grasses, include the roots, stem, leaves and inflorescence where practical.
5. Avoid collecting diseased, damaged or incomplete specimens unless the purpose is to study the disease or damage.

Step 2: Obtaining permission and collecting responsibly

1. Obtain permission before collecting plants from private or protected land.
2. Do not collect endangered, rare or protected plants.
3. Collect only the quantity needed for the study.
4. Avoid uprooting entire plants where a small representative sample is sufficient.
5. Use photographs and field observations where collecting is not permitted.

Step 3: Recording field information

Record the following details in a field notebook:

- Local name of the plant, if known.
- Date of collection.
- Location of collection.
- Habitat in which the plant was growing.
- Growth form, such as herb, shrub, climber or tree.
- Flower and fruit colour, where present.
- Height or approximate size.
- Any special identifying features.
- Collector's name or identification number.

Step 4: Arranging the specimen

1. Place the specimen between sheets of newspaper or blotting paper.
2. Spread out the leaves to show their arrangement.
3. Arrange the flowers so that their important structures can be seen.
4. Avoid excessive overlapping.
5. Fold long stems carefully to fit the mounting sheet.
6. Ensure that both sides of important leaves or flowers can be examined where possible.

Step 5: Pressing the specimen

1. Place the newspaper containing the specimen inside a plant press.
2. Add layers of absorbent paper and cardboard as required.
3. Apply even pressure using straps or weights.
4. Ensure that the specimen remains flat.
5. Replace damp papers regularly to prevent mould growth.

Step 6: Drying the specimen

1. Keep the pressed specimen in a dry, well-ventilated place.
2. Replace damp absorbent papers.
3. Allow the specimen to dry completely.
4. Check for fungal growth or decay.
5. Avoid excessive heat that may damage delicate plant structures.

Step 7: Mounting the specimen

1. Carefully remove the dried specimen.
2. Place it on a herbarium mounting sheet.
3. Attach it using suitable adhesive strips or archival glue.
4. Avoid covering important identifying structures.

5. Ensure that the specimen is firmly attached.

Step 8: Labelling

Attach a label containing accurate information about the specimen.

Step 9: Classification and storage

1. Arrange specimens according to their taxonomic groups.
2. Store them in clean, dry and labelled folders or cabinets.
3. Protect them from insects, moisture and direct sunlight.
4. Maintain a specimen register for easy retrieval.

19.5 Example of a herbarium label

HERBARIUM SPECIMEN LABEL

Institution: _____

Scientific name: *Zea mays*

Common name: Maize

Family: Poaceae

Division: Spermatophyta

Subdivision: Angiospermae

Class: Monocotyledonae

Habitat: Cultivated farmland

Location of collection: _____

Date of collection: _____

Collector: _____

Specimen number: _____

Identifying features: Parallel leaf venation, fibrous root system, jointed stem and maize cob.

Illustrative herbarium label. Confirm the scientific identification before assigning the final taxonomic name.

19.6 Precautions when preparing herbarium specimens

1. Collect specimens only with the necessary permission.
2. Avoid collecting endangered or protected plants.
3. Use gloves when handling unknown plants.
4. Avoid plants with irritating sap or poisonous structures.
5. Do not taste or directly smell unknown plant materials.
6. Use clean equipment.
7. Ensure specimens are completely dry before storage.
8. Label specimens accurately.

9. Keep the collection away from moisture and pests.
10. Avoid overcrowding specimens on mounting sheets.

20.0 OTHER BIOLOGY PROJECTS

Projects enable learners to apply biological knowledge to real-life situations. They develop observation, investigation, collaboration, creativity, critical thinking and problem-solving skills.

The following projects are suitable for school-based learning in Kenya.

Project 1: Preparation of a school plant herbarium

Objective: To collect, preserve, classify and document different plant species found in the school environment.

Materials: Newspapers, plant press, labels, mounting sheets, hand lens, notebook and identification guides.

Procedure:

1. Survey the school compound and nearby permitted areas.
2. Identify different plant species.
3. Record their habitats and observable features.
4. Collect suitable specimens responsibly.
5. Press and dry the specimens.
6. Mount them on herbarium sheets.
7. Identify and classify each specimen.
8. Prepare labels.
9. Arrange the specimens into a school herbarium.
10. Present the collection to the class.

Expected outcome: A labelled herbarium containing representative plant species from the school environment.

Project 2: Preparing an insect collection

Objective: To study the diversity and distinguishing characteristics of insects.

Procedure:

1. Observe insects in the school compound or garden.
2. Photograph insects without disturbing them.
3. Identify their body regions, antennae, legs and wings.
4. Group them according to observable characteristics.
5. Record their habitats and feeding behaviour.
6. Use photographs or ethically obtained specimens to prepare a labelled display.
7. Identify beneficial and harmful insects.
8. Present findings to the class.

Expected outcome: A labelled insect biodiversity chart or photographic collection.

Safety and conservation: Avoid collecting dangerous insects, protected species or large numbers of living organisms. Do not handle bees, wasps or unfamiliar insects.

Project 3: Constructing a dichotomous key for plants in the school compound

Objective: To develop a simple dichotomous key for identifying common plants.

Procedure:

1. Select at least six different plant species.
2. Observe their leaf shape, venation, stem type, flowers and roots where visible.
3. Record the distinguishing features.
4. Identify features that separate the plants into pairs.
5. Construct a bracketed dichotomous key.
6. Exchange keys with another group.
7. Test whether the other group can correctly identify the plants.
8. Improve the key based on feedback.

Expected outcome: A tested dichotomous key for identifying plants in the school environment.

Project 4: Investigating insect diversity in different habitats

Objective: To compare insect diversity in two or more habitats.

Possible study sites:

- School garden.
- Grassland.
- Flowering hedge.
- Shaded area.
- Farm boundary.

Procedure:

1. Select two or more study habitats.
2. Observe insects for equal periods of time.
3. Use photographs and observation records.
4. Record the different types of insects observed.
5. Group insects into broad categories.
6. Compare the number and types of insects recorded.
7. Suggest reasons for differences in diversity.
8. Present findings using tables, graphs and photographs.

Expected outcome: A report showing how habitat conditions influence insect diversity.

Project 5: Investigating pollination by insects

Objective: To investigate the role of insects in pollination.

Procedure:

1. Identify flowering plants in the school garden.
2. Observe insect visits to selected flowers.

3. Record the type of insect and the number of visits.
4. Observe which flower structures the insects contact.
5. Compare insect activity at different times of the day.
6. Record the findings.
7. Explain how insect visits may contribute to pollination.

Expected outcome: A report explaining the importance of insects in pollination.

Project 6: Comparing monocotyledonous and dicotyledonous plants

Objective: To identify distinguishing features of monocots and dicots.

Materials: Maize seedlings, bean seedlings, hand lens, ruler and notebook.

Procedure:

1. Obtain maize and bean seedlings.
2. Observe their roots.
3. Examine the leaves.
4. Compare leaf venation.
5. Examine seeds where available.
6. Record the number of cotyledons.
7. Compare the observed features.
8. Present the results in a table.

Expected outcome: A comparison showing the distinguishing features of monocotyledons and dicotyledons.

Project 7: Studying arthropods in soil

Objective: To investigate the presence and diversity of arthropods in soil habitats.

Procedure:

1. Select two different soil habitats.
2. Observe the soil surface carefully.
3. Use a hand lens to examine small organisms.
4. Photograph organisms without unnecessary handling.
5. Group them into broad arthropod classes where identification is possible.
6. Record the habitat conditions.
7. Compare the organisms found in the different sites.
8. Explain the ecological importance of the organisms.

Expected outcome: A report on soil arthropod diversity and their roles in the ecosystem.

Project 8: Investigating plant viral diseases

Objective: To identify common symptoms associated with suspected viral diseases in crops.

Possible crops: Maize, cassava, tomato, beans and other locally grown crops.

Procedure:

1. Observe crops in a farm or school garden with permission.
2. Look for symptoms such as mosaic patterns, leaf curling, stunting and yellow streaks.
3. Photograph affected plants.
4. Compare symptoms on healthy and affected plants.
5. Research possible viral diseases affecting the crops.
6. Identify likely insect vectors where relevant.
7. Suggest preventive measures.
8. Present the findings.

Expected outcome: A report on plant disease symptoms and methods of preventing viral disease spread.

Important: Visible symptoms alone cannot confirm that a plant has a viral infection. Laboratory diagnosis or confirmation by a qualified agricultural specialist may be required.

Project 9: Preparing a biodiversity photographic catalogue

Objective: To document the diversity of plants and animals within a selected locality.

Procedure:

1. Select a suitable study area.
2. Take photographs of organisms observed.
3. Record their local names where known.
4. Identify their major taxonomic groups.
5. Record the habitats in which they occur.
6. Group organisms according to classification.
7. Prepare a catalogue with photographs and descriptions.
8. Present the catalogue to the class.

Expected outcome: A photographic biodiversity catalogue of the selected area.

Project 10: Investigating the economic importance of insects

Objective: To investigate the beneficial and harmful effects of insects on Kenyan agriculture and human welfare.

Procedure:

1. Select a local farm or agricultural environment.
2. Identify insects found in the area.
3. Interview a farmer or agricultural extension officer with permission.
4. Record beneficial insects such as pollinators and predators.
5. Record harmful insects such as crop pests and disease vectors.
6. Investigate the methods used to manage harmful insects.

7. Suggest environmentally responsible control measures.
8. Present findings in a report.

Expected outcome: A report showing the economic importance of insects and the value of sustainable insect management.

REVISION SUMMARY

22.1 Kingdom Plantae

- Bryophyta are non-vascular plants that reproduce by spores.
- Pteridophyta are vascular plants that reproduce by spores.
- Spermatophyta are vascular plants that produce seeds.
- Gymnosperms produce naked seeds.
- Angiosperms produce flowers and seeds enclosed in fruits.
- Monocotyledons typically possess one cotyledon.
- Dicotyledons typically possess two cotyledons.

22.2 Kingdom Animalia

- Chordates possess a notochord and other characteristic features at some stage of development.
- Vertebrates possess a vertebral column.
- Fish respire using gills.
- Amphibians commonly have moist skin and undergo metamorphosis.
- Reptiles have dry, scaly skin.
- Birds possess feathers and wings.
- Mammals possess mammary glands and hair at some stage of life.
- Arthropods possess jointed appendages and a chitinous exoskeleton.
- Insects have three pairs of legs.
- Arachnids have four pairs of legs.
- Crustaceans commonly have two pairs of antennae.
- Centipedes have one pair of legs on most body segments.
- Millipedes have two pairs of legs on most apparent body segments.

22.3 Dichotomous keys

- A dichotomous key identifies organisms through paired contrasting statements.
- Each pair of statements is called a couplet.
- The features used should be clear, observable and reliable.
- Keys may be indented or bracketed.

22.4 Viruses

- Viruses are acellular infectious agents.
- They contain either DNA or RNA.
- Their genetic material is surrounded by a protein coat.
- Some have an envelope.
- They reproduce only inside suitable living host cells.
- They affect humans, animals and plants.
- They also have beneficial applications in research, biotechnology and biological control.

REVISION QUESTIONS

Strand 1: Cell Biology and Biodiversity | Sub-strand 1.3: Taxonomy II

SECTION A: MULTIPLE-CHOICE QUESTIONS

Instructions: Answer all questions. Choose the correct answer from the alternatives A, B, C and D.

1. Which one of the following characteristics distinguishes organisms in Division Bryophyta from those in Division Pteridophyta?

A. Presence of chlorophyll
B. Absence of well-developed vascular tissues
C. Ability to reproduce sexually
D. Presence of a cell wall

2. Which structure anchors moss plants to their substrate?

A. Rhizoids B. True roots C. Stolons D. Tendrils

3. The dominant generation in the life cycle of most bryophytes is the

A. embryo B. sporophyte C. gametophyte D. seedling

4. Which one of the following features is associated with Pteridophyta?

A. Seeds enclosed in fruits B. Absence of vascular tissues
C. Production of flowers D. Reproduction using spores

5. Which one of the following structures produces spores in many ferns?

A. Ovary B. Sorus C. Anther D. Stigma

6. The major distinguishing characteristic of Gymnospermae is that they

A. produce seeds enclosed in fruits B. reproduce only through spores
C. produce naked seeds D. lack vascular tissues

7. Which one of the following plants belongs to Gymnospermae?

A. Maize B. Bean C. Pine D. Mango

8. A learner observes a plant with parallel leaf venation, fibrous roots and one cotyledon. The plant is most likely a

A. dicotyledon B. monocotyledon C. bryophyte D. gymnosperm

9. Which one of the following features is commonly associated with dicotyledonous plants?

A. One cotyledon B. Parallel leaf venation C. Fibrous root system D. Two cotyledons

10. Double fertilisation is a characteristic feature of

A. Bryophyta B. Pteridophyta C. Angiospermae D. Gymnospermae

11. Which one of the following is a characteristic feature of Chordata?

A. Jointed appendages B. Notochord at some stage of development
C. Chitinous exoskeleton D. Three pairs of legs

12. Which one of the following vertebrate classes has feathers?

A. Reptilia B. Mammalia C. Amphibia D. Aves

13. A vertebrate with moist skin, eggs without hard shells and a larval stage with gills most likely belongs to class

A. Amphibia B. Reptilia C. Aves D. Mammalia

14. Which one of the following features distinguishes mammals from other vertebrate classes?

A. Presence of lungs
B. Presence of a backbone
C. Presence of mammary glands
D. Presence of a four-chambered heart

15. Which one of the following animals belongs to class Chondrichthyes?

A. Tilapia B. Shark C. Frog D. Crocodile

16. Which one of the following features is characteristic of most bony fish?

A. Cartilaginous skeleton
B. Absence of gills
C. Presence of an operculum
D. Presence of feathers

17. An animal has three body regions, three pairs of legs and one pair of antennae. It belongs to class

A. Arachnida B. Insecta C. Crustacea D. Diplopoda

18. Which one of the following arthropods has four pairs of walking legs and no antennae?

A. Grasshopper B. Crab C. Spider D. Centipede

19. Which one of the following characteristics distinguishes crustaceans from insects?

A. Presence of a chitinous exoskeleton
B. Jointed appendages
C. Two pairs of antennae
D. Segmented body

20. A learner observes an elongated arthropod with one pair of legs on most body segments. The organism belongs to class

A. Diplopoda B. Chilopoda C. Arachnida D. Insecta

21. Which one of the following arthropods plays an important role in decomposition of dead plant materials?

A. Millipede B. Mosquito C. Spider D. Scorpion

22. The transfer of pollen grains from anther to stigma is known as

A. fertilisation B. germination C. pollination D. dispersal

23. Which one of the following insects has siphoning mouthparts?

A. Grasshopper B. Butterfly C. Housefly D. Cockroach

24. The stage between larva and adult in complete insect metamorphosis is called

A. nymph B. embryo C. pupa D. spore

25. Which one of the following insects is beneficial because it produces honey and assists in pollination?

A. Mosquito B. Honeybee C. Maize weevil D. Locust

26. A dichotomous key is mainly used to

A. measure the height of plants
B. identify organisms using paired contrasting features
C. determine the age of organisms
D. measure population growth

27. Each pair of contrasting statements in a dichotomous key is called a

A. class B. family C. couplet D. species

28. Which one of the following is the most suitable feature to use in a dichotomous key?

A. An organism's popularity
B. The collector's opinion
C. A clearly observable structural feature
D. The economic value of the organism

29. Which one of the following statements about viruses is correct?

A. They possess fully developed cells.
B. They reproduce independently in water.
C. They contain either DNA or RNA as genetic material.
D. They possess ribosomes for independent protein synthesis.

30. The protein coat surrounding the genetic material of a virus is called the

A. capsule
B. capsid
C. cytoplasm
D. nucleus

31. Viruses are described as obligate intracellular parasites because they

A. reproduce only inside suitable living host cells
B. feed on dead organic matter
C. possess chlorophyll
D. divide through binary fission

32. Which one of the following is a plant viral disease?

A. Malaria
B. Maize streak disease
C. Tuberculosis
D. Ringworm

33. Which one of the following viruses infects bacteria?

A. Influenza virus
B. Tobacco mosaic virus
C. Bacteriophage
D. Rabies virus

34. A major reason for pressing plant specimens during herbarium preparation is to

A. encourage their growth
B. flatten and preserve their structures
C. increase their water content
D. cause them to produce seeds

35. Which one of the following details should be included on a herbarium specimen label?

A. Collector's favourite plant
B. Specimen's selling price
C. Date and location of collection
D. Name of the school head teacher only

SECTION B: STRUCTURED QUESTIONS

36. a) Define the term taxonomy. (2 marks)

b) State four reasons why organisms are classified. (4 marks)

c) List the seven main taxonomic ranks in their correct order, beginning with the broadest. (7 marks)

37. a) State five general characteristics of organisms in Division Bryophyta. (5 marks)

b) Explain four ways in which bryophytes are economically or ecologically important. (4 marks)

c) Name one example of a liverwort. (1 mark)

38. a) State six characteristics of organisms in Division Pteridophyta. (6 marks)

b) Explain four distinguishing features of ferns. (4 marks)

39. a) Define Spermatophyta. (2 marks)

b) State four general characteristics of seed-producing plants. (4 marks)

c) Distinguish between Gymnospermae and Angiospermae using four characteristics. (4 marks)

40. a) State five characteristics of organisms in Gymnospermae. (5 marks)

b) Name four groups of gymnosperms commonly studied in biology. (4 marks)

c) Give one example of a conifer. (1 mark)

41. a) State six characteristics of angiosperms. (6 marks)

b) State four differences between monocotyledonous and dicotyledonous plants. (4 marks)

42. a) State six general characteristics of organisms in Phylum Chordata. (6 marks)

b) Explain four distinguishing characteristics of mammals. (4 marks)

43. a) State five characteristics of class Amphibia. (5 marks)

b) Explain three adaptations of amphibians to life in aquatic and terrestrial habitats. (3 marks)

c) Give two examples of amphibians. (2 marks)

44. a) State six characteristics of class Reptilia. (6 marks)

b) Explain four adaptations of reptiles to terrestrial life. (4 marks)

45. a) State six general characteristics of class Aves. (6 marks)

b) Explain four economic or ecological benefits of birds. (4 marks)

46. a) State six general characteristics of Phylum Arthropoda. (6 marks)

b) State four distinguishing features of class Insecta. (4 marks)

47. a) State five characteristics of class Arachnida. (5 marks)

b) Give three examples of arachnids. (3 marks)

c) State two ways in which spiders are beneficial to farmers. (2 marks)

48. a) State four characteristics of class Crustacea. (4 marks)

b) State three characteristics that distinguish centipedes from millipedes. (3 marks)

c) Explain three economic or ecological benefits of crustaceans. (3 marks)

49. a) Define a dichotomous key. (2 marks)

b) State five principles followed when constructing a dichotomous key. (5 marks)

c) Explain three practical applications of dichotomous keys in Kenya. (3 marks)

50. a) Define a virus. (2 marks) b) Describe the structure of a typical virus. (4 marks)

c) Explain four reasons why viruses cannot reproduce independently outside living host cells. (4 marks)

51. a) State five general characteristics of viruses. (5 marks)

b) Explain three harmful effects of viruses on agriculture and human health. (3 marks)

c) State two beneficial applications of viruses. (2 marks)

52. a) Define a herbarium. (2 marks)

b) Describe six steps followed when preparing a herbarium specimen. (6 marks)

c) State two precautions observed during herbarium preparation. (2 marks)

53. a) Explain the economic importance of insects under the following headings:

i. Agriculture. (4 marks)

ii. Human health. (3 marks)

iii. Industry and income generation. (3 marks)

54. A learner collected five plant specimens during a biodiversity study. The specimens had the following characteristics:

- Specimen A had no true roots, stems or leaves and reproduced by spores.
- Specimen B had true roots, stems and leaves but reproduced by spores.
- Specimen C produced cones containing naked seeds.
- Specimen D produced flowers and had one cotyledon.
- Specimen E produced flowers and had two cotyledons.

Answer the following questions:

a) Identify the plant division or subdivision to which specimens A, B and C belong. (3 marks)

b) Identify the class of specimens D and E. (2 marks)

c) Give two distinguishing features of specimen D. (2 marks)

d) Explain three reasons why classification of the five specimens is important. (3 marks)

55:

A Grade 11 learner observed different plants growing around the school compound. One plant had parallel leaf venation and fibrous roots. Another had net-like leaf venation and a taproot system. A third plant had needle-like leaves and produced cones.

a) Identify the likely plant group of each specimen. (3 marks)

b) Explain the importance of leaf venation in plant identification. (2 marks)

c) Give three other characteristics that can be used to distinguish monocotyledons from dicotyledons. (3 marks)

d) Explain two reasons why learners should prepare a school herbarium. (2 marks)

56:

A farmer in Nakuru County noticed that some insects were destroying maize crops while others were visiting flowering plants in the farm.

a) Identify two insects that may be beneficial to the farmer. (2 marks)

b) Explain how beneficial insects improve agricultural production. (4 marks)

c) Identify two harmful insects that may affect maize production. (2 marks)

d) Suggest two environmentally responsible ways of managing harmful insects. (2 marks)

57:

Learners visited a nearby forest and observed mosses, ferns, flowering plants, insects, spiders, birds and mammals.

a) Identify two organisms that belong to Division Bryophyta or Pteridophyta. (2 marks)

b) Explain how the forest provides suitable habitats for different organisms. (3 marks)

c) Explain three benefits of biodiversity to the local community. (3 marks)

d) Suggest two activities that learners can undertake to support biodiversity conservation. (2 marks)

58:

A learner observed an unknown animal with a segmented body, four pairs of legs and no antennae.

a) Identify its likely arthropod class. (1 mark)

b) State three characteristics supporting your answer. (3 marks)

c) Explain three ecological benefits of the organism if it is a spider. (3 marks)

d) Explain three steps the learner could follow to identify the organism using a dichotomous key. (3 marks)

59:

A farmer noticed yellow streaks and reduced growth in maize plants. The agricultural officer suspected a viral infection.

a) Name one viral disease that may affect maize. (1 mark)

b) State three symptoms that may be associated with viral infections in crops. (3 marks)

c) Explain three ways in which viral diseases may reduce agricultural production. (3 marks)

d) Suggest three measures for preventing the spread of viral diseases in crops. (3 marks)

60:

Your class has been asked to prepare a biodiversity catalogue of plants and arthropods found in the school compound.

a) State four materials needed for the investigation. (4 marks)

b) Describe four procedures the learners should follow. (4 marks)

c) State two ethical considerations to observe during the investigation. (2 marks)

25.0 PRACTICAL ACTIVITIES AND ASSESSMENT TASKS

The following practical tasks can be used for continuous assessment and competency development.

Practical task	Expected learner product or evidence
Observe moss and fern specimens	Labelled drawings showing distinguishing structures
Compare maize and bean seedlings	Comparison table of monocot and dicot features
Observe pine cones	Labelled drawing showing cone structure
Examine arthropod photographs or models	Classification chart of arthropod classes
Construct a dichotomous key	A tested identification key
Prepare a herbarium	Labelled and mounted plant specimens
Investigate insects in a school garden	Biodiversity observation report
Study viral disease symptoms in crops	Illustrated report on plant viral diseases
Prepare a biodiversity catalogue	Photographic or illustrated catalogue
Present a conservation proposal	Group presentation on biodiversity protection

Suggested practical assessment rubric

Assessment criterion	Marks
Appropriate planning and selection of materials	4
Correct observation and data collection	4
Accuracy of identification and classification	4
Quality of drawings, labels or records	4
Interpretation and explanation of findings	4
Safety, teamwork and responsible handling	4
Total	24

26.0 KEY BIOLOGY TERMS AND DEFINITIONS

Term	Meaning
Taxonomy	Identification, naming, description and classification of organisms
Classification	Grouping organisms according to shared characteristics
Species	Basic unit of biological classification
Binomial nomenclature	Scientific naming system using two names
Bryophyte	A simple non-vascular plant that reproduces by spores
Rhizoid	A root-like structure that anchors bryophytes
Pteridophyte	A vascular, seedless plant that reproduces by spores
Sorus	A cluster of sporangia, commonly found on fern fronds
Sporophyte	Diploid generation that produces spores
Gametophyte	Haploid generation that produces gametes

Spermatophyte	A seed-producing plant
Gymnosperm	A seed plant with seeds not enclosed in fruits
Angiosperm	A flowering plant with seeds enclosed in fruits
Cotyledon	An embryonic seed leaf
Pollination	Transfer of pollen from anther to stigma
Fertilisation	Fusion of male and female gametes
Notochord	Flexible supporting rod found in chordates at some stage of development
Vertebrate	An animal possessing a vertebral column
Arthropod	An invertebrate with jointed appendages and an exoskeleton
Exoskeleton	External supporting and protective skeleton
Ecdysis	Shedding of an old exoskeleton
Cephalothorax	A body region formed by the fusion of the head and thorax
Metamorphosis	Developmental change in body form during an organism's life cycle
Dichotomous key	Identification tool using paired contrasting statements
Couplet	A pair of contrasting statements in a dichotomous key
Virus	An acellular infectious agent containing DNA or RNA enclosed in a protein coat
Capsid	Protein coat surrounding viral genetic material
Host	Organism or cell in which a virus lives and replicates
Herbarium	Organised collection of preserved and labelled plant specimens
Biodiversity	Variety of living organisms in a given area or on Earth

STRAND 1: CELL BIOLOGY AND BIODIVERSITY

SUB-STRAND 1.4: CELL DIVISION

1.0 MEANING OF CELL DIVISION

Definition of cell division

Cell division is the biological process through which a parent cell divides to form two or more daughter cells.

- It is an important process in the life cycle of living organisms.
- It ensures continuity of life by producing new cells from existing cells.
- It enables organisms to grow, repair damaged tissues and replace worn-out or dead cells.
- In unicellular organisms, cell division may result in the formation of new individuals.
- In multicellular organisms, cell division increases the number of cells and supports the development and maintenance of the body.

Example:

- In human beings, cell division enables a fertilised egg (zygote) to develop into an embryo and eventually an adult.
- In plants such as maize and beans, cell division in growing regions enables the formation of new roots, stems and leaves.
- In bacteria, binary fission produces two new bacterial cells from one parent cell.

Important terms used in cell division

1. Parent cell

- The original cell that undergoes division.
- It contains genetic material that is passed to the daughter cells.

2. Daughter cells

- New cells formed after a parent cell divides.
- They receive genetic material from the parent cell.

3. Chromosome

- A thread-like structure made of DNA and proteins.
- It carries genes responsible for inherited characteristics.

4. Chromatin

- A network of long, thin DNA and protein fibres found in the nucleus of a non-dividing cell.
- It condenses to form visible chromosomes during cell division.

5. Gene

- A section of DNA that carries instructions for a particular characteristic or biological function.
- Genes are arranged along chromosomes.

6. Genome

- The complete set of genetic material found in an organism or cell.

7. Diploid cell (2n)

- A cell containing two complete sets of chromosomes.
- One set is inherited from each parent.

- Most human body cells are diploid and contain 46 chromosomes.

8. Haploid cell (n)

- A cell containing one complete set of chromosomes.
- Human gametes (sperm and ova) are haploid and contain 23 chromosomes.

9. Homologous chromosomes

- A pair of chromosomes similar in size, shape and gene arrangement.
- One chromosome is inherited from the mother and the other from the father.
- They carry genes for the same characteristics, although the alleles may differ.

10. Sister chromatids

- Two identical copies of a replicated chromosome.
- They remain attached at a region called the centromere until they separate during cell division.

11. Centromere

- The region of a chromosome where sister chromatids are held together.
- It provides the attachment region for spindle fibres through a protein structure called the kinetochore.

12. Spindle fibres

- Protein structures that develop during cell division.
- They help move and separate chromosomes or chromatids to opposite poles of the cell.

2.0 STRUCTURE OF CHROMOSOMES

Meaning of a chromosome

A chromosome is a thread-like structure made up of DNA and associated proteins, mainly histones, which carries hereditary information in a cell.

- Chromosomes are mainly located in the nucleus of eukaryotic cells.
- They become clearly visible under a light microscope when the cell is undergoing division.
- They contain genes that determine inherited characteristics.
- They ensure that genetic information is organised and passed from parent cells to daughter cells during cell division.
- The number of chromosomes is generally constant within the body cells of a particular species.

Examples of chromosome numbers in different organisms

Organism	Diploid chromosome number (2n)
Human beings	46
Maize	20
Common bean	22

Fruit fly	8
Domestic dog	78
Cat	38
Onion	16
Rice	24
Pea	14
Chimpanzee	48

Note: Chromosome numbers refer to the diploid number in ordinary body cells. Chromosome number alone does not determine the complexity of an organism.

2.1 Main parts of a chromosome

A replicated chromosome consists of the following structures:

1. Sister chromatids

- These are the two identical copies of a replicated chromosome.
- They are produced during DNA replication in the interphase stage.
- They are joined at the centromere.
- During mitosis, they separate and move to opposite poles of the cell.

2. Centromere

- It is the constricted region joining the two sister chromatids.
- It helps maintain the association of sister chromatids.
- It provides the site for kinetochore formation.
- Spindle fibres attach to the kinetochores to facilitate chromosome movement.

3. Telomeres

- These are protective structures found at the ends of chromosomes.
- They contain repetitive DNA sequences and associated proteins.
- They protect chromosomes from damage and prevent chromosome ends from joining together.
- They help maintain chromosome stability during repeated cell divisions.

4. Chromosome arms

- These are the sections of a chromosome extending from the centromere.
- The shorter arm is called the p-arm.
- The longer arm is called the q-arm.

5. Kinetochore

- It is a protein structure that develops at the centromere.
- It provides an attachment point for spindle microtubules.
- It assists in the movement of chromosomes during cell division.

6. DNA

- DNA is the hereditary material that carries genetic instructions.
- It contains genes responsible for inherited characteristics.
- It replicates before cell division to ensure that genetic information is passed to daughter cells.

7. Histone proteins

- These are proteins around which DNA winds.
- They help package DNA into a compact structure.
- They also contribute to the regulation of gene activity.

2.2 Organisation of DNA into chromosomes

DNA is organised into chromosomes through several levels of packaging.

The organisation takes place as follows:

1. **DNA double helix:** DNA consists of two complementary strands twisted around each other to form a double helix.
2. **Histone proteins:** DNA winds around histone proteins to form nucleosomes.
3. **Nucleosomes:** These are repeating units of DNA wrapped around histone protein complexes.
4. **Chromatin fibres:** Nucleosomes are organised into chromatin fibres.
5. **Condensed chromatin:** During cell division, chromatin becomes increasingly compact.
6. **Chromosomes:** The highly condensed chromatin forms visible chromosomes.

2.3 Types of chromosomes based on centromere position

Chromosomes can be classified according to the position of their centromeres.

1. Metacentric chromosomes

- The centromere is located approximately at the middle of the chromosome.
- The two chromosome arms are almost equal in length.
- They often appear V-shaped during anaphase.

2. Submetacentric chromosomes

- The centromere is slightly away from the middle.
- One arm is shorter than the other.
- They may appear L-shaped during movement.

3. Acrocentric chromosomes

- The centromere is located close to one end.
- One arm is very short while the other is much longer.
- They may appear J-shaped during movement.

4. Telocentric chromosomes

- The centromere is located at the terminal end.

- The chromosome has effectively one main arm.
- This type occurs in some animal species but is absent in normal human chromosomes.

2.4 Importance of chromosomes

Chromosomes are important because they:

1. Carry genes responsible for inherited characteristics.
2. Store hereditary information in DNA.
3. Control cellular activities through the genetic instructions contained in genes.
4. Ensure the transmission of genetic information from parent cells to daughter cells.
5. Help maintain the characteristic chromosome number of a species.
6. Contribute to genetic variation through recombination during meiosis.
7. Determine biological sex in species with genetic sex-determination systems.
8. Provide a basis for studying inheritance and genetic disorders.
9. Help scientists understand evolutionary relationships among organisms.
10. Support the continuity of life through accurate genetic transmission.

3.0 TYPES OF CELL DIVISION

Cell division occurs through different processes depending on the organism, cell type and biological function.

The main forms covered in this sub-strand include:

1. Mitosis.
2. Meiosis.
3. Binary fission.
4. Budding.

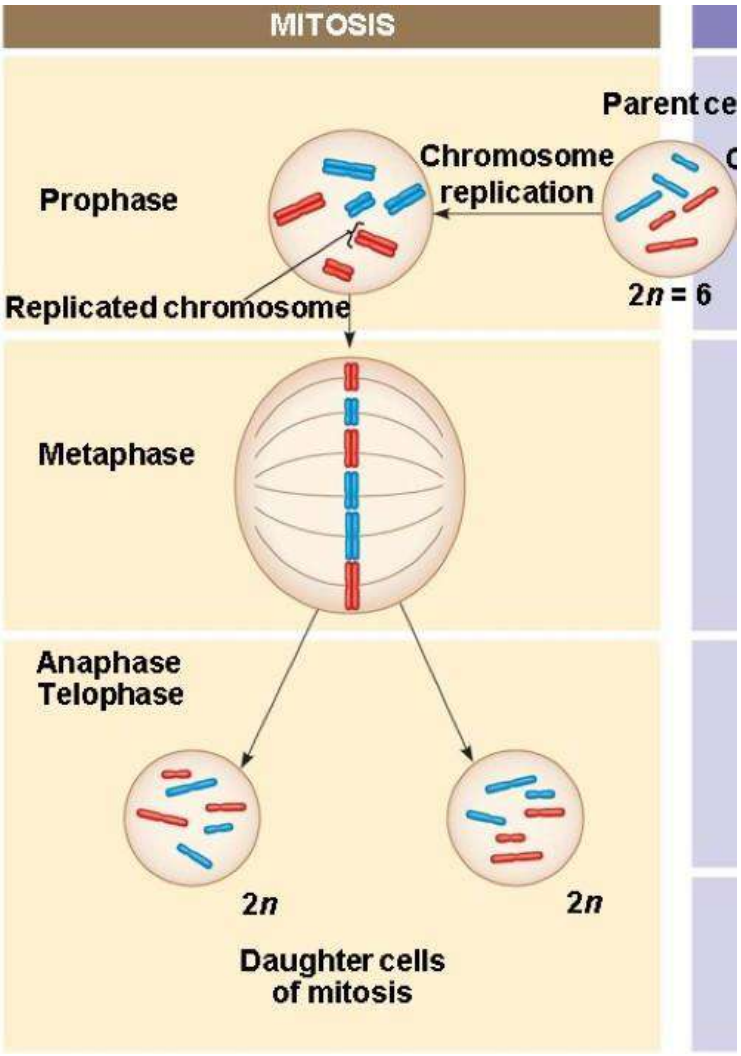
Tissue culture is also an important application of cell division, particularly in plant propagation.

3.1 MITOSIS

Meaning of mitosis

Mitosis is a type of cell division in which one parent cell divides to produce two genetically similar daughter cells, each having the same chromosome number as the parent cell.

- It mainly occurs in somatic (body) cells of multicellular organisms.
- It involves one nuclear division.
- The replicated chromosomes are equally distributed between the two daughter cells.
- It maintains the chromosome number of the parent cell.
- The daughter cells are usually genetically identical to the parent cell and to each other, provided no mutations occur.



Example:

A human body cell with 46 chromosomes divides through mitosis to produce two daughter cells, each with 46 chromosomes.

3.1.1 Interphase before mitosis

Before mitosis begins, the cell passes through interphase.

Interphase is the period during which the cell grows, carries out its normal activities and prepares for division.

It consists of three main stages:

1. G1 phase (First growth phase)

- The cell increases in size.
- New cell organelles are produced.
- Proteins and other substances needed for cell activities are synthesised.
- The cell carries out its normal metabolic activities.

2. S phase (Synthesis phase)

- DNA replication takes place.

- Each chromosome is copied to form two identical sister chromatids.
- The sister chromatids remain joined at the centromere.
- The amount of DNA in the nucleus doubles, but the chromosome number remains unchanged.

3. G2 phase (Second growth phase)

- The cell continues growing.
- Proteins required for cell division are synthesised.
- The cell checks and repairs replicated DNA where possible.
- It prepares the structures required for mitosis.

Important: Interphase is not a stage of mitosis. It is the preparatory period before mitosis.

3.1.2 Stages of mitosis

Mitosis is commonly divided into four main stages:

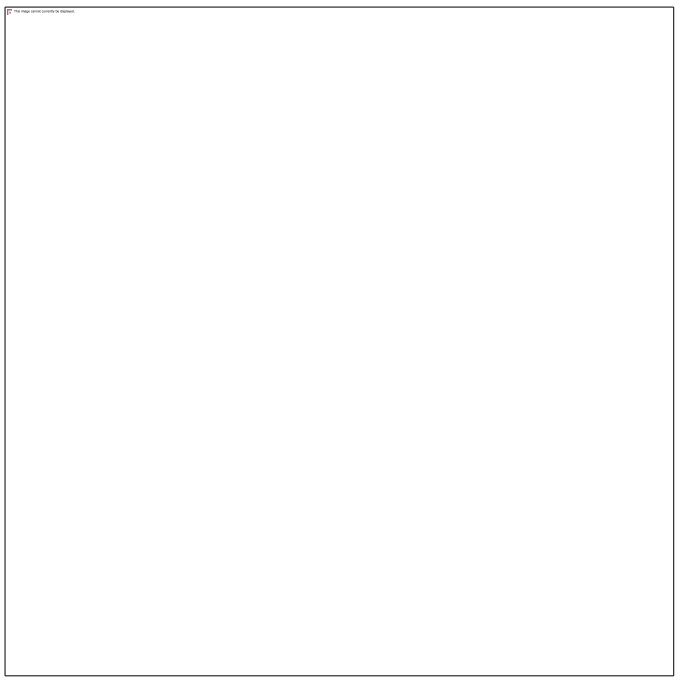
1. Prophase.
2. Metaphase.
3. Anaphase.
4. Telophase.

Cytokinesis usually follows or overlaps with the later stages of mitosis.

DNA has been copied before mitosis, but it still remains uncondensed inside one nucleus.

Move the phase slider to step through the current stage of cell division.

A. Prophase



This is the first stage of mitosis.

Main events:

1. Chromatin fibres condense and become shorter, thicker and clearly visible as chromosomes.

2. Each chromosome consists of two sister chromatids joined at the centromere.
3. The nucleolus gradually disappears.
4. The nuclear envelope begins to break down.
5. Spindle fibres begin to form.
6. In animal cells, centrosomes move towards opposite poles of the cell.
7. The spindle apparatus becomes organised to facilitate chromosome movement.

Importance of prophase

- It prepares chromosomes for movement.
- It enables the formation of the spindle apparatus.
- It makes the genetic material compact, reducing the likelihood of tangling during separation.

B. Metaphase

This is the second stage of mitosis.

Main events:

1. Chromosomes become arranged along the equator of the cell.
2. The equatorial region is also called the metaphase plate.
3. Spindle microtubules attach to the kinetochores of the chromosomes.
4. Sister chromatids are connected to spindle microtubules from opposite poles.
5. Chromosomes become maximally condensed and clearly visible.

Importance of metaphase

- It ensures chromosomes are properly positioned before separation.
- It promotes accurate distribution of genetic material to daughter cells.
- The cell checks that chromosomes are correctly attached to the spindle apparatus before anaphase proceeds.

C. Anaphase

This is the third stage of mitosis.

Main events:

1. The centromeric cohesion holding sister chromatids together is released.
2. Sister chromatids separate.
3. Each separated chromatid becomes an independent chromosome.
4. Spindle microtubules help move the chromosomes towards opposite poles.
5. Each pole receives an identical set of chromosomes.

Importance of anaphase

- It ensures equal distribution of chromosomes.
- It ensures that each future daughter cell receives a complete set of genetic information.

- It prevents unequal distribution of genetic material under normal conditions.

D. Telophase

This is the fourth stage of mitosis.

Main events:

1. Chromosomes reach opposite poles of the cell.
2. Chromosomes begin to uncoil and become less visible.
3. New nuclear envelopes form around each set of chromosomes.
4. Nucleoli reappear.
5. Spindle fibres break down.
6. Two daughter nuclei are formed.

Importance of telophase

- It restores the normal nuclear organisation.
- It separates the genetic material into two distinct nuclei.
- It prepares the cell for completion of division.

3.1.3 Cytokinesis

Meaning of cytokinesis

Cytokinesis is the division of the cytoplasm of a parent cell to form separate daughter cells.

It usually follows telophase.

Cytokinesis in animal cells

1. A contractile ring made mainly of actin and myosin forms beneath the cell membrane.
2. The ring contracts.
3. The cell membrane develops an inward depression called a cleavage furrow.
4. The furrow deepens gradually.
5. The cytoplasm is divided into two separate daughter cells.

Cytokinesis in plant cells

1. Vesicles derived mainly from the Golgi apparatus move towards the equatorial region.
2. The vesicles fuse to form a cell plate.
3. The cell plate expands towards the existing cell wall.
4. It eventually joins the parent cell membrane.
5. New plasma membranes and a new cell wall develop between the daughter cells.
6. Two separate daughter cells are formed.

Why is cytokinesis different in plant and animal cells?

- Animal cells have flexible cell membranes and no rigid cell wall, allowing a cleavage furrow to develop.
- Plant cells have rigid cell walls that prevent the cell from pinching inwards.
- Therefore, plant cells form a cell plate to separate the daughter cells.

3.1.4 Summary of mitosis stages

Stage	Main events
Prophase	Chromosomes condense; spindle forms; nuclear envelope breaks down.
Metaphase	Chromosomes line up at the equator.
Anaphase	Sister chromatids separate and move to opposite poles.
Telophase	Two new nuclei form.
Cytokinesis	Cytoplasm divides to form two daughter cells.

3.1.5 Characteristics of mitosis

1. It involves one nuclear division.
2. It produces two daughter cells.
3. It maintains the chromosome number.
4. Daughter cells are usually genetically identical.
5. It occurs mainly in somatic cells of multicellular organisms.
6. DNA replicates once before nuclear division.
7. Homologous chromosomes do not pair to form bivalents.
8. Crossing over between homologous chromosomes does not normally occur.
9. Sister chromatids separate during anaphase.
10. It is important in growth, repair and asexual reproduction.

3.1.6 Examples of mitosis in living organisms

In animals

- Growth of a human baby from a fertilised egg.
- Replacement of worn-out skin cells.
- Healing of cuts and wounds.
- Formation of new cells in the bone marrow.
- Replacement of cells lining the digestive tract.
- Growth and development of animal embryos.

In plants

- Growth of root tips.
- Growth of shoot tips.
- Formation of new leaves.
- Development of young stems.
- Growth of lateral meristems during increase in stem and root thickness.
- Formation of new plant tissues after injury.

3.1.7 Significance of mitosis

1. **Growth:** It increases the number of cells, enabling organisms to increase in size.
2. **Repair of damaged tissues:** It replaces cells damaged by injuries.
3. **Replacement of worn-out cells:** It replaces old and dead cells, such as skin cells.
4. **Asexual reproduction:** It enables some organisms to reproduce without fusion of gametes.
5. **Vegetative propagation:** It supports the formation of new plants from stems, roots and leaves.
6. **Maintenance of chromosome number:** It ensures daughter cells receive the same chromosome number as the parent cell.
7. **Embryonic development:** It enables a zygote to divide repeatedly to form an embryo.
8. **Regeneration:** It enables certain organisms to replace lost body parts or tissues.
9. **Tissue maintenance:** It maintains normal functioning of tissues by replacing cells.
10. **Tissue culture:** It enables plant cells to multiply under controlled conditions.

Examples in the Kenyan context

- Growth of maize seedlings after germination.
- Development of new roots in beans.
- Healing of wounds in human beings and livestock.
- Production of new shoots from sugarcane stem cuttings.
- Multiplication of banana plantlets through tissue culture.

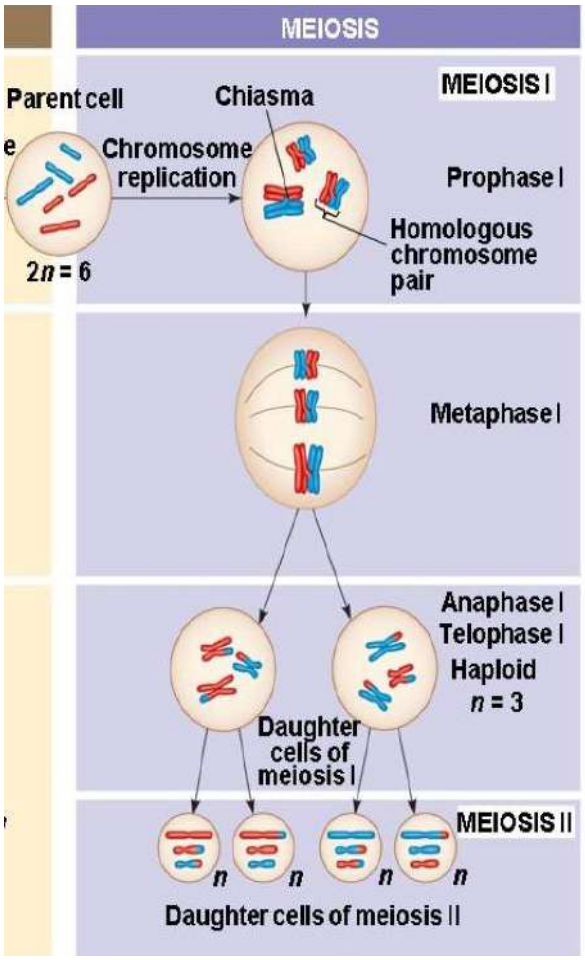
4.0 MEIOSIS

4.1 Meaning of meiosis

Meiosis is a type of cell division in which one diploid parent cell undergoes two successive nuclear divisions to produce four haploid daughter cells, each containing half the chromosome number of the parent cell.

- It is also known as reduction division because it reduces the chromosome number by half.
- It occurs in specialised reproductive cells during the formation of gametes in animals and spores in plants.
- It involves two successive nuclear divisions called meiosis I and meiosis II.
- DNA replicates once before meiosis begins.
- It produces daughter cells that are genetically different from one another due to crossing over and independent assortment.

- It is essential for sexual reproduction because it ensures that the chromosome number is maintained across generations after fertilisation.



Example in human beings:

- Ordinary human body cells contain 46 chromosomes (23 pairs).
- During meiosis, reproductive cells undergo division to produce haploid cells containing 23 chromosomes.
- During fertilisation, a haploid sperm cell (23 chromosomes) fuses with a haploid ovum (23 chromosomes).
- The resulting zygote has 46 chromosomes.

4.2 Where does meiosis occur?

Meiosis occurs in specialised reproductive tissues.

In animals

- In males, it occurs in the seminiferous tubules of the testes during sperm production.
- In females, it occurs in the ovaries during egg formation.
- It produces haploid gametes.

In flowering plants

- In anthers, meiosis occurs in pollen mother cells to produce haploid microspores, which develop into pollen grains.

- In ovules, meiosis occurs in megaspore mother cells to produce haploid megaspores, usually one of which develops into the female gametophyte.

In other plants

- In ferns and mosses, meiosis occurs in structures called sporangia, where haploid spores are produced.

4.3 Interphase before meiosis

Before meiosis begins, the parent cell undergoes interphase.

The following activities take place:

1. The cell grows in size.
2. Cell organelles increase in number.
3. DNA replicates during the S phase.
4. Each chromosome forms two sister chromatids.
5. Proteins required for cell division are produced.
6. The cell prepares for the first meiotic division.

Important: DNA replicates only once before meiosis I. There is no DNA replication between meiosis I and meiosis II.

4.4 Stages of meiosis

Meiosis consists of two successive divisions:

- Meiosis I – Reduction division.
- Meiosis II – Equational division.

4.5 MEIOSIS I – REDUCTION DIVISION

Meiosis I reduces the chromosome number from diploid (2n) to haploid (n).

It consists of four main stages:

1. Prophase I.
2. Metaphase I.
3. Anaphase I.
4. Telophase I.

A. Prophase I

Prophase I is the longest and most complex stage of meiosis.

Main events:

1. Chromatin condenses to form visible chromosomes.
2. Each chromosome consists of two sister chromatids joined at the centromere.
3. Homologous chromosomes come together and pair in a process called synapsis.
4. The paired homologous chromosomes form a structure called a bivalent.

5. A bivalent consists of two homologous chromosomes containing four chromatids and is also called a tetrad.
6. Crossing over occurs between non-sister chromatids of homologous chromosomes.
7. Corresponding DNA segments are exchanged between non-sister chromatids.
8. The points where crossing over occurs become visible as chiasmata.
9. The nuclear envelope breaks down.
10. The nucleolus disappears.
11. Spindle fibres develop and attach to the chromosomes.

Sub-stages of prophase I

Prophase I is further divided into five sub-stages.

1. Leptotene

- Chromosomes begin to condense.
- They appear as long, thin threads.
- Each chromosome has already replicated, although the sister chromatids may not be clearly distinguishable.

2. Zygotene

- Homologous chromosomes begin pairing.
- Pairing is called synapsis.
- A protein structure called the synaptonemal complex helps hold homologous chromosomes together.

3. Pachytene

- Homologous chromosomes are fully paired.
- Crossing over takes place between non-sister chromatids.
- Genetic material is exchanged between homologous chromosomes.
- This produces new combinations of alleles.

4. Diplotene

- Homologous chromosomes begin to separate.
- They remain attached at points called chiasmata.
- Chiasmata indicate sites where crossing over has occurred.

5. Diakinesis

- Chromosomes become highly condensed.
- Chiasmata move towards the ends of chromosomes through a process called terminalisation.
- The nuclear envelope breaks down.
- The spindle apparatus becomes fully organised.

Meaning of crossing over

Crossing over is the exchange of corresponding segments of DNA between non-sister chromatids of homologous chromosomes during prophase I of meiosis.

Significance of crossing over

1. It creates new combinations of alleles.
2. It increases genetic variation among offspring.
3. It contributes to differences between individuals of the same species.
4. It increases the genetic diversity of populations.
5. It provides genetic variation upon which natural selection can act.
6. It helps establish connections between homologous chromosomes during meiosis I.

B. Metaphase I

Main events:

1. Homologous chromosome pairs (bivalents) arrange themselves along the equator of the cell.
2. Each bivalent consists of two homologous chromosomes.
3. Spindle fibres attach to the kinetochores of homologous chromosomes.
4. Homologous chromosomes are oriented towards opposite poles.
5. The orientation of each bivalent is random and independent of the orientation of other bivalents.

Importance of metaphase I

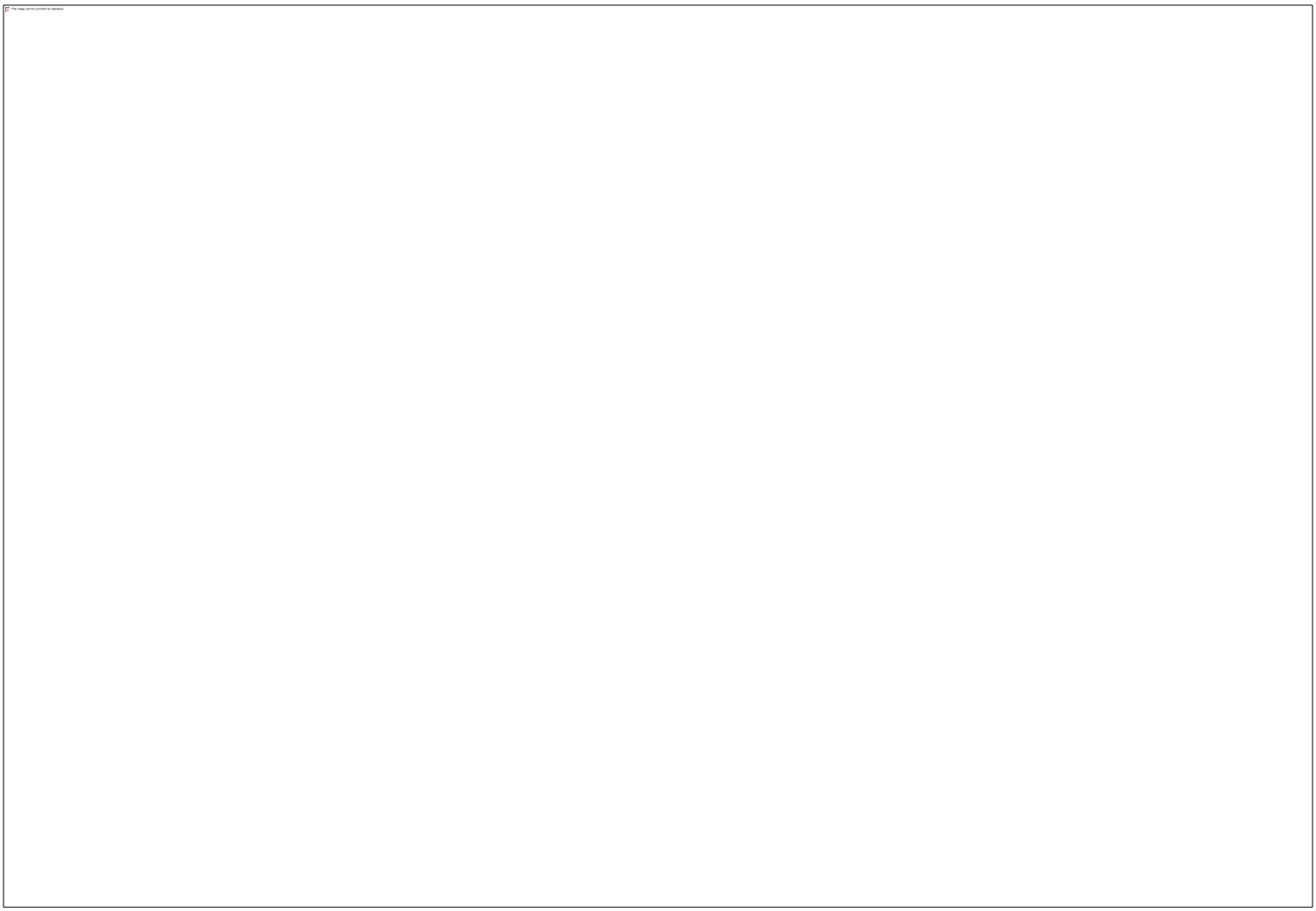
- It ensures proper positioning of homologous chromosomes.
- It contributes to genetic variation through independent assortment.
- It prepares homologous chromosomes for separation during anaphase I.

Meaning of independent assortment

Independent assortment is the random orientation and subsequent separation of homologous chromosome pairs during meiosis I, resulting in different combinations of maternal and paternal chromosomes in daughter cells.

Example:

In a cell with two pairs of homologous chromosomes, the chromosomes may be distributed into daughter cells in different combinations.



C. Anaphase I

Main events:

1. Homologous chromosomes separate from each other.
2. Each homologous chromosome moves towards an opposite pole of the cell.
3. Sister chromatids remain attached at their centromeres.
4. One chromosome from each homologous pair moves to each pole.
5. The chromosome number is reduced by half.

Important distinction: In anaphase I, homologous chromosomes separate, not sister chromatids.

Importance of anaphase I

- It reduces the chromosome number by half.
- It ensures each daughter nucleus receives one chromosome from each homologous pair.
- It helps distribute different combinations of chromosomes.

D. Telophase I

Main events:

1. Homologous chromosomes reach opposite poles.
2. Chromosomes may partially uncoil.

3. Nuclear envelopes may reform around each chromosome set, depending on the organism.
4. Spindle fibres break down.
5. Cytokinesis may occur.
6. Two haploid daughter cells are formed.

Important: Although the cells are haploid, each chromosome still consists of two sister chromatids.

4.6 Interkinesis

Interkinesis is a short period between meiosis I and meiosis II in some organisms.

- The two cells may undergo a brief resting period.
- Some cellular structures reorganise.
- No DNA replication takes place.
- The cells prepare for the second meiotic division.

4.7 MEIOSIS II – EQUATIONAL DIVISION

Meiosis II is the second meiotic division.

- It resembles mitosis in the way sister chromatids separate.
- It occurs without another round of DNA replication.
- It separates sister chromatids.
- It produces four haploid daughter cells from the two cells formed during meiosis I.

The four stages are:

1. Prophase II.
2. Metaphase II.
3. Anaphase II.
4. Telophase II.

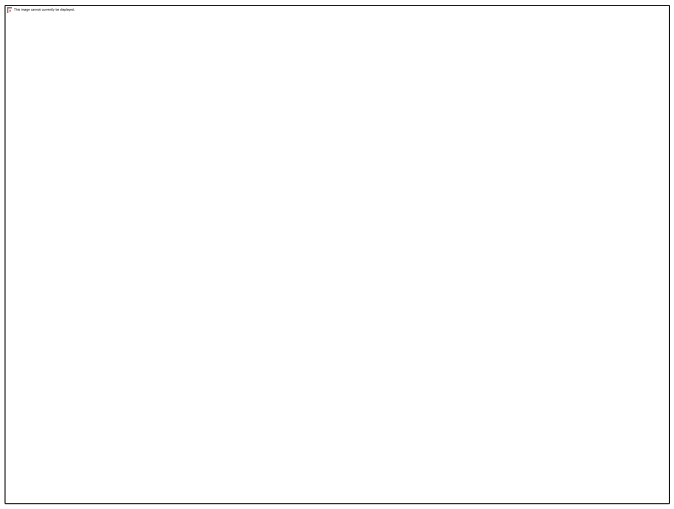
A. Prophase II

Main events:

1. Chromosomes become more condensed if they had partially uncoiled.
2. The nuclear envelope breaks down if it had reformed.
3. New spindle fibres form in each cell.
4. The spindle apparatus becomes organised.

5. Chromosomes prepare for alignment at the equator.

B. Metaphase II



Main events:

1. Chromosomes arrange themselves along the equator of each cell.
2. Spindle fibres attach to the kinetochores of sister chromatids.
3. Sister chromatids become attached to spindle fibres from opposite poles.
4. Chromosomes are positioned for separation.

C. Anaphase II

Main events:

1. Centromeric cohesion is released.
2. Sister chromatids separate.
3. Each chromatid becomes an independent chromosome.
4. Spindle fibres move the chromosomes towards opposite poles.
5. Each pole receives a haploid set of chromosomes.

D. Telophase II

Main events:

1. Chromosomes reach opposite poles.
2. Chromosomes begin to uncoil.
3. Nuclear envelopes reform around each set of chromosomes.
4. Nucleoli reappear.
5. Spindle fibres break down.
6. Cytokinesis occurs.
7. Four haploid daughter cells are produced.

4.8 Summary of meiosis

Stage	Main events
Prophase I	Homologous chromosomes pair; crossing over occurs.
Metaphase I	Homologous pairs line up at the equator.
Anaphase I	Homologous chromosomes separate.
Telophase I	Two haploid cells form.
Prophase II	New spindle apparatus forms.
Metaphase II	Chromosomes line up at the equator.
Anaphase II	Sister chromatids separate.
Telophase II	Four haploid cells form.

4.9 Characteristics of meiosis

1. It involves two successive nuclear divisions.
2. It produces four haploid daughter cells.
3. It reduces the chromosome number by half.
4. DNA replicates once before meiosis I.
5. Homologous chromosomes pair during prophase I.
6. Crossing over occurs during prophase I.
7. Independent assortment occurs during metaphase I.
8. Homologous chromosomes separate during anaphase I.
9. Sister chromatids separate during anaphase II.
10. The resulting cells are genetically varied.
11. It is essential for sexual reproduction.
12. It occurs in specialised reproductive tissues or spore-producing structures.

4.10 Examples of meiosis

In human beings

- Formation of sperm cells in the testes.
- Formation of ova in the ovaries.

In flowering plants

- Formation of microspores in the anthers.
- Formation of megaspores in the ovules.

In other organisms

- Formation of spores in ferns.
- Formation of spores in mosses.
- Formation of reproductive spores in many fungi.

4.11 Significance of meiosis

1. **Formation of haploid gametes:** It produces cells containing half the diploid chromosome number, which is necessary for sexual reproduction.
2. **Maintenance of chromosome number:** It prevents the chromosome number from doubling in every generation when fertilisation occurs.
3. **Genetic variation:** Crossing over produces new combinations of genetic material.
4. **Independent assortment:** Random distribution of homologous chromosomes produces different chromosome combinations.
5. **Evolution:** Genetic variation provides raw material for natural selection and evolution.
6. **Adaptation:** Genetic diversity increases the possibility that some individuals will possess characteristics suitable for changing environments.
7. **Sexual reproduction:** It provides haploid cells that participate in fertilisation.
8. **Species continuity:** It contributes to maintaining the characteristic chromosome number of a species across generations.
9. **Plant reproduction:** It enables the production of spores in plants with alternation of generations.
10. **Genetic diversity:** It reduces genetic uniformity among sexually produced offspring.

5.0 DIFFERENCES BETWEEN MITOSIS AND MEIOSIS

Both mitosis and meiosis are forms of cell division, but they differ in their processes and outcomes.

Feature	Mitosis	Meiosis
Meaning	Division producing two genetically similar daughter cells.	Division producing four haploid daughter cells.
Number of nuclear divisions	One	Two
Number of daughter cells	Two	Usually four
Chromosome number	Maintained	Reduced by half
Parent cell	Usually diploid in the standard examples	Diploid
Daughter cells	Usually genetically similar	Genetically varied
Pairing of homologous chromosomes	Does not occur	Occurs in prophase I
Crossing over	Normally absent	Occurs in prophase I
Independent assortment	Not a characteristic feature	Occurs in metaphase I
Separation in first division	Sister chromatids separate	Homologous chromosomes separate
DNA replication	Once before division	Once before meiosis I
Occurrence	Mainly somatic cells	Specialised reproductive cells
Main function	Growth, repair and replacement	Production of haploid

		reproductive cells
Genetic variation	Does not normally introduce variation	Promotes genetic variation
Example	Skin cell division	Sperm and ovum formation

Important examination point

Do not confuse the separation of chromosomes in the two processes:

- **Mitosis:** Sister chromatids separate during anaphase.
- **Meiosis I:** Homologous chromosomes separate during anaphase I.
- **Meiosis II:** Sister chromatids separate during anaphase II.

6.0 SIGNIFICANCE OF CELL DIVISION IN LIVING ORGANISMS

Cell division is essential for the survival, growth, reproduction and continuity of living organisms.

The significance depends on the type of cell division and the organism involved.

6.1 Growth and development

- Cell division increases the number of cells in an organism.
- It enables a fertilised egg to develop into an embryo.
- It supports the development of tissues, organs and body systems.
- It enables seedlings to develop into mature plants.
- It contributes to an increase in the size and complexity of multicellular organisms.

Examples:

- Growth of a human child.
- Development of maize seedlings.
- Growth of roots and shoots in beans.

6.2 Repair of damaged tissues

- Cell division replaces cells destroyed by injuries.
- It enables damaged tissues to recover.
- It helps close wounds by producing new cells.
- It supports the repair of damaged skin and other tissues.

Examples:

- Healing of cuts on human skin.
- Recovery of damaged plant stems.
- Repair of tissues following minor injuries in livestock.

6.3 Replacement of worn-out cells

- Some body cells have a short lifespan.
- Cell division replaces old, damaged or dead cells.
- It maintains the normal functioning of tissues.

- It helps maintain the protective barriers of the body.

Examples:

- Replacement of skin cells.
- Replacement of cells lining the intestine.
- Production of new blood cells in the bone marrow.

6.4 Asexual reproduction

- Cell division enables organisms to reproduce without the fusion of male and female gametes.
- It allows some organisms to produce offspring rapidly.
- The offspring are usually genetically similar to the parent, apart from mutations.

Examples:

- Binary fission in bacteria.
- Budding in yeast.
- Vegetative propagation in sugarcane.
- Growth of new shoots from potato tubers.

6.5 Sexual reproduction

- Meiosis produces haploid reproductive cells or spores.
- It ensures that gametes contain half the normal chromosome number.
- Fertilisation restores the diploid chromosome number.
- It supports the continuity of sexually reproducing species.

Examples:

- Formation of sperm and ova in humans.
- Formation of spores in ferns.
- Production of pollen-related microspores in flowering plants.

6.6 Genetic variation

- Meiosis produces genetically varied cells.
- Crossing over exchanges genetic material between homologous chromosomes.
- Independent assortment produces different combinations of maternal and paternal chromosomes.
- Genetic variation contributes to differences among offspring.

6.7 Regeneration

- Cell division enables some organisms to replace lost or damaged body parts.
- It supports the formation of new tissues.
- It is especially pronounced in some simple animals and plants.

Examples:

- Regrowth of lost arms in starfish.

- Regeneration of body parts in planarians.
- Development of new shoots from plant cuttings.

6.8 Maintenance of chromosome number

- Mitosis maintains the chromosome number in body cells.
- Meiosis reduces the chromosome number in reproductive cells.
- Fertilisation restores the diploid number.
- These processes help preserve the genetic stability of a species.

6.9 Tissue culture and agriculture

- Cell division enables plant cells to multiply under controlled conditions.
- It allows the production of many plants from small pieces of plant tissue.
- It supports rapid multiplication of desirable crop varieties.
- It helps produce uniform planting materials.

Examples in Kenya:

- Tissue culture bananas.
- Disease-free potato planting materials.
- Commercial multiplication of ornamental plants.
- Propagation of selected horticultural crops.

6.10 Production of blood cells

- Cell division in bone marrow produces new blood cells.
- It helps replace red blood cells, white blood cells and platelets.
- It supports oxygen transport, defence against infection and blood clotting.

6.11 Importance in agriculture and food production

- It enables vegetative propagation of crops.
- It supports the development of new plant tissues.
- It enables the multiplication of desirable crop varieties.
- It helps maintain productive crop populations.
- It supports the development of improved planting materials.

6.12 Importance in medicine and biotechnology

- It supports research into cell growth and development.
- It helps scientists understand cancer and other cell division disorders.
- It is used in the production of tissues for research.
- It supports stem cell research and regenerative medicine.
- It enables laboratory cultivation of cells for scientific investigations.

7.0 TISSUE CULTURE

7.1 Meaning of tissue culture

Tissue culture is a technique in which cells, tissues or small organs are grown under sterile and controlled conditions on a suitable nutrient medium.

In plants, tissue culture is commonly used to produce many new plants from a small piece of plant tissue.

- It is also called in-vitro culture because the process takes place outside the living organism, usually in a laboratory.
- It depends on the ability of plant cells to divide and develop into complete plants under suitable conditions.
- It is widely used in agriculture, horticulture, forestry and biotechnology.
- It allows the rapid multiplication of selected plant varieties.



7.2 Meaning of important terms in tissue culture

1. Explant

- A small piece of plant tissue removed from a parent plant for tissue culture.
- It may be obtained from a shoot tip, leaf, stem, root or other suitable plant part.

2. Culture medium

- A nutrient-rich material on which plant tissues are grown.
- It supplies minerals, sugars, vitamins and other substances required for growth.

3. Aseptic technique

- Procedures used to prevent contamination by bacteria, fungi and other microorganisms.

- It involves sterilising equipment, containers, media and plant materials.

4. Callus

- An unorganised mass of actively dividing plant cells.
- It may develop from an explant under suitable culture conditions.
- It can be induced to form shoots and roots.

5. Plant growth regulators

- Chemical substances that control plant growth and development.
- Auxins and cytokinins are commonly used in plant tissue culture.
- Their relative concentrations influence root and shoot development.

6. Totipotency

- The ability of a single plant cell, under suitable conditions, to develop into a complete plant.

7. Acclimatisation

- The process of gradually adapting tissue-cultured plantlets to external environmental conditions before field planting.

7.3 Principle of tissue culture

Plant tissue culture is based mainly on the principle of cellular totipotency.

- Most living plant cells contain the complete genetic information required to produce an entire plant.
- Under suitable conditions, certain plant cells can divide repeatedly.
- They can develop into specialised tissues and organs.
- They can eventually form a complete plant.

Example:

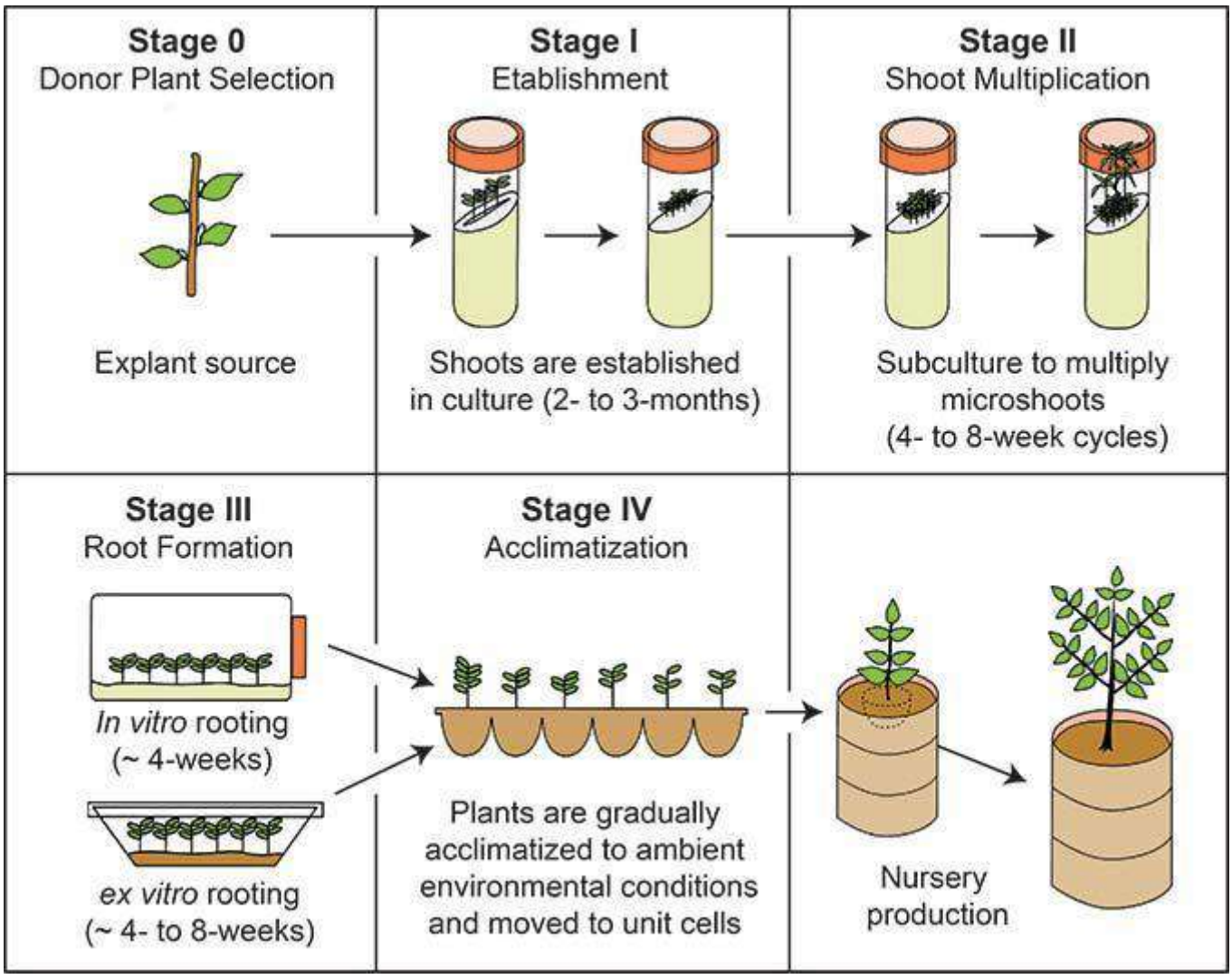
A small shoot tip taken from a healthy banana plant can be cultured in a laboratory to produce many banana plantlets.

7.4 Requirements for successful plant tissue culture

1. **Healthy parent plant:** The source plant should be healthy and preferably free from pests and diseases.
2. **Suitable explant:** A suitable part of the plant must be selected.
3. **Sterile equipment:** Instruments and containers must be sterilised to prevent contamination.
4. **Nutrient medium:** The culture medium must provide essential minerals, sugars and vitamins.
5. **Plant growth regulators:** Appropriate auxins and cytokinins are supplied to regulate growth.
6. **Suitable temperature:** The culture should be maintained at an appropriate temperature.
7. **Adequate light:** Light conditions should suit the stage of development.

8. **Controlled humidity:** Suitable moisture conditions should be maintained.
9. **Clean working environment:** The laboratory should be kept clean to minimise contamination.
10. **Skilled personnel:** Workers should understand aseptic procedures and culture management.

7.5 Steps involved in plant tissue culture



Step 1: Selection of the parent plant

- A healthy and desirable parent plant is selected.
- The plant should possess useful characteristics such as high yield, good fruit quality or disease resistance.
- The selected plant provides the explant.

Step 2: Selection of explant

- A small piece of plant tissue is removed from the parent plant.
- Shoot tips and axillary buds are commonly used.
- The explant should be healthy and suitable for multiplication.

Step 3: Sterilisation

- The explant is cleaned to remove soil and other impurities.
- It is treated using suitable sterilising agents under controlled conditions.

- The culture vessels and instruments are also sterilised.
- This prevents contamination by microorganisms.

Step 4: Preparation of culture medium

- A suitable nutrient medium is prepared.
- It contains mineral salts, sugars, vitamins and plant growth regulators.
- The medium is placed in sterile culture containers.
- It provides the substances required for cell division and development.

Step 5: Inoculation

- The sterilised explant is placed onto the prepared culture medium.
- This is done using sterile instruments.
- The container is sealed to maintain aseptic conditions.

Step 6: Incubation and multiplication

- The cultures are maintained under controlled environmental conditions.
- Cells divide repeatedly through mitosis.
- Multiple shoots may develop.
- The shoots can be separated and transferred to fresh multiplication medium.

Step 7: Root formation

- The developing shoots are transferred to a rooting medium.
- Suitable growth regulator concentrations are provided.
- Roots develop to form complete plantlets.

Step 8: Acclimatisation

- Plantlets are removed from the culture containers.
- They are carefully transferred into suitable growing media.
- They are gradually exposed to normal environmental conditions.
- Humidity and light are adjusted gradually to reduce transplanting stress.

Step 9: Transplanting

- Established plantlets are transferred to nursery conditions or the field.
- They are properly watered and managed.
- They continue growing into mature plants.

7.6 Applications of tissue culture

1. **Rapid multiplication of crops:** Large numbers of plants can be produced from a small amount of plant tissue.
2. **Production of disease-free plants:** Suitable meristem culture techniques can produce planting materials free from certain systemic pathogens.
3. **Conservation of endangered plants:** Rare plant species can be multiplied and conserved.

4. **Production of uniform plants:** Plants produced from the same selected parent may have similar genetic characteristics.
5. **Commercial horticulture:** It is used to multiply ornamental plants such as orchids.
6. **Crop improvement:** It supports plant breeding and biotechnology.
7. **Production of planting materials throughout the year:** It reduces dependence on seasonal availability of conventional planting materials.
8. **Germplasm conservation:** Valuable genetic materials can be maintained under controlled conditions.
9. **Research:** It enables the study of plant growth, development and cell differentiation.
10. **Production of secondary metabolites:** Plant cell cultures can be used to produce useful substances such as pigments and medicinal compounds.

7.7 Examples of crops propagated through tissue culture in Kenya

Examples include:

- Bananas.
- Potatoes.
- Sugarcane.
- Pineapples.
- Strawberries.
- Orchids.
- Various ornamental plants.
- Selected horticultural crops.

7.8 Advantages of tissue culture

1. It produces many plants within a relatively short period.
2. It requires only a small amount of starting plant material.
3. It enables the multiplication of desirable plant varieties.
4. It can produce disease-free planting materials when suitable explants and procedures are used.
5. It allows production throughout the year.
6. It supports the conservation of rare plant species.
7. It produces relatively uniform planting materials when clonal propagation is used.
8. It is useful for plants that produce few viable seeds.
9. It enables rapid distribution of improved planting materials.
10. It supports commercial farming and horticultural enterprises.

7.9 Disadvantages of tissue culture

1. It requires specialised laboratory equipment.

2. It is expensive to establish and maintain.
3. It requires trained personnel.
4. Cultures can easily be contaminated by microorganisms.
5. Some plantlets may experience difficulties during acclimatisation.
6. Somaclonal variation may occur, resulting in differences among regenerated plants.
7. Electricity and controlled environmental conditions may be required.
8. Some species are difficult to regenerate through tissue culture.
9. Large-scale multiplication requires careful management.
10. Disease-free status is not guaranteed unless suitable testing and procedures are followed.

7.10 Economic importance of tissue culture in Kenya

- It supports commercial banana farming.
- It improves the availability of quality planting materials.
- It can increase agricultural productivity.
- It creates employment opportunities in laboratories, nurseries and farms.
- It supports horticultural exports.
- It helps farmers access improved crop varieties.
- It supports food security through reliable planting material production.
- It promotes agricultural research and biotechnology development.

8.0 BUDDING

8.1 Meaning of budding

Budding is a form of asexual reproduction in which a new individual develops as an outgrowth or bud from the body of the parent organism.

- The bud develops through repeated cell division, mainly mitosis.
- It grows while attached to the parent organism.
- In many organisms, the bud eventually separates to form an independent individual.
- The offspring is usually genetically similar to the parent.
- Budding occurs in some unicellular and multicellular organisms.

8.2 Examples of organisms that reproduce through budding

1. Yeast.
2. Hydra.
3. Some sponges.

4. Some corals.
5. Certain colonial organisms.

8.3 Budding in yeast

Yeast is a unicellular fungus commonly found in environments containing sugars, such as fruit surfaces and fermenting materials.

Process of budding in yeast

1. A small outgrowth develops on the surface of the parent yeast cell.
2. The nucleus divides through mitosis.
3. One of the daughter nuclei moves into the developing bud.
4. The bud increases in size.
5. The cytoplasm is distributed between the parent cell and the bud.
6. A partition called a septum forms at the junction in many budding yeasts.
7. The bud separates from the parent cell.
8. The bud develops into a new yeast cell.

Important points

- Budding in yeast is an asexual process.
- It involves mitotic nuclear division.
- The new yeast cell is genetically similar to the parent cell.
- Under favourable conditions, budding can occur rapidly.

8.4 Budding in Hydra

Hydra is a small freshwater animal belonging to the phylum Cnidaria.

Process of budding in Hydra

1. Cells in a particular region of the body wall divide repeatedly through mitosis.
2. A small outgrowth develops on the body surface.
3. The outgrowth gradually increases in size.
4. The developing bud forms a mouth and tentacles.
5. The bud develops structures similar to those of the parent Hydra.
6. When fully developed, it separates from the parent.
7. It becomes an independent Hydra capable of feeding and reproducing.

8.5 Characteristics of budding

1. It is a form of asexual reproduction.
2. It involves one parent organism.

3. It involves repeated mitotic cell division.
4. A bud develops as an outgrowth of the parent.
5. The bud grows while attached to the parent.
6. The bud may eventually detach.
7. The offspring is usually genetically similar to the parent.
8. It does not involve the fusion of gametes.
9. It can occur rapidly under favourable conditions.

8.6 Advantages of budding

1. It enables rapid reproduction.
2. It does not require a mating partner.
3. It requires relatively little energy compared with sexual reproduction.
4. It enables organisms to increase their numbers under favourable conditions.
5. It preserves desirable parental characteristics.
6. It enables organisms such as yeast to reproduce efficiently.
7. In colonial organisms, it supports colony formation.

8.7 Disadvantages of budding

1. It produces little genetic variation among offspring.
2. Offspring may be vulnerable to the same diseases as the parent.
3. Environmental changes may affect genetically similar individuals in similar ways.
4. Overcrowding may occur when reproduction is rapid.
5. It may limit the ability of a population to adapt to changing environmental conditions.

9.0 BINARY FISSION

9.1 Meaning of binary fission

Binary fission is a form of asexual reproduction in which a single parent cell divides into two approximately equal-sized daughter cells.

- It is common in prokaryotic organisms such as bacteria and archaea.
- It usually involves replication of the genetic material followed by separation of the copies.
- The parent cell elongates before division.
- The cell membrane and cell wall grow inwards to form a division septum in many bacteria.
- The parent cell separates into two daughter cells.
- The daughter cells are usually genetically similar, except where mutations occur.

9.2 Binary fission in bacteria

Bacteria are unicellular prokaryotic organisms.

Unlike eukaryotic cells, bacteria do not have a membrane-bound nucleus. Their main genetic material is usually a circular DNA molecule found in a region called the nucleoid.

Steps involved in binary fission

Step 1: Replication of DNA

- The bacterial DNA molecule replicates.
- Two copies of the genetic material are formed.
- Each copy contains the genetic information needed by a daughter cell.

Step 2: Cell elongation

- The bacterial cell increases in length.
- The two DNA copies become positioned towards different regions of the cell.

Step 3: Separation of DNA copies

- The DNA copies become distributed to opposite regions of the elongating cell.
- Cellular proteins help organise chromosome segregation.

Step 4: Formation of septum

- The cell membrane grows inwards at the middle region.
- In many bacteria, new cell wall material is deposited.
- A partition called a septum develops.

Step 5: Separation of daughter cells

- The septum develops fully.
- The parent cell separates into two daughter cells.
- Each daughter cell receives a copy of the genetic material.

9.3 Examples of organisms that reproduce through binary fission

1. *Escherichia coli*.
2. *Salmonella* species.
3. *Bacillus* species.
4. *Streptococcus* species.
5. *Staphylococcus* species.
6. *Amoeba* (through binary fission, a eukaryotic cell division process).
7. *Paramecium* (through transverse binary fission).
8. Some other unicellular protozoans.

Note: Binary fission in bacteria is not mitosis because bacteria do not have a membrane-bound nucleus or a typical eukaryotic mitotic spindle.

9.4 Types of binary fission

Binary fission may be classified according to the plane or direction in which the parent cell divides.

1. Irregular binary fission

- Division takes place without a fixed plane.
- The parent cell divides into two daughter cells.
- It is commonly illustrated using Amoeba.

2. Transverse binary fission

- Division takes place across the transverse axis of the organism.
- The cell divides into two daughter cells across its width.
- It occurs in Paramecium.

3. Longitudinal binary fission

- Division takes place along the longitudinal axis.
- The parent cell divides lengthwise.
- It occurs in some flagellated protozoans, such as Euglena.

9.5 Characteristics of binary fission

1. It is a form of asexual reproduction.
2. It involves one parent cell.
3. It produces two daughter cells.
4. It involves replication of genetic material.
5. It does not involve the fusion of gametes.
6. It usually occurs rapidly under favourable conditions.
7. Daughter cells are generally genetically similar to the parent.
8. It is common in unicellular organisms.
9. It enables rapid population increase.
10. In bacteria, it occurs without mitosis.

9.6 Advantages of binary fission

1. It enables rapid reproduction.
2. It requires only one parent organism.
3. It does not require the formation of gametes.
4. It requires relatively little energy.
5. It enables bacteria to colonise suitable environments rapidly.
6. It allows rapid multiplication under favourable conditions.
7. It preserves successful genetic characteristics in stable environments.

9.7 Disadvantages of binary fission

1. It produces limited genetic variation.
2. Harmful environmental changes may affect many individuals similarly.
3. Harmful mutations may be passed to daughter cells.
4. Rapid reproduction may cause overcrowding.
5. Competition for nutrients and space may increase.
6. The population may be vulnerable to diseases or antibiotics if individuals have similar susceptibility.

10.0 DIFFERENCES BETWEEN BUDDING AND BINARY FISSION

Budding and binary fission are both forms of asexual reproduction, but they differ in how new individuals develop.

Feature	Budding	Binary fission
Meaning	New individual develops as an outgrowth of the parent.	Parent cell divides into two daughter cells.
Number of offspring	Usually one bud develops at a time.	Usually two daughter cells are formed.
Size of offspring	The bud is initially smaller than the parent.	Daughter cells are usually approximately equal in size.
Method of formation	An outgrowth develops on the parent.	The parent cell divides across a division plane.
Cytoplasmic division	Cytoplasm is distributed unequally in many examples.	Cytoplasm is generally distributed approximately equally.
Parent cell	Usually remains intact after the bud separates.	The original parent cell ceases to exist as a separate individual.
Examples	Yeast and Hydra.	Bacteria, Amoeba and Paramecium.
Nuclear division	Mitosis in eukaryotic examples such as yeast and Hydra.	DNA replication and segregation; bacterial binary fission does not involve mitosis.
Growth of offspring	The bud grows while attached to the parent.	Daughter cells begin growing after separation.
Site of development	A specific region of the parent forms a bud.	Division occurs across the parent cell.

Similarities between budding and binary fission

1. Both are forms of asexual reproduction.
2. Both involve only one parent organism.
3. Both produce new individuals.
4. Both do not require the fusion of gametes.
5. Both can occur rapidly under favourable conditions.
6. Both generally produce genetically similar offspring.

7. Both contribute to population increase.
8. Both depend on the accurate transmission of genetic material.

Differences between haploid and diploid cells

Feature	Haploid cell	Diploid cell
Meaning	Contains one set of chromosomes.	Contains two sets of chromosomes.
Symbol	n	2n
Chromosome sets	One	Two
Homologous pairs	Does not contain homologous pairs as pairs.	Usually contains homologous chromosome pairs.
Examples in humans	Sperm and ovum	Skin cells, muscle cells and other ordinary body cells
Chromosome number in humans	23	46
Formation	Usually produced through meiosis	Usually produced through fertilisation or mitotic division

12.4 Chromosome number during mitosis and meiosis

Understanding chromosome number is important when studying cell division.

Consider a hypothetical organism with four chromosomes (2n = 4).

During mitosis:

- Parent cell: 4 chromosomes.
- After DNA replication: 4 replicated chromosomes, each consisting of two sister chromatids.
- After mitosis and cytokinesis: Two daughter cells, each with 4 chromosomes.

During meiosis:

- Parent cell: 4 chromosomes.
- After DNA replication: 4 replicated chromosomes.
- After meiosis I: Two haploid cells, each with 2 replicated chromosomes.
- After meiosis II: Four haploid cells, each with 2 chromosomes.

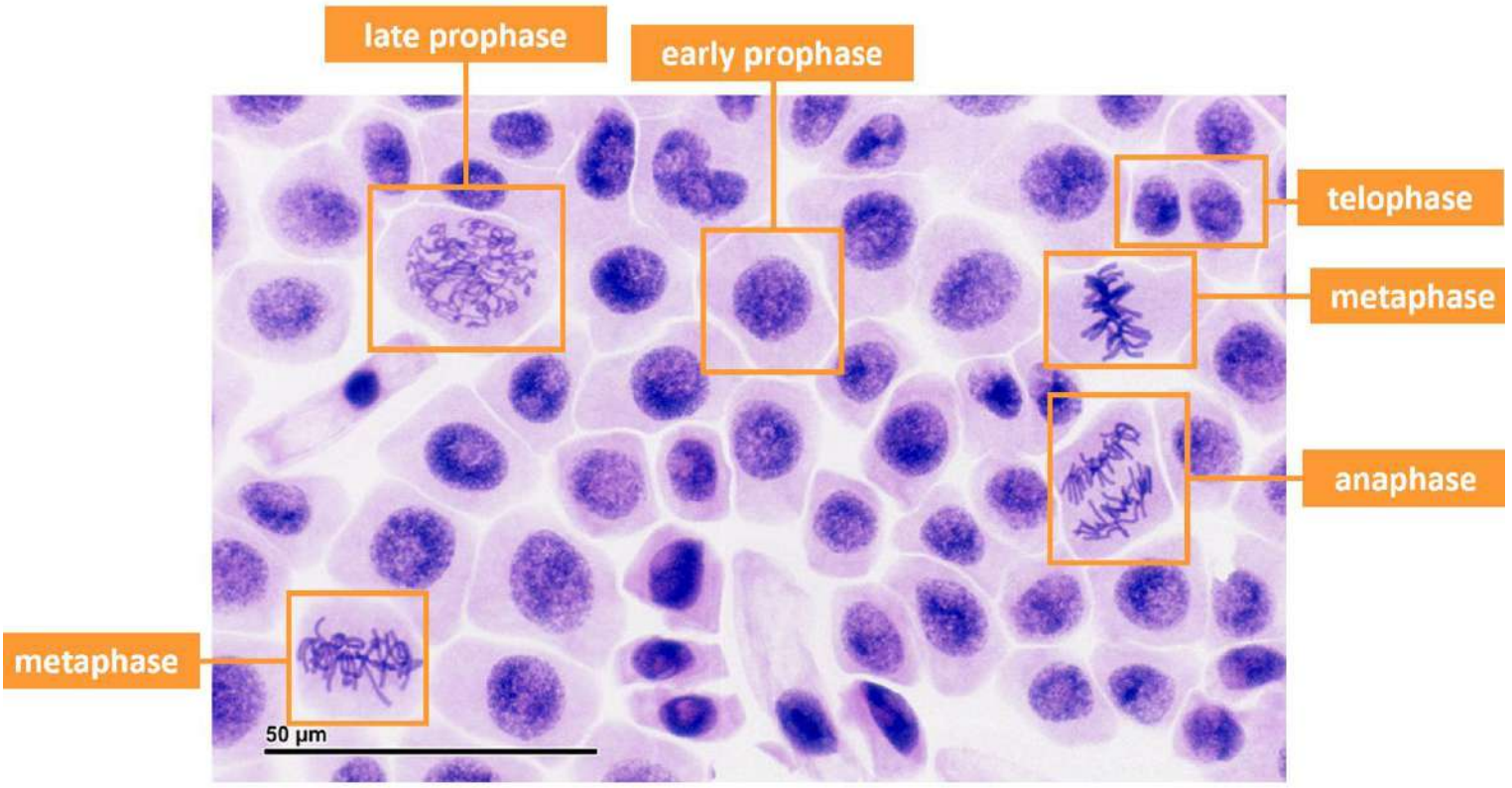
Remember:

- DNA replication doubles the amount of DNA but does not double the chromosome number.
- In meiosis I, homologous chromosomes separate.
- In meiosis II, sister chromatids separate.
- At the end of meiosis, four haploid cells are produced.

13.0 PRACTICAL ACTIVITIES AND LEARNING EXPERIENCES

The following activities can be carried out by Grade 11 learners to develop practical skills, critical thinking, collaboration and problem-solving abilities.

Activity 1: Observing mitosis in onion root tips



Aim: To observe different stages of mitosis in actively dividing plant cells.

Materials required

- Onion bulb.
- Microscope.
- Microscope slides.
- Cover slips.
- Forceps.
- Scalpel or razor blade.
- Aceto-orcein or suitable chromosome stain.
- Dropper.
- Watch glass.
- Blotting paper.

Procedure

1. Place an onion bulb in water and allow roots to grow.
2. Cut a small section of the root tip.
3. Place the root tip on a clean microscope slide.
4. Add a suitable chromosome stain.
5. Gently tease the root tip to separate the cells.
6. Carefully place a cover slip over the specimen.
7. Gently squash the preparation to spread the cells into a thin layer.

8. Observe under low power and then high power of the microscope.
9. Identify cells at different stages of mitosis.
10. Draw and label the observed stages.

Expected observations

- Interphase cells have an intact nucleus with uncondensed chromatin.
- Prophase cells show condensed chromosomes.
- Metaphase cells show chromosomes arranged at the equator.
- Anaphase cells show chromatids moving towards opposite poles.
- Telophase cells show two developing nuclei.

Conclusion

Onion root tips contain actively dividing meristematic cells, making them suitable for observing mitosis.

Activity 2: Modelling mitosis using materials

Aim: To demonstrate the stages of mitosis using locally available materials.

Materials

- Different coloured wool or strings.
- Plasticine or modelling clay.
- Cardboard.
- Marker pens.
- Scissors.

Procedure

1. Form chromosomes using different coloured wool.
2. Use two colours to represent homologous chromosomes.
3. Model chromosome condensation during prophase.
4. Arrange chromosomes along the equator during metaphase.
5. Separate sister chromatids towards opposite poles during anaphase.
6. Form two nuclei during telophase.
7. Show cytokinesis by dividing the model into two daughter cells.
8. Label all the structures.

Expected learning outcome

Learners should be able to explain chromosome movement and the distribution of genetic material during mitosis.

Activity 3: Modelling meiosis

Aim: To demonstrate the processes of meiosis I and meiosis II.

Procedure

1. Use different coloured strings to represent maternal and paternal homologous chromosomes.
2. Model pairing of homologous chromosomes during prophase I.
3. Demonstrate crossing over by exchanging corresponding string segments.
4. Arrange homologous chromosome pairs at the equator.
5. Separate homologous chromosomes during anaphase I.
6. Form two haploid cells.
7. Model the second meiotic division.
8. Separate sister chromatids.
9. Produce four haploid daughter cells.
10. Compare the genetic composition of the resulting cells.

Conclusion

Meiosis involves two successive divisions and produces four haploid cells with genetic variation.

Activity 4: Observing yeast budding

Aim: To observe budding in yeast.

Materials

- Baker's yeast.
- Warm water.
- Sugar.
- Microscope.
- Slides.
- Cover slips.
- Dropper.
- Beaker.

Procedure

1. Mix a small quantity of yeast with warm water.
2. Add a small quantity of sugar.
3. Allow the mixture to stand for a short period.
4. Place a drop of the mixture on a microscope slide.
5. Cover with a cover slip.
6. Observe under a microscope.
7. Identify yeast cells with developing buds.
8. Draw and label the observed cells.

Observation

Some yeast cells may show small outgrowths attached to larger parent cells.

Conclusion

Yeast reproduces asexually through budding.

Activity 5: Investigating tissue culture

Aim: To understand how tissue culture is used in plant propagation.

Procedure

1. Visit a tissue culture laboratory, nursery or agricultural research centre where possible.
2. Observe the equipment used in tissue culture.
3. Identify explants and culture containers.
4. Observe plantlets at different developmental stages.
5. Identify the rooting and acclimatisation stages.
6. Discuss the benefits of tissue culture to Kenyan farmers.
7. Prepare a report on the importance of tissue culture in agriculture.

Expected learning outcomes

Learners should be able to:

- Explain the principle of tissue culture.
- Identify the materials required.
- Describe the steps involved.
- Explain its importance in crop production.

14.0 APPLICATION OF CELL DIVISION

Cell division has many practical applications in Kenya, particularly in agriculture, health, biotechnology and environmental conservation.

Sector	Application of cell division	Example
Agriculture	Multiplication of planting materials	Tissue culture bananas
Horticulture	Rapid multiplication of ornamental plants	Orchids
Crop production	Vegetative propagation	Sugarcane cuttings
Livestock production	Growth and repair of tissues	Wound healing in cattle
Human health	Replacement of blood cells	Bone marrow activity
Medicine	Understanding cancer development	Study of uncontrolled mitosis
Forestry	Propagation of desirable trees	Tissue-cultured tree seedlings
Conservation	Multiplication of rare plants	Endangered indigenous plant species

Food production	Multiplication of yeast	Bread making
Biotechnology	Laboratory cultivation of cells	Plant cell culture

Case study: Tissue culture banana farming in Kenya

A farmer in Kisii County wants to establish a commercial banana farm. The farmer needs many healthy and uniform banana seedlings within a short period.

The farmer decides to purchase tissue-cultured banana plantlets from a reputable supplier.

Questions

1. Explain why tissue culture is suitable for the farmer.
2. Identify four advantages of tissue-cultured banana seedlings.
3. Explain the role of mitosis in the production of the seedlings.
4. Why should the farmer acclimatise the plantlets before transplanting them to the field?
5. State three factors the farmer should consider when selecting a tissue culture laboratory.

Expected learning points

- Tissue culture allows rapid multiplication of banana plants.
- Large numbers of plantlets can be produced from a small explant.
- Suitable procedures can provide healthy, disease-free planting materials.
- Mitosis increases the number of cells in developing plantlets.
- Acclimatisation prepares plantlets for external environmental conditions.
- The farmer should consider laboratory reputation, quality of planting materials and disease-testing procedures.

15.0 SUMMARY OF KEY TERMS

Term	Meaning
Cell division	Process by which a parent cell divides to form daughter cells.
Chromosome	DNA and protein structure carrying hereditary information.
Chromatin	DNA and associated proteins in a less condensed form.
Gene	A section of DNA containing genetic information.
Centromere	Region that holds sister chromatids together.
Chromatid	One of the two copies of a replicated chromosome.
Mitosis	Nuclear division producing two genetically similar nuclei.

Meiosis	Two successive nuclear divisions producing haploid cells.
Cytokinesis	Division of the cytoplasm.
Synapsis	Pairing of homologous chromosomes during prophase I.
Bivalent	A pair of homologous chromosomes associated during meiosis I.
Tetrad	A paired structure consisting of four chromatids.
Crossing over	Exchange of DNA segments between non-sister chromatids.
Chiasma	Visible point of attachment between homologous chromosomes where crossing over has occurred.
Haploid	Having one set of chromosomes.
Diploid	Having two sets of chromosomes.
Binary fission	Asexual reproduction in which one cell divides into two daughter cells.
Budding	Asexual reproduction through development of an outgrowth on the parent.
Tissue culture	Growing cells or tissues under controlled conditions on a suitable medium.
Explant	Small piece of plant tissue used to initiate a tissue culture.
Callus	Mass of relatively undifferentiated plant cells.
Totipotency	Ability of a cell to develop into a complete organism under suitable conditions.
Acclimatisation	Gradual adaptation of tissue-cultured plants to external conditions.
Tumour	Abnormal mass of cells resulting from excessive cell multiplication.
Metastasis	Spread of cancer cells from the original site to other parts of the body.

REVISION QUESTIONS

Revision and assessment

The following questions assess knowledge, understanding, application, analysis, practical skills and problem-solving abilities in line with Competency-Based Education.

SECTION A: MULTIPLE-CHOICE QUESTIONS

Choose the correct answer from the alternatives provided.

1. Which one of the following best describes cell division?

A. Movement of substances across a cell membrane.

B. Process through which a parent cell produces daughter cells.

C. Process through which cells obtain nutrients.

D. Breakdown of food substances to release energy.

2. The main function of chromosomes in a cell is to:

A. Produce energy for cellular activities.

B. Transport nutrients around the cell.

C. Carry hereditary information.

D. Control water movement.

3. Which structure holds sister chromatids together?

A. Nucleolus.

B. Centromere.

C. Ribosome.

D. Nuclear envelope.

4. Which one of the following is responsible for packaging DNA into chromosomes?

A. Cellulose.

B. Starch.

C. Histone proteins.

D. Glycogen.

5. During which phase of mitosis do sister chromatids separate and pull apart toward opposite poles of the cell?

A. Prophase B. Metaphase

C. Anaphase D. Telophase

6. Which one of the following is the correct sequence of stages of mitosis?

A. Metaphase, prophase, telophase, anaphase.

B. Prophase, metaphase, anaphase, telophase.

C. Anaphase, metaphase, prophase, telophase.

D. Telophase, anaphase, metaphase, prophase.

7. During which stage of mitosis do chromosomes arrange themselves along the equator of the cell?

A. Prophase.

B. Metaphase.

C. Anaphase.

D. Telophase.

8. Separation of sister chromatids during mitosis occurs in:

A. Prophase.

B. Metaphase.

C. Anaphase.

D. Telophase.

9. Which structure develops between two daughter cells during cytokinesis in plant cells?

A. Cleavage furrow.

B. Cell plate.

C. Centromere.

D. Spindle fibre.

10. Which one of the following is the main outcome of mitosis?

A. Four haploid cells.

B. Two genetically similar daughter cells.

C. Four genetically different cells.

D. Two haploid gametes.

11. Meiosis is described as reduction division because it:

A. Doubles the chromosome number.

B. Reduces the chromosome number by half.

C. Produces identical daughter cells.

D. Increases the size of the parent cell.

12. Pairing of homologous chromosomes occurs during:

A. Prophase I. B. Metaphase II.

C. Anaphase II. D. Telophase I.

13. Crossing over takes place between:

A. Sister chromatids of the same chromosome.

B. Non-sister chromatids of homologous chromosomes.

C. Two unrelated chromosomes.

D. Chromosomes and spindle fibres.

14. The point at which crossing over occurs between homologous chromosomes is called:

A. Centromere.

B. Kinetochore.

C. Chiasma.

D. Telomere.

15. During anaphase I of meiosis:

A. Sister chromatids separate.

B. Homologous chromosomes separate.

C. DNA replication occurs.

D. Chromosomes disappear.

16. Which stage of meiosis is responsible for the separation of sister chromatids?

A. Anaphase I.

B. Metaphase I.

C. Anaphase II.

D. Prophase I.

17. How many daughter cells are normally produced at the end of meiosis?

A. One.

B. Two.

C. Three.

D. Four.

18. A human cell containing 46 chromosomes undergoes meiosis. Each resulting haploid cell normally contains:

A. 12 chromosomes. B. 23 chromosomes.

C. 46 chromosomes. D. 92 chromosomes.

19. Which one of the following contributes to genetic variation during meiosis?

A. Cytokinesis only.

B. Crossing over and independent assortment.

C. Cell enlargement only.

D. Formation of the nuclear envelope.

20. Which one of the following is a major function of meiosis?

A. Repair of damaged skin.

B. Production of haploid reproductive cells.

C. Replacement of worn-out body cells.

D. Increase in the size of body cells.

21. Tissue culture is based mainly on the ability of plant cells to:

A. Carry out photosynthesis only.

B. Develop into a complete plant under suitable conditions.

C. Absorb water without dividing.

D. Produce flowers immediately.

22. A small piece of plant tissue used to initiate tissue culture is called:

A. Callus.

B. Explant.

C. Embryo.

D. Spore.

23. The unorganised mass of actively dividing cells formed during some tissue culture procedures is called:

A. Zygote.

B. Callus.

C. Gamete.

D. Pollen grain.

24. Which combination of plant hormones is commonly used in tissue culture?

A. Insulin and glucagon.

B. Auxins and cytokinins.

C. Oestrogen and progesterone.

D. Adrenaline and thyroxine.

25. Which one of the following is an advantage of tissue culture?

A. It always produces genetically different plants.

B. It requires large quantities of planting material.

C. It enables rapid multiplication of desirable plants.

D. It prevents all forms of plant disease under every condition.

26. Budding in yeast involves:

A. Fusion of male and female gametes.

B. Development of a small outgrowth on the parent cell.

C. Formation of four haploid cells.

D. Separation of homologous chromosomes.

27. Which one of the following organisms reproduces through budding?

A. Hydra. B. Maize.

C. Human being. D. Earthworm.

28. Binary fission is commonly observed in:

A. Bacteria.

B. Mammals.

C. Flowering plants.

D. Birds.

29. Which one of the following correctly describes binary fission in bacteria?

A. A parent cell produces a small bud.

B. A parent cell divides into two daughter cells.

C. Four haploid cells are formed.

D. Male and female gametes fuse.

30. Which one of the following correctly differentiates budding from binary fission?

A. Budding produces an outgrowth while binary fission divides the parent cell into two daughter cells.

B. Budding occurs only in bacteria while binary fission occurs only in plants.

C. Budding involves meiosis while binary fission involves fertilisation.

D. Budding produces four cells while binary fission produces one cell.

SECTION B: STRUCTURED QUESTIONS

31. Cell division and chromosomes

a) Define cell division. (2 marks)

b) State four functions of chromosomes in living organisms. (4 marks)

c) Describe the organisation of DNA into chromosomes. (5 marks)

d) Explain the functions of the following chromosome structures:

i. Centromere. (2 marks)

ii. Telomere. (2 marks)

iii. Kinetochore. (2 marks)

e) Distinguish between haploid and diploid cells. (3 marks)

32. Mitosis

a) Define mitosis. (2 marks)

b) State four characteristics of mitosis. (4 marks)

c) Describe the events that take place during:

i. Prophase. (4 marks)

ii. Metaphase. (3 marks)

iii. Anaphase. (3 marks)

iv. Telophase. (3 marks)

d) Explain how cytokinesis takes place in plant cells. (4 marks)

e) State five biological processes in which mitosis is important. (5 marks)

33. Meiosis

a) Define meiosis. (2 marks)

b) State four characteristics of meiosis. (4 marks)

c) Describe the events that occur during prophase I of meiosis. (6 marks)

d) Explain the significance of:

i. Crossing over. (3 marks)

ii. Independent assortment. (3 marks)

e) Distinguish between anaphase I and anaphase II. (4 marks)

f) Explain why meiosis is important in sexually reproducing organisms. (4 marks)

34. Comparison of mitosis and meiosis

a) State six differences between mitosis and meiosis. (6 marks)

b) Explain why mitosis is important in multicellular organisms. (5 marks)

c) Explain how meiosis contributes to genetic variation. (4 marks)

d) A diploid organism has 20 chromosomes in each body cell. Determine the number of chromosomes found in:

i. Each daughter cell after mitosis. (1 mark)

ii. Each daughter cell after meiosis. (1 mark)

iii. The zygote formed after fertilisation of two normal haploid gametes. (1 mark)

35. Tissue culture

a) Define tissue culture. (2 marks)

b) Explain the principle of totipotency in plant tissue culture. (3 marks)

c) Define the following terms:

i. Explant. (2 marks)

ii. Callus. (2 marks)

iii. Acclimatisation. (2 marks)

d) Describe the stages involved in the production of banana seedlings through tissue culture. (8 marks)

e) Explain five advantages of tissue culture to Kenyan farmers. (5 marks)

f) State four challenges associated with tissue culture. (4 marks)

36. Budding and binary fission

a) Define budding. (2 marks)

b) Describe the process of budding in yeast. (5 marks)

c) Describe the process of binary fission in bacteria. (5 marks)

d) Give three examples of organisms that reproduce through budding. (3 marks)

e) Give four examples of organisms that reproduce through binary fission. (4 marks)

f) State six differences between budding and binary fission. (6 marks)

37. Significance of cell division

a) Explain six ways in which cell division contributes to the survival of living organisms. (12 marks)

b) Explain the importance of cell division in:

i. Agriculture. (3 marks)

ii. Medicine. (3 marks)

iii. Biotechnology. (3 marks)

c) Explain why uncontrolled cell division may be harmful to human beings. (4 marks)

38. Application and problem-solving

A farmer in Nakuru County intends to establish a commercial banana farm. The farmer has been advised to use tissue-cultured banana seedlings instead of conventional suckers.

a) Explain the meaning of tissue culture. (2 marks)

b) State four advantages of using tissue-cultured banana seedlings. (4 marks)

c) Explain the role of mitosis in the production of tissue-cultured banana seedlings. (3 marks)

d) Explain why the plantlets must undergo acclimatisation before field planting. (3 marks)

e) Identify four factors that may cause contamination during tissue culture. (4 marks)

f) Explain how tissue culture can contribute to food security in Kenya. (4 marks)

39.

A Grade 11 learner observed cells from an onion root tip under a microscope.

a) Explain why an onion root tip is suitable for observing mitosis. (2 marks)

b) Name the stage of mitosis in which:

i. Chromosomes line up along the equator. (1 mark)

ii. Sister chromatids separate. (1 mark)

iii. Two new nuclei form. (1 mark)

c) State four precautions to observe when preparing an onion root tip slide. (4 marks)

d) Explain why a chromosome stain is used during the preparation. (2 marks)

e) Draw and label a cell undergoing metaphase. (4 marks)

40.

A bacterial population in a suitable nutrient medium increases rapidly in number.

a) Name the process responsible for bacterial reproduction. (1 mark)

b) Describe the stages involved in the process. (5 marks)

c) Explain three conditions that may favour rapid bacterial multiplication. (3 marks)

d) Explain why bacterial binary fission is not classified as mitosis. (3 marks)

e) State three factors that may limit bacterial population growth. (3 marks)

PROJECT-BASED LEARNING TASKS

These tasks encourage learners to apply biological knowledge to real-life situations.

Task 1: Agricultural investigation

Visit a local nursery or agricultural institution that produces tissue-cultured seedlings.

Prepare a report showing:

1. The meaning of tissue culture.
2. Materials used in the process.
3. Steps involved in producing seedlings.
4. Benefits of tissue culture to farmers.
5. Challenges experienced during production.
6. Recommendations for improving tissue culture in Kenya.

Task 2: Model construction

Working in groups, construct models showing:

- The structure of a chromosome.
- Stages of mitosis.
- Stages of meiosis.
- Budding in yeast.
- Binary fission in bacteria.

Use locally available materials such as cardboard, coloured paper, clay, wool, strings and recyclable materials.

Present your models to the class and explain the processes represented.

Task 3: Community awareness

Prepare an educational poster explaining the importance of cell division in:

- Human growth.
- Wound healing.
- Plant propagation.
- Food production.
- Genetic variation.
- Medical research.

Task 4: Research and discussion

Research why genetic variation is important in crop production and livestock breeding in Kenya.

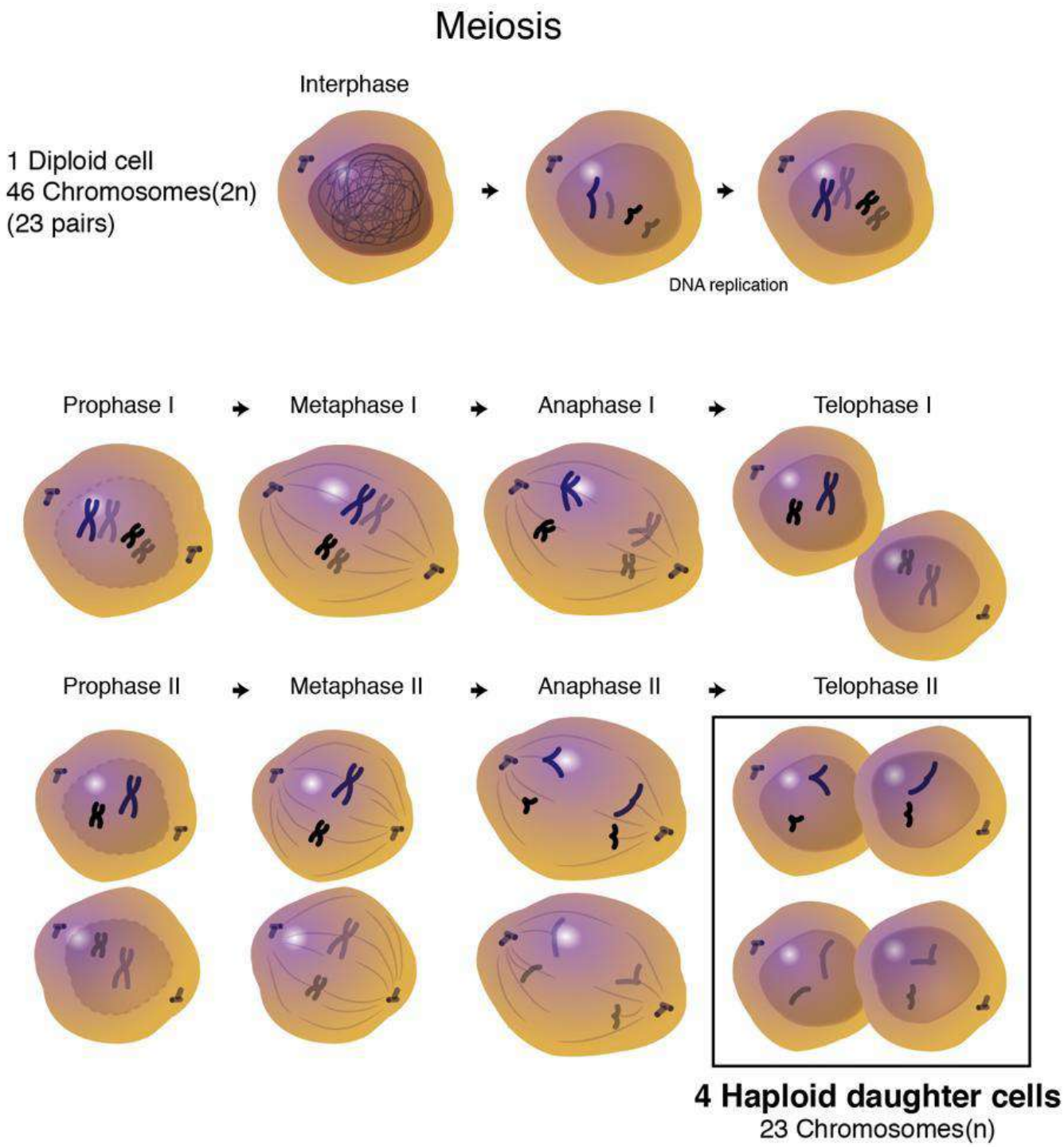
Discuss how meiosis contributes to genetic variation and how farmers may benefit from genetically diverse populations.

18.0 KEY TAKEAWAYS

Remember these important facts for assessment and examination.

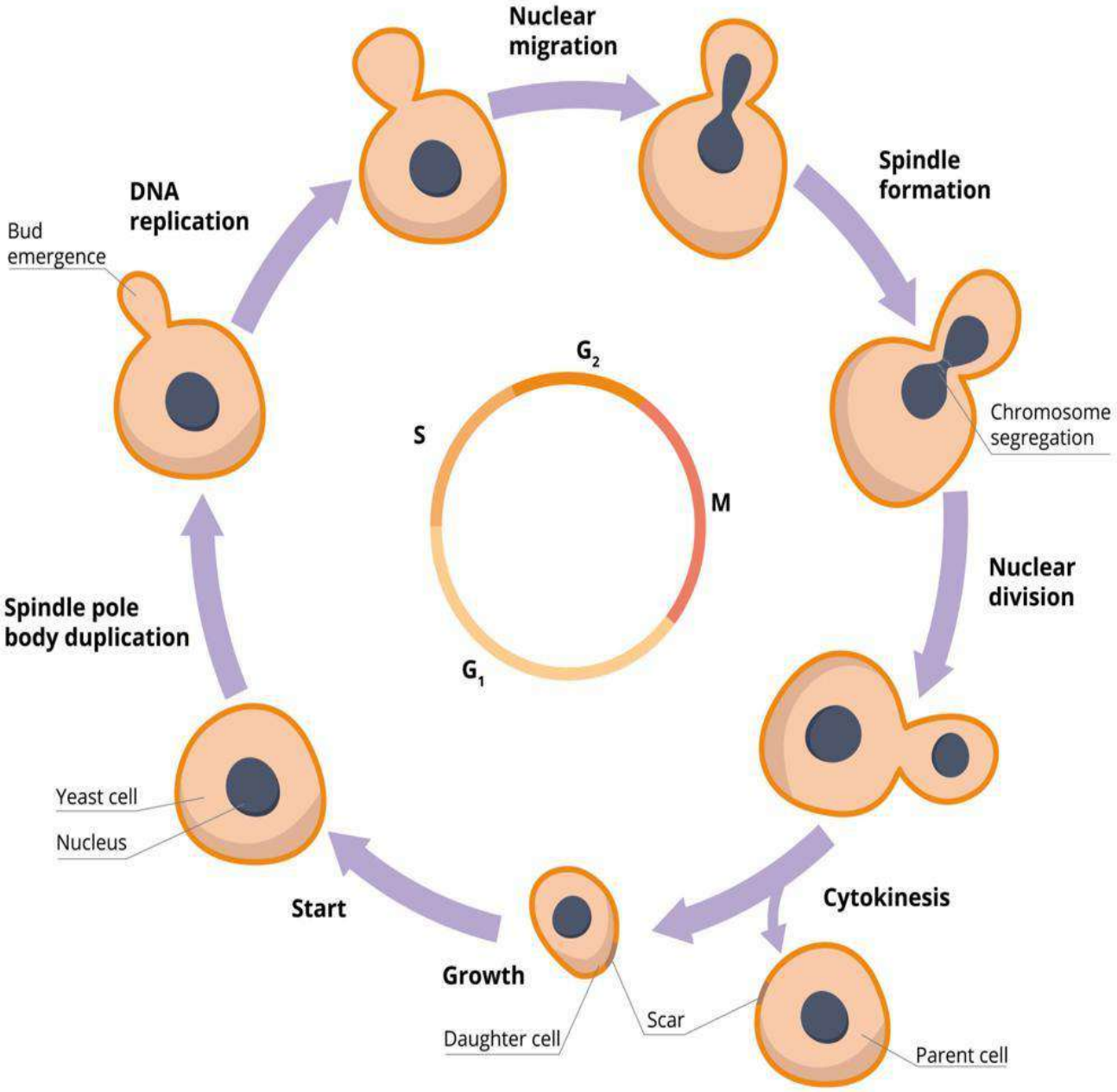
MITOSIS

One nuclear division produces two genetically similar daughter cells with the same chromosome number as the parent.



MEIOSIS

Two nuclear divisions produce four haploid cells and contribute to genetic variation.



BUDDING

A new individual develops as an outgrowth of the parent organism.

BINARY FISSION

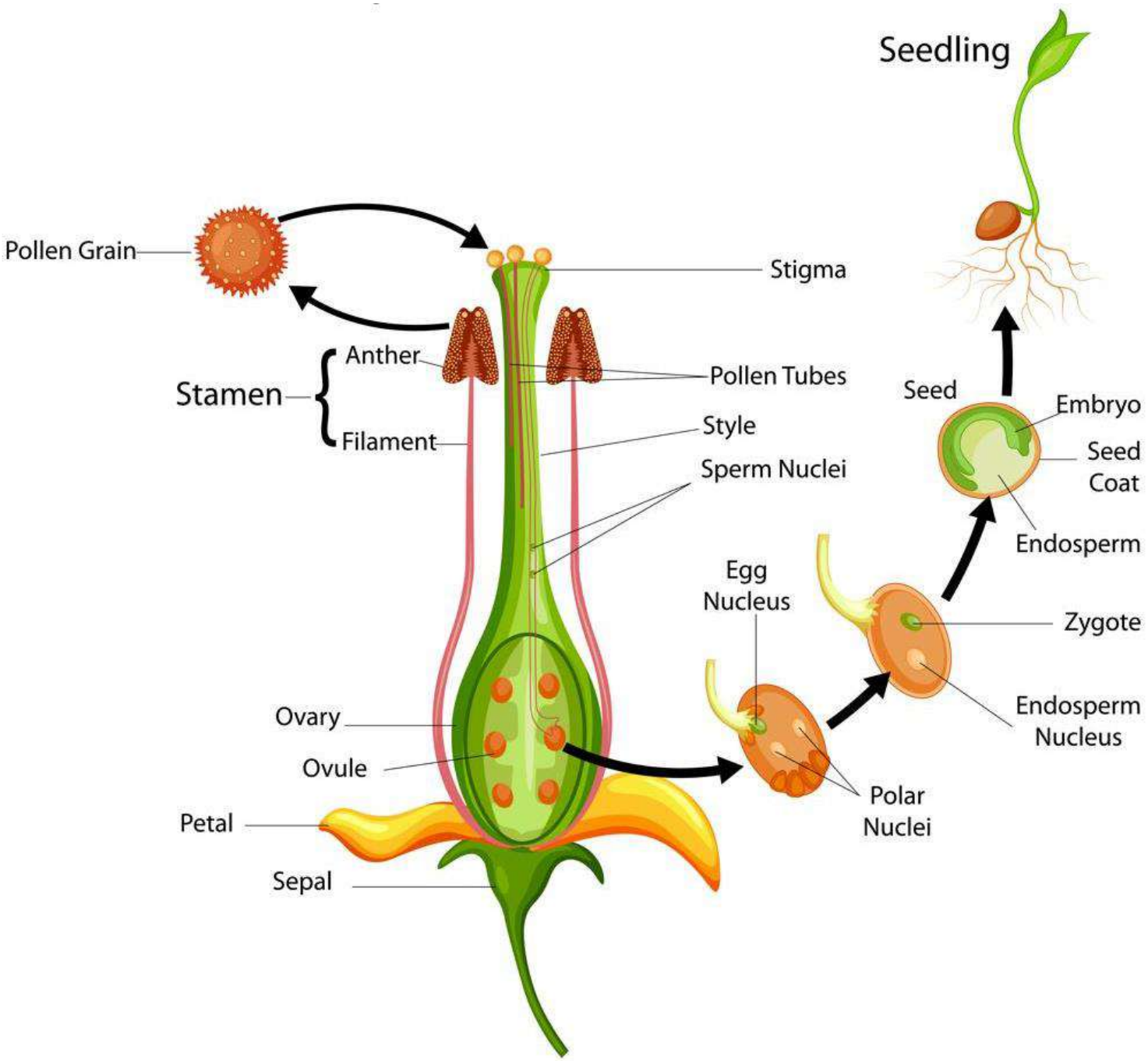
One parent cell divides into two daughter cells.

TISSUE CULTURE

Cells or tissues are grown under controlled laboratory conditions to produce new plant material.

STRAND 2.0: ANATOMY AND PHYSIOLOGY OF PLANTS

SUB-STRAND 2.1: REPRODUCTION IN PLANTS



1.0 INTRODUCTION TO REPRODUCTION IN PLANTS

1.1 Meaning of reproduction

Reproduction is the biological process through which living organisms produce new individuals of their own kind.

- It is one of the basic characteristics of living organisms.
- It ensures the continuation of plant species from one generation to another.
- It enables plants to colonise new environments.
- It contributes to the maintenance of plant populations.
- It facilitates the transmission of hereditary characteristics from parent plants to offspring.
- It may involve one parent or two reproductive gametes, depending on the type of reproduction.

Plants reproduce through two main methods:

1. Asexual reproduction.
2. Sexual reproduction.

1.2 Types of reproduction in plants

A. Asexual reproduction

Asexual reproduction is a type of reproduction in which a new plant develops from a single parent without the fusion of male and female gametes.

Characteristics:

1. It usually involves one parent plant.
2. It does not involve fertilisation.
3. It generally involves mitotic cell division.
4. Offspring are usually genetically similar to the parent plant.
5. It enables rapid multiplication of plants.
6. It can occur naturally or through artificial methods.
7. It is common in many flowering plants and some non-flowering plants.

Examples:

- Irish potato through tubers.
- Ginger through rhizomes.
- Onion through bulbs.
- Strawberries through runners.
- Sugarcane through stem cuttings.
- Ferns through spores.

B. Sexual reproduction

Sexual reproduction is the process through which male and female gametes fuse to form a diploid zygote, which develops into a new organism.

Characteristics:

1. It involves the production of male and female gametes.
2. It involves meiosis during the formation of reproductive cells or spores in the plant life cycle.
3. It involves pollination in seed-producing plants.
4. Fertilisation involves fusion of male and female gametes.
5. It results in the formation of a zygote.
6. It usually produces genetically varied offspring.
7. It contributes to genetic variation within plant populations.

Examples:

- Maize.

- Beans.
- Peas.
- Sunflower.
- Mango.
- Avocado.
- Tomatoes.

1.3 Differences between asexual and sexual reproduction in plants

Feature	Asexual reproduction	Sexual reproduction
Number of parents	Usually one	Usually involves male and female gametes
Gametes	Not involved	Involved
Fertilisation	Absent	Present
Cell division	Mainly mitosis	Meiosis and mitosis occur at different stages
Genetic variation	Usually limited	Usually considerable
Speed	Often faster	Often takes longer
Offspring	Usually genetically similar to parent	Usually genetically varied
Examples	Potato tubers, ginger rhizomes	Maize, beans, mango

2.0 ASEXUAL REPRODUCTION IN PLANTS

2.1 Meaning of asexual reproduction

Asexual reproduction in plants is the formation of new plants from vegetative parts or reproductive structures of a parent plant without the fusion of gametes.

It occurs through two major methods:

1. Sporulation.
2. Vegetative propagation.

2.2 SPORULATION

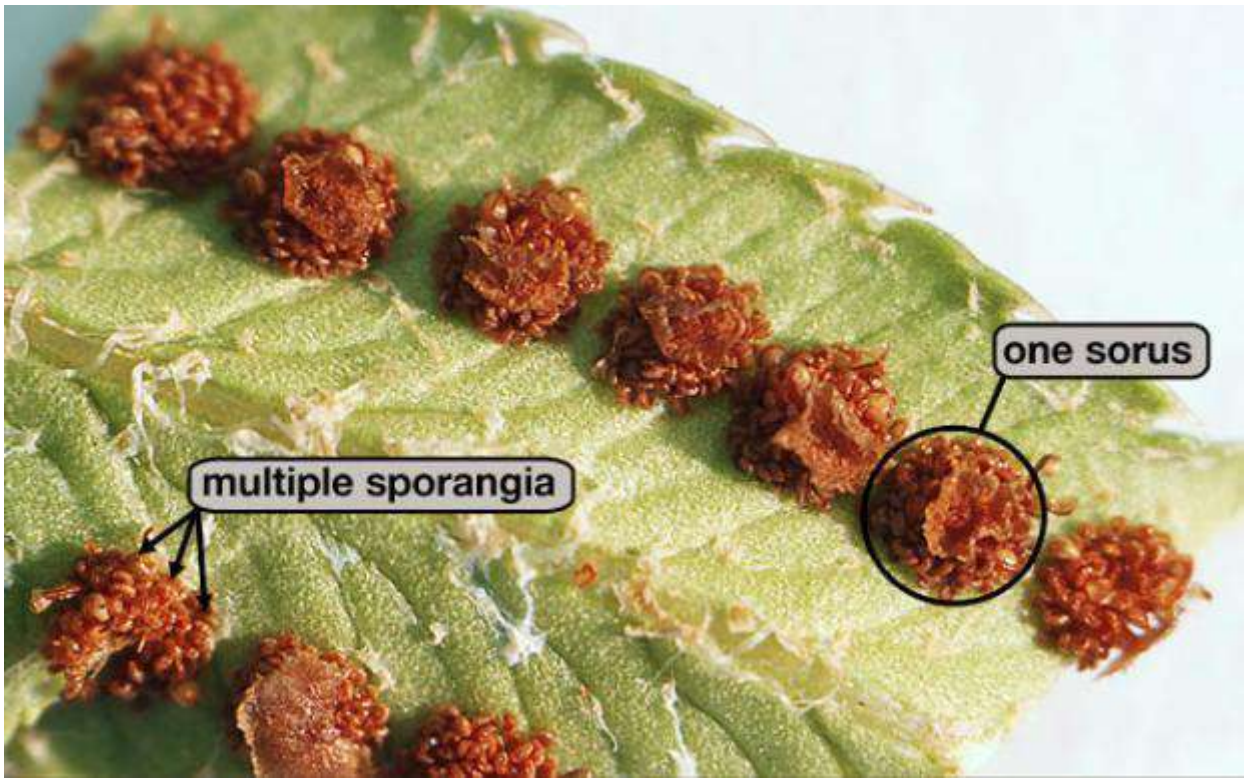
Meaning of sporulation

Sporulation is a reproductive process in which plants or plant-like organisms produce specialised reproductive cells called spores that can develop into new individuals under favourable conditions.

- Spores are usually small and lightweight.
- They are often produced in specialised structures called sporangia.
- They can be dispersed by wind, water or other agents.
- They may remain dormant during unfavourable conditions.
- Under suitable conditions, they germinate and develop into new organisms.

Examples of organisms that reproduce through spores include:

1. Ferns.
2. Mosses.
3. Liverworts.
4. Some fungi, although fungi are not classified as plants.



2.2.1 Spore formation in ferns

Ferns are non-flowering vascular plants that reproduce through spores.

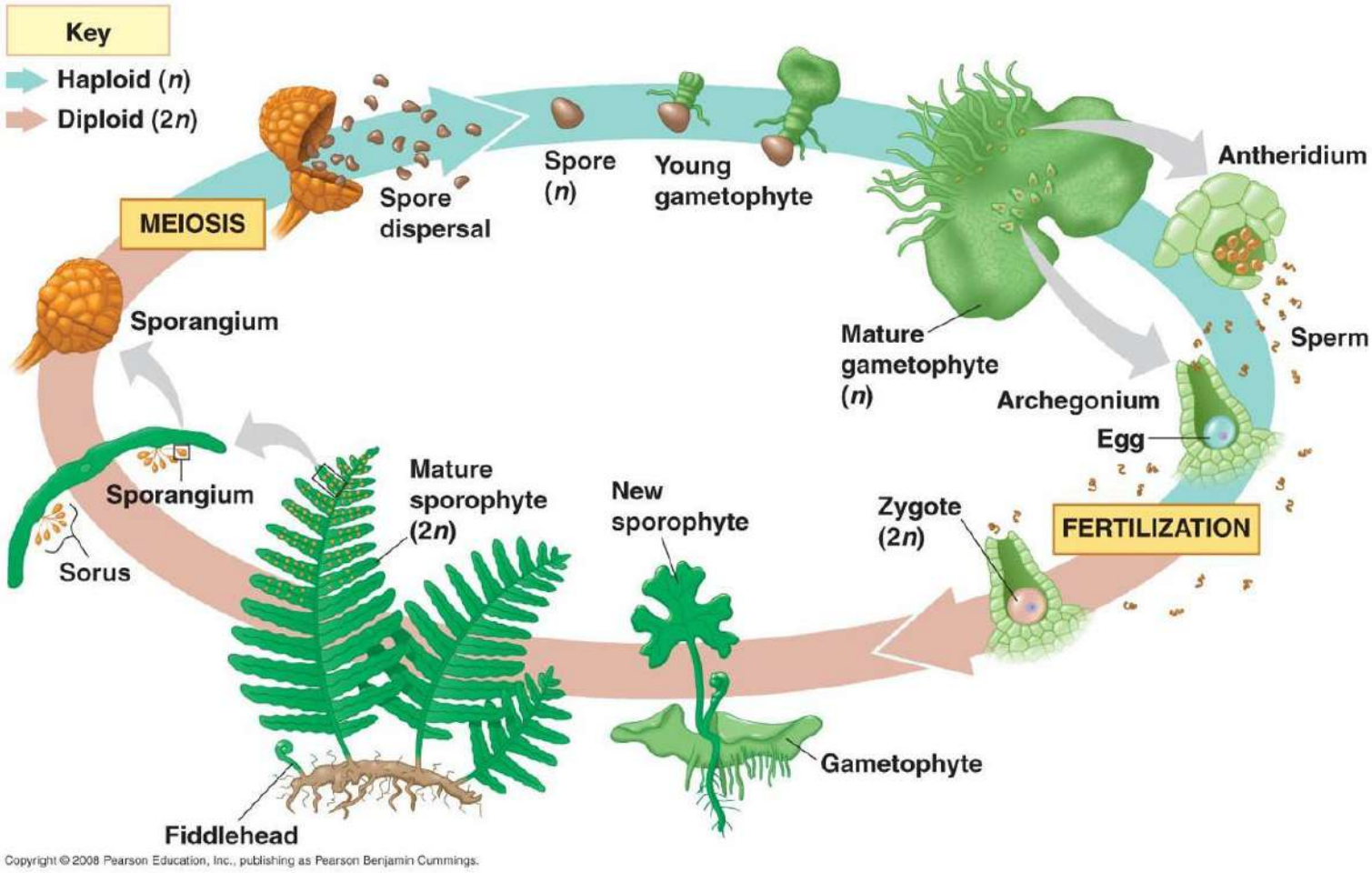
Main structures involved

- Fronds: The leaves of ferns.
- Sori: Clusters of sporangia usually found on the underside of fertile fronds.
- Sporangia: Structures in which spores are produced.
- Spores: Reproductive units that develop into gametophytes.

Process of spore formation in ferns

1. Mature fern plants develop specialised fertile fronds.
2. Clusters of sporangia called sori develop on the underside of the fronds in many fern species.
3. Spore mother cells inside the sporangia undergo meiosis.
4. Haploid spores are produced.
5. When mature, the sporangia release the spores.
6. The spores are dispersed, mainly by wind.

7. Under favourable conditions, a spore germinates to form a small, heart-shaped structure called a prothallus.
8. The prothallus is the gametophyte generation.
9. It produces male and female reproductive structures.
10. Fertilisation takes place when a male gamete fuses with a female gamete in the presence of water.
11. The resulting zygote develops into a young sporophyte.
12. The young sporophyte grows into a mature fern plant.



Important biological point

Fern reproduction involves alternation of generations:

- The sporophyte is diploid and produces haploid spores through meiosis.
- The gametophyte is haploid and produces gametes through mitosis.
- Fertilisation restores the diploid chromosome number.

2.2.2 Spore formation in mosses

Mosses are small, non-flowering plants that commonly grow in moist and shaded environments.

Examples include mosses growing on damp walls, rocks, tree trunks and moist soil in forested areas.

Process of reproduction in mosses

1. A mature moss gametophyte produces male and female reproductive structures.
2. The male reproductive structure, called an antheridium, produces sperm cells.
3. The female reproductive structure, called an archegonium, contains an egg cell.
4. In the presence of water, sperm cells swim towards the egg cell.
5. A sperm cell fuses with the egg cell to form a diploid zygote.
6. The zygote develops into a sporophyte attached to the female gametophyte.
7. The sporophyte develops a stalk called a seta and a capsule.
8. Spore mother cells in the capsule undergo meiosis.
9. Haploid spores are produced.
10. Mature spores are released and dispersed.
11. Under favourable conditions, spores germinate and develop into new moss gametophytes.

2.2.3 Importance of sporulation

1. It enables the reproduction of ferns and mosses.
2. It facilitates the dispersal of organisms to new habitats.
3. It enables organisms to colonise suitable environments.
4. Spores may survive unfavourable conditions through dormancy.
5. It supports the continuation of plant life cycles.
6. It enables the production of large numbers of reproductive units.
7. It supports the establishment of vegetation in suitable habitats.
8. It contributes to the maintenance of biodiversity.

2.2.4 Conditions necessary for spore germination

- Adequate moisture.
- Suitable temperature.
- Adequate oxygen for respiration.
- Suitable environmental conditions.
- A suitable substrate for establishment and growth.

3.0 VEGETATIVE PROPAGATION

3.1 Meaning of vegetative propagation

Vegetative propagation is a form of asexual reproduction in which new plants develop from vegetative parts of the parent plant, such as roots, stems or leaves.

- It does not involve the formation or fusion of gametes.
- It mainly involves mitotic cell division.
- It produces offspring that are usually genetically similar to the parent.
- It enables farmers to multiply desirable crop varieties.

- It may occur naturally or through artificial methods.

3.2 Types of vegetative propagation

Vegetative propagation is classified into:

A. Natural vegetative propagation

This occurs when plants produce new individuals naturally from specialised vegetative structures.

Examples:

- Runners.
- Rhizomes.
- Bulbs.
- Tubers.
- Corms.
- Offshoots.
- Suckers.
- Vegetative plantlets.

B. Artificial vegetative propagation

This involves human intervention to produce new plants from vegetative parts.

Examples:

- Cuttings.
- Grafting.
- Layering.
- Budding.
- Division.
- Micropropagation or tissue culture.

4.0 SPECIALISED VEGETATIVE STRUCTURES

Specialised vegetative structures are modified plant organs that enable plants to reproduce asexually, survive unfavourable conditions and store food.

They may be modified stems, roots or leaves.

The main structures include:

1. Runners.
2. Bulbs.
3. Rhizomes.
4. Tubers.
5. Offshoots.
6. Corms.

7. Suckers.
8. Vegetative plantlets.

4.1 RUNNERS

Meaning of runners

Runners are horizontal, slender stems that grow along the surface of the soil and produce new plants at their nodes.

- They are also called stolons when they are above-ground horizontal stems.
- They grow away from the parent plant.
- Their nodes produce adventitious roots and shoots.
- The developing plantlets can eventually become independent plants.
- They enable plants to spread over large areas.

Structure of runners

1. **Parent plant:** The original plant from which the runner develops.
2. **Horizontal stem:** The slender stem that grows along the soil surface.
3. **Nodes:** Points along the runner where leaves, roots or buds develop.
4. **Internodes:** Sections of the stem between adjacent nodes.
5. **Adventitious roots:** Roots that develop from the nodes.
6. **Young shoots:** New aerial structures that develop at the nodes.

Process of vegetative propagation through runners

1. The parent plant produces a horizontal stem.
2. The stem grows along the surface of the soil.
3. Nodes develop along the runner.
4. Adventitious roots emerge from the nodes.
5. New shoots and leaves develop at the nodes.
6. The young plants obtain nutrients from the parent initially.
7. The young plants become established.
8. The runner may eventually die or be severed, leaving independent plants.

Examples of plants that reproduce through runners

- Strawberries.
- Lawn grasses such as couch grass.
- Spider plants (through stolon-like structures).

Importance of runners

1. They enable rapid vegetative propagation.

2. They help plants spread across the soil surface.
3. They enable the establishment of new plants near the parent.
4. They help maintain desirable characteristics.
5. They are useful in establishing lawns and ground cover.
6. They enable strawberry farmers to multiply selected varieties.

4.2 BULBS

Meaning of bulbs

A bulb is a specialised underground shoot consisting of a short, compressed stem surrounded by thick, fleshy leaf bases that store food.

- It is mainly an underground storage and reproductive structure.
- The fleshy leaves store food, especially carbohydrates.
- The short stem forms the basal plate.
- Adventitious roots develop from the basal plate.
- Lateral buds may develop into daughter bulbs.

Structure of a bulb

1. Basal plate

- A short, flattened stem at the base of the bulb.
- It bears roots and buds.

2. Fleshy scale leaves

- These are thickened leaf bases.
- They store food for future growth.

3. Terminal bud

- It is located at the centre of the bulb.
- It develops into the main shoot.

4. Lateral buds

- These are buds that develop on the sides of the bulb.
- They may develop into daughter bulbs.

5. Adventitious roots

- These develop from the basal plate.
- They absorb water and mineral salts from the soil.

6. Protective outer scales

- They protect the inner fleshy leaves.
- They reduce physical damage and water loss.

Process of reproduction through bulbs

1. The parent plant develops an underground bulb.
2. Food is stored in the fleshy scale leaves.
3. Lateral buds develop on the basal plate.
4. The buds grow into daughter bulbs.
5. Under favourable conditions, daughter bulbs produce shoots and roots.
6. The daughter bulbs may eventually become independent plants.

Examples of plants with bulbs

- Onion.
- Garlic.
- Lily.
- Daffodil.
- Tulip.

Importance of bulbs

1. They enable vegetative propagation.
2. They store food for future growth.
3. They help plants survive unfavourable seasons.
4. They enable rapid regeneration when favourable conditions return.
5. They are important in the production of horticultural crops.
6. They help preserve desirable characteristics in cultivated varieties.

4.3 RHIZOMES

Meaning of rhizomes

Rhizomes are horizontal underground stems that grow beneath the soil surface and produce roots and aerial shoots from their nodes.

- They are modified stems rather than roots.
- They have nodes and internodes.
- They possess buds that can develop into new shoots.
- Adventitious roots arise from the nodes.
- They may store food and enable plants to survive unfavourable conditions.
- They enable vegetative propagation.

Characteristics of rhizomes

1. They grow horizontally beneath the soil.
2. They possess distinct nodes and internodes.
3. They have scale leaves.

4. They possess buds at the nodes.
5. They produce adventitious roots.
6. They may store food.
7. They can produce new aerial shoots.

Process of reproduction through rhizomes

1. The parent plant develops an underground horizontal stem.
2. The rhizome grows horizontally through the soil.
3. Buds develop at its nodes.
4. Adventitious roots grow from the nodes.
5. Under suitable conditions, buds develop into aerial shoots.
6. Sections of the rhizome containing viable buds can develop into independent plants.

Examples of plants with rhizomes

- Ginger.
- Turmeric.
- Canna lily.
- Bamboo.
- Some grasses.
- Some ferns.

Importance of rhizomes

1. They enable vegetative propagation.
2. They store food for future growth.
3. They help plants survive unfavourable conditions.
4. They enable rapid spread of plants.
5. They support the regeneration of aerial shoots.
6. They are useful in crop multiplication.
7. They provide useful food products, such as ginger and turmeric.

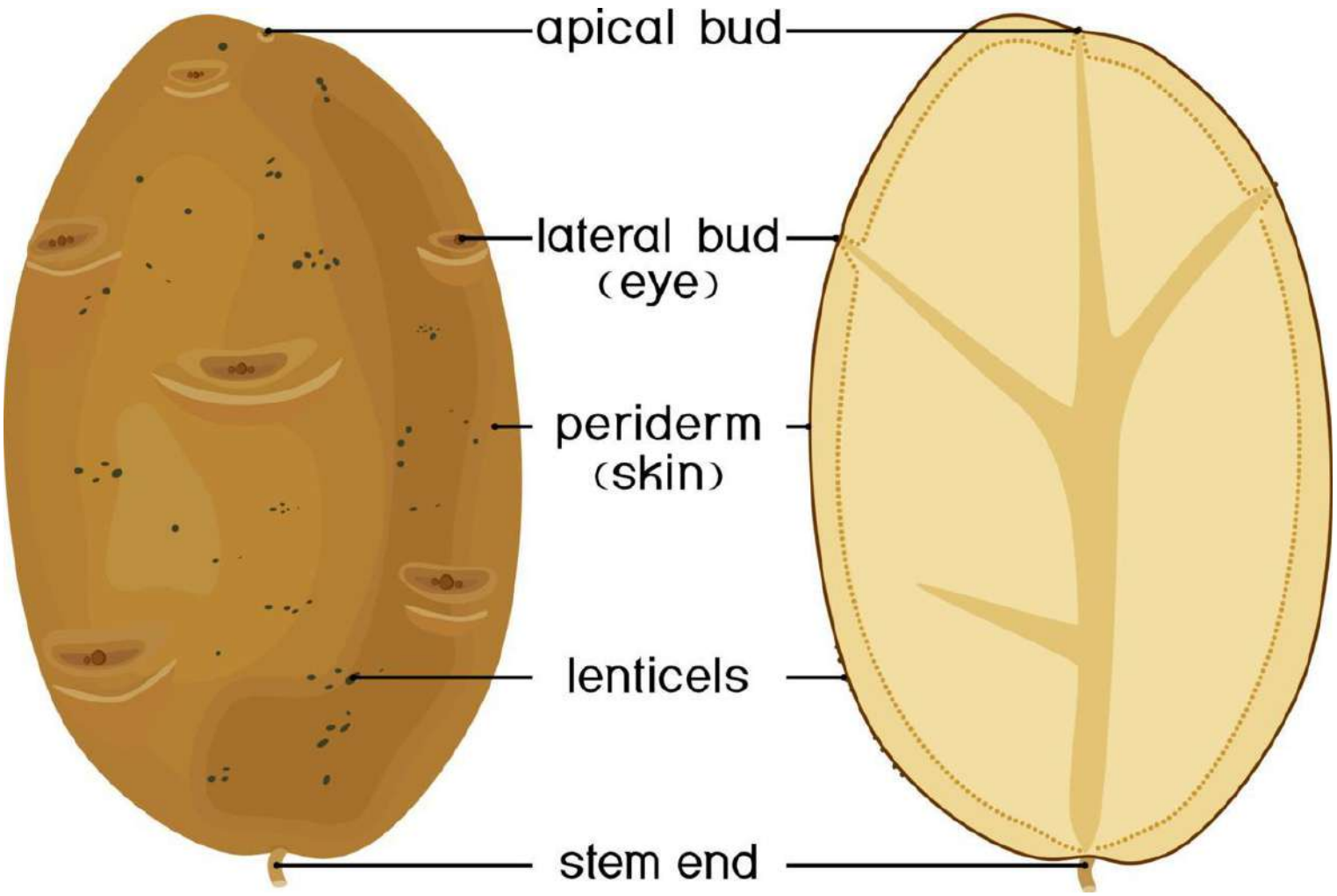
Important examination point: Ginger is a modified underground stem because it has nodes, internodes, scale leaves and buds. It is not a root.

4.4 TUBERS

Meaning of tubers

Tubers are swollen underground storage structures that contain stored food and possess buds capable of developing into new plants.

In Irish potato, the tuber is a modified underground stem.



Structure of a potato tuber

1. Eyes

- These are small depressions found on the surface of a potato tuber.
- Each eye contains one or more buds.
- The buds can develop into new shoots.

2. Buds

- These are growing points found in the eyes.
- They develop into new stems under suitable conditions.

3. Periderm

- This is the protective outer covering of the tuber.
- It reduces water loss and protects against injury and infection.

4. Lenticels

- These are small openings on the surface.
- They allow gaseous exchange.

5. Stolon scar

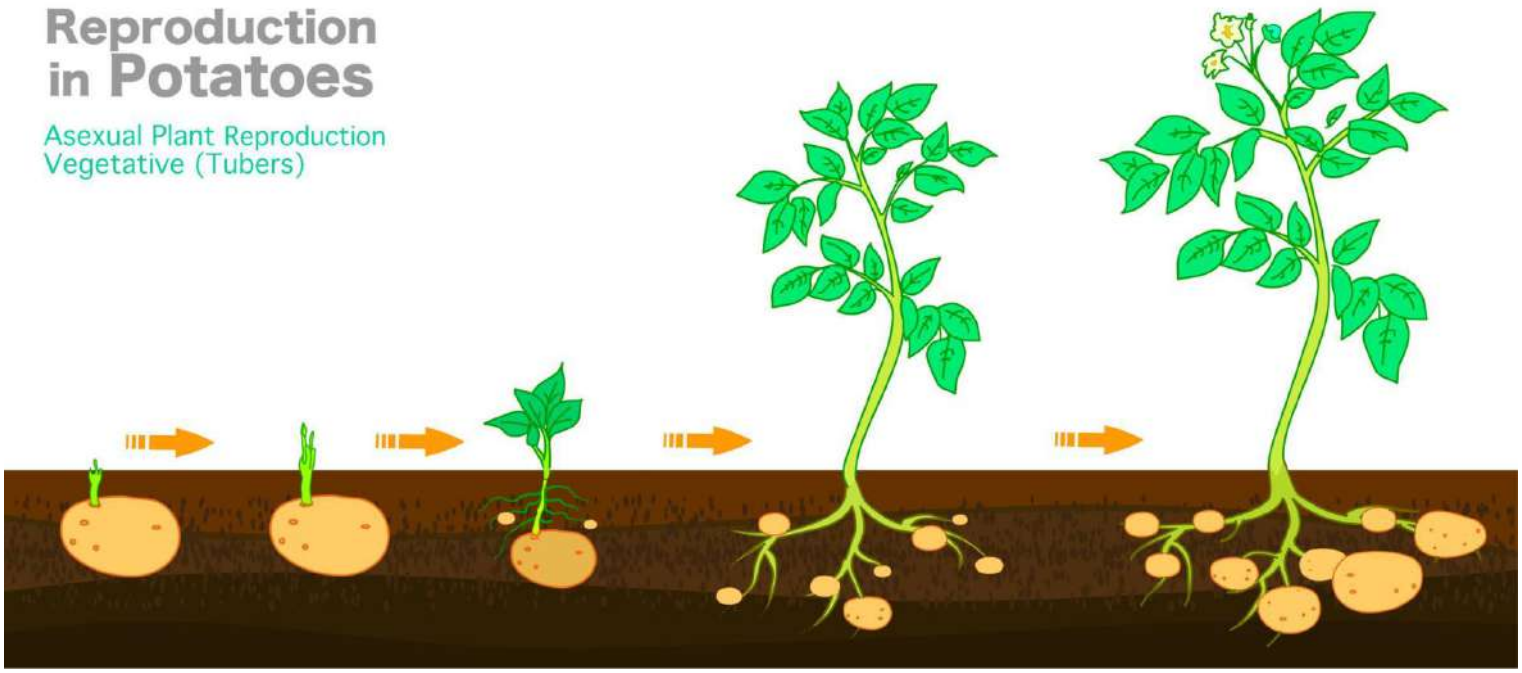
- This is the region where the tuber was attached to the underground stem or stolon.

6. Stored food

- The tuber contains stored starch.
- This provides energy for sprouting and early growth.

Process of reproduction through potato tubers

1. A potato plant develops underground stolons.
2. The tips of the stolons swell due to the accumulation of stored food.
3. The swollen structures develop into tubers.
4. Buds develop on the tuber surface.
5. Under suitable conditions, the buds sprout.
6. New shoots and roots develop.
7. A new potato plant is established.



Examples of plants that reproduce through tubers

- Irish potato.
- Yam, through underground stem tubers.
- Jerusalem artichoke.

Importance of tubers

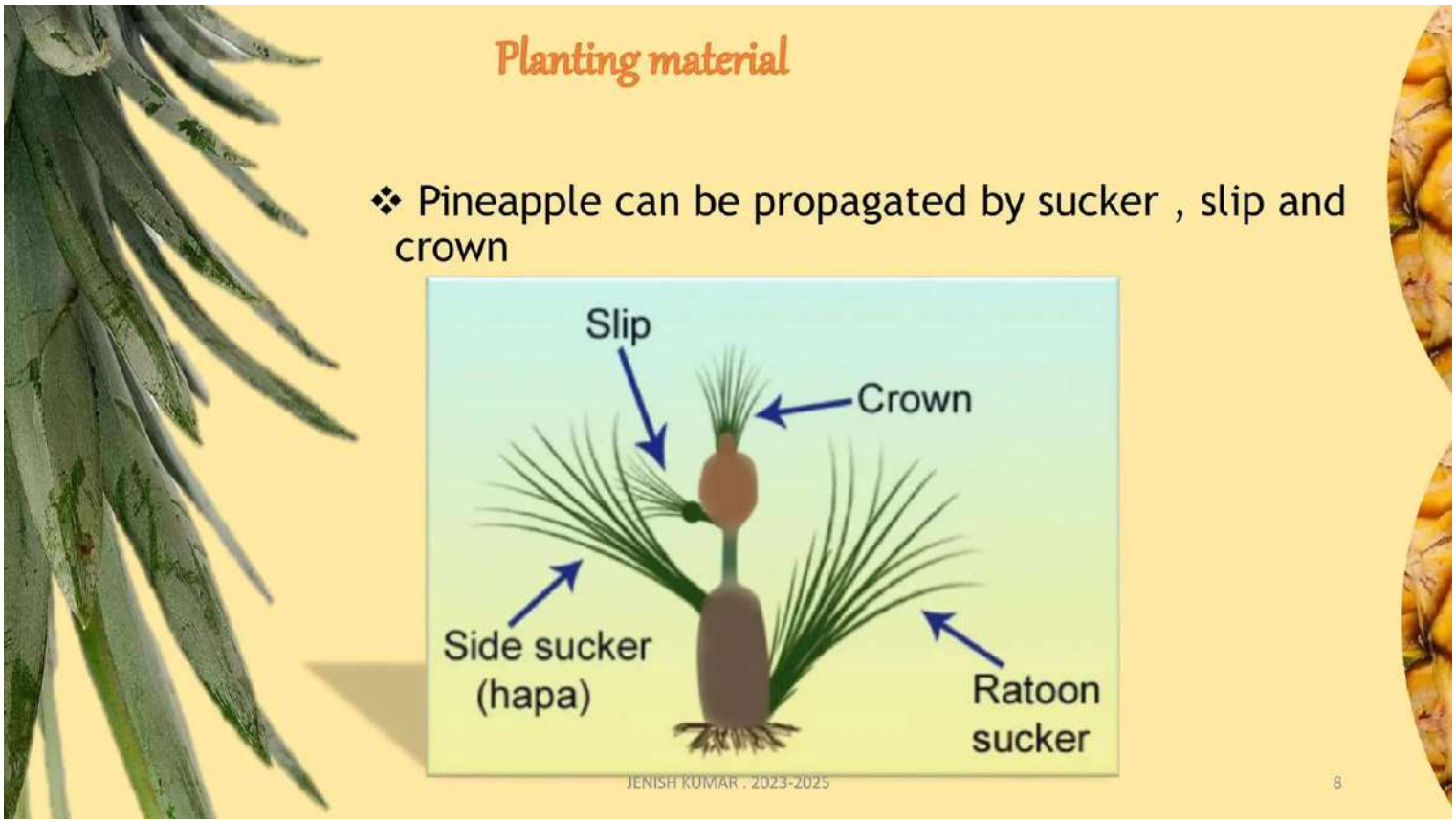
1. They store food for future growth.
2. They enable vegetative propagation.
3. They help plants survive unfavourable conditions.
4. They enable rapid establishment of new plants.
5. They are important sources of food.
6. They help farmers multiply desirable crop varieties.

4.5 OFFSHOOTS

Meaning of offshoots

Offshoots are young lateral shoots that develop from the base or lower parts of a parent plant and can grow into independent plants.

- They develop from buds near the base of the parent plant.
- They may produce their own roots.
- They initially remain attached to the parent.
- They can be separated and transplanted.
- They are commonly used in vegetative propagation.



Process of reproduction through offshoots

1. The parent plant develops lateral buds near its base.
2. The buds grow into young shoots.
3. The shoots develop leaves and roots.
4. The offshoots grow while attached to the parent.
5. Mature offshoots are separated carefully.
6. They are planted in suitable soil.
7. They develop into independent plants.

Examples of plants that produce offshoots

- Pineapple.
- Aloe vera.
- Date palm.

- Banana, through basal suckers or related shoots.
- Some ornamental plants.

Importance of offshoots

1. They enable rapid multiplication of plants.
2. They preserve desirable parental characteristics.
3. They reduce the need for seeds.
4. They enable the production of planting materials.
5. They are useful in establishing pineapple and ornamental plantations.

4.6 CORMS

Meaning of corms

A corm is a short, swollen, solid underground stem that stores food and produces buds capable of developing into new plants.

- It is a modified stem.
- It has nodes and internodes.
- It is covered by dry, papery scale leaves.
- It stores food in its solid stem tissue.
- It may produce smaller daughter corms.

Examples of plants with corms

- Gladiolus.
- Crocus.
- Taro.
- Cocoyam.

Process of reproduction through corms

1. The parent plant develops an underground swollen stem.
2. Food accumulates in the stem.
3. Buds develop on the corm.
4. Daughter corms or cormels may form.
5. Under suitable conditions, buds sprout.
6. New roots and shoots develop.
7. New independent plants are established.

Importance of corms

- They store food.
- They enable vegetative reproduction.
- They support survival during unfavourable conditions.

- They are useful in the propagation of ornamental and food crops.

4.7 SUCKERS

Meaning of suckers

Suckers are shoots that develop from underground stems or roots near the base of a parent plant and can develop into independent plants.

- They usually arise from lateral or adventitious buds.
- They grow near the parent plant.
- They may develop their own roots.
- They can be separated and transplanted.

Examples

- Banana.
- Plantain.
- Raspberry.
- Some citrus plants.
- Some ornamental shrubs.

Importance of suckers

1. They enable natural vegetative propagation.
2. They preserve the characteristics of the parent plant.
3. They provide planting materials for farmers.
4. They support the establishment of new plantations.
5. They reduce the cost of obtaining seeds in crops propagated vegetatively.

Distinguishing offshoots and suckers: These terms can overlap in horticultural use. A sucker generally arises from a basal or underground bud, while offshoot is a broader term for a young side shoot developing from the parent plant.

4.8 VEGETATIVE PLANTLETS

Meaning of vegetative plantlets

Vegetative plantlets are small, already-developed young plants that grow on the parent plant and can eventually detach to establish independent plants.

Examples

- Bryophyllum (Kalanchoe).
- Some ferns.
- Spider plants.

Process in Bryophyllum

1. Small buds develop along the margins of mature leaves.

2. The buds develop into miniature plantlets.
3. Adventitious roots and small leaves form.
4. The plantlets eventually detach.
5. They fall onto suitable soil.
6. They develop into independent plants.

Importance of vegetative plantlets

- They enable rapid multiplication.
- They allow reproduction without seeds.
- They preserve desirable characteristics.
- They help plants colonise suitable habitats.

5.0 ARTIFICIAL VEGETATIVE PROPAGATION

Artificial vegetative propagation refers to the production of new plants from vegetative parts through methods carried out with human assistance.

It is widely used in agriculture, horticulture, forestry and commercial crop production.

The main methods include:

1. Cuttings.
2. Grafting.
3. Layering.
4. Budding.
5. Tissue culture.

5.1 CUTTINGS

Meaning of cuttings

Cuttings are pieces of plant parts, such as stems, leaves or roots, that are removed from a parent plant and planted under suitable conditions to develop into new plants.

- They are used in artificial vegetative propagation.
- They enable farmers to multiply desirable plants.
- They usually produce plants genetically similar to the parent.
- They may develop adventitious roots and shoots.
- Rooting hormones may be applied to encourage root development.

Types of cuttings

A. Stem cuttings

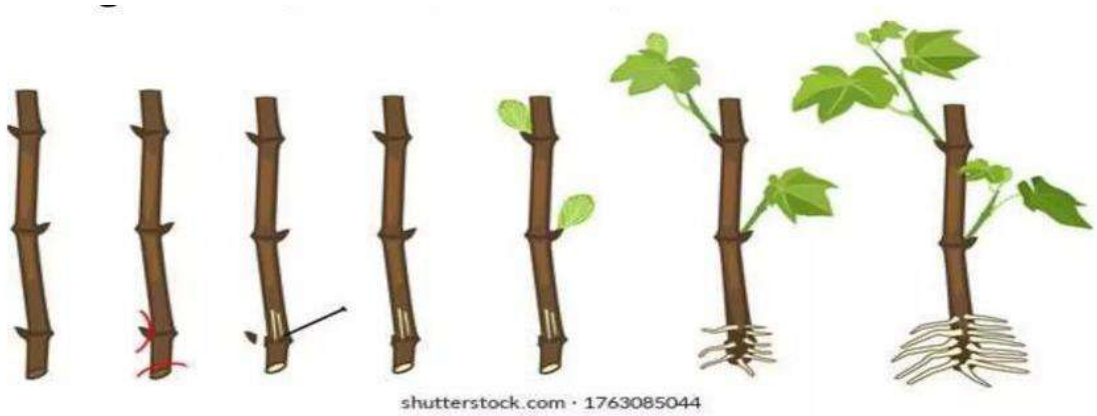
These are sections of stems used to produce new plants.

- A healthy stem is selected from the parent plant.

- The stem is cut into suitable sections.
- Each section should preferably contain one or more viable buds or nodes.
- The cutting is planted in a suitable growing medium.
- Adventitious roots develop from the cutting.
- New shoots grow from the buds.

Examples:

- Sugarcane.
- Cassava.
- Rose.
- Hibiscus.
- Bougainvillea.
- Coleus.



B. Leaf cuttings

These are leaves or sections of leaves used to produce new plants.

- A healthy leaf is selected from the parent plant.
- It is placed in a suitable growing medium.
- Adventitious roots and shoots develop.
- A new plant develops from the leaf tissue.

Examples:

- Begonia.
- African violet.
- Sansevieria (snake plant).
- Some Kalanchoe species.

C. Root cuttings

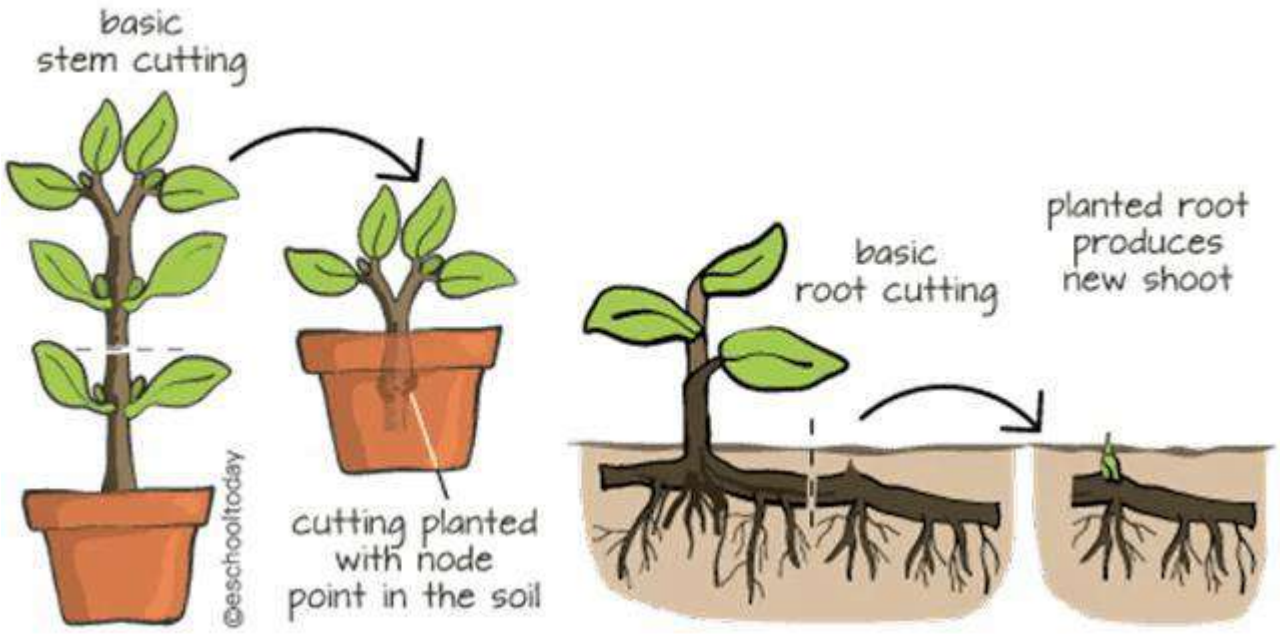
These are sections of roots used to produce new plants.

- A healthy root is selected.

- It is cut into suitable sections.
- The sections are planted in moist soil.
- Adventitious shoots develop from suitable buds on the root.
- New plants become established.

Examples:

- Some varieties of raspberry.
- Blackberry.
- Horseradish.
- Some ornamental plants.



Procedure for planting stem cuttings

1. Select a healthy parent plant with desirable characteristics.
2. Choose a healthy stem with suitable nodes.
3. Use a clean, sharp cutting tool.
4. Cut the stem into suitable sections.
5. Remove some lower leaves to reduce water loss.
6. Apply an appropriate rooting hormone where necessary.
7. Plant the cutting in a suitable moist growing medium.
8. Place it under suitable environmental conditions.
9. Water appropriately without waterlogging the medium.
10. Allow roots and new shoots to develop.
11. Harden the rooted cutting before transplanting it to the field.

Factors affecting successful rooting of cuttings

1. Age and health of the parent plant.

2. Type of plant species.
3. Size and condition of the cutting.
4. Availability of moisture.
5. Suitable temperature.
6. Adequate oxygen in the growing medium.
7. Presence of viable buds.
8. Use of suitable rooting hormones.
9. Cleanliness of tools and planting materials.
10. Suitable growing medium.

Advantages of propagation through cuttings

- It is relatively inexpensive.
- It is simple to carry out.
- It produces plants similar to the parent.
- It enables rapid multiplication of selected varieties.
- It reduces the time required to establish some crops.
- It is useful for plants that produce few viable seeds.

Disadvantages of propagation through cuttings

- Some plants do not root easily.
- Diseases may be transmitted from the parent plant.
- Large quantities of parent material may be required.
- Root systems may be less extensive than those of seed-grown plants in some species.
- Plants may be vulnerable to adverse conditions during establishment.

5.2 GRAFTING

Meaning of grafting

Grafting is an artificial vegetative propagation technique in which parts of two different plants are joined so that they grow together as one plant.

The two main parts are:

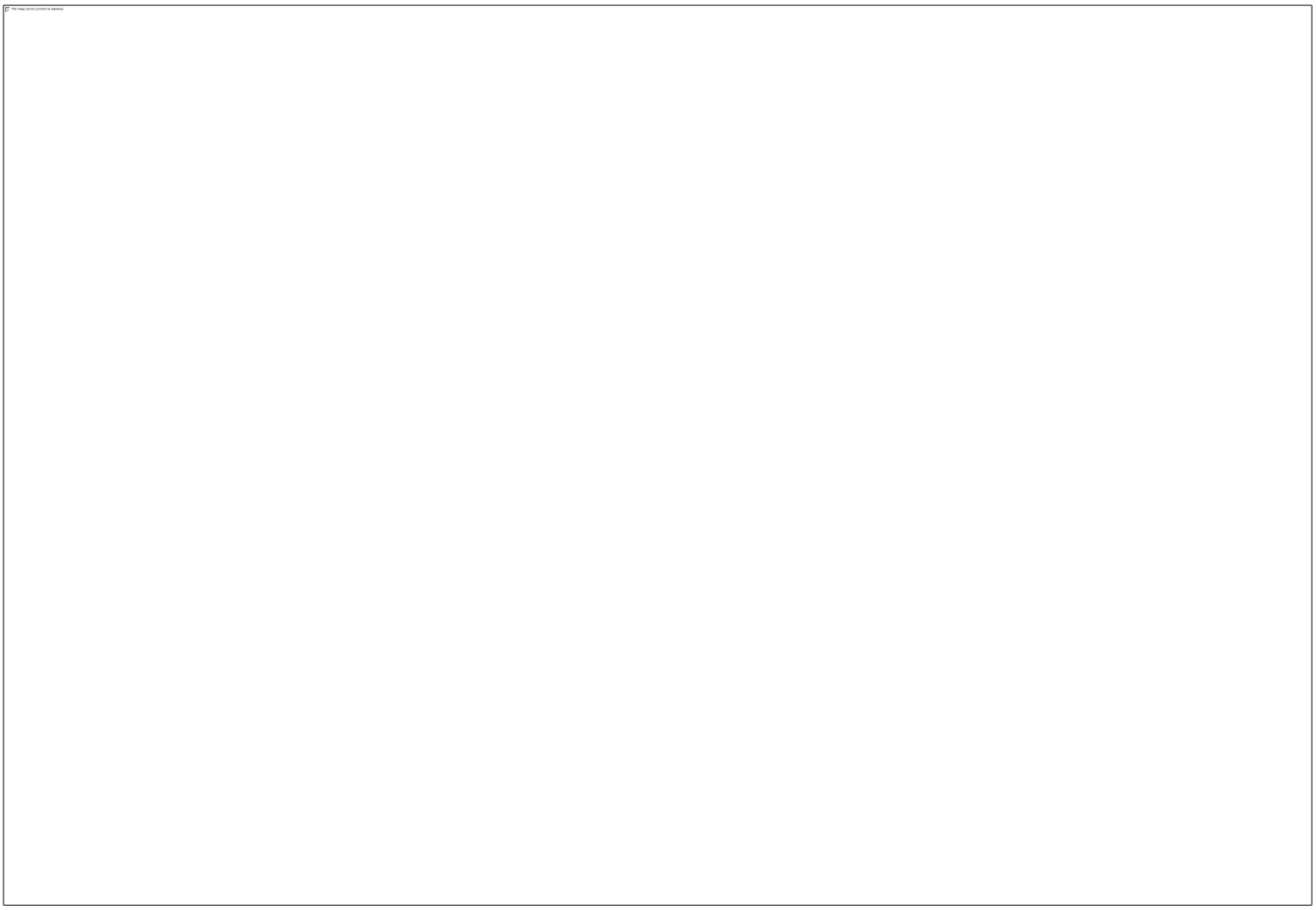
1. Scion

- The upper part of the graft.
- It is obtained from a plant with desirable characteristics.
- It develops into the shoot system of the new plant.

2. Rootstock

- The lower part of the graft.
- It provides the root system.

- It may contribute desirable characteristics such as strong roots, disease resistance or adaptability to particular soil conditions.



Procedure for grafting

1. Select a suitable rootstock.
2. Obtain a healthy scion from a desirable plant.
3. Make compatible cuts on the scion and rootstock.
4. Join the two parts so that their cambium layers align.
5. Secure the graft using grafting tape.
6. Protect the graft union from drying out.
7. Allow the tissues to unite and form a functional connection.
8. Remove unwanted shoots from the rootstock.
9. Maintain the plant until the scion becomes established.

Examples of crops propagated through grafting

- Mango.
- Avocado.
- Citrus.
- Apple.

- Pear.
- Rose.

Importance of grafting

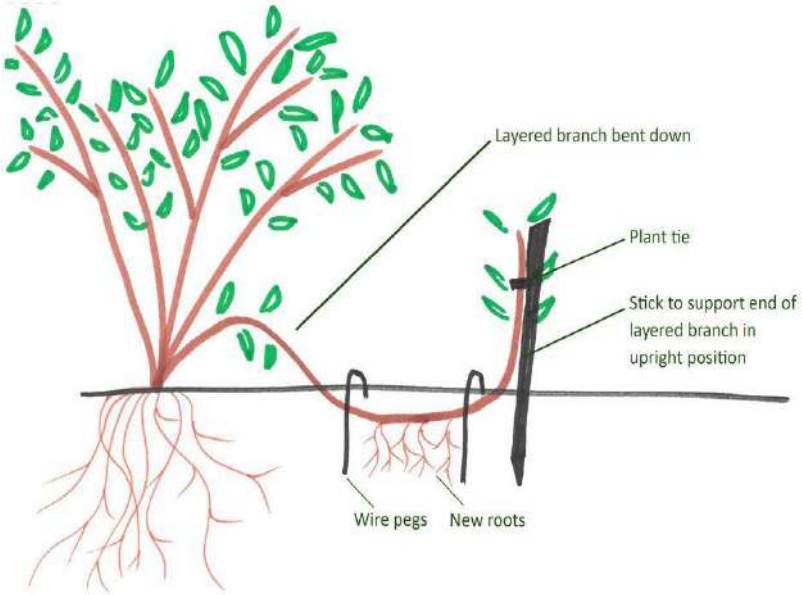
1. It combines desirable characteristics of two plants.
2. It enables propagation of selected fruit varieties.
3. It can improve disease resistance through suitable rootstocks.
4. It may reduce the time taken for some fruit trees to begin producing fruits.
5. It enables propagation of plants that are difficult to root through cuttings.
6. It helps maintain desirable fruit quality.

5.3 LAYERING

Meaning of layering

Layering is a method of artificial vegetative propagation in which roots are induced to develop on a stem while it is still attached to the parent plant.

- The developing stem receives water and nutrients from the parent.
- Roots develop on the selected section.
- The rooted section is later separated.
- It is planted independently.



Types of layering

A. Simple layering

- A flexible branch is bent towards the ground.
- A section is buried in moist soil.
- The tip is left above the soil.
- Roots develop on the buried section.

- The rooted section is separated and planted.

Examples: Jasmine, bougainvillea and some ornamental shrubs.

B. Air layering

- A healthy branch is selected.
- A ring of bark is removed from a section of the branch.
- Moist rooting material is wrapped around the exposed region.
- The material is covered with a suitable protective wrapping.
- Roots develop around the treated section.
- The rooted branch is cut from the parent and planted.

Examples: Guava, litchi, lemon and some ornamental plants.

C. Compound layering

- A long flexible branch is bent repeatedly.
- Several sections are buried in the soil.
- Roots develop at the buried sections.
- Each rooted section can be separated to form a new plant.

Advantages of layering

1. It produces plants similar to the parent.
2. The developing stem receives nutrients from the parent.
3. It is useful for plants that do not root easily from ordinary cuttings.
4. It is relatively simple to carry out.
5. It may result in successful establishment of new plants.

6.0 CONES IN PLANT REPRODUCTION

Important botanical distinction

Cones are not specialised vegetative propagation structures like bulbs, rhizomes and tubers. They are specialised reproductive structures found mainly in gymnosperms.

6.1 Meaning of cones

Cones, also called strobili, are reproductive structures found in gymnosperms in which reproductive organs are arranged on specialised leaves called scales.

- They are commonly found in conifers such as pine and cypress.
- They are involved in sexual reproduction.
- Male cones produce pollen grains.
- Female cones bear ovules.

- Fertilisation eventually leads to the formation of seeds.

6.2 Types of cones

A. Male cones (pollen cones)

- Usually smaller than female cones.
- Produce pollen grains.
- Contain microsporophylls.
- Microsporangia occur on the microsporophylls.
- Microspore mother cells undergo meiosis to produce haploid microspores.
- Microspores develop into pollen grains.

B. Female cones (seed cones)

- Usually larger and more woody than male cones.
- Contain ovuliferous scales.
- Each ovuliferous scale commonly bears ovules.
- The ovules contain the female gametophyte.
- Fertilisation results in the development of seeds.
- Seeds are generally exposed on the cone scales rather than enclosed in an ovary.

6.3 Differences between male and female cones

Male cones	Female cones
Produce pollen grains.	Bear ovules.
Contain microsporophylls.	Contain ovuliferous scales.
Usually smaller.	Usually larger.
Produce male gametophytes.	Contain female gametophytes.
Associated with microsporangia.	Associated with ovules and megasporangia.
Release pollen.	Develop seeds after fertilisation.

6.4 Importance of cones

1. They facilitate sexual reproduction in gymnosperms.
2. Male cones produce pollen grains.
3. Female cones bear ovules.
4. They enable the formation of seeds.
5. They contribute to genetic variation through sexual reproduction.
6. They support the continuation of gymnosperm species.

7.0 SEXUAL REPRODUCTION IN FLOWERING PLANTS

7.1 Meaning of sexual reproduction in flowering plants

Sexual reproduction in flowering plants is the process through which male and female gametes are produced, followed by pollination and fertilisation, resulting in the formation of seeds and fruits.

- It takes place mainly in flowers.
- Flowers contain specialised reproductive structures.

- Male gametes develop within pollen grains.
- Female gametes develop within ovules.
- Pollination transfers pollen grains from the anther to the stigma.
- Fertilisation occurs when the male gametes fuse with the female gametes.
- The fertilised ovule develops into a seed.
- The ovary usually develops into a fruit.

7.2 Structure of a typical flower

A flower is a specialised reproductive shoot of an angiosperm that contains structures responsible for sexual reproduction.

A typical complete flower consists of four main floral whorls:

1. Calyx.
2. Corolla.
3. Androecium.
4. Gynoecium.

A. Calyx

The calyx is the outermost floral whorl consisting of sepals.

Functions of the calyx

1. Protects the developing flower while it is still in the bud stage.
2. Supports the petals when the flower opens.
3. In some plants, green sepals carry out photosynthesis.
4. In some species, sepals help attract pollinators through their colour.

B. Corolla

The corolla consists of petals.

Characteristics of petals

- They are often brightly coloured.
- They may produce scent.
- Some have markings that guide pollinators towards nectar.
- Their shape and arrangement vary among plant species.

Functions of the corolla

1. Attracts pollinators.
2. Provides landing surfaces for insects.
3. May guide pollinators towards nectar.
4. Helps protect the reproductive structures in some flowers.

C. Androecium

The androecium is the male reproductive whorl of a flower. It consists of stamens.

A typical stamen has two main parts:

1. Anther

- It is usually found at the tip of the filament.
- It contains pollen sacs called microsporangia.
- Microspore mother cells undergo meiosis to produce haploid microspores.
- Microspores develop into pollen grains.

2. Filament

- It is a slender stalk supporting the anther.
- It positions the anther appropriately for pollen release.
- Its length varies among different flowers.

Functions of the androecium

1. Produces pollen grains.
2. Houses the structures involved in male gamete formation.
3. Facilitates pollen release.
4. Supports the male reproductive function of the flower.

D. Gynoecium

The gynoecium is the female reproductive whorl of a flower. It consists of one or more carpels.

A carpel has three main parts:

1. Stigma

- It is the terminal part of the carpel.
- It receives pollen grains during pollination.
- It may be sticky, hairy or feathery to trap pollen.
- It provides a suitable surface for pollen germination.

2. Style

- It is the stalk connecting the stigma to the ovary.
- It provides a pathway through which the pollen tube grows.
- Its length and structure vary among plant species.

3. Ovary

- It is the enlarged basal part of the carpel.
- It contains one or more ovules.
- After fertilisation, it usually develops into a fruit.

4. Ovule

- It is a structure found inside the ovary.

- It contains the female gametophyte.
- The egg cell is located within the embryo sac.
- After fertilisation, it develops into a seed.

Functions of the gynoecium

1. Receives pollen grains.
2. Provides a pathway for pollen tube growth.
3. Houses the ovules.
4. Contains the female gametophyte and egg cell.
5. Provides the site where fertilisation takes place.
6. Develops into the fruit after fertilisation.

7.3 Functions of the four floral whorls

Floral whorl	Main structure	Function
Calyx	Sepals	Protects the flower bud.
Corolla	Petals	Attracts pollinators.
Androecium	Stamens	Produces pollen grains.
Gynoecium	Carpels	Bears ovules and receives pollen.

Important flower-related terms

Complete flower: A flower containing all four floral whorls.

Incomplete flower: A flower lacking one or more of the four floral whorls.

Perfect or bisexual flower: A flower containing both stamens and carpels.

Imperfect or unisexual flower: A flower containing either stamens or carpels but not both.

Hermaphrodite flower: Another term for a bisexual flower.

8.0 IDENTIFICATION AND CLASSIFICATION OF FLOWERS

Flowers can be classified according to several observable structural features.

These include:

1. Position of the ovary.
2. Floral symmetry.
3. Type of inflorescence.
4. Presence or absence of male and female reproductive parts.

8.1 Classification according to position of the ovary

The position of the ovary in relation to the other floral parts is an important feature used in flower identification.

There are three main categories:

1. Hypogynous flowers.
2. Perigynous flowers.
3. Epigynous flowers.



A. Hypogynous flowers

A hypogynous flower is a flower in which the ovary is superior, with the sepals, petals and stamens attached below the ovary.

Characteristics

1. The ovary is positioned above the point of attachment of the other floral parts.
2. The sepals are attached below the ovary.
3. The petals are attached below the ovary.
4. The stamens are attached below the ovary.
5. The receptacle does not form a cup surrounding the ovary.

Examples

- Tomato.
- Hibiscus.
- Mustard.
- Brinjal (eggplant).
- Bean.

B. Perigynous flowers

A perigynous flower is a flower in which the sepals, petals and stamens are attached around the ovary on the rim of a cup-shaped floral receptacle called a hypanthium.

The ovary is generally described as half-inferior or free within the floral cup, depending on the botanical interpretation and species.

Characteristics

1. The receptacle forms a cup-shaped structure around the ovary.
2. The floral parts are attached to the rim of the cup.
3. The ovary is not completely fused with the receptacle.
4. The ovary is surrounded by the floral cup.

Examples

- Rose.
- Peach.
- Cherry.
- Plum.

C. Epigynous flowers

An epigynous flower is a flower in which the ovary is inferior, with the sepals, petals and stamens attached above the ovary.

Characteristics

1. The ovary is located below the attachment of the other floral parts.
2. The sepals appear above the ovary.
3. The petals appear above the ovary.
4. The stamens are attached above the ovary.
5. The ovary is usually fused with surrounding floral tissues.

Examples

- Guava.
- Cucumber.
- Pumpkin.
- Sunflower.
- Apple.

Summary of ovary position

Feature	Hypogynous	Perigynous	Epigynous
Ovary position	Superior	Generally free within a floral cup	Inferior
Floral parts	Attached below ovary	Attached around ovary	Attached above ovary

Receptacle	Does not surround ovary	Forms a cup	Fused with ovary in typical examples
Examples	Hibiscus, tomato	Rose, peach	Guava, cucumber

Examination tip:

- Hypogynous = superior ovary.
- Perigynous = floral parts around the ovary.
- Epigynous = inferior ovary.

8.2 Classification according to floral symmetry

Floral symmetry refers to the arrangement of floral parts in relation to the central axis of a flower.

There are three main categories:

1. Actinomorphic flowers.
2. Zygomorphic flowers.
3. Asymmetric flowers.

A. Actinomorphic flowers

An actinomorphic flower is a flower that can be divided into two equal halves through two or more vertical planes passing through its centre.

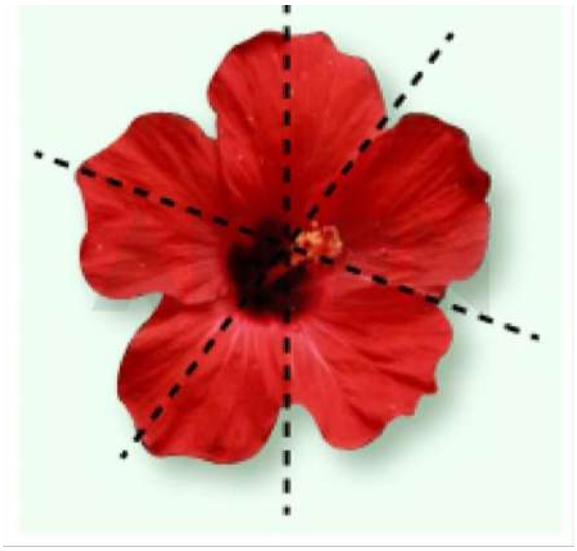
It is also called a radially symmetrical flower.

Characteristics

1. Floral parts are arranged radially around the centre.
2. Several vertical planes can divide the flower into equal halves.
3. The flower has radial symmetry.
4. The floral parts are usually arranged in a regular pattern.

Examples

- Hibiscus.
- Mustard.
- Datura.
- Tomato.
- Lily.



B. Zygomorphic flowers

A zygomorphic flower is a flower that can be divided into two equal halves through only one particular vertical plane.

It is also called a bilaterally symmetrical flower.

Characteristics

1. The flower has bilateral symmetry.
2. Only one vertical plane divides it into two equal halves.
3. Floral parts are often arranged in an unequal pattern.
4. The structure may be adapted to particular pollinators.

Examples

- Pea.
- Bean.
- Orchid.
- Cassia.
- Snapdragon.

C. Asymmetric flowers

An asymmetric flower is a flower that cannot be divided into two equal halves by any vertical plane passing through its centre.

Characteristics

1. Floral parts are irregularly arranged.
2. No vertical plane divides the flower into equal halves.
3. The flower lacks radial and bilateral symmetry.

Example

- Canna lily.

Differences between actinomorphic and zygomorphic flowers

Actinomorphic flowers	Zygomorphic flowers
Radially symmetrical.	Bilaterally symmetrical.
Two or more planes can divide the flower into equal halves.	Only one plane divides the flower into equal halves.
Floral parts are usually regularly arranged around the centre.	Floral parts are usually arranged in an unequal pattern.
Example: Hibiscus.	Example: Pea.

8.3 Classification according to inflorescence

Meaning of inflorescence

Inflorescence is the arrangement of flowers on the floral axis or peduncle of a plant.

- It describes how individual flowers are grouped on a flowering shoot.
- It may consist of one or many flowers.
- The arrangement influences flower display and pollination.
- It is an important feature used in plant identification.

Inflorescences are broadly classified into two main types:

1. Racemose inflorescence.
2. Cymose inflorescence.

A. Racemose inflorescence

Racemose inflorescence is an arrangement of flowers in which the main floral axis continues growing and does not normally terminate in a flower.

Characteristics

1. The main axis continues to grow.
2. Flowers are produced laterally.
3. Older flowers are generally found towards the base or outside.
4. Younger flowers are generally found towards the apex or centre.
5. Flowering is usually described as acropetal or centripetal, depending on the form.

Types of racemose inflorescence

i. Raceme

- The main axis is elongated.

- Flowers are attached to the main axis by individual stalks called pedicels.
- Older flowers are at the base.
- Younger flowers are towards the apex.

Examples: Mustard and radish.

ii. Spike

- The main axis is elongated.
- Flowers are attached directly to the axis without individual pedicels.
- Flowers are sessile.
- Older flowers are usually towards the base.

Examples: Plantain (Plantago) and some grasses.

iii. Spadix

- It has a thick, fleshy main axis.
- Flowers are usually small and sessile.
- It is often surrounded by a large leaf-like bract called a spathe.

Examples: Maize inflorescence is not a spadix; typical examples include Colocasia and Arum.

iv. Umbel

- Several flower stalks arise from approximately the same point.
- The flower stalks are of nearly equal length.
- Flowers form an umbrella-like arrangement.

Examples: Onion and carrot.

v. Corymb

- The lower flower stalks are longer than the upper ones.
- Flowers are arranged at approximately the same level.
- It produces a relatively flat-topped inflorescence.

Examples: Candytuft and some members of the mustard family.

vi. Capitulum or head

- Numerous small sessile flowers are arranged on a flattened receptacle.
- The whole structure may appear like one large flower.
- It is commonly surrounded by involucral bracts.

Examples: Sunflower, daisy and marigold.



vii. Panicle

- It is a branched form of racemose inflorescence.
- The main axis produces several lateral branches.
- Each branch may bear flowers or smaller flower clusters.

Examples: Rice, oats and sorghum.

B. Cymose inflorescence

Cymose inflorescence is an arrangement of flowers in which the main axis terminates in a flower, limiting its further growth.

Characteristics

1. The main axis ends in a flower.
2. Growth of the main axis is limited.
3. The terminal flower is usually the oldest.
4. Younger flowers develop below or towards the outside.
5. Flowering is usually described as basipetal or centrifugal, depending on the form.

Types of cymose inflorescence

i. Monochasial cyme

- The main axis ends in a flower.
- Only one lateral branch develops at a time.
- The lateral branch also terminates in a flower.

Examples: Heliotropium and some species of Solanum.

ii. Dichasial cyme

- The main axis ends in a flower.
- Two lateral branches develop below the terminal flower.
- Each branch may also terminate in a flower.

Examples: Jasmine and Dianthus.

iii. Polychasial cyme

- The main axis ends in a flower.
- More than two lateral branches develop below the terminal flower.
- Each lateral branch may also terminate in a flower.

Examples: Calotropis and some members of the Euphorbiaceae.

Differences between racemose and cymose inflorescence

Racemose	**Cymose**
Main axis continues growing.	Main axis terminates in a flower.
Main axis is indeterminate.	Main axis is determinate.
Older flowers are usually at the base or outside.	Older flowers are usually at the apex or centre.
Younger flowers occur towards the apex or	Younger flowers occur towards the base or

centre.	outside.
Flowering is generally acropetal or centripetal.	Flowering is generally basipetal or centrifugal.
Example: Mustard raceme.	Example: Dichasial cyme in Dianthus.

8.4 Classification according to the presence of male and female reproductive parts

Flowers may be classified according to whether they possess stamens, carpels or both.

The main categories are:

1. Bisexual flowers.
2. Unisexual flowers.

A. Bisexual flowers

A bisexual flower is a flower containing both male reproductive structures (stamens) and female reproductive structures (carpels).

Characteristics

1. It contains an androecium.
2. It contains a gynoecium.
3. Both reproductive structures occur in the same flower.
4. It may undergo self-pollination or cross-pollination, depending on the species and its reproductive mechanisms.

Examples

- Hibiscus.
- Tomato.
- Bean.
- Mustard.
- Rose.
- Pea.

B. Unisexual flowers

A unisexual flower is a flower containing either male or female reproductive structures, but not both.

There are two types:

i. Staminate flowers (male flowers)

- They contain functional stamens.
- They produce pollen grains.
- They lack functional carpels.

Examples:

- Male maize flowers in the tassel.

- Male flowers of cucumber.
- Male flowers of pumpkin.

ii. Pistillate flowers (female flowers)

- They contain functional carpels.
- They bear ovules.
- They lack functional stamens.

Examples:

- Female maize flowers on the cob.
- Female flowers of cucumber.
- Female flowers of pumpkin.

8.4.1 Classification of plants based on the arrangement of unisexual flowers

A. Monoecious plants

A monoecious plant is a plant that bears separate male and female flowers on the same individual plant.

Examples:

- Maize.
- Pumpkin.
- Cucumber.
- Castor.

B. Dioecious plants

A dioecious plant is a plant in which male and female flowers occur on separate individual plants.

Examples:

- Pawpaw (papaya) in dioecious varieties.
- Date palm.
- Some kiwi varieties.

C. Polygamous plants

A polygamous plant bears bisexual flowers together with unisexual male or female flowers on the same plant.

Examples include some varieties of mango and certain other flowering plants.

Differences between monoecious and dioecious plants

Monoecious plants	Dioecious plants

Male and female flowers occur on the same plant.	Male and female flowers occur on separate plants.
One plant bears both sexes of flowers.	Individual plants are usually male or female.
Pollination may occur between different flowers on the same plant.	Transfer of pollen between separate plants is necessary for reproduction.
Examples: Maize, pumpkin.	Examples: Date palm, dioecious papaya varieties.

8.4.2 Summary of flower identification

Basis of classification	Types	Examples
Ovary position	Hypogynous	Hibiscus, tomato
	Perigynous	Rose, peach
	Epigynous	Guava, cucumber
Symmetry	Actinomorphic	Hibiscus, mustard
	Zygomorphic	Pea, bean
	Asymmetric	Canna
Inflorescence	Racemose	Mustard, sunflower, onion
	Cymose	Jasmine, Dianthus
Reproductive parts	Bisexual	Hibiscus, bean
	Unisexual	Maize, pumpkin
Plant sexuality	Monoecious	Maize, cucumber
	Dioecious	Date palm, dioecious papaya

9.0 POLLINATION IN FLOWERING PLANTS

9.1 Meaning of pollination

Pollination is the transfer of pollen grains from the anther to the stigma of a flower of the same species.

- It is an important process in sexual reproduction.
- It occurs before fertilisation.

- It enables pollen grains to reach the female reproductive structure.
- It provides an opportunity for pollen germination and pollen tube formation.
- It may involve wind, water, insects, birds and other animals.

9.2 Types of pollination

There are two main types of pollination:

1. Self-pollination.
2. Cross-pollination.

A. Self-pollination

Self-pollination is the transfer of pollen grains from the anther to the stigma of the same flower or another flower on the same plant.

It occurs in two main forms.

i. Autogamy

Autogamy is the transfer of pollen grains from the anther to the stigma of the same flower.

Characteristics:

1. It occurs within one flower.
2. It does not require pollen transfer between different plants.
3. It may occur when anthers and stigma are positioned close to one another.
4. It is common in some bisexual flowers.

Examples:

- Pea.
- Wheat.
- Rice.
- Some varieties of beans.

ii. Geitonogamy

Geitonogamy is the transfer of pollen grains from the anther of one flower to the stigma of another flower on the same plant.

Characteristics:

1. It occurs between different flowers on the same plant.
2. It may require an external pollinating agent.
3. It is genetically similar to self-pollination because both flowers belong to the same plant.
4. It does not usually introduce the same degree of genetic variation as cross-pollination between different plants.

B. Cross-pollination

Cross-pollination is the transfer of pollen grains from the anther of a flower on one plant to the stigma of a flower on another plant of the same species.

Characteristics:

1. It involves two different plants of the same species.
2. It requires a pollinating agent.
3. It increases genetic variation.
4. It may produce offspring with new combinations of characteristics.
5. It can improve adaptability within plant populations.

Examples:

- Maize.
- Pawpaw.
- Sunflower.
- Pumpkin.
- Avocado.
- Passion fruit.

9.3 Agents of pollination

Pollinating agents are organisms or physical factors that transfer pollen grains from anthers to stigmas.

The main agents include:

1. Wind.
2. Water.
3. Insects.
4. Birds.

A. Wind pollination

Wind pollination is the transfer of pollen grains from anthers to stigmas by air currents.

It is also called anemophily.

Characteristics of wind-pollinated flowers

1. Flowers are usually small and inconspicuous.
2. Petals are often reduced or absent.
3. They generally lack strong scents.
4. They usually produce little or no nectar.
5. They produce large quantities of pollen.
6. Pollen grains are usually small, light and dry.

7. Anthers are often exposed to air currents.
8. Stigmas are often large, feathery or exposed to trap airborne pollen.
9. Flowers may be arranged in exposed inflorescences.

Examples

- Maize.
- Wheat.
- Rice.
- Barley.
- Sorghum.
- Many grasses.

Adaptations of wind-pollinated flowers

- Exposed anthers release pollen easily.
- Large quantities of pollen compensate for wastage.
- Light pollen grains remain suspended in air.
- Feathery stigmas provide a large surface area for trapping pollen.
- Flowers are positioned where air currents can reach them.

B. Insect pollination

Insect pollination is the transfer of pollen grains from anthers to stigmas by insects.

It is also called entomophily.

Characteristics of insect-pollinated flowers

1. Flowers are often brightly coloured.
2. They may produce nectar.
3. They often have attractive scents.
4. Pollen grains are usually relatively large and sticky.
5. Pollen grains may have rough or spiny surfaces.
6. Anthers are positioned where insects can come into contact with them.
7. Stigmas are adapted to receive pollen carried by insects.
8. Flowers may have landing platforms for insects.

Examples

- Sunflower.
- Pumpkin.
- Passion fruit.
- Beans.

- Avocado.
- Mango.
- Citrus.

Adaptations of insect-pollinated flowers

- Bright petals attract insects.
- Nectar provides a food reward.
- Scent attracts pollinating insects.
- Sticky pollen adheres to insect bodies.
- Sticky stigmas trap pollen.
- Flower shape facilitates contact between insects and reproductive structures.

C. Bird pollination

Bird pollination is the transfer of pollen grains from anthers to stigmas by birds.

It is also called ornithophily.

Characteristics

1. Flowers are often brightly coloured.
2. They may be red, orange or yellow.
3. They usually produce abundant nectar.
4. They may have strong structures that support visiting birds.
5. They often have little scent.
6. Their reproductive structures are positioned to contact visiting birds.

Examples:

- Some Aloe species.
- Some Erythrina species.
- Some bird-of-paradise relatives and other ornithophilous plants.

D. Water pollination

Water pollination is the transfer of pollen grains by water currents.

It is also called hydrophily.

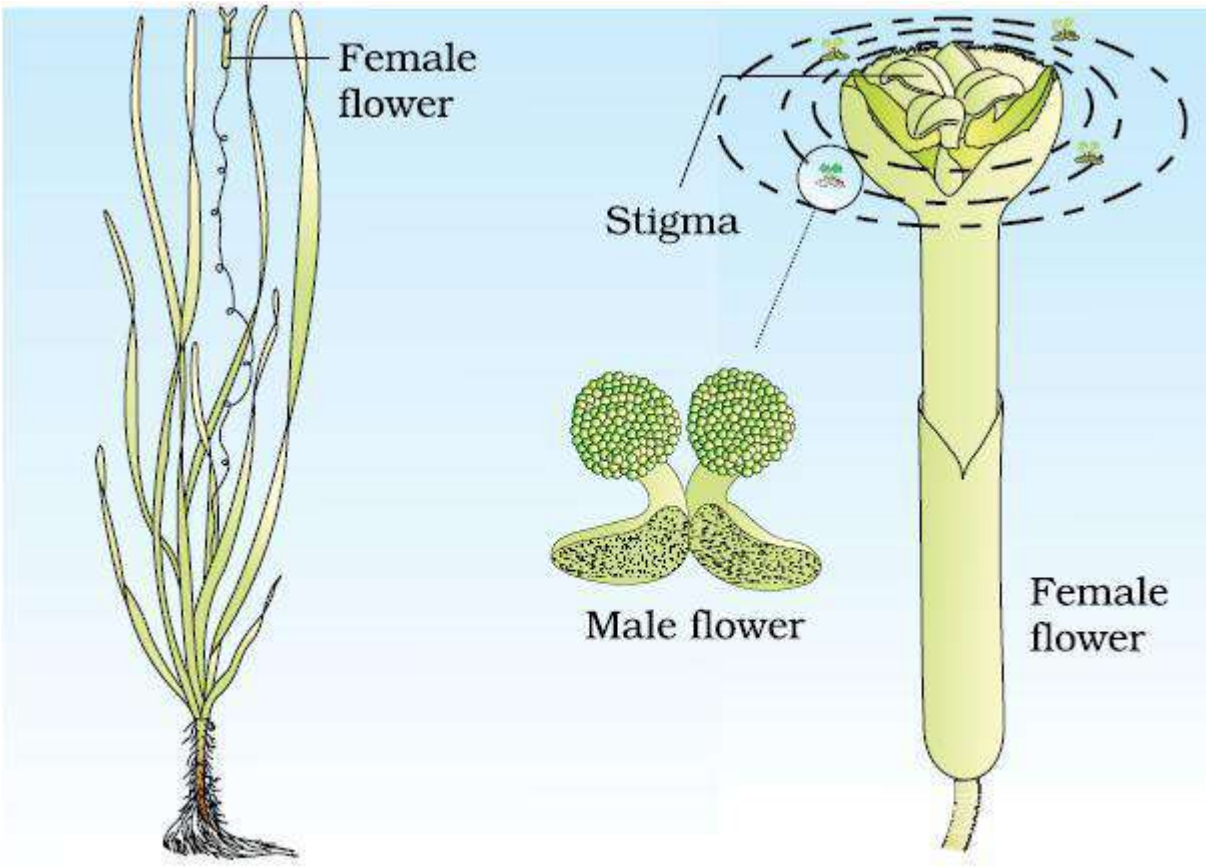
Characteristics

1. It occurs in certain aquatic plants.
2. Pollen is adapted to move through water.

3. Flowers may be small and inconspicuous.
4. Pollen may be carried on or beneath the water surface.
5. It is relatively uncommon among flowering plants.

Examples:

- Vallisneria.
- Zostera.



9.4 Comparison of wind and insect pollination

Wind-pollinated flowers	Insect-pollinated flowers
Usually small and inconspicuous.	Often brightly coloured.
Petals may be reduced.	Petals are often well developed.
Usually lack scent.	May produce scent.
Usually produce little or no nectar.	Often produce nectar.
Pollen is light and dry.	Pollen is often sticky and relatively heavy.
Produce large quantities of pollen.	Usually produce less pollen.
Stigmas are often feathery.	Stigmas are often sticky.
Anthers are usually exposed.	Anthers are often positioned to contact insects.
Example: Maize.	Example: Sunflower.

9.5 Importance of pollination

1. It enables pollen grains to reach the stigma.
2. It facilitates fertilisation.
3. It supports the formation of seeds.
4. It contributes to fruit production.
5. It promotes genetic variation through cross-pollination.
6. It supports the reproduction of flowering plants.
7. It contributes to food production through successful crop pollination.
8. It supports biodiversity by enabling the reproduction of many wild plants.
9. It supports agricultural productivity.
10. It maintains ecological relationships between flowering plants and pollinators.

10.0 MECHANISMS THAT HINDER SELF-POLLINATION AND SELF-FERTILISATION

10.1 Meaning of self-pollination

Self-pollination is the transfer of pollen from the anther to the stigma of the same flower or another flower on the same plant.

10.2 Meaning of self-fertilisation

Self-fertilisation refers to the fusion of male and female gametes originating from the same plant.

Important distinction:

- Self-pollination concerns the transfer of pollen.
- Self-fertilisation concerns the fusion of gametes.
- A flower may undergo self-pollination without successful self-fertilisation if the pollen is incompatible or the reproductive structures are not functional.

10.3 Meaning of mechanisms that prevent self-pollination

These are structural, temporal or physiological adaptations that reduce or prevent the transfer of pollen to the stigma of the same flower or plant.

They encourage cross-pollination and increase genetic variation.

The main mechanisms include:

1. Dichogamy.
2. Herkogamy.
3. Heterostyly.
4. Unisexuality.
5. Self-incompatibility.
6. Male sterility.

10.4 Dichogamy

Dichogamy is a condition in which the anthers and stigma of a bisexual flower mature at different times.

- It reduces the possibility of self-pollination.
- It encourages pollen transfer between different flowers.
- It may occur in two main forms.

A. Protandry

Protandry occurs when the anthers mature and release pollen before the stigma becomes receptive.

Characteristics

1. The male reproductive structures mature first.
2. Pollen is released before the stigma becomes receptive.
3. Self-pollination is reduced.
4. Cross-pollination is encouraged.

Examples:

- Sunflower.
- Some members of the Asteraceae family.
- Some Salvia species.

B. Protogyny

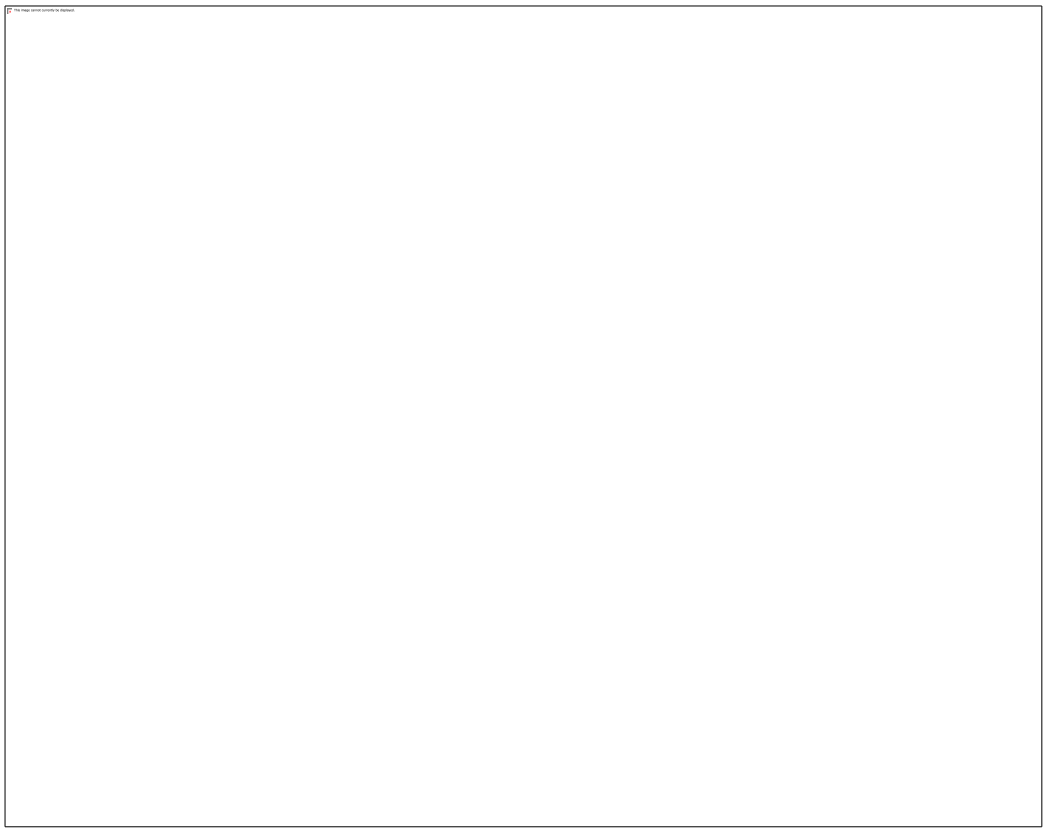
Protogyny occurs when the stigma becomes receptive before the anthers mature and release pollen.

Characteristics

1. The stigma becomes receptive first.
2. The anthers mature later.
3. Self-pollination is reduced.
4. Cross-pollination is encouraged.

Examples:

- Avocado, in many cultivars with different daily flowering phases.
- Some members of the Araceae family.



Difference between protandry and protogyny

Protandry	Protogyny
Anthers mature first.	Stigma becomes receptive first.
Pollen is released before stigma receptivity.	Stigma is receptive before pollen release.
Male phase occurs first.	Female phase occurs first.

10.5 Herkogamy

Herkogamy is the spatial separation or physical arrangement of anthers and stigmas within a flower that reduces the likelihood of self-pollination.

Characteristics

1. Anthers and stigma are positioned at different locations.
2. Pollen may not easily reach the stigma of the same flower.
3. The arrangement encourages pollen transfer by pollinating agents.
4. It reduces self-pollination.

Examples:

- Hibiscus, where the stigma branches may extend beyond the anthers.
- Some orchids with specialised floral structures.

10.6 Heterostyly

Heterostyly is a condition in which flowers of the same species have styles and stamens of different lengths.

- It promotes cross-pollination.
- It reduces the likelihood of pollen reaching the stigma of the same flower type.
- Different flower forms may have complementary positions of anthers and stigmas.

Types of heterostyly

A. Distyly

- There are two flower forms.
- One form has a long style and short stamens.
- The other has a short style and long stamens.

Example: Primula (primrose).

B. Tristyly

- There are three flower forms.
- They possess long, medium and short styles.
- The stamens occur at corresponding different heights.
- This arrangement promotes cross-pollination between compatible flower forms.

Example: Some species of Lythrum.

10.7 Unisexuality

Unisexuality is the condition in which a flower possesses either male or female reproductive organs, but not both.

- Male flowers produce pollen.
- Female flowers receive pollen.
- A unisexual flower cannot self-pollinate using its own reproductive structures.
- However, self-pollination at the plant level may still occur in monoecious plants.

Examples

- Maize.
- Pumpkin.
- Cucumber.

Important distinction

- Monoecious plants have male and female flowers on the same individual.
- Dioecious plants have male and female flowers on separate individuals.
- Dioecy prevents self-pollination within an individual plant because male and female flowers occur on different plants.

10.8 Self-incompatibility

Self-incompatibility is a genetically controlled mechanism in which a plant rejects pollen from itself or genetically similar individuals, preventing successful fertilisation.

Characteristics

1. Pollen may land on the stigma.
2. The stigma recognises the pollen as incompatible.
3. Pollen germination may be prevented.
4. Alternatively, pollen tube growth may be stopped in the stigma or style.
5. Fertilisation does not occur.
6. Cross-pollination with compatible pollen is encouraged.

Examples:

- Some varieties of apple.
- Brassica species.
- Some varieties of pear.

10.9 Male sterility

Male sterility is a condition in which a plant is unable to produce functional pollen grains.

- The male reproductive structures may be absent or non-functional.
- The plant may still possess functional female reproductive structures.
- It encourages fertilisation using pollen from another plant.
- It is useful in plant breeding and hybrid seed production.

Summary of mechanisms preventing self-pollination and self-fertilisation

Mechanism	Description	How it reduces self-pollination
Dichogamy	Anthers and stigma mature at different times.	Prevents simultaneous pollen release and stigma receptivity.
Protandry	Anthers mature first.	Pollen is released before stigma receptivity.
Protogyny	Stigma matures first.	Stigma receptivity occurs before pollen release.
Herkogamy	Anthers and stigma are spatially separated.	Reduces contact between pollen and the same flower's stigma.

Heterostyly	Different flower forms have different style and stamen lengths.	Encourages compatible cross-pollination.
Unisexuality	A flower has either stamens or carpels.	Prevents self-pollination within a single flower.
Dioecy	Male and female flowers occur on separate plants.	Prevents self-pollination within an individual plant.
Self-incompatibility	Genetic rejection of self-pollen.	Prevents successful pollen germination or pollen tube growth.
Male sterility	Production of non-functional pollen.	Prevents self-pollination using the plant's own pollen.

Importance of mechanisms preventing self-pollination

1. They encourage cross-pollination.
2. They increase genetic variation.
3. They reduce repeated self-fertilisation.
4. They may reduce the expression of harmful recessive characteristics.
5. They promote genetic recombination in populations.
6. They may improve adaptability to changing environmental conditions.
7. They support plant breeding programmes.

11.0 FERTILISATION IN FLOWERING PLANTS

11.1 Meaning of fertilisation

Fertilisation is the process in which the male and female gametes fuse to form a diploid zygote.

In flowering plants, fertilisation takes place inside the ovule, which is located within the ovary.

- It occurs after successful pollination.
- The pollen grain germinates on the stigma.
- A pollen tube grows through the style towards the ovule.
- Male gametes travel through the pollen tube.
- The male and female gametes fuse to form a zygote.
- In flowering plants, a second fusion event produces the endosperm.

11.2 Structure of the ovule

The ovule is the structure inside the ovary that contains the female gametophyte.

Main parts of an ovule

1. Funicle

- The stalk attaching the ovule to the placenta.
- It supplies support and provides a connection with the ovary.

2. Hilum

- The point where the funicle attaches to the ovule.

3. Integuments

- Protective layers surrounding the ovule.
- They develop into the seed coats after fertilisation.

4. Micropyle

- A small opening in the integuments.
- It provides the route through which the pollen tube commonly enters the ovule.

5. Nucellus

- The tissue surrounding the embryo sac.
- It provides nourishment and support to the developing female gametophyte.

6. Embryo sac

- The female gametophyte of flowering plants.
- It contains the egg cell and central cell with two polar nuclei in the typical mature embryo sac.

7. Chalaza

- The region opposite the micropyle where the integuments and nucellus meet.

11.3 Structure of the embryo sac

The typical mature embryo sac in flowering plants is seven-celled and eight-nucleate.

It consists of:

At the micropylar end

1. One egg cell.
2. Two synergids.

At the central region

3. One large central cell containing two polar nuclei.

At the chalazal end

4. Three antipodal cells.

Functions of the parts

Egg cell

- It is the female gamete.
- It fuses with one male gamete to form the diploid zygote.

Synergids

- They are located beside the egg cell.
- They help guide the pollen tube into the embryo sac.
- They assist in pollen tube reception.

Polar nuclei

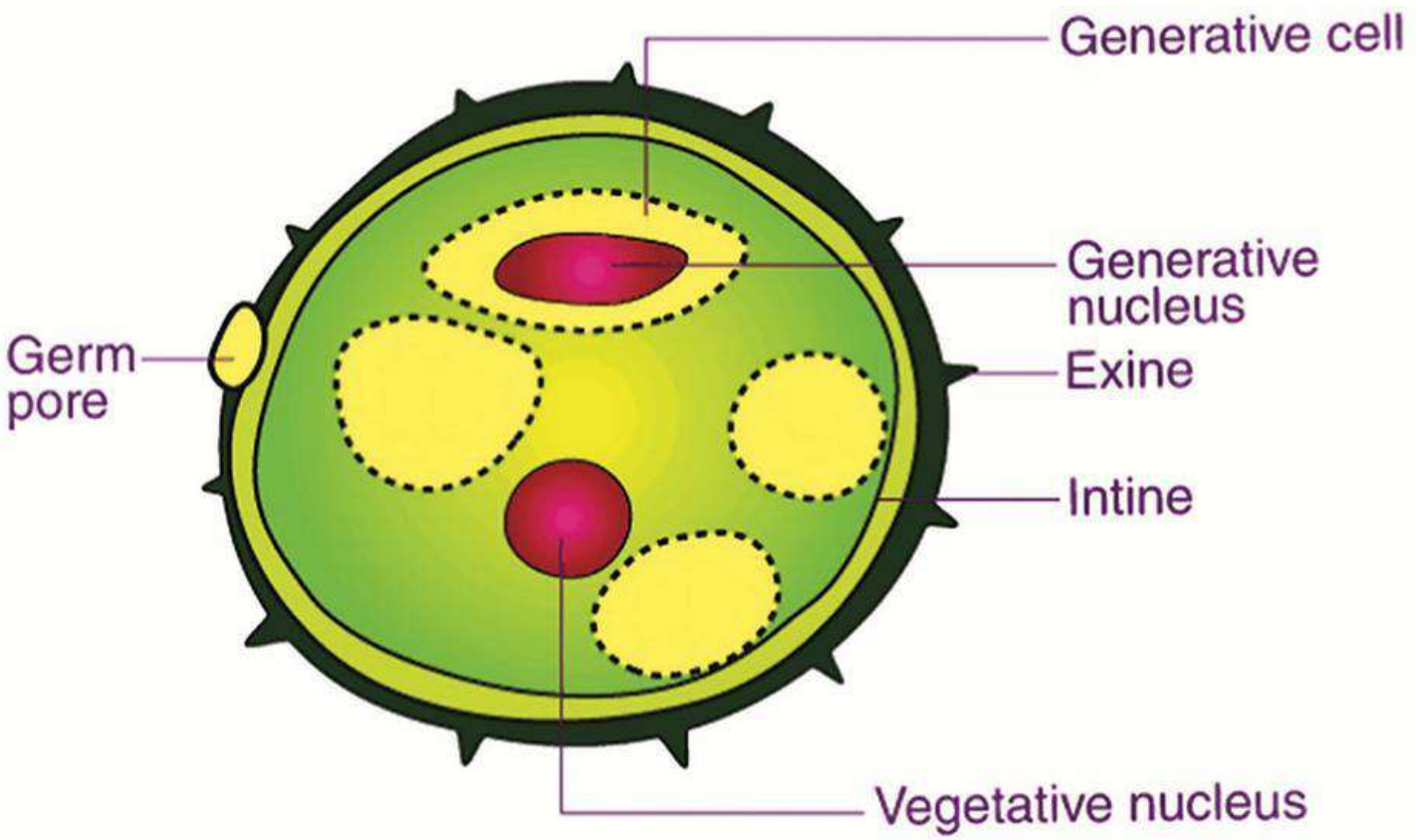
- They are found in the central cell.
- They fuse with the second male gamete to form the primary endosperm nucleus.

Antipodal cells

- They are located at the chalazal end.
- They are generally involved in supporting the embryo sac, although their precise functions vary among species.

11.4 Pollen grain structure

A pollen grain is the male gametophyte of a flowering plant.



Main structures:

1. Exine

- The tough outer wall of the pollen grain.
- It contains a highly resistant substance called sporopollenin.
- It protects the pollen grain from mechanical damage and drying.

2. Intine

- The inner wall of the pollen grain.
- It is made mainly of cellulose and pectin.
- It contributes to the formation of the pollen tube.

3. Vegetative cell

- It contains the tube nucleus.
- It directs the development of the pollen tube.

4. Generative cell

- It divides mitotically to form two male gametes in most flowering plants.
- These male gametes participate in double fertilisation.

12.0 DOUBLE FERTILISATION

12.1 Meaning of double fertilisation

Double fertilisation is a characteristic reproductive process in flowering plants in which two male gametes participate in two separate fusion events within the same embryo sac.

It involves:

1. Syngamy.
2. Triple fusion.

12.2 Events leading to double fertilisation

Step 1: Pollination

- A pollen grain is transferred from the anther to the stigma.
- The pollen grain lands on a suitable stigma.

Step 2: Pollen germination

- The pollen grain absorbs moisture and nutrients from the stigma.
- It germinates and produces a pollen tube.
- The pollen tube grows through the style towards the ovary.

Step 3: Formation of male gametes

- The generative cell divides by mitosis to form two male gametes if this division has not already occurred.
- The male gametes are carried within the pollen tube.

Step 4: Growth of the pollen tube

- The pollen tube grows towards an ovule.
- It usually enters the ovule through the micropyle.
- It reaches the embryo sac, commonly entering through one of the synergids.

Step 5: Release of male gametes

- The pollen tube releases two male gametes into the embryo sac.

Step 6: Syngamy

- One male gamete fuses with the egg cell.
- A diploid zygote is formed.
- This process is called syngamy.

n+n=2nn+n=2n

Step 7: Triple fusion

- The second male gamete fuses with the two polar nuclei in the central cell.
- A triploid primary endosperm nucleus is formed.

n+n+n=3n

Step 8: Development

- The zygote develops into an embryo.
- The primary endosperm nucleus develops into the endosperm.
- The ovule develops into a seed.
- The ovary usually develops into a fruit.

12.3 Products of double fertilisation

Fusion event	Structures involved	Product
Syngamy	One male gamete + egg cell	Diploid zygote (2n)
Triple fusion	One male gamete + two polar nuclei	Triploid primary endosperm nucleus (3n)

12.4 Significance of double fertilisation

1. **Formation of the zygote:** It produces the diploid zygote that develops into the embryo.
2. **Formation of endosperm:** It initiates the development of endosperm, which provides nourishment to the developing embryo.
3. **Efficient use of resources:** Endosperm development is generally initiated following successful fertilisation, reducing unnecessary investment in unfertilised ovules.
4. **Seed development:** It initiates the processes that lead to the formation of a viable seed.
5. **Continuity of plant species:** It enables sexual reproduction and the production of offspring.

6. **Genetic variation:** Fusion of genetically different gametes can produce genetically varied offspring.
7. **Embryo nourishment:** It ensures the development of nutritive tissue that supports embryo growth.

Important examination point: Double fertilisation is a distinctive feature of angiosperms (flowering plants). It does not occur in the same way in gymnosperms.

13.0 SEED DEVELOPMENT

13.1 Meaning of a seed

A seed is a mature fertilised ovule containing an embryo, stored food or nutritive tissue and a protective seed coat.

- It develops after fertilisation.
- It contains the young plant embryo.
- It may contain stored food for germination.
- It protects the developing embryo.
- It enables the plant to survive unfavourable conditions.
- It facilitates dispersal and establishment of new plants.

13.2 Changes that occur during seed development

After double fertilisation, the following changes take place:

1. The zygote develops into an embryo.
2. The primary endosperm nucleus develops into endosperm.
3. The integuments of the ovule develop into the seed coat.
4. The ovule develops into a mature seed.
5. The micropyle may remain as a small opening in the seed coat.
6. The funicle attachment point may be visible as the hilum.
7. The seed accumulates food reserves in the endosperm, cotyledons or other tissues.
8. The seed undergoes maturation and usually loses much of its water content.
9. In many species, the seed becomes dormant before germination.

13.3 Structure of a typical dicotyledonous seed

A dicotyledonous seed contains an embryo with two cotyledons.

Example: Bean.

Main parts

1. Testa

- The outer protective seed coat.
- It develops from the outer integument of the ovule.

- It protects the embryo from mechanical damage and infection.

2. Hilum

- A scar showing where the seed was attached to the funicle.

3. Micropyle

- A small opening in the seed coat.
- It may allow water and oxygen to enter during germination.

4. Cotyledons

- The seed leaves.
- In many beans, they store food for the developing embryo.

5. Plumule

- The embryonic shoot.
- It develops into the stem and leaves.

6. Radicle

- The embryonic root.
- It develops into the primary root.

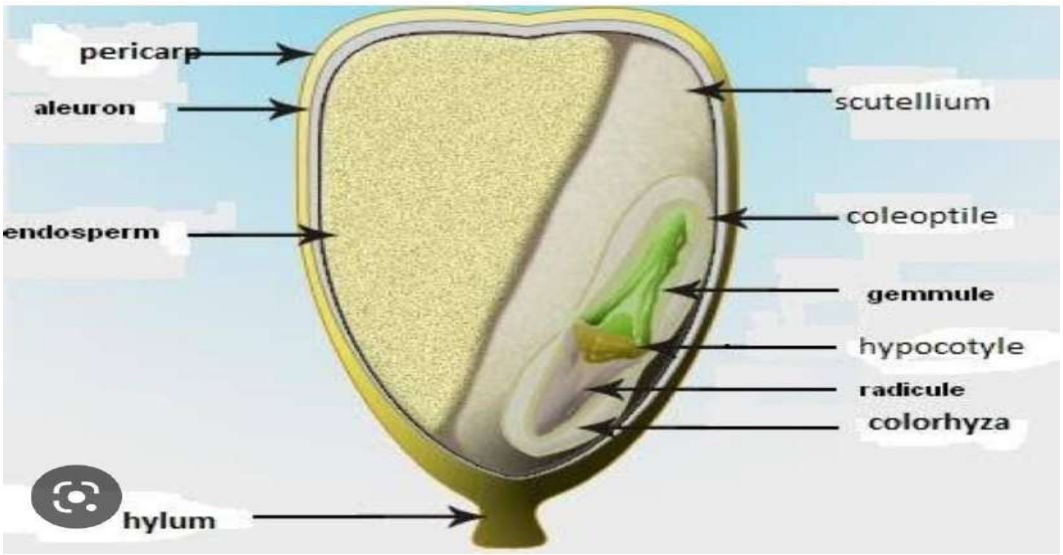
7. Embryonic axis

- The central part of the embryo.
- It connects the plumule and radicle.

13.4 Structure of a typical monocotyledonous seed

A monocotyledonous seed contains an embryo with one cotyledon.

Example: Maize.



Main parts

1. Pericarp

- The outer fruit wall surrounding the maize grain.

- It is closely fused with the seed coat.

2. Seed coat

- The protective layer surrounding the seed tissues.
- In maize, it is closely associated with the pericarp.

3. Endosperm

- The main food-storage tissue.
- It contains starch and proteins.

4. Aleurone layer

- The outer layer of the endosperm.
- It contains protein-rich cells.
- It contributes to the processes involved in germination.

5. Scutellum

- The single cotyledon of the maize embryo.
- It absorbs nutrients from the endosperm during germination.

6. Plumule

- The embryonic shoot.
- It develops into the stem and leaves.

7. Coleoptile

- A protective sheath surrounding the plumule.
- It protects the young shoot as it emerges through the soil.

8. Radicle

- The embryonic root.
- It develops into the primary root.

9. Coleorhiza

- A protective sheath surrounding the radicle.
- It protects the developing root during germination.

13.5 Differences between monocotyledonous and dicotyledonous seeds

Feature	Monocotyledonous seed	Dicotyledonous seed
Number of cotyledons	One	Two
Example	Maize	Bean
Food storage	Usually mainly in endosperm in maize	Often in cotyledons in bean
Embryo	Has one cotyledon	Has two cotyledons
Protective sheath	Coleoptile and coleorhiza occur in maize	Usually absent
Endosperm	Often persists in mature seeds	May be absent or reduced in mature

		seeds

13.6 Importance of seeds

1. They enable reproduction in seed-producing plants.
2. They protect the developing embryo.
3. They store food for germination.
4. They facilitate plant dispersal.
5. They help plants survive unfavourable environmental conditions.
6. They enable the colonisation of new habitats.
7. They provide food for human beings and animals.
8. They provide raw materials for industries.
9. They are important in crop production and food security.
10. They preserve hereditary information for the next generation.

14.0 FRUIT DEVELOPMENT

14.1 Meaning of a fruit

A fruit is a mature or ripened ovary of a flower, usually formed after fertilisation, containing one or more seeds.

- It develops from the ovary after fertilisation in typical flowering plants.
- The ovary wall develops into the pericarp.
- The pericarp surrounds and protects the seeds.
- Fruits help in seed dispersal.
- Some fruits provide food for human beings and animals.

14.2 Changes during fruit development

1. The ovary enlarges after fertilisation.
2. The ovary wall develops into the pericarp.
3. The ovules develop into seeds.
4. The style and stigma usually wither and fall off.
5. Petals and stamens usually wither and fall off.
6. In some plants, other floral parts persist and contribute to fruit formation.
7. The fruit develops and matures.
8. The fruit may undergo changes in colour, texture, flavour and composition.
9. Mature fruits facilitate seed protection and dispersal.

14.3 Structure of a typical fruit

Main parts of a fruit

1. Pericarp

- The fruit wall that develops from the ovary wall.
- It surrounds the seed or seeds.
- It may be fleshy, dry, thick or thin.

The pericarp is commonly divided into three layers:

A. Exocarp

- The outermost layer.
- It forms the outer skin or peel of many fruits.
- It protects the inner tissues.

Example: The skin of a mango.

B. Mesocarp

- The middle layer.
- It may be fleshy or fibrous.
- It may store water and nutrients.

Example: The fleshy edible part of a mango.

C. Endocarp

- The innermost layer of the pericarp.
- It surrounds the seed.
- It may be soft, papery or hard.

Example: The hard stone surrounding the seed in a mango.

2. Seed

- It develops from the ovule.
- It contains the embryo and associated protective and nutritive tissues.

14.4 Importance of fruits

1. They protect developing seeds.
2. They facilitate seed dispersal.
3. They provide food for human beings.
4. They provide food for animals.
5. They support natural regeneration of plants.
6. They are sources of vitamins and minerals.
7. They provide raw materials for food-processing industries.
8. They generate income for farmers.
9. They support biodiversity by attracting seed-dispersing animals.

10. They contribute to food security.

Examples in Kenya

- Mangoes from Makueni and other fruit-growing areas.
- Avocados from Murang'a, Kiambu and other highland counties.
- Oranges from coastal and other suitable regions.
- Bananas from Kisii, Meru and other growing regions.
- Passion fruits from central and Rift Valley farming areas.
- Pineapples from Thika and other production areas.

15.0 PLACENTATION IN FLOWERING PLANTS

15.1 Meaning of placentation

Placentation is the arrangement of ovules within the ovary of a flower.

- The ovules are attached to a specialised tissue called the placenta.
- The placenta provides an attachment point for the ovules.
- The arrangement of ovules varies among plant species.
- Placentation is useful in the identification and classification of flowering plants.

15.2 Types of placentation

The main types include:

1. Marginal placentation.
2. Axile placentation.
3. Parietal placentation.
4. Free-central placentation.
5. Basal placentation.
6. Superficial placentation.

A. Marginal placentation

Marginal placentation is the arrangement in which ovules are attached along the ventral suture or margin of a single carpel.

Characteristics

1. The ovary is usually formed from one carpel.
2. The ovary is generally unilocular.
3. Ovules are attached along one margin.
4. It is common in plants belonging to the pea family.

Examples

- Pea.
- Bean.

- Groundnut.

B. Axile placentation

Axile placentation is the arrangement in which ovules are attached to a central axis within a compound ovary divided into two or more chambers.

Characteristics

1. The ovary is formed from two or more fused carpels.
2. The ovary is usually multilocular.
3. Ovules are attached to a central axis.
4. Septa divide the ovary into chambers.

Examples

- Tomato.
- Hibiscus.
- Orange.
- Lemon.
- Cotton.

C. Parietal placentation

Parietal placentation is the arrangement in which ovules are attached to the inner wall of a unilocular ovary.

Characteristics

1. Ovules are attached to the inner wall of the ovary.
2. The ovary is usually unilocular.
3. The placenta develops along the inner ovary wall.
4. False septa may develop in some species.

Examples

- Cucumber.
- Pumpkin.
- Mustard.
- Passion fruit.

D. Free-central placentation

Free-central placentation is the arrangement in which ovules are attached to a central column within a unilocular ovary, without septa extending to the ovary wall.

Characteristics

1. Ovules are attached to a central column.
2. The ovary is unilocular.
3. Septa are absent.

4. The central placenta is free within the ovary.

Examples

- Primula.
- Dianthus in some classifications and species.

E. Basal placentation

Basal placentation is the arrangement in which one or a few ovules are attached at the base of the ovary.

Characteristics

1. The placenta is located at the base of the ovary.
2. The ovary is usually unilocular.
3. One or a few ovules may be present.
4. The ovule develops from the basal region.

Examples

- Sunflower.
- Marigold.
- Some other members of the Asteraceae family.

F. Superficial placentation

Superficial placentation is the arrangement in which ovules are attached to the inner surfaces of the septa or locule walls in a multilocular ovary.

Characteristics

1. Ovules are attached to the inner surfaces of the ovary chambers.
2. The ovary is usually multilocular.
3. Ovules may occur on the surfaces of the septa.
4. Many ovules may be present.

Example

- Water lily (Nymphaea).

15.3 Summary of placentation

Type	Arrangement of ovules	Examples
Marginal	Along the margin of a single carpel.	Pea, bean
Axile	On a central axis in a multilocular ovary.	Tomato, orange
Parietal	Attached to the inner ovary wall.	Cucumber, passion fruit
Free-central	On a free central column without septa.	Primula
Basal	Attached at the base of the ovary.	Sunflower
Superficial	Attached to inner surfaces of septa or locules.	Water lily

Importance of placentation

1. It determines the arrangement of ovules in the ovary.
2. It provides attachment for developing ovules.

3. It helps in flower identification.
4. It is useful in the classification of flowering plants.
5. It provides information about the organisation of the ovary.
6. It helps botanists understand the reproductive structures of different plant species.

16.0 CLASSIFICATION OF FRUITS

Fruits are classified according to their origin, structure, texture and method of seed release.

The major categories include:

1. Simple fruits.
2. Aggregate fruits.
3. Multiple fruits.
4. True fruits and accessory fruits.
5. Fleshy fruits.
6. Dry fruits.

16.1 Classification according to origin

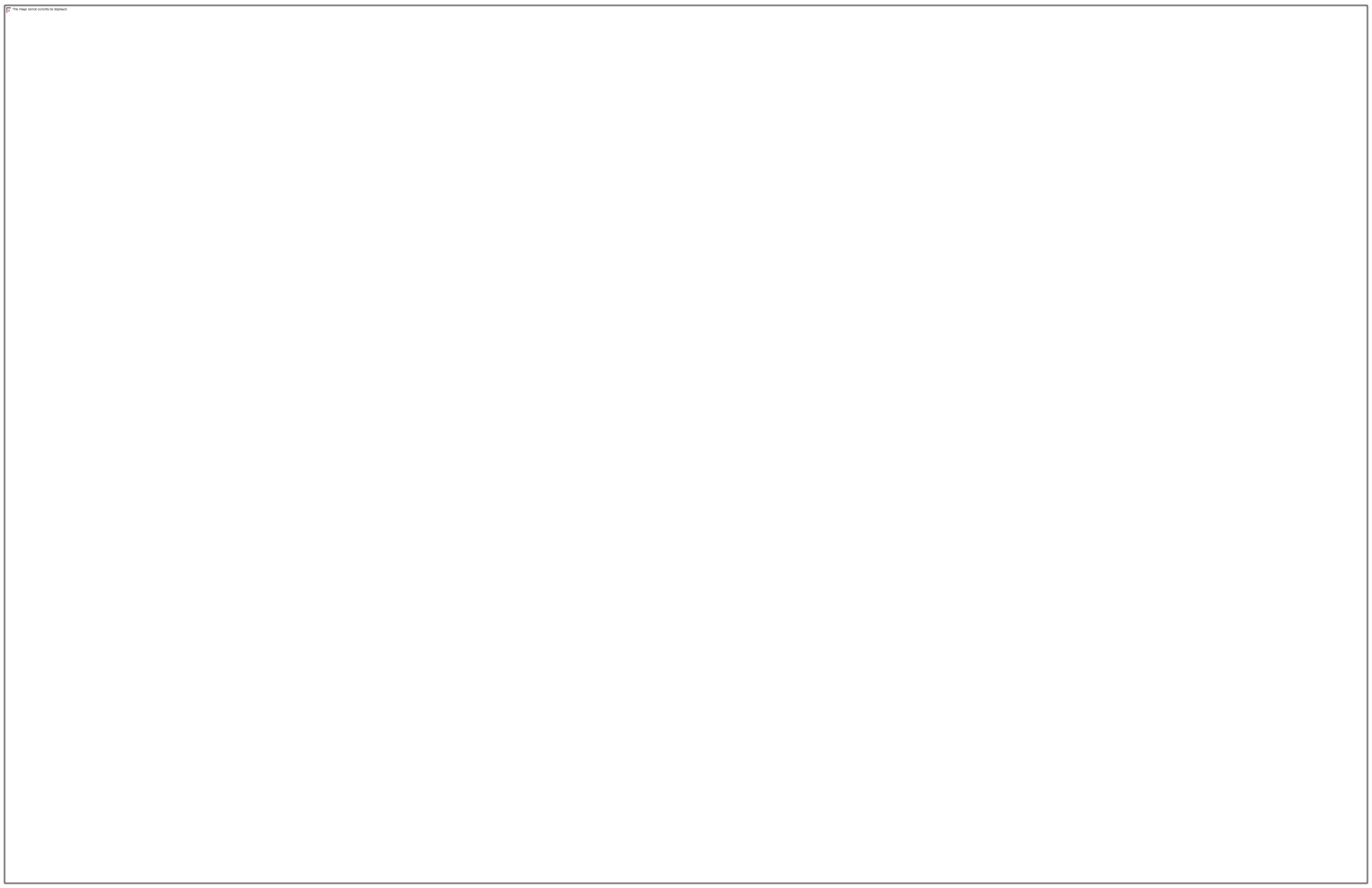
A. Simple fruits

A simple fruit is a fruit that develops from the single ovary of one flower, whether the ovary consists of one carpel or several fused carpels.

- It develops from one flower.
- It may contain one or several seeds.
- The pericarp may be fleshy or dry.
- It may be dehiscent or indehiscent.

Examples:

- Mango.
- Tomato.
- Orange.
- Bean.
- Maize.
- Avocado.



B. Aggregate fruits

An aggregate fruit is a fruit that develops from several separate carpels of a single flower.

- A single flower has several free ovaries.
- Each ovary develops into a small fruitlet.
- The fruitlets form a cluster on a common receptacle.
- The fruit appears as a group of small fruits joined together.

Examples:

- Strawberry.
- Raspberry.
- Blackberry.
- Custard apple.

Example: Strawberry

- A strawberry develops from a single flower with many separate carpels.
- The fleshy red part is largely an enlarged receptacle.
- The small structures on the outer surface are individual dry fruits called achenes.
- Each achene contains a seed.

C. Multiple fruits

A multiple fruit is a fruit that develops from the ovaries of several flowers in an inflorescence that become joined together into one mass.

- It develops from an entire inflorescence.
- Several flowers contribute to the formation of the fruit.
- The individual fruits become fused or closely united.
- The resulting structure appears as one large fruit.

Examples:

- Pineapple.
- Jackfruit.
- Mulberry.

Example: Pineapple

1. An inflorescence contains many individual flowers.
2. Each flower develops into a small fruit.
3. The fruits become joined together.
4. The floral axis and associated tissues contribute to the fleshy fruit structure.
5. A compound fruit develops.

Differences between simple, aggregate and multiple fruits

Simple fruit	**Aggregate fruit**	**Multiple fruit**
Develops from one ovary of one flower.	Develops from several separate ovaries of one flower.	Develops from ovaries of several flowers in an inflorescence.
One flower contributes to the fruit.	One flower contributes to the fruit.	Several flowers contribute to the fruit.
May be fleshy or dry.	Usually consists of clustered fruitlets.	Usually consists of fused or united fruits.
Mango, tomato, bean.	Strawberry, raspberry.	Pineapple, jackfruit.

16.2 Classification according to development

A. True fruits

A true fruit is a fruit that develops from the ovary of a flower after fertilisation, without significant contribution from other floral parts.

Examples:

- Mango.
- Tomato.
- Orange.

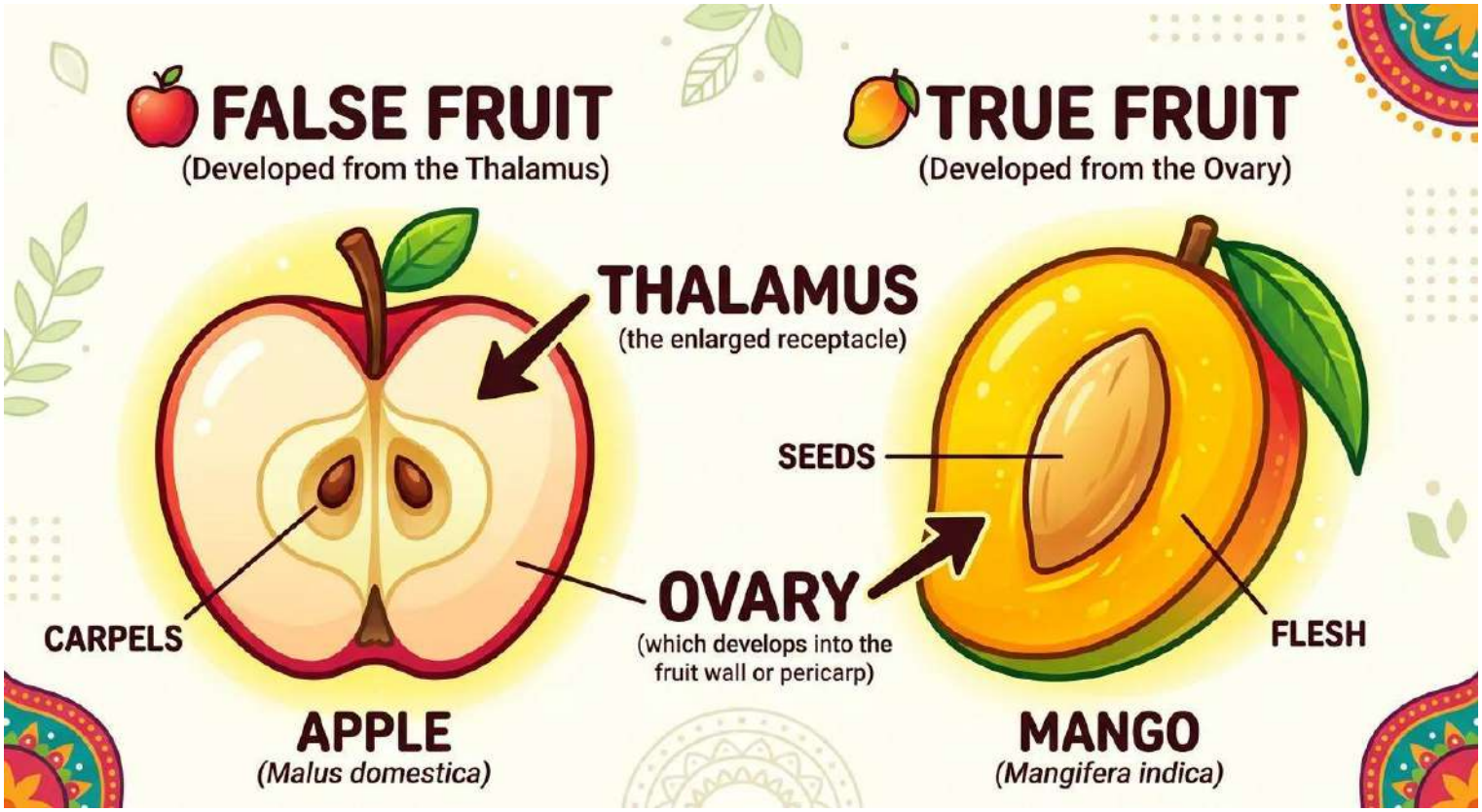
- Bean.
- Avocado.

B. Accessory fruits (false fruits)

An accessory fruit is a fruit in which tissues other than the ovary, such as the receptacle or hypanthium, contribute significantly to the fleshy edible structure.

Examples:

- Apple.
- Strawberry.
- Pear.
- Cashew apple.



Examples explained

Apple

- The fleshy edible portion develops mainly from the hypanthium and associated floral tissues.
- The core develops from the ovary.
- It is therefore classified as an accessory fruit.

Cashew

- The fleshy cashew apple develops from the swollen peduncle or receptacle.
- The true fruit is the kidney-shaped structure commonly called the cashew nut.

Strawberry

- The fleshy edible part is mainly the enlarged receptacle.

- The small achenes on the surface are the true fruits.

16.3 Classification according to texture

Fruits are also classified into:

1. Fleshy fruits.
2. Dry fruits.

A. Fleshy fruits

Fleshy fruits are fruits in which the pericarp becomes soft, juicy or fleshy when mature.

Characteristics:

1. The pericarp is usually soft.
2. The fruit often contains water and stored nutrients.
3. The edible parts may attract animals.
4. Animals may disperse the seeds after eating the fruit.
5. They are important sources of food.

Examples:

- Mango.
- Tomato.
- Orange.
- Avocado.
- Guava.
- Passion fruit.
- Watermelon.
- Pawpaw.

Types of fleshy fruits

1. Berry

A berry is a simple fleshy fruit in which the entire pericarp, except the outer skin, is generally soft or fleshy, and seeds are embedded in the fleshy tissue.

Characteristics:

- It usually develops from a single ovary.
- The pericarp is mostly fleshy.
- It may contain one or many seeds.
- It usually does not split open naturally when mature.

Examples:

- Tomato.
- Guava.

- Banana.
- Pawpaw.
- Passion fruit.

2. Drupe

A drupe is a fleshy fruit with a thin outer skin, a fleshy middle layer and a hard, stony inner layer surrounding the seed.

Characteristics:

- The exocarp is usually thin.
- The mesocarp is generally fleshy.
- The endocarp is hard and stony.
- It usually contains one seed.

Examples:

- Mango.
- Peach.
- Coconut.
- Olive.

3. Pepo

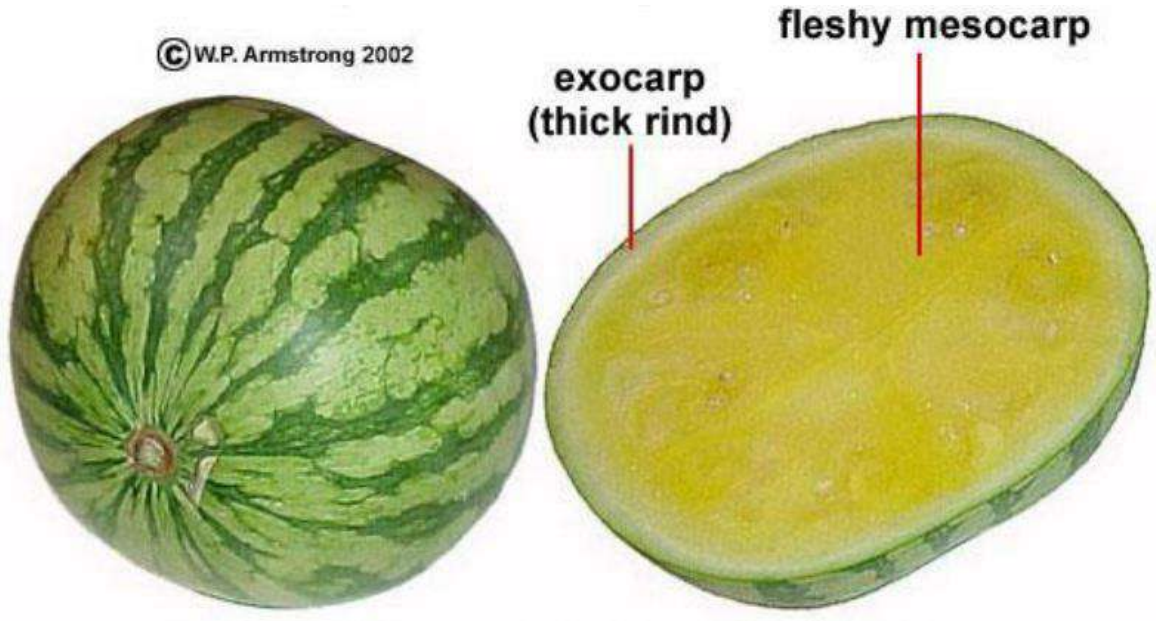
A pepo is a type of fleshy fruit with a hard or leathery outer rind, developing from an inferior ovary.

Characteristics:

- It has a relatively thick outer rind.
- It is usually fleshy inside.
- It often contains numerous seeds.
- It is typical of plants in the cucumber family.

Examples:

- Pumpkin.
- Watermelon.
- Cucumber.
- Butternut.
- Melon.



4. Hesperidium

A hesperidium is a specialised berry with a leathery rind containing oil glands and an internal fleshy region divided into segments.

Characteristics:

- It has a thick leathery outer rind.
- The rind contains oil glands.
- The inside is divided into segments.
- The segments contain juicy sacs.

Examples:

- Orange.
- Lemon.
- Lime.
- Grapefruit.

5. Pome

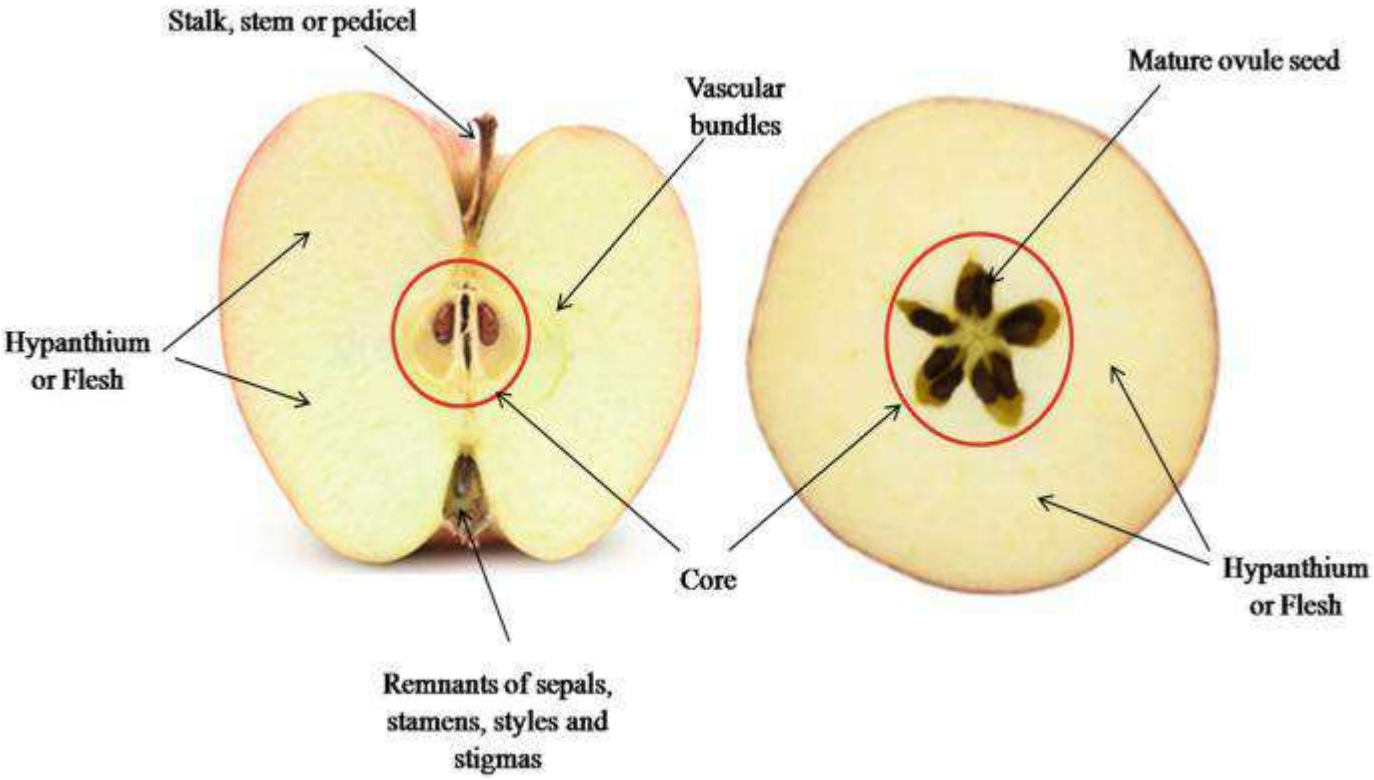
A pome is an accessory fleshy fruit in which much of the edible portion develops from the hypanthium surrounding the ovary.

Characteristics:

- It has a fleshy outer edible portion.
- The ovary forms a central core.
- The fruit commonly contains several seeds.
- It develops from an inferior ovary.

Examples:

- Apple.
- Pear.



Summary of fleshy fruit types

Type	Main identifying feature	Examples
Berry	Generally fleshy pericarp with seeds embedded inside.	Tomato, guava
Drupe	Hard, stony endocarp.	Mango, coconut
Pepo	Thick rind, usually from an inferior ovary.	Pumpkin, watermelon
Hesperidium	Leathery oil-containing rind and segmented juicy interior.	Orange, lemon
Pome	Fleshy accessory tissue surrounding a central core.	Apple, pear

B. Dry fruits

Dry fruits are fruits in which the pericarp becomes dry and hard or papery when mature.

They are classified into:

1. Dehiscent dry fruits.
2. Indehiscent dry fruits.
3. Schizocarpic fruits.

16.4 DEHISCENT DRY FRUITS

Meaning

Dehiscent dry fruits are dry fruits that split open naturally when mature to release their seeds.

Characteristics

1. The pericarp becomes dry at maturity.
2. The fruit develops natural lines or regions of splitting.
3. It opens when mature.
4. Seeds are released without the fruit being eaten or destroyed.

Types of dehiscent fruits

1. Legume (pod)

- Develops from a single carpel.
- Usually splits along two sutures.
- Seeds are attached along one margin.
- It is common in the family Fabaceae.

Examples:

- Bean.
- Pea.
- Groundnut.
- Cowpea.
- Acacia.

2. Capsule

- Develops from a compound ovary.
- Contains several seeds.
- Opens through different methods depending on the plant species.

Examples:

- Cotton.
- Okra.
- Datura.
- Hibiscus.

3. Siliqua

- It is a long, narrow dry fruit.
- It develops from a bicarpellary ovary.
- It has two valves that separate from a persistent central partition called the replum.
- Seeds are attached to the central partition.

Examples:

- Mustard.
- Cabbage.
- Radish.

4. Silicula

- It resembles a siliqua but is shorter and broader.
- It usually has a length not greatly exceeding its width.
- It develops from a bicarpellary ovary.

Examples:

- Shepherd's purse.
- Candytuft.

16.5 INDEHISCENT DRY FRUITS

Meaning

Indehiscent dry fruits are dry fruits that do not split open naturally when mature.

- The seeds remain enclosed within the fruit.
- The entire fruit may be dispersed.
- The fruit wall may be thin, hard or winged.

Types of indehiscent fruits

1. Achene

- A small, dry, one-seeded fruit.
- The pericarp is not fused with the seed coat.
- It does not split open at maturity.

Examples:

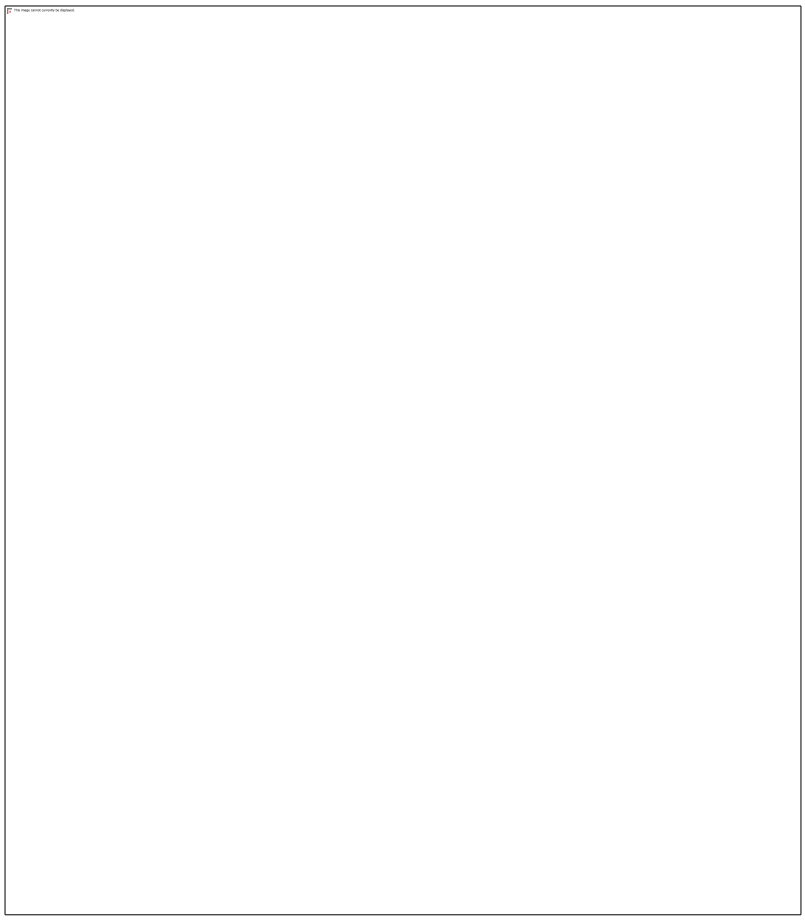
- Individual fruits of sunflower.
- Strawberry achenes.
- Clematis.

2. Caryopsis (grain)

- A dry, one-seeded fruit.
- The pericarp is fused with the seed coat.
- It is characteristic of grasses.

Examples:

- Maize.
- Wheat.
- Rice.
- Barley.
- Sorghum.



3. Nut

- A dry, usually one-seeded fruit.
- It has a hard, woody pericarp.
- It does not split open at maturity.

Examples:

- Hazelnut.
- Acorn.
- Chestnut.

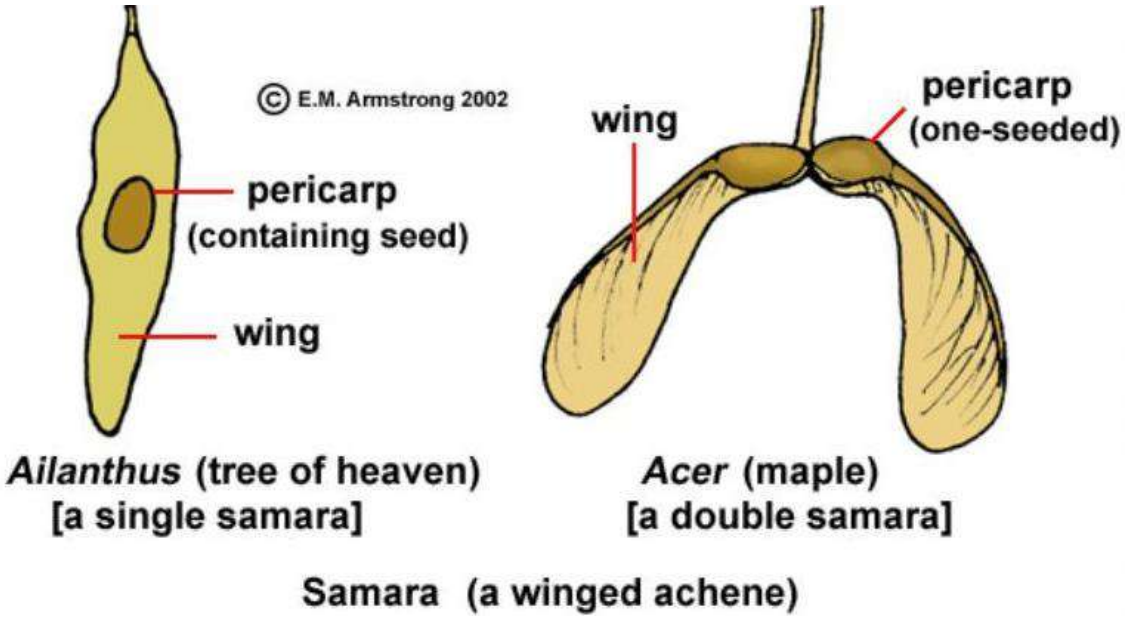
Important: A botanical nut is not the same as every food commonly called a nut. For example, groundnut is a legume, while cashew is a drupe with an accessory cashew apple.

4. Samara

- A dry, one-seeded fruit.
- It has a wing-like extension.
- The wing assists in wind dispersal.

Examples:

- Maple.
- Ash.
- Some indigenous tree species.



Samara (a winged achene)

16.6 SCHIZOCARPIC FRUITS

Meaning

Schizocarpic fruits are dry fruits that split into separate one-seeded sections called mericarps when mature, but the individual sections do not normally split open to release the seeds.

Characteristics:

1. They develop from a compound ovary.
2. The ovary divides into separate sections.
3. Each section contains one or more seeds depending on the plant.
4. The sections separate at maturity.
5. Each mericarp may be dispersed separately.

Examples:

- Coriander.
- Carrot.
- Fennel.
- Castor.

Summary of dry fruits

Category	Meaning	Examples
Dehiscent	Splits open at maturity.	Bean, cotton, mustard
Indehiscent	Does not split open at maturity.	Maize, wheat, sunflower
Schizocarpic	Splits into separate one-seeded sections.	Coriander, carrot, fennel

16.7 Classification of fruits using Kenyan crop examples

Crop	Botanical fruit type
Mango	Drupe
Avocado	Berry
Tomato	Berry
Orange	Hesperidium
Lemon	Hesperidium
Watermelon	Pepo
Pumpkin	Pepo
Cucumber	Pepo
Apple	Pome
Bean	Legume
Pea	Legume
Cotton	Capsule
Okra	Capsule
Maize	Caryopsis
Wheat	Caryopsis
Rice	Caryopsis
Sunflower	Achene-like fruit
Pineapple	Multiple fruit
Strawberry	Aggregate accessory fruit
Cashew	Drupe with an accessory cashew apple

17.0 SEED AND FRUIT DISPERSAL

17.1 Meaning of seed dispersal

Seed dispersal is the process through which seeds or fruits are spread away from the parent plant to different locations.

- It reduces overcrowding around the parent plant.
- It reduces competition for light, water, nutrients and space.
- It enables plants to colonise new habitats.
- It contributes to the distribution of plant populations.
- It supports biodiversity and ecological balance.

17.2 Agents of seed and fruit dispersal

The main agents include:

1. Wind.
2. Water.
3. Animals.
4. Explosive mechanisms.
5. Gravity.

A. Wind dispersal

Wind dispersal is the movement of seeds or fruits from the parent plant by air currents.

Adaptations

- Small and light seeds.
- Wing-like structures.
- Hair-like structures.
- Feathery appendages.
- Large surface area relative to mass.

Examples:

- Dandelion.
- Cotton.
- Milkweed.
- Some orchids.
- Maple.

B. Water dispersal

Water dispersal is the movement of seeds or fruits by water currents.

Adaptations

- Waterproof outer coverings.
- Air spaces that provide buoyancy.
- Fibrous husks.
- Ability to remain afloat for some time.

Examples:

- Coconut.
- Some mangroves.
- Water lilies.

C. Animal dispersal

Animal dispersal occurs when animals carry seeds or fruits from one location to another.

It takes place in two main ways.

i. Internal dispersal

- Animals eat fleshy fruits.
- The seeds pass through the digestive tract.
- Some seeds remain undamaged.
- They are deposited in faeces away from the parent plant.

Examples:

- Guava.
- Mango.
- Pawpaw.
- Wild berries.

ii. External dispersal

- Some fruits possess hooks, spines or sticky surfaces.
- They attach to animal fur, feathers or human clothing.
- They are transported to different locations.
- They eventually fall off.

Examples:

- Black jack.
- Xanthium.
- Bidens.

D. Explosive dispersal

Explosive dispersal occurs when mature fruits split suddenly and scatter seeds away from the parent plant.

Adaptations

- Dry fruit walls develop tension as they mature.
- The fruit splits suddenly.
- Seeds are thrown away from the parent plant.

Examples:

- Touch-me-not (Impatiens).
- Castor.
- Some legumes.

E. Gravity dispersal

Gravity dispersal occurs when heavy fruits fall from the parent plant to the ground.

Examples:

- Mango.
- Avocado.
- Jackfruit.
- Some large indigenous fruits.

17.3 Importance of seed dispersal

1. Reduces overcrowding around the parent plant.
2. Reduces competition for resources.
3. Enables colonisation of new habitats.
4. Promotes distribution of plant species.
5. Increases the chances of seed establishment in suitable environments.
6. Supports regeneration of natural vegetation.
7. Maintains ecological balance.
8. Contributes to biodiversity conservation.

18.0 IMPORTANCE OF SEXUAL AND ASEXUAL REPRODUCTION IN AGRICULTURE

Reproduction in plants has great importance in Kenyan agriculture, horticulture, forestry and food production.

18.1 Importance of asexual reproduction

1. **Rapid multiplication:** Large numbers of plants can be produced within a short period.
2. **Preservation of desirable characteristics:** New plants usually retain the characteristics of the parent.
3. **Early maturity:** Some vegetatively propagated crops mature earlier than seed-grown plants.
4. **Propagation of seedless plants:** It enables multiplication of plants that produce few or no viable seeds.
5. **Uniformity:** It produces relatively uniform crop populations.
6. **Food security:** It supports the production of crops such as bananas, potatoes and cassava.
7. **Commercial horticulture:** It supports the propagation of flowers and ornamental plants.
8. **Conservation:** It helps preserve valuable plant varieties.
9. **Reliable establishment:** Suitable vegetative planting materials can establish more predictably than some seeds.
10. **Disease-free planting materials:** Appropriate tissue culture methods can produce planting materials free from particular pathogens.

18.2 Importance of sexual reproduction

1. **Genetic variation:** It creates new combinations of hereditary characteristics.
2. **Adaptation:** It increases the likelihood that some offspring will survive changing environmental conditions.
3. **Plant breeding:** It provides the basis for developing improved crop varieties.
4. **Disease resistance:** It enables breeders to combine useful resistance characteristics.
5. **Improved crop performance:** It can produce varieties with desirable yield and quality characteristics.
6. **Species continuity:** It ensures continuation of plant populations.

7. **Seed production:** It provides seeds for crop propagation.
8. **Evolution:** Genetic variation supports evolutionary processes.
9. **Environmental resilience:** Genetic diversity may improve population resilience.
10. **Conservation:** Sexual reproduction contributes to maintaining genetic diversity in wild plant populations.

18.3 Differences between sexual and asexual reproduction in crop production

Sexual reproduction	Asexual reproduction
Produces genetically varied offspring.	Usually produces genetically similar offspring.
Involves fertilisation.	Does not involve fertilisation.
Produces seeds in seed plants.	Produces new plants from vegetative parts.
Useful in crop breeding.	Useful in multiplying selected varieties.
May take longer for some crops to reach maturity.	Some crops establish and mature earlier.
Examples: Maize, beans, rice.	Examples: Potato, banana, cassava.

19.0 PRACTICAL ACTIVITIES AND LEARNING EXPERIENCES

The following activities help Grade 11 learners acquire practical skills, scientific inquiry skills, observation skills, creativity and problem-solving abilities.

Activity 1: Identification of specialised vegetative structures

Aim: To identify specialised vegetative structures in plants.

Materials

- Irish potato.
- Onion bulb.
- Ginger rhizome.
- Strawberry runner or suitable grass stolon.
- Gladiolus corm, where available.
- Hand lens.
- Knife or scalpel.
- Dissecting board.
- Labels.

Procedure

1. Collect the different plant specimens.
2. Observe their external features.
3. Use a hand lens to examine buds, nodes and internodes.
4. Cut the onion bulb longitudinally.
5. Observe the fleshy scale leaves and basal plate.
6. Examine the potato eyes.
7. Observe nodes and buds on the ginger rhizome.
8. Identify the runner and its developing plantlets.
9. Draw and label each structure.
10. State the function of each structure in vegetative propagation.

Expected outcomes

Learners should be able to:

- Identify specialised vegetative structures.
- Distinguish modified stems from roots.
- Explain the role of buds in vegetative propagation.
- Relate the structures to crop production.

Activity 2: Propagation using stem cuttings

Aim: To demonstrate artificial vegetative propagation.

Materials

- Sugarcane or cassava stems.
- Sharp knife.
- Planting containers.
- Suitable soil.
- Water.
- Labels.

Procedure

1. Select healthy sugarcane or cassava stems.
2. Cut the stems into sections containing viable buds.
3. Prepare planting containers with suitable soil.
4. Plant the cuttings appropriately.
5. Water the cuttings.
6. Place them under suitable conditions.
7. Observe the development of roots and shoots.
8. Record changes over time.
9. Compare the growth of the different cuttings.

Expected outcome

The cuttings may develop roots and shoots, resulting in new plants.

Activity 3: Identification of flower structures

Aim: To identify the reproductive and non-reproductive structures of a flower.

Materials

- Hibiscus flower.
- Bean flower.
- Hand lens.
- Forceps.
- Dissecting needle.
- Razor blade.
- Microscope.
- White paper.

Procedure

1. Collect fresh flowers from different plant species.
2. Observe the external structure.

3. Identify sepals and petals.
4. Remove the petals carefully.
5. Identify the stamens.
6. Separate the anther from the filament.
7. Identify the stigma, style and ovary.
8. Cut the ovary transversely.
9. Observe the ovules inside the ovary.
10. Draw and label the different structures.

Expected outcome

Learners should identify the four floral whorls and explain their functions.

Activity 4: Classification of flowers

Aim: To classify flowers using observable characteristics.

Materials

- Hibiscus.
- Bean.
- Maize.
- Pumpkin.
- Sunflower.
- Cucumber.
- Hand lens.
- Dissecting tools.

Procedure

1. Observe each flower carefully.
2. Identify the position of the ovary.
3. Determine whether the flower is radially or bilaterally symmetrical.
4. Examine whether it contains stamens, carpels or both.
5. Observe the arrangement of flowers on the plant.
6. Record the findings in a table.
7. Classify each flower according to the four criteria.

Activity 5: Investigating pollen grains

Aim: To observe pollen grains under a microscope.

Materials

- Fresh flowers.
- Microscope.

- Microscope slides.
- Cover slips.
- Dropper.
- Water or suitable mounting medium.

Procedure

1. Collect mature flowers.
2. Remove anthers carefully.
3. Tap the anthers gently onto a clean slide.
4. Add a drop of water or suitable mounting medium.
5. Place a cover slip over the specimen.
6. Observe under low and high power.
7. Draw the pollen grains.
8. Compare pollen grains from different flowers.

Expected outcomes

Learners should observe differences in pollen grain size, shape and surface features.

Activity 6: Investigating fruit structure

Aim: To identify the parts and types of fruits.

Materials

- Mango.
- Orange.
- Tomato.
- Bean pod.
- Maize grain.
- Pumpkin.
- Knife.
- Dissecting board.
- Hand lens.

Procedure

1. Collect the different fruits.
2. Observe their external characteristics.
3. Cut the fleshy fruits longitudinally.
4. Identify the exocarp, mesocarp and endocarp where distinguishable.
5. Observe the seeds.

6. Examine the bean pod and maize grain.
7. Classify each fruit according to its structure.
8. Record the results.

Activity 7: Investigation of seed germination

Aim: To investigate the conditions required for seed germination.

Materials

- Bean seeds.
- Maize seeds.
- Cotton wool.
- Water.
- Containers.
- Labels.

Procedure

Set up different experimental conditions:

- Container A: Moist cotton wool and adequate air.
- Container B: Dry cotton wool.
- Container C: Seeds completely submerged in water.
- Container D: Moist cotton wool kept under suitable warm conditions.

Observe and record the changes over several days.

Expected outcome

Seeds require adequate moisture, oxygen and a suitable temperature for successful germination. Light is not essential for germination of many common seeds, although it is important for subsequent seedling growth.

Safety: Do not consume experimental seeds. Dispose of mouldy specimens safely.

REVISION QUESTIONS

SECTION A: MULTIPLE-CHOICE QUESTIONS

Choose the correct answer from the alternatives provided.

1. Which one of the following best describes reproduction in plants?

A. Process through which plants manufacture food.

B. Process through which plants produce new individuals of their own kind.

C. Process through which plants absorb mineral salts.

D. Process through which plants lose excess water.

2. Which one of the following is a characteristic of asexual reproduction?

A. It involves fusion of gametes.

B. It requires two parent plants.

C. It produces offspring usually genetically similar to the parent.

D. It always involves seed formation.

3. The reproductive structures responsible for spore production in ferns are called:

A. Anthers.

B. Sporangia.

C. Ovules.

D. Stigmas.

4. In ferns, spores are produced through:

A. Mitosis.

B. Meiosis.

C. Fertilisation.

D. Pollination.

5. Which one of the following structures is responsible for vegetative propagation in strawberries?

A. Bulbs.

B. Runners.

C. Tubers.

D. Rhizomes.

6. The fleshy scale leaves of an onion bulb mainly function in:

A. Absorption of mineral salts.

B. Food storage.

C. Pollen production.

D. Seed dispersal.

7. Which one of the following is a modified underground stem with distinct nodes and internodes?

A. Carrot.

B. Ginger.

C. Sweet potato.

D. Radish.

8. The small depressions on the surface of an Irish potato tuber are called:

A. Lenticels.

B. Eyes.

C. Scales.

D. Internodes.

9. Which one of the following is an example of a plant that reproduces through corms?

A. Gladiolus.

B. Mango.

C. Maize.

D. Bean.

10. Which one of the following statements about offshoots is correct?

A. They develop from fertilised ovules.

B. They are young lateral shoots that may develop into independent plants.

C. They are produced inside pollen sacs.

D. They are always produced through meiosis.

11. A farmer cuts a section of sugarcane stem containing viable buds and plants it in moist soil. The method used is:

A. Layering.

B. Grafting.

C. Stem cutting.

D. Pollination.

12. In grafting, the upper part that develops into the shoot system is called:

A. Rootstock.

B. Scion.

C. Explant.

D. Rhizome.

13. Which one of the following structures is responsible for sexual reproduction in flowering plants?

A. Root.

B. Flower.

C. Stem.

D. Leaf.

14. The male reproductive whorl of a flower is called:

A. Calyx.

B. Corolla.

C. Androecium.

D. Gynoecium.

15. Which one of the following is the female reproductive part of a flower?

A. Stamen.

B. Carpel.

C. Filament.

D. Anther.

16. A flower in which the ovary is positioned above the attachment of the other floral parts is described as:

A. Epigynous.

B. Perigynous.

C. Hypogynous.

D. Zygomorphic.

17. Which one of the following plants produces hypogynous flowers?

A. Hibiscus.

B. Guava.

C. Cucumber.

D. Apple.

18. A flower that can be divided into two equal halves through only one vertical plane is described as:

A. Actinomorphic.

B. Zygomorphic.

C. Asymmetric.

D. Hypogynous.

19. Which one of the following is an example of a zygomorphic flower?

A. Hibiscus.

B. Mustard.

C. Pea.

D. Tomato.

20. The arrangement of flowers on a floral axis is called:

A. Placentation.

B. Inflorescence.

C. Fertilisation.

D. Germination.

21. Which one of the following is an example of racemose inflorescence?

A. Mustard raceme.

B. Jasmine dichasial cyme.

C. Dianthus cyme.

D. A terminal solitary flower.

22. In a cymose inflorescence:

A. The main axis continues growing indefinitely.

B. The main axis terminates in a flower.

C. Flowers are always arranged in a circle.

D. Flowers develop only underground.

23. A flower containing both stamens and carpels is described as:

A. Unisexual. B. Bisexual. C. Dioecious. D. Staminate.

24. A plant that bears male and female flowers on the same individual plant is described as:

A. Dioecious. B. Monoecious.

C. Zygomorphic. D. Epigynous.

25. Which one of the following is a dioecious plant?

A. Maize. B. Pumpkin.

C. Date palm. D. Cucumber.

26. The transfer of pollen grains from anther to stigma is called:

A. Fertilisation.

B. Pollination.

C. Germination.

D. Placentation.

27. Transfer of pollen from the anther to the stigma of the same flower is called:

A. Xenogamy.

B. Geitonogamy.

C. Autogamy.

D. Cross-fertilisation.

28. Which one of the following is an adaptation of wind-pollinated flowers?

A. Brightly coloured petals.

B. Large quantities of nectar.

C. Feathery stigmas.

D. Strong floral scent.

29. When anthers mature before the stigma becomes receptive, the condition is called:

A. Protogyny.

B. Protandry.

C. Herkogamy.

D. Heterostyly.

30. The spatial separation of anthers and stigma in a flower is called:

A. Herkogamy.

B. Syngamy.

C. Triple fusion.

D. Placentation.

31. Which one of the following mechanisms involves different lengths of styles and stamens?

A. Protandry.

B. Protogyny.

C. Heterostyly.

D. Self-incompatibility.

32. Which one of the following is the main function of self-incompatibility?

A. To promote self-fertilisation.

B. To prevent successful fertilisation by self-pollen.

C. To increase pollen production.

D. To promote seed dormancy.

33. Double fertilisation is a characteristic feature of:

A. Ferns. B. Mosses.

C. Gymnosperms. D. Angiosperms.

34. Fusion of one male gamete with the egg cell is called:

A. Triple fusion.

B. Syngamy.

C. Pollination.

D. Germination.

35. The fusion of the second male gamete with two polar nuclei produces:

A. A diploid zygote.

B. A haploid embryo.

C. A triploid primary endosperm nucleus.

D. A pollen grain.

36. After fertilisation, the ovule normally develops into a:

A. Fruit.

B. Seed.

C. Petal.

D. Stigma.

37. The ovary wall develops into the:

A. Testa.

B. Pericarp.

C. Embryo.

D. Cotyledon.

38. The arrangement of ovules within an ovary is called:

A. Inflorescence.

B. Placentation.

C. Pollination.

D. Germination.

39. Which type of placentation has ovules attached to a central axis in a multilocular ovary?

A. Marginal. B. Basal.

C. Axile. D. Parietal.

40. The type of placentation commonly found in pea is:

A. Axile.

B. Marginal.

C. Basal.

D. Superficial.

41. Which one of the following fruits develops from several separate ovaries of one flower?

A. Simple fruit.

B. Aggregate fruit.

C. Multiple fruit.

D. Accessory fruit.

42. Pineapple is classified as a:

A. Simple fruit.

B. Aggregate fruit.

C. Multiple fruit.

D. Dry fruit.

43. Which one of the following is a drupe?

A. Tomato.

B. Mango.

C. Orange.

D. Pumpkin.

44. The fruit type characterised by a leathery rind and juicy segments is:

A. Pepo.

B. Berry.

C. Hesperidium.

D. Pome.

45. Which one of the following is a caryopsis?

A. Mango.

B. Maize.

C. Orange.

D. Tomato.

46. A dry fruit that splits open naturally when mature is described as:

A. Indehiscent.

B. Dehiscent.

C. Fleshy.

D. Accessory.

47. Which one of the following is an example of a capsule?

A. Cotton. B. Mango.

C. Orange. D. Avocado.

48. Which one of the following is an adaptation for wind dispersal?

A. Thick fleshy mesocarp.

B. Hooks and spines.

C. Wing-like structures.

D. Hard stony endocarp.

49. The edible fleshy part of a strawberry develops mainly from the:

A. Ovule.

B. Receptacle.

C. Seed coat.

D. Anther.

50. Which one of the following is an important advantage of sexual reproduction in plants?

A. Production of genetically identical offspring.

B. Increased genetic variation.

C. Elimination of fertilisation.

D. Absence of gamete formation.

SECTION B: STRUCTURED QUESTIONS

51. Reproduction in plants

a) Define reproduction in plants. (2 marks)

b) State four characteristics of asexual reproduction. (4 marks)

c) Distinguish between sexual and asexual reproduction in plants. (6 marks)

d) Explain four advantages of asexual reproduction in crop production. (4 marks)

e) Explain four advantages of sexual reproduction in plants. (4 marks)

52. Sporulation

a) Define sporulation. (2 marks)

b) Name four organisms that reproduce through spores. (4 marks)

c) Describe the process of spore formation in ferns. (6 marks)

d) Explain the role of the following structures in fern reproduction:

i. Sorus. (2 marks)

ii. Sporangium. (2 marks)

iii. Prothallus. (2 marks)

e) Explain three advantages of reproduction through spores. (3 marks)

53. Vegetative propagation

a) Define vegetative propagation. (2 marks)

b) Distinguish between natural and artificial vegetative propagation. (4 marks)

c) Name six specialised vegetative structures found in plants. (6 marks)

d) Describe the process of vegetative propagation through:

i. Runners. (4 marks)

ii. Bulbs. (4 marks)

iii. Rhizomes. (4 marks)

iv. Tubers. (4 marks)

e) Explain four advantages of vegetative propagation in agriculture. (4 marks)

54. Specialised vegetative structures

a) Explain why ginger is classified as a modified underground stem rather than a root. (4 marks)

b) Describe the structure of an Irish potato tuber. (5 marks)

c) Explain how onion bulbs enable vegetative propagation. (4 marks)

d) Differentiate between:

i. Runners and rhizomes. (4 marks)

ii. Bulbs and corms. (4 marks)

iii. Offshoots and suckers. (4 marks)

e) Give two examples of plants that reproduce through each of the following:

i. Corms. (2 marks)

ii. Offshoots. (2 marks)

iii. Vegetative plantlets. (2 marks)

55. Artificial vegetative propagation

a) Define artificial vegetative propagation. (2 marks)

b) Describe the procedure for propagating sugarcane through stem cuttings. (5 marks)

c) Explain the process of grafting in fruit trees. (6 marks)

d) Distinguish between scion and rootstock. (4 marks)

e) Describe two methods of layering. (4 marks)

f) State four advantages of artificial vegetative propagation. (4 marks)

56. Sexual reproduction in flowering plants

a) Define sexual reproduction in flowering plants. (2 marks)

b) Draw and label a longitudinal section of a typical bisexual flower. (8 marks)

c) Describe the functions of:

i. Sepals. (2 marks)

ii. Petals. (2 marks)

iii. Anthers. (2 marks)

iv. Filaments. (2 marks)

v. Stigma. (2 marks)

vi. Style. (2 marks)

vii. Ovary. (2 marks)

d) Differentiate between a complete flower and an incomplete flower. (2 marks)

57. Classification of flowers

a) Explain how flowers are classified according to the position of the ovary. (6 marks)

b) Distinguish between hypogynous and epigynous flowers. (4 marks)

c) Give two examples of each of the following:

i. Hypogynous flowers. (2 marks)

ii. Perigynous flowers. (2 marks)

iii. Epigynous flowers. (2 marks)

d) Explain the meaning of floral symmetry. (2 marks)

e) Differentiate between actinomorphic and zygomorphic flowers. (4 marks)

f) Give two examples of asymmetric flowers. (2 marks)

58. Inflorescence

a) Define inflorescence. (2 marks)

b) Distinguish between racemose and cymose inflorescence. (6 marks)

c) Describe the characteristics of the following types of racemose inflorescence:

i. Raceme. (3 marks)

ii. Spike. (3 marks)

iii. Umbel. (3 marks)

iv. Capitulum. (3 marks)

v. Panicle. (3 marks)

d) Describe the structure of a dichasial cyme. (3 marks)

e) Give two examples of plants exhibiting racemose inflorescence. (2 marks)

59. Classification according to reproductive structures

a) Distinguish between bisexual and unisexual flowers. (4 marks)

b) Explain the difference between staminate and pistillate flowers. (4 marks)

c) Define the following terms:

i. Monoecious plant. (2 marks)

ii. Dioecious plant. (2 marks)

iii. Polygamous plant. (2 marks)

d) Give three examples of monoecious plants. (3 marks)

e) Give three examples of dioecious plants. (3 marks)

f) Explain how dioecy promotes cross-pollination. (3 marks)

60. Pollination

a) Define pollination. (2 marks)

b) Distinguish between:

i. Self-pollination and cross-pollination. (4 marks)

ii. Autogamy and geitonogamy. (4 marks)

c) Describe five characteristics of wind-pollinated flowers. (5 marks)

d) Explain five adaptations of insect-pollinated flowers. (5 marks)

e) Describe the role of the following pollinating agents:

i. Wind. (2 marks)

ii. Insects. (2 marks)

iii. Birds. (2 marks)

iv. Water. (2 marks)

f) State four advantages of cross-pollination. (4 marks)

61. Mechanisms preventing self-pollination

a) Define dichogamy. (2 marks)

b) Distinguish between protandry and protogyny. (4 marks)

c) Explain how herkogamy prevents self-pollination. (3 marks)

d) Describe heterostyly and explain its importance in cross-pollination. (4 marks)

e) Explain how self-incompatibility prevents self-fertilisation. (3 marks)

f) Distinguish between monoecy and dioecy. (4 marks)

g) Explain four mechanisms that promote cross-pollination in flowering plants. (4 marks)

62. Double fertilisation

a) Define fertilisation. (2 marks)

b) Define double fertilisation. (3 marks)

c) Draw and label the structure of a typical mature embryo sac. (7 marks)

d) Describe the events that occur from pollen germination to double fertilisation. (8 marks)

e) Distinguish between syngamy and triple fusion. (4 marks)

f) State four advantages of double fertilisation in flowering plants. (4 marks)

63. Seed development

a) Define a seed. (2 marks)

b) Explain the changes that occur in an ovule following fertilisation. (5 marks)

c) Draw and label the longitudinal section of a bean seed. (6 marks)

d) State the functions of the following structures:

i. Testa. (2 marks)

ii. Cotyledons. (2 marks)

iii. Plumule. (2 marks)

iv. Radicle. (2 marks)

v. Micropyle. (2 marks)

e) Differentiate between monocotyledonous and dicotyledonous seeds. (5 marks)

64. Fruit development

a) Define a fruit. (2 marks)

b) Explain the changes that occur in the ovary after fertilisation. (5 marks)

c) Describe the structure of a typical fleshy fruit. (5 marks)

d) Explain the functions of:

i. Exocarp. (2 marks)

ii. Mesocarp. (2 marks)

iii. Endocarp. (2 marks)

e) Explain five biological and economic importance of fruits. (5 marks)

65. Placentation

a) Define placentation. (2 marks)

b) Describe the following types of placentation:

i. Marginal. (3 marks)

ii. Axile. (3 marks)

iii. Parietal. (3 marks)

iv. Free-central. (3 marks)

v. Basal. (3 marks)

vi. Superficial. (3 marks)

c) Give one example of a plant for each type of placentation. (6 marks)

d) Explain three reasons why placentation is important in plant identification. (3 marks)

66. Classification of fruits

a) Explain the meaning of:

i. Simple fruit. (2 marks)

ii. Aggregate fruit. (2 marks)

iii. Multiple fruit. (2 marks)

iv. Accessory fruit. (2 marks)

b) Differentiate between simple, aggregate and multiple fruits. (6 marks)

c) Classify the following fruits according to their botanical types:

i. Mango. (1 mark)

ii. Orange. (1 mark)

iii. Pumpkin. (1 mark)

iv. Tomato. (1 mark)

v. Pineapple. (1 mark)

vi. Maize. (1 mark)

vii. Bean. (1 mark)

viii. Apple. (1 mark)

d) Explain the differences between dehiscent and indehiscent fruits. (4 marks)

e) Give three examples of dry dehiscent fruits. (3 marks)

f) Give three examples of dry indehiscent fruits. (3 marks)

STRAND: ANATOMY AND PHYSIOLOGY OF PLANTS

SUB-STRAND: GROWTH AND DEVELOPMENT IN PLANTS

1.0 MEANING OF GROWTH AND DEVELOPMENT IN PLANTS

1.1 Meaning of Growth

Growth is a permanent and irreversible increase in the size, volume, dry mass or number of cells of an organism resulting from cell division and cell enlargement.

In plants, growth occurs when cells divide through mitosis, enlarge and sometimes differentiate into specialised tissues.

Characteristics of plant growth

1. Growth is permanent because the increase in size and mass is normally irreversible.
2. Growth involves an increase in the number of cells through cell division.
3. Growth involves enlargement of existing cells through absorption of water and synthesis of new cellular materials.
4. Growth leads to an increase in the height, length, width and volume of plant organs.
5. Growth involves an increase in the dry mass of a plant due to the accumulation of organic substances produced during photosynthesis.
6. Growth occurs mainly in regions containing meristematic tissues.
7. Growth is influenced by environmental conditions such as water, light, temperature, oxygen and mineral salts.
8. Growth is regulated by plant hormones.

Examples of growth in plants

- Increase in the height of a maize plant.
- Enlargement of a mango fruit.
- Increase in the length of roots in bean plants.
- Increase in the diameter of a tree trunk.
- Development of new leaves and branches.
- Enlargement of storage roots such as sweet potatoes.

1.2 Meaning of Development

Development is the series of progressive changes that occur in a plant throughout its life, resulting in the formation of a mature and functional organism.

It involves changes in the structure, form, organisation and functions of plant cells, tissues and organs.

Development includes cell division, cell enlargement, cell differentiation, tissue formation, flowering, fruit formation and ageing.

Examples of development in plants

1. Differentiation of unspecialised cells into specialised xylem and phloem cells.
2. Development of roots, stems and leaves from the embryo.
3. Formation of flowers from vegetative buds.
4. Development of fruits from fertilised flowers.

5. Formation of seeds following fertilisation.
6. Maturation of a young plant into a reproductive adult plant.

1.3 Differences Between Growth and Development

Growth	Development
Involves a permanent increase in size and mass.	Involves progressive changes in form and function.
Mainly quantitative.	Mainly qualitative, although quantitative changes also occur.
Can be measured using height, length, mass and volume.	Assessed through changes in structure, maturity and function.
Involves cell division and enlargement.	Involves growth, differentiation and maturation.
Example: Increase in maize plant height.	Example: Formation of flowers in a mature maize plant.

Relationship between growth and development

- Growth contributes to development.
- Development involves growth together with differentiation and maturation.
- Both processes are controlled by genetic factors, plant hormones and environmental conditions.

1.4 Factors Affecting Plant Growth and Development

Plant growth and development are influenced by internal and external factors.

A. Internal factors

1. **Genetic constitution**

- Genes determine the inherited characteristics of a plant.
- They influence maximum height, growth rate, flowering time, fruit size and maturity period.
- For example, different varieties of maize have different maturity periods.

2. **Plant hormones**

- These are chemical substances that regulate plant growth and development.
- They influence cell division, elongation, flowering, fruit development and seed germination.

3. **Age of the plant**

- Young plants generally have actively dividing tissues.
- Mature plants may begin flowering and producing fruits.
- Old plants may experience reduced growth and senescence.

4. **Nutritional status**

- Plants require essential mineral elements for normal growth.

- Nitrogen promotes vegetative growth, while phosphorus supports root development and energy transfer.

B. External factors

1. **Water**

- Water is required for photosynthesis, transport of dissolved substances and maintenance of cell turgidity.
- It also facilitates cell enlargement.

2. **Light**

- Light provides energy for photosynthesis.
- It influences chlorophyll formation, flowering and directional growth.

3. **Temperature**

- Temperature affects enzyme activity and metabolic reactions.
- Extremely high or low temperatures may slow down or stop growth.

4. **Oxygen**

- Oxygen is required for aerobic respiration.
- Respiration provides energy needed for cell division and other growth processes.

5. **Mineral salts**

- Mineral elements are required for the synthesis of proteins, chlorophyll and other essential substances.
- Examples include nitrogen, phosphorus, potassium, magnesium and calcium.

6. **Carbon dioxide**

- Carbon dioxide is used during photosynthesis to manufacture carbohydrates.

7. **Soil conditions**

- Soil texture, structure, pH, drainage and fertility influence root development and nutrient availability.

2.0 STRUCTURE OF THE SEED

2.1 Meaning of a Seed

A seed is a mature fertilised ovule that contains an embryo, stored food and a protective covering.

Seeds are reproductive structures in flowering plants. Under favourable environmental conditions, a viable seed can germinate and develop into a new plant.

A typical seed consists of:

1. Seed coat.
2. Embryo.
3. Stored food.

2.2 General Structure of a Seed

A. Seed coat

The seed coat is the protective outer covering of a seed.

Functions of the seed coat

1. Protects the embryo against mechanical injury.
2. Protects the internal parts of the seed from harmful microorganisms.
3. Reduces water loss from the seed.
4. Regulates the entry of water and gases into the seed.
5. May contribute to seed dormancy by preventing water absorption or gaseous exchange.

B. Embryo

The embryo is the young developing plant contained inside the seed.

It develops into a new plant after germination.

The embryo consists of the following parts:

i. Radicle

- It is the embryonic root.
- It is usually the first part of the embryo to emerge during germination.
- It develops into the primary root.
- It anchors the young plant into the soil.
- It absorbs water and mineral salts from the soil.

ii. Plumule

- It is the embryonic shoot.
- It develops into the stem and leaves of the young plant.
- It grows upwards towards the soil surface in normal germination.

iii. Hypocotyl

- It is the portion of the embryonic axis below the cotyledons.
- It connects the radicle to the cotyledons.
- It elongates during germination in some plants, helping to lift the cotyledons above the soil.

iv. Epicotyl

- It is the portion of the embryonic axis above the cotyledons.
- It develops into the upper part of the shoot.
- It supports the developing plumule.

C. Cotyledons

Cotyledons are embryonic seed leaves found in the seed.

Functions of cotyledons

1. Store food for the developing embryo in some seeds.

2. Absorb and transfer stored food from the endosperm to the embryo in some seeds.
3. May emerge above the soil during epigeal germination.
4. May become green and carry out photosynthesis in certain plants.
5. Supply nutrients during the early stages of seedling development.

D. Endosperm

The endosperm is a food-storage tissue found in many seeds.

It develops following double fertilisation in flowering plants.

Functions

1. Stores food for the developing embryo.
2. Supplies nutrients during seed germination.
3. Supports early seedling development before the young plant becomes fully photosynthetic.

The stored food may include carbohydrates, proteins and oils.

E. Hilum

The hilum is the scar on the seed coat marking the point where the seed was attached to the fruit through the funicle.

Function:

- It indicates the point of attachment of the seed to the fruit.

F. Micropyle

The micropyle is a tiny opening in the seed coat.

Functions

1. Allows water to enter the seed during germination in many seeds.
2. Facilitates gaseous exchange.
3. Provides an opening through which the radicle may emerge.

3.0 MONOCOTYLEDONOUS AND DICOTYLEDONOUS SEEDS

Flowering plants are commonly classified into monocotyledonous and dicotyledonous plants based on the number of cotyledons in their embryos.

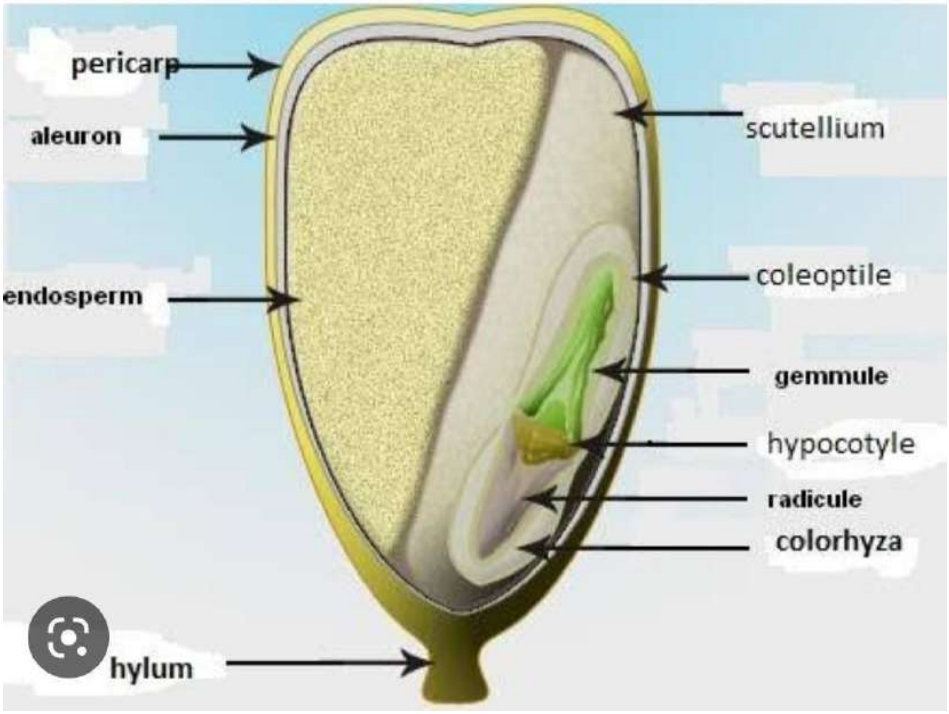
3.1 Monocotyledonous Seeds

Monocotyledonous seeds are seeds whose embryos contain only one cotyledon.

Examples include:

- Maize.
- Rice.
- Wheat.
- Sorghum.
- Millet.

- Barley.



Structure of a maize grain

A maize grain is a typical monocotyledonous seed. Botanically, it is a caryopsis because the fruit wall is fused with the seed coat.

Its main structures include:

1. Pericarp and seed coat

- The pericarp is the fruit wall surrounding the grain.
- It is fused with the seed coat.
- It protects the internal structures from mechanical damage and water loss.

2. Endosperm

- It occupies the largest portion of the maize grain.
- It stores food mainly in the form of starch.
- It provides nutrients to the developing embryo during germination.

3. Scutellum

- It is the single cotyledon of the maize embryo.
- It lies between the embryo and the endosperm.
- It absorbs digested food from the endosperm.
- It transfers the absorbed nutrients to the developing embryo.

4. Plumule

- It is the embryonic shoot.
- It develops into the stem and leaves.
- It is protected by a sheath called the coleoptile.

5. Radicle

- It is the embryonic root.
- It develops into the primary root.
- It is protected by a sheath called the coleorhiza.

6. Coleoptile

- It is a protective sheath surrounding the plumule.
- It protects the delicate young shoot as it pushes through the soil.

7. Coleorhiza

- It is a protective sheath surrounding the radicle.
- It protects the young root during emergence.

Functions of the maize seed structures

Structure	Function
Pericarp/seed coat	Protection
Endosperm	Food storage
Scutellum	Absorption and transfer of food
Plumule	Develops into the shoot
Radicle	Develops into the root
Coleoptile	Protects the plumule
Coleorhiza	Protects the radicle

3.2 Dicotyledonous Seeds

Dicotyledonous seeds are seeds whose embryos contain two cotyledons.

Examples include:

- Beans.
- Peas.
- Groundnuts.
- Green grams.
- Cowpeas.
- Sunflower.

Structure of a bean seed

A bean seed is a typical dicotyledonous seed.

Its main structures include:

1. Testa (seed coat)

- It is the outer protective covering of the seed.
- It protects the embryo against physical damage and infection.
- It helps prevent excessive loss of water.

2. Two cotyledons

- These are the two large embryonic seed leaves.
- In beans, they contain stored food.
- They provide nutrients to the embryo during germination.
- They may emerge above the soil during epigeal germination.

3. Plumule

- It develops into the shoot system.
- It produces the stem and leaves.

4. Radicle

- It develops into the primary root.
- It is normally the first embryonic structure to emerge during germination.

5. Hypocotyl

- It is the portion of the embryonic axis below the cotyledons.
- It elongates during epigeal germination, lifting the cotyledons above the soil.

6. Epicotyl

- It is the part of the embryonic axis above the cotyledons.
- It develops into the upper shoot system.

7. Hilum

- It is the scar showing where the seed was attached to the fruit.

8. Micropyle

- It is a small opening in the seed coat.
- It facilitates the entry of water during germination.

3.3 Differences Between Monocotyledonous and Dicotyledonous Seeds

Monocotyledonous seed	**Dicotyledonous seed**
Has one cotyledon.	Has two cotyledons.
Example: maize.	Example: bean.
Food is commonly stored in the	Food is commonly stored in the cotyledons, although some

endosperm.	dicots retain endosperm.
Cotyledon is called the scutellum in maize.	Has two distinct cotyledons.
Embryo has a coleoptile.	No coleoptile.
Embryo has a coleorhiza.	No coleorhiza.
Commonly associated with fibrous root systems.	Commonly associated with taproot systems.

Important examination point: Not all monocots and dicots store food in exactly the same way. Maize retains a large endosperm, while bean stores much of its food in the cotyledons.

4.0 SEED DORMANCY

4.1 Meaning of Seed Dormancy

Seed dormancy is a temporary condition in which a viable seed fails to germinate even when some or all external environmental conditions appear favourable for germination.

During dormancy, the embryo remains alive but its growth is temporarily prevented or restricted by internal or external factors.

Dormancy allows seeds to survive unfavourable environmental conditions and germinate when conditions become suitable.

Examples of plants whose seeds may exhibit dormancy

- Acacia species.
- Some varieties of beans.
- Wild sunflower.
- Some grass species.
- Certain fruit trees.

Important distinction: Dormancy versus quiescence

- **Dormancy:** Germination is prevented by internal factors within the seed or by particular seed coverings, even when external conditions are otherwise suitable.
- **Quiescence:** A viable seed fails to germinate because an essential external condition, such as water or suitable temperature, is unavailable.

4.2 Significance of Seed Dormancy

Seed dormancy is important to plants in several ways.

1. **Survival during unfavourable conditions**

- Dormancy enables seeds to remain alive during periods of drought, extreme temperatures or other unfavourable conditions.
- The seed resumes germination when suitable conditions return.

2. **Prevention of premature germination**

- It prevents seeds from germinating while they are still attached to the parent plant or immediately after dispersal when conditions may not support seedling survival.

3. **Ensures survival of the species**

- Dormancy enables seeds to remain viable for extended periods.
- This increases the chances of successful regeneration of plant populations.

4. **Ensures favourable timing of germination**

- Seeds may germinate at the beginning of a rainy season when water is readily available.
- This improves seedling establishment.

5. **Allows seed dispersal**

- Dormancy provides time for seeds to be dispersed away from the parent plant before germination.
- This reduces competition for light, water, mineral salts and space.

6. **Prevents simultaneous germination**

- Seeds of the same plant species may germinate at different times.
- This reduces the risk of all seedlings dying if environmental conditions suddenly become unfavourable.

7. **Facilitates long-term survival**

- Some dormant seeds remain viable in the soil seed bank until suitable environmental conditions occur.

8. **Supports natural regeneration**

- Dormancy helps maintain plant populations in natural ecosystems, including grasslands, forests and woodlands.

4.3 Causes of Seed Dormancy

Seed dormancy may result from physical, physiological, morphological or environmental factors.

A. Hard or impermeable seed coat

- Some seeds have very hard seed coats that prevent water from entering.
- The hard covering may also restrict oxygen entry.
- As a result, the embryo cannot begin active growth.
- Such dormancy is common in some leguminous plants.

Examples: Some Acacia seeds and other hard-coated legumes.

B. Immature embryo

- Some seeds are dispersed before the embryo has completed its development.
- The embryo must undergo further development before germination can occur.
- The seed therefore remains dormant until the embryo becomes sufficiently mature.

C. Presence of chemical inhibitors

- Some seeds contain substances that prevent premature germination.
- These substances may be present in the seed coat, endosperm or embryo.
- Abscisic acid (ABA) is an important hormone associated with maintaining seed dormancy.
- Other inhibitory compounds may also occur in seeds.

D. Unfavourable temperature requirements

- Some seeds require exposure to a period of cold or warm conditions before they can germinate.
- Without this temperature treatment, the seeds remain dormant.

E. Light requirements

- Some seeds require exposure to particular light conditions before germination can take place.
- Other seeds may be inhibited by light and require darkness.
- This is associated with light-sensitive dormancy.

F. Immature seed coverings

- In certain species, the seed coverings restrict germination mechanically.
- The coverings may need to weaken or undergo changes before the embryo can emerge.

G. Physiological restrictions within the embryo

- Some embryos have internal physiological conditions that prevent immediate germination.
- These restrictions may involve hormone balance and metabolic processes.

4.4 Methods of Breaking Seed Dormancy

Seed dormancy can be broken through different treatments depending on the cause of dormancy.

1. Scarification

Scarification is the process of weakening, scratching, cracking or removing part of a hard seed coat to allow water and oxygen to enter.

Methods of scarification

- Mechanical scarification: scratching the seed coat using sandpaper or carefully nicking it.
- Hot-water treatment: exposing suitable seeds to hot water under controlled conditions.
- Chemical scarification: treating certain seeds with suitable chemicals to weaken the seed coat.

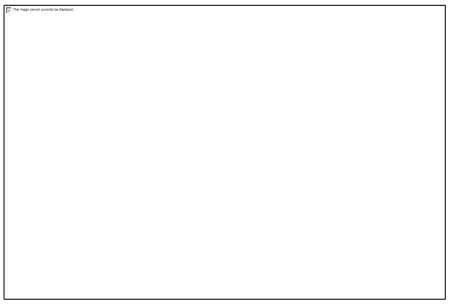
Importance

- Promotes water absorption.
- Facilitates gaseous exchange.
- Allows the embryo to resume growth.
- Improves germination in hard-coated seeds.

Agricultural example: Scarification may be used when propagating some Acacia species.

Precaution: Hot-water treatment must be appropriate for the particular seed species. Excessive heat can kill the embryo.

2. Stratification



Stratification is the process of exposing seeds to moist conditions at a particular temperature, commonly cold conditions, for a specified period to overcome physiological dormancy.

Procedure

1. Seeds are mixed with moist sand, peat or another suitable medium.
2. The mixture is placed under controlled cold conditions.
3. The seeds are maintained for the period required by the species.
4. The seeds are removed and planted under suitable germination conditions.

Importance

- Mimics natural seasonal temperature conditions.
- Helps overcome physiological dormancy.
- Promotes uniform germination in species that require chilling.

3. Soaking seeds in water

- Seeds are soaked in clean water for a suitable period.
- Water enters the seed through the seed coat.
- The seed swells as water is absorbed.
- This softens certain seed coverings and initiates metabolic activities.

Examples: Some beans and vegetable seeds.

4. Removal of chemical inhibitors

- Some seeds contain chemical substances that inhibit germination.
- Washing or leaching seeds may remove water-soluble inhibitors.
- This allows germination to proceed when other conditions are favourable.

5. Exposure to light

- Some seeds require light to stimulate germination.
- Exposing such seeds to appropriate light conditions helps overcome light-related dormancy.
- Light-sensitive seeds may require exposure to red light.

6. Exposure to suitable temperatures

- Certain seeds require alternating temperatures or exposure to specific temperature ranges.
- Such treatment helps overcome physiological dormancy.

7. Use of plant hormones

- Gibberellins, especially gibberellic acid, can promote germination in some dormant seeds.
- They stimulate enzyme production and the mobilisation of stored food.
- This may overcome certain forms of physiological dormancy.

8. After-ripening

- Some seeds require a period of dry storage after harvesting before they become capable of germinating.
- During this period, internal physiological changes take place.
- The seed eventually becomes ready to germinate under favourable conditions.

4.5 Summary of Methods of Breaking Seed Dormancy

Method	How it works	Type of dormancy addressed
Scarification	Weakens hard seed coat.	Physical dormancy
Stratification	Exposes seeds to moist chilling or suitable temperature treatment.	Physiological dormancy
Soaking	Promotes water absorption.	Certain physical restrictions
Leaching	Removes soluble inhibitors.	Chemical inhibition
Exposure to light	Provides the required light stimulus.	Light-related dormancy
Temperature treatment	Provides required temperature conditions.	Physiological dormancy
Gibberellin application	Stimulates germination processes.	Certain physiological dormancies
After-ripening	Allows internal changes during storage.	Physiological dormancy

5.0 SEED GERMINATION

5.1 Meaning of Seed Germination

Germination is the process by which a viable seed resumes active growth under favourable environmental conditions and develops into a seedling.

During germination, the embryo becomes metabolically active, uses stored food and develops into a young plant.

Germination begins with the absorption of water by the seed and is generally considered complete when the radicle emerges through the seed coverings.

5.2 Process of Seed Germination

Germination occurs through a series of coordinated stages.

Stage 1: Absorption of water (Imbibition)

- The dry seed absorbs water from the surrounding environment.
- Water enters mainly through the micropyle and other permeable regions of the seed coat.
- The seed swells and increases in volume.
- The seed coat becomes soft and may eventually split.
- Water activates enzymes and metabolic activities within the seed.

Stage 2: Activation of enzymes and respiration

- Water activates enzymes within the seed.
- The rate of respiration increases.
- Stored food is broken down into simpler soluble substances.
- Oxygen is used during aerobic respiration to release energy.
- The energy released is used for cell division, enlargement and development.

Stage 3: Mobilisation of stored food

Stored food is converted into soluble substances that can be transported to the growing embryo.

Examples:

1. Starch is broken down into simple sugars by enzymes such as amylases.
2. Proteins are broken down into amino acids by proteases.
3. Fats are broken down into fatty acids and glycerol by lipases.

These substances are transported to the embryo and used in respiration and the synthesis of new cellular materials.

Stage 4: Emergence of the radicle

- The embryo begins to grow.
- The radicle emerges through the seed coverings.
- It grows downwards due to positive gravitropism.
- It develops into the primary root.
- Lateral roots may subsequently develop.

Stage 5: Development of the plumule

- The plumule begins to grow.
- It develops into the young shoot.
- The shoot grows towards the soil surface.
- Leaves begin to develop.

Stage 6: Development of the seedling

- The young plant develops roots, stems and leaves.
- The seedling begins to manufacture its own food through photosynthesis once functional green leaves have developed.
- It gradually becomes independent of stored food in the seed.

5.3 Types of Seed Germination

There are two main types of seed germination based on the position of the cotyledons during germination.

1. Epigeal germination.
2. Hypogeal germination.

A. Epigeal Germination

Epigeal germination is a type of germination in which the cotyledons are lifted above the soil surface due to elongation of the hypocotyl.

Process of epigeal germination

1. The seed absorbs water and swells.
2. The seed coat splits.
3. The radicle emerges and develops into the primary root.
4. The hypocotyl elongates rapidly.
5. The elongating hypocotyl bends and lifts the cotyledons above the soil surface.
6. The plumule develops into the young shoot.
7. The cotyledons may become green and photosynthetic before eventually drying up.

Examples of plants showing epigeal germination

- Bean.
- Castor.
- Sunflower.
- Cotton.

Characteristics of epigeal germination

- Hypocotyl elongates considerably.
- Cotyledons are lifted above the ground.
- Cotyledons may become green and photosynthetic.
- Cotyledons may eventually wither after their stored food is exhausted.

B. Hypogeal Germination

Hypogeal germination is a type of germination in which the cotyledons remain below the soil surface due to elongation of the epicotyl.

Process of hypogeal germination

1. The seed absorbs water.
2. The seed coat splits.
3. The radicle emerges and develops into the primary root.
4. The epicotyl elongates.
5. The plumule is pushed above the soil surface.
6. The cotyledons remain underground.
7. The young shoot develops leaves and begins photosynthesis.

Examples of plants showing hypogeal germination

- Maize.
- Peas.
- Broad beans.
- Some other grass species.

Characteristics of hypogeal germination

- Epicotyl elongates considerably.
- Cotyledons remain below the soil.
- The cotyledons usually remain protected underground.
- The plumule emerges above the soil to form the shoot.

5.4 Differences Between Epigeal and Hypogeal Germination

Epigeal germination	**Hypogeal germination**
Cotyledons are lifted above the soil.	Cotyledons remain below the soil.
Hypocotyl elongates.	Epicotyl elongates.
Cotyledons may become green.	Cotyledons usually remain non-green.
Cotyledons may carry out photosynthesis.	Cotyledons mainly provide stored food.
Example: Bean.	Example: Pea and maize.

5.5 Conditions Necessary for Seed Germination

Seeds require certain environmental conditions to germinate successfully.

The major conditions are water, oxygen and suitable temperature. Light is also necessary for certain species.

1. Water (Moisture)

Water is essential for seed germination.

Importance of water

1. Activates enzymes within the seed.
2. Softens the seed coat.
3. Causes the seed to swell through imbibition.
4. Dissolves stored food substances into soluble forms.
5. Facilitates transport of nutrients to the embryo.
6. Provides a medium for metabolic reactions.
7. Maintains cell turgidity during cell enlargement.

What happens when water is insufficient?

- Enzyme activities remain low.
- Stored food is not mobilised effectively.
- The embryo cannot grow normally.
- Germination is delayed or prevented.

What happens when there is excess water?

- Air spaces in the soil may become filled with water.
- Oxygen supply to the seed is reduced.
- Aerobic respiration is limited.
- Seeds may die or rot due to poor aeration and microbial infection.

2. Oxygen

Oxygen is required for aerobic respiration.

Importance of oxygen

1. Enables the seed to carry out aerobic respiration.
2. Helps release energy from stored food.
3. Provides energy for cell division.
4. Supports cell enlargement.
5. Facilitates the development of the radicle and plumule.

What happens when oxygen is insufficient?

- The rate of respiration decreases.
- Less energy is released.
- Germination becomes slow or may fail.
- The embryo may die under prolonged oxygen deficiency.

3. Suitable temperature

Seeds require suitable temperatures for germination.

Importance of temperature

1. Controls enzyme activity.

2. Influences the rate of respiration.
3. Affects the breakdown of stored food.
4. Influences the rate of cell division and enlargement.
5. Determines the speed of germination.

Different plant species have different optimum germination temperatures.

For example:

- Maize and beans generally germinate well under warm conditions.
- Some temperate plant species require cooler conditions or chilling before germination.

Very low temperatures slow down enzyme activity, while excessively high temperatures may denature enzymes and damage the embryo.

4. Light

Light is required by some seeds but not all seeds.

Importance of light

- It stimulates germination in positively photoblastic seeds.
- It may inhibit germination in negatively photoblastic seeds.
- It influences germination timing and seedling establishment.

Examples of some seeds that respond positively to light include lettuce seeds.

5. Viability of the seed

A viable seed contains a living embryo capable of germination.

Even if all environmental conditions are favourable, a dead or severely damaged seed cannot germinate.

Factors affecting seed viability

- Age of the seed.
- Storage conditions.
- Moisture content during storage.
- Temperature during storage.
- Mechanical damage.
- Attack by insects and microorganisms.

5.6 Summary of Conditions Necessary for Germination

Condition	Importance
Water	Activates enzymes and initiates metabolic activities.
Oxygen	Required for aerobic respiration and energy production.
Suitable temperature	Ensures proper enzyme activity.

Light	Required by certain light-sensitive seeds.
Viability	Ensures the presence of a living embryo.

5.7 Differences Between Germination and Growth

Germination	Growth
Involves the resumption of development of a seed embryo.	Involves a permanent increase in size, mass or cell number.
Occurs at the beginning of seedling development.	Occurs throughout the life of the plant.
Begins with water absorption.	Involves cell division and enlargement.
Results in the emergence of a seedling.	Results in an increase in plant size and biomass.

6.0 PRIMARY AND SECONDARY GROWTH IN PLANTS

Plants increase in size through two major types of growth: primary growth and secondary growth.

These processes occur in different meristematic tissues.

6.1 Primary Growth

Primary growth is the increase in the length of roots and shoots due to cell division and enlargement at the apical meristems.

It results in the elongation of the plant body.

Primary growth occurs mainly at the tips of roots and shoots.

Regions involved in primary growth

The apical meristem is located at the growing tips of roots and shoots.

In roots, three main regions are associated with primary growth.

1. Region of cell division

- It is located close to the root tip, behind the root cap.
- It contains actively dividing meristematic cells.
- Cells divide repeatedly through mitosis.
- New cells are produced to support root growth.

2. Region of cell elongation

- It is located behind the region of cell division.
- Newly formed cells increase in length and volume.
- The cells absorb water and enlarge.
- This region contributes significantly to the increase in root length.

3. Region of cell differentiation (maturation)

- It is located behind the region of elongation.
- Cells develop specialised structures and functions.
- Different tissues such as xylem, phloem and epidermis are formed.
- Root hairs develop, increasing the surface area for water and mineral absorption.

Importance of primary growth

1. Increases the length of roots.
2. Increases the height of shoots.
3. Enables plants to reach sunlight.
4. Enables roots to penetrate deeper into the soil.
5. Increases the area available for water and mineral absorption.
6. Helps plants explore a wider soil area.
7. Contributes to the formation of primary tissues.
8. Supports the establishment of young plants.

Examples: Elongation of maize stems, bean shoots and young tree roots.

6.2 Secondary Growth

Secondary growth is the increase in the thickness or diameter of stems and roots due to the activity of lateral meristems.

It occurs mainly in woody dicotyledonous plants and gymnosperms.

Secondary growth is associated with two major lateral meristems:

1. Vascular cambium.
2. Cork cambium.

A. Vascular cambium

The vascular cambium is a lateral meristem that produces secondary vascular tissues.

Functions

1. Produces secondary xylem towards the inside of the stem or root.
2. Produces secondary phloem towards the outside.
3. Increases the diameter of stems and roots.
4. Contributes to the formation of wood.

Secondary xylem

- It is produced towards the inside of the vascular cambium.
- It consists mainly of xylem tissues.
- It conducts water and mineral salts.
- It provides mechanical support.
- Accumulation of secondary xylem forms wood.

Secondary phloem

- It is produced towards the outside of the vascular cambium.
- It transports manufactured food substances from leaves to other parts of the plant.

B. Cork cambium

The cork cambium is a lateral meristem that produces protective tissues during secondary growth.

Functions

1. Produces cork cells towards the outside.
2. Produces secondary protective tissues.
3. Replaces the epidermis as the stem increases in thickness.
4. Protects the internal tissues against mechanical injury.
5. Reduces water loss from the plant surface.

Formation of annual rings

In many woody plants growing under seasonal conditions, the vascular cambium produces different types of secondary xylem at different times of the year.

- Spring or early-season wood usually has larger vessels and thinner walls.
- Late-season wood commonly has smaller cells with thicker walls.
- The contrast between these tissues may form visible annual rings.

Importance of annual rings

1. They can help estimate the age of a tree.
2. They provide information about past environmental conditions.
3. They may indicate periods of favourable and unfavourable growth.
4. They are useful in studying past climatic conditions.

6.3 Differences Between Primary and Secondary Growth

Primary growth	Secondary growth
Increases length of roots and shoots.	Increases thickness of stems and roots.
Occurs at apical meristems.	Occurs at lateral meristems.
Involves cell division at root and shoot tips.	Involves activity of vascular and cork cambia.
Produces primary tissues.	Produces secondary tissues.

Common in both monocots and dicots.	Common in woody dicots and gymnosperms.
Results in elongation.	Results in an increase in girth.
Example: Elongation of maize shoots.	Example: Thickening of a mango tree trunk.

Important note: Most monocotyledonous plants do not undergo typical secondary growth because they generally lack a continuous vascular cambium. However, some monocots exhibit unusual forms of secondary thickening.

7.0 MEASUREMENT OF PLANT GROWTH

7.1 Meaning of Measurement of Growth

Measurement of plant growth is the process of determining the increase in size, length, volume, mass or other measurable characteristics of a plant over a given period.

Plant growth can be measured quantitatively by recording changes at regular intervals.

Growth measurements help determine how fast a plant grows and how different environmental conditions influence its development.

7.2 Methods of Measuring Plant Growth

1. Measurement of plant height

- A ruler or measuring tape is used to measure the height of a plant.
- The measurement is taken from the soil surface to the growing tip of the shoot.
- Measurements are taken at regular intervals.
- The increase in height is calculated by subtracting the initial height from the final height.

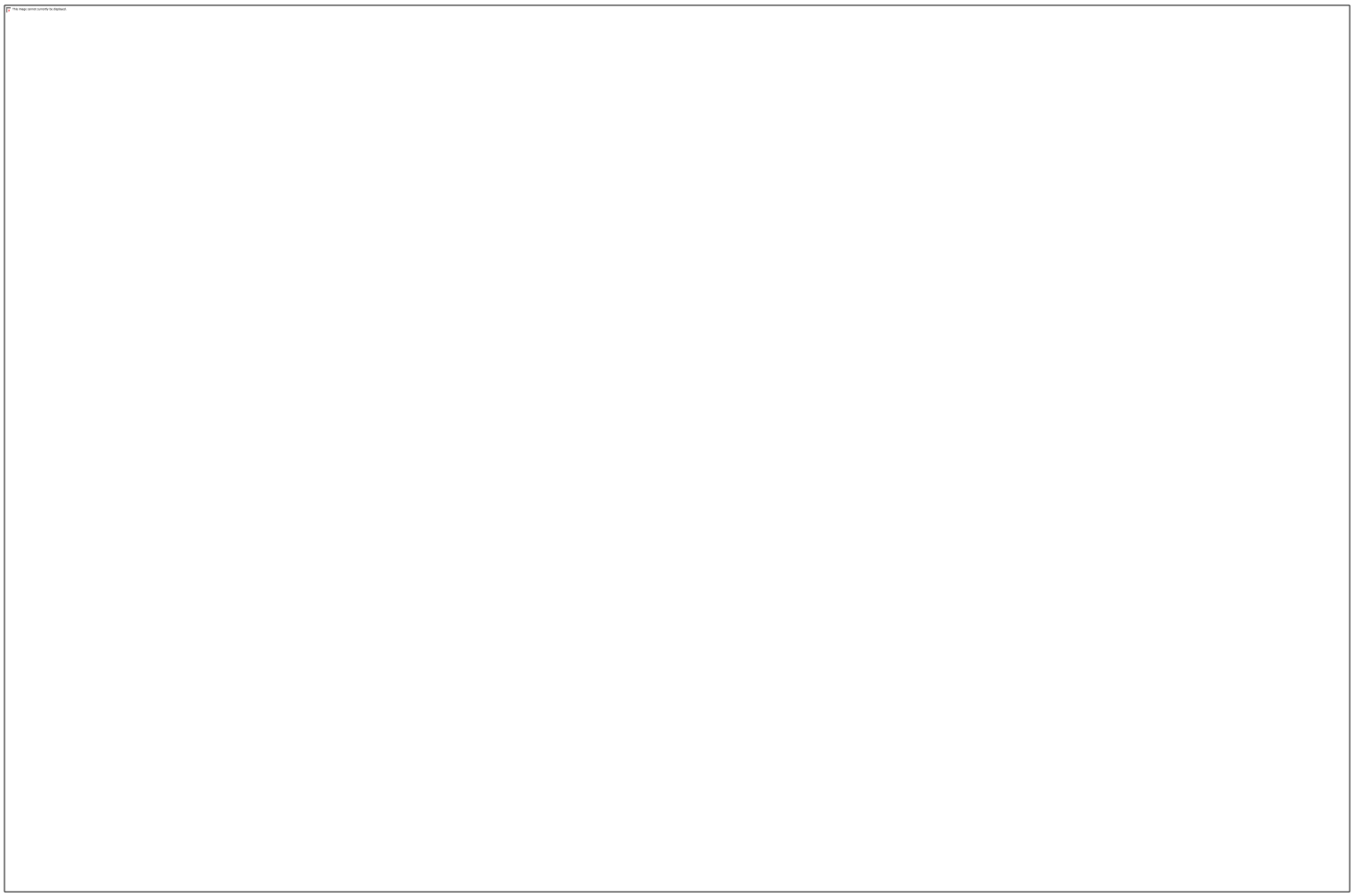
Example

A maize plant measures 10 cm at the beginning of an experiment and 25 cm after one week.

Increase in height:

$25 - 10 = 15$ cm

Therefore, the plant has grown by 15 cm.



2. Measurement of plant length

- A measuring tape or ruler is used.
- It can be used to measure the length of roots, stems and branches.
- It is useful in experiments involving seedling growth.

3. Measurement of plant mass

Plant mass can be measured using a weighing balance.

There are two main types of mass measurement.

A. Fresh mass

- It is the mass of a plant immediately after harvesting.
- It includes the mass of water contained in plant tissues.
- It may be affected by the amount of water in the plant at the time of measurement.

B. Dry mass

- It is the mass of a plant after its water has been removed by drying.
- Plant material is dried in an oven at a suitable controlled temperature until a constant mass is obtained.
- It gives a more reliable indication of the amount of accumulated organic matter than fresh mass.

Importance of measuring dry mass

1. It reduces the effect of variations in water content.
2. It provides an estimate of accumulated organic matter.
3. It is useful when comparing plant growth under different conditions.
4. It helps determine the effect of fertilisers, water and light on plant biomass.

4. Measurement of stem diameter or girth

- A vernier caliper may be used to measure the diameter of small stems.
- A measuring tape may be used to measure the circumference or girth of larger stems.
- Measurements are taken at the same point on the stem each time.
- An increase in diameter indicates secondary growth.

5. Measurement of leaf area

- Leaf area can be determined using graph paper.
- The outline of a leaf is traced onto graph paper.
- The number of covered squares is counted.
- Partial squares are estimated.
- The total area is calculated.

Modern laboratories may also use digital leaf-area meters.

6. Measurement of root growth

- Roots can be measured using a ruler or measuring tape.
- Root length is recorded at regular intervals.
- Root growth may also be studied using transparent growth chambers or suitable root observation systems.

7. Measurement of cell number and cell size

- A microscope is used to observe and measure cells.
- Cell numbers and cell dimensions can be compared at different stages.
- This method is useful in laboratory studies of plant growth.

7.3 Instruments Used in Measuring Plant Growth

Instrument	Use
Ruler	Measures plant height and short lengths.
Measuring tape	Measures plant height, root length and stem girth.
Weighing balance	Measures fresh and dry mass.
Vernier calipers	Measures stem and organ diameter.
Microscope	Observes and measures cells.
Graph paper	Estimates leaf area.
Auxanometer	Measures the rate of elongation of plant shoots.
Leaf-area meter	Measures leaf surface area.

7.4 Auxanometer

An auxanometer is an instrument used to measure the rate of elongation of a plant shoot.

Working principle

- A thread is attached to the growing tip of a plant shoot.
- The thread passes over a pulley.
- A pointer or indicator is attached to the pulley system.
- As the shoot elongates, the thread moves.
- The movement of the pointer indicates the amount of shoot elongation.
- The rate of growth can then be calculated over a given period.

Importance of an auxanometer

1. Measures shoot elongation.
2. Helps determine the rate of plant growth.
3. Helps investigate the effects of environmental factors on growth.
4. Can be used to study the influence of plant hormones on shoot elongation.

7.5 Calculation of Growth Rate

Growth rate is the increase in a measurable growth parameter per unit time.

The general formula is:

Growth rate=Final measurement−Initial measurementTime takenGrowth rate=Time takenFinal measurement−Initial measurement

Example

A seedling increases in height from 8 cm to 20 cm in 6 days.

$$Growth\ rate = \frac{20 - 8}{6}$$

Therefore, the average growth rate is 2 cm per day.

Absolute growth rate

Absolute growth rate is the total increase in size or mass per unit time.

$$AGR = \frac{(W2 - W1)}{t2 - t1}$$

Where:

- W1 = initial mass.
- W2 = final mass.
- t1= initial time.
- t2= final time.

Relative growth rate

Relative growth rate is the increase in plant mass per unit of existing mass per unit time.

It is useful when comparing the growth of plants that initially have different sizes.

8.0 GROWTH CURVES IN PLANTS

8.1 Meaning of a Growth Curve

A growth curve is a graphical representation showing the changes in the size, length, mass or other growth characteristics of an organism over a given period.

Growth curves are useful in understanding the rate and pattern of plant growth.

A typical plant growth curve is sigmoid or S-shaped.

8.2 The Sigmoid Growth Curve

A sigmoid growth curve is an S-shaped graph that represents the typical pattern of growth in many plants and plant organs over time.

It consists of four main phases.

1. Lag phase

The lag phase is the initial period during which growth occurs slowly.

Characteristics

1. Growth rate is relatively low.
2. Cells become metabolically active.
3. Enzymes are synthesised.
4. Cells prepare for rapid division and enlargement.
5. The increase in size is relatively small.

Explanation

During this phase, plant cells are adapting to their conditions and preparing for active growth.

2. Logarithmic or exponential phase

The logarithmic phase is the period during which growth occurs rapidly.

Characteristics

1. Growth rate is very high.
2. Cells divide rapidly.
3. Cell enlargement occurs actively.
4. Plant size increases significantly.
5. Metabolic activities are high.

Explanation

The plant has adequate resources and actively produces new cells and tissues.

3. Deceleration phase

The deceleration phase is the period during which the rate of growth gradually decreases.

Characteristics

1. Growth continues but at a decreasing rate.
2. Cell division becomes slower.
3. Cells and tissues begin to mature.
4. Competition for available resources may increase.
5. The plant approaches its maximum size under the existing conditions.

4. Stationary phase

The stationary phase is the period during which the overall measured growth approaches a maximum and becomes relatively constant.

Characteristics

1. There is little or no net increase in the measured parameter.
2. Most tissues have reached maturity.
3. Cell division and enlargement are reduced in the measured organ.
4. Growth may be limited by genetic and environmental factors.

Note: In whole plants, individual organs may show different growth curves. A plant may also continue producing new leaves, roots or reproductive organs while the growth of a particular organ has levelled off.

Decline or senescence

Some growth records may show a decline after the stationary phase, especially when measuring fresh mass, leaf area or living tissue.

This may occur due to:

- Ageing of tissues.
- Loss of leaves.
- Breakdown of stored substances.
- Water loss.
- Death of plant organs.

8.3 Importance of Growth Curves

1. They help determine the rate of plant growth.
2. They show the different stages of growth.
3. They help compare growth under different environmental conditions.
4. They help farmers determine suitable harvesting periods.
5. They are useful in agricultural research.
6. They help evaluate the effects of fertilisers and irrigation.

7. They help determine the effectiveness of plant growth regulators.
8. They help identify periods of rapid growth and nutrient demand.

8.4 Factors Affecting the Shape of Plant Growth Curves

- Availability of water.
- Availability of mineral nutrients.
- Light intensity.
- Temperature.
- Genetic characteristics.
- Plant hormones.
- Disease and pest attack.
- Competition for resources.
- Age of the plant.

9.0 PLANT HORMONES

9.1 Meaning of Plant Hormones

Plant hormones, also known as phytohormones, are naturally occurring organic chemical substances produced in small quantities by plants that regulate and coordinate growth, development and responses to environmental stimuli.

They may be produced in one part of the plant and transported to another part where they influence physiological activities.

Plant hormones regulate processes such as:

- Cell division.
- Cell elongation.
- Root formation.
- Shoot development.
- Seed germination.
- Seed dormancy.
- Flowering.
- Fruit development.
- Fruit ripening.
- Leaf fall.
- Ageing.

9.2 Major Plant Hormones

The five classical plant hormones are:

1. Auxins.
2. Gibberellins.

3. Cytokinins.
4. Abscisic acid.
5. Ethylene.

Other important plant growth regulators include brassinosteroids, jasmonates and salicylic acid.

9.3 Auxins

Auxins are plant hormones that mainly promote cell elongation and influence directional growth and development.

The most common naturally occurring auxin is indole-3-acetic acid (IAA).

Sites of production

- Shoot apical meristems.
- Young developing leaves.
- Developing seeds.
- Developing fruits.

Roles of auxins in plant growth and development

1. **Promote cell elongation**
   - Auxins stimulate the elongation of cells, particularly in young shoots.
   - This contributes to the increase in plant height.
2. **Control apical dominance**
   - Auxins produced by the shoot tip suppress the growth of lateral buds.
   - This encourages the main shoot to grow more strongly than side branches.
3. **Promote root formation**
   - Auxins stimulate the formation of adventitious roots in suitable concentrations.
   - They are therefore used in vegetative propagation through stem cuttings.
4. **Promote cell differentiation**
   - Auxins influence the development and differentiation of plant tissues.
5. **Promote fruit development**
   - Auxins contribute to fruit growth after fertilisation.
   - In some plants, synthetic auxins can stimulate the development of seedless fruits.
6. **Prevent premature leaf and fruit fall**
   - Auxins may delay abscission in young leaves and fruits under certain conditions.
7. **Control phototropism**
   - Auxin redistribution contributes to the bending of shoots towards light.

8. **Control gravitropism**

- Unequal auxin distribution in roots and shoots contributes to their different growth responses to gravity.

Agricultural applications of auxins

- Used in rooting powders for stem cuttings.
- Used in certain fruit-production practices.
- Synthetic auxins such as 2,4-D are used as selective herbicides against certain broad-leaved weeds.

9.4 Gibberellins

Gibberellins are plant hormones that promote stem elongation, seed germination and other developmental processes.

A commonly studied gibberellin is gibberellic acid (GA_3).

Sites of production

- Young leaves.
- Developing embryos.
- Developing seeds.
- Root and shoot tissues.

Roles of gibberellins in plant growth and development

1. **Promote stem elongation**
   - Gibberellins stimulate cell elongation and, in some tissues, cell division.
   - This increases the length of stems and shoots.
2. **Break seed dormancy**
   - Gibberellins help overcome certain forms of seed dormancy.
   - They promote processes that allow the embryo to resume growth.
3. **Promote seed germination**
   - Gibberellins stimulate the production of hydrolytic enzymes such as amylase.
   - Amylase breaks down stored starch into simpler sugars.
   - The sugars are used in respiration and growth.
4. **Promote flowering in certain plants**
   - Gibberellins can stimulate flowering in some plant species under suitable conditions.
5. **Promote fruit development**
   - They stimulate fruit growth in certain crops.
6. **Influence fruit size**
   - Gibberellins may increase the size of certain fruits.

7. **Break bud dormancy**

- They can stimulate the growth of dormant buds in some plants.

Agricultural applications of gibberellins

- Used to improve germination in certain crops.
- Used in fruit production to influence fruit size.
- Used in malting barley to promote enzyme production.
- Used to stimulate stem elongation in certain crops.

9.5 Cytokinins

Cytokinins are plant hormones that promote cell division and influence the growth of shoots and the development of plant tissues.

Sites of production

- Mainly root tips.
- Developing seeds.
- Young fruits.
- Other actively growing tissues.

Roles of cytokinins in plant growth and development

1. **Promote cell division**
   - Cytokinins stimulate mitosis in plant tissues.
   - They are important in the formation of new cells.
2. **Promote shoot formation**
   - Cytokinins encourage the development of lateral buds and shoots.
3. **Overcome apical dominance**
   - They stimulate lateral bud growth.
   - This may encourage the development of side branches.
4. **Delay leaf senescence**
   - Cytokinins delay the ageing of leaves.
   - They help maintain chlorophyll and other cellular components.
5. **Promote chloroplast development**
   - They contribute to chloroplast development in suitable tissues.
6. **Promote nutrient mobilisation**
   - They influence the movement of nutrients towards actively growing tissues.
7. **Promote tissue culture growth**
   - In plant tissue culture, cytokinins encourage shoot formation, especially when used in suitable ratios with auxins.

Agricultural applications

- Used in plant tissue culture.
- Used to promote shoot multiplication.
- Used in certain post-harvest treatments to delay leaf ageing.

9.6 Abscisic Acid (ABA)

Abscisic acid is a plant hormone that mainly regulates responses to stress, promotes seed dormancy and inhibits certain growth processes.

Sites of production

- Leaves.
- Roots.
- Developing seeds.
- Other plant tissues, especially under stress.

Roles of abscisic acid in plant growth and development

1. **Promotes seed dormancy**
   - ABA helps maintain seed dormancy.
   - It prevents premature germination.
2. **Inhibits seed germination**
   - High ABA activity can suppress germination.
   - It helps ensure that seeds germinate at an appropriate time.
3. **Causes stomatal closure**
   - During water shortage, ABA signals guard cells to close stomata.
   - This reduces water loss through transpiration.
4. **Promotes drought tolerance**
   - ABA helps plants respond to water stress.
   - It activates protective physiological responses.
5. **Promotes bud dormancy**
   - It contributes to the maintenance of dormancy in certain buds.
6. **Influences seed maturation**
   - It supports seed development and the acquisition of desiccation tolerance in many species.

Agricultural importance

- Helps plants respond to drought.
- Regulates seed dormancy.
- Helps control water loss through stomatal closure.
- Contributes to seed maturation and survival.

9.7 Ethylene

Ethylene is a gaseous plant hormone that regulates fruit ripening, senescence and other developmental processes.

It is produced in various plant tissues, especially ripening fruits, ageing leaves and stressed tissues.

Roles of ethylene in plant growth and development

1. **Promotes fruit ripening**
    - Ethylene stimulates the ripening of climacteric fruits.
    - It causes changes in colour, texture, flavour and aroma.
2. **Promotes leaf abscission**
    - It encourages the separation of leaves from stems.
    - This results in leaf fall.
3. **Promotes fruit abscission**
    - Ethylene may stimulate fruit dropping at maturity.
4. **Promotes senescence**
    - It accelerates ageing in certain plant tissues.
    - It contributes to the breakdown of chlorophyll.
5. **Influences stem growth**
    - It may inhibit stem elongation in some conditions.
    - It can promote lateral swelling and other growth responses.
6. **Promotes flowering in certain plants**
    - It stimulates flowering in some species, such as pineapple.
7. **Promotes responses to mechanical stress**
    - It influences growth changes in plants exposed to physical stress.

Agricultural applications of ethylene

- Used in controlled fruit-ripening processes.
- Helps synchronise pineapple flowering.
- Used to regulate certain aspects of crop maturity and harvest management.

9.8 Summary of the Five Major Plant Hormones

Hormone	Major functions
Auxins	Cell elongation, apical dominance, root formation and tropisms.
Gibberellins	Stem elongation, seed germination and breaking dormancy.
Cytokinins	Cell division, shoot formation and delay of senescence.
Abscisic acid	Seed dormancy, stomatal closure and stress responses.
Ethylene	Fruit ripening, senescence and abscission.

9.9 Comparison Between Auxins, Gibberellins and Cytokinins

These three hormones are generally associated with the promotion of plant growth, although their effects depend on the concentration, tissue and developmental stage.

Auxins	Gibberellins	Cytokinins
Promote cell elongation.	Promote stem elongation.	Promote cell division.
Promote adventitious root formation.	Promote seed germination.	Promote shoot formation.
Maintain apical dominance.	Promote flowering in certain species.	Encourage lateral bud development.
Influence tropisms.	Break certain forms of dormancy.	Delay leaf ageing.

9.10 Interaction Between Plant Hormones

Plant hormones do not work independently. They interact to coordinate plant growth and development.

Examples:

1. **Auxins and cytokinins**
   - Their relative concentrations influence root and shoot formation.
   - A high auxin-to-cytokinin ratio commonly favours root formation in tissue culture.
   - A high cytokinin-to-auxin ratio commonly favours shoot formation.
2. **Gibberellins and abscisic acid**
   - Gibberellins promote germination.
   - Abscisic acid promotes and maintains dormancy.
   - Their balance helps determine whether a seed remains dormant or begins germination.
3. **Auxins and ethylene**
   - Auxins may influence ethylene production.
   - Both hormones interact in controlling growth and responses to environmental stimuli.
4. **Cytokinins and abscisic acid**
   - Cytokinins generally promote cell division and growth.
   - Abscisic acid promotes stress responses and may inhibit growth.

10.0 APICAL DOMINANCE

10.1 Meaning of Apical Dominance

Apical dominance is the phenomenon in which the actively growing terminal bud of a shoot suppresses the growth of lateral or axillary buds.

It is mainly controlled by auxins produced in the shoot apex.

10.2 How Apical Dominance Occurs

1. The terminal bud at the shoot tip produces auxins.
2. Auxins are transported downwards through the shoot.
3. The auxin signal suppresses the growth of lateral buds, partly through interactions with other hormones and signalling pathways.
4. The main shoot continues growing.

5. Lateral branches remain relatively inactive.

10.3 Effects of Apical Dominance

1. Encourages the main shoot to grow upwards.
2. Reduces the development of lateral branches.
3. Influences the overall shape of the plant.
4. Helps plants compete for sunlight.
5. Controls the distribution of growth between the main shoot and side branches.

10.4 What Happens When the Shoot Tip Is Removed?

When the terminal bud is removed through pruning or pinching:

1. The major source of auxin from the shoot apex is removed.
2. The suppression of lateral buds is reduced.
3. Cytokinin activity and other signals encourage lateral bud development.
4. Side branches begin to grow.
5. The plant may become bushier.

10.5 Agricultural Importance of Apical Dominance

1. **Pruning fruit trees**
   - Farmers remove terminal buds to encourage lateral branching.
   - This helps develop a suitable tree canopy.
2. **Increasing branching**
   - Removal of the shoot tip encourages the development of side branches.
   - This may increase the number of flowering and fruit-bearing branches.
3. **Tea production**
   - Regular plucking and pruning encourage branching and the development of young shoots.
4. **Hedge management**
   - Pruning promotes lateral growth, helping maintain dense hedges.
5. **Shaping ornamental plants**
   - Gardeners use pinching and pruning to produce attractive plant shapes.

Difference between apical dominance and apical growth

- Apical growth refers to elongation at the tips of roots and shoots.
- Apical dominance refers to suppression of lateral bud growth by the terminal shoot bud.

REVISION EXERCISE

STRAND: Anatomy and Physiology of Plants

SUB-STRAND: Growth and Development in Plants

SECTION A: MULTIPLE CHOICE QUESTIONS (20 MARKS)

Choose the correct answer from the alternatives A, B, C and D.

1. Which of the following best describes growth in plants?

A. Temporary increase in plant size.

B. Permanent increase in size, mass or cell number.

C. Development of reproductive structures only.

D. Conversion of green leaves into yellow leaves.

2. The part of a seed embryo that develops into the primary root is called the:

A. Plumule.

B. Cotyledon.

C. Radicle.

D. Epicotyl.

3. Which one of the following is a characteristic of a monocotyledonous seed?

A. It has two cotyledons.

B. It has one cotyledon.

C. It has no embryo.

D. It lacks a seed coat.

4. In a maize grain, the main food-storage tissue is the:

A. Plumule.

B. Radicle.

C. Coleoptile.

D. Endosperm.

5. The structure that protects the plumule in a maize embryo is the:

A. Coleorhiza. B. Coleoptile.

C. Scutellum. D. Testa.

6. Seed dormancy is best described as:

A. Permanent death of the embryo.

B. Immediate germination after harvesting.

C. Failure of a viable seed to germinate under otherwise favourable conditions.

D. Continuous growth of the embryo inside the seed.

7. Which of the following hormones is mainly associated with maintaining seed dormancy?

A. Auxin.

B. Cytokinin.

C. Gibberellin.

D. Abscisic acid.

8. The process of weakening a hard seed coat to allow water entry is known as:

A. Stratification.

B. Scarification.

C. Photosynthesis.

D. Transpiration.

9. The first structure of the embryo to emerge during normal seed germination is usually the:

A. Plumule.

B. Cotyledon.

C. Radicle.

D. Epicotyl.

10. Which of the following is not a major external condition necessary for the germination of most seeds?

A. Water.

B. Oxygen.

C. Suitable temperature.

D. Carbon dioxide.

11. A seed in which the cotyledons are lifted above the soil surface exhibits:

A. Hypogeal germination.

B. Epigeal germination.

C. Photodormancy.

D. Secondary growth.

12. Which part of the embryo elongates during hypogeal germination?

A. Radicle. B. Hypocotyl. C. Epicotyl. D. Cotyledon.

13. Primary growth in plants is responsible for:

A. Increase in stem thickness.

B. Formation of annual rings.

C. Increase in root and shoot length.

D. Production of cork tissues.

14. The lateral meristem responsible for producing secondary xylem and secondary phloem is the:

A. Apical meristem.

B. Vascular cambium.

C. Root cap.

D. Epidermis.

15. Which instrument is specifically used to measure the rate of shoot elongation?

A. Thermometer.

B. Barometer.

C. Auxanometer.

D. Hygrometer.

16. The phase in which plant growth occurs most rapidly on a typical sigmoid growth curve is the:

A. Lag phase.

B. Exponential phase.

C. Stationary phase.

D. Decline phase.

17. Which plant hormone promotes cell division?

A. Cytokinin.

B. Abscisic acid.

C. Ethylene.

D. Auxin.

18. A farmer applies a rooting hormone to stem cuttings before planting them. The hormone most likely to be used is:

A. Ethylene.

B. Abscisic acid.

C. Auxin.

D. Cytokinin.

19. The hormone responsible for promoting fruit ripening in many climacteric fruits is:

A. Gibberellin. B. Ethylene.

C. Auxin. D. Cytokinin.

20. The suppression of lateral bud growth by the terminal shoot bud is referred to as:

A. Phototropism.

B. Geotropism.

C. Apical dominance.

D. Secondary growth.

SECTION B: STRUCTURED QUESTIONS (50 MARKS)

21. Growth and Development (5 marks)

a) Define the term growth as used in plant physiology. (2 marks)

b) State three differences between growth and development in plants. (3 marks)

22. Structure of Seeds (6 marks)

a) Name four structures found in a typical dicotyledonous seed. (2 marks)

b) State the functions of the following structures:

i. Radicle. (1 mark)

ii. Plumule. (1 mark)

iii. Cotyledons. (1 mark)

iv. Seed coat. (1 mark)

23. Monocotyledonous and Dicotyledonous Seeds (5 marks)

a) State two differences between monocotyledonous and dicotyledonous seeds. (2 marks)

b) Name three structures found in a maize grain that are associated with the protection and nourishment of the embryo. (3 marks)

24. Seed Dormancy (6 marks)

a) Define seed dormancy. (2 marks)

b) Explain two causes of seed dormancy. (2 marks)

c) State two methods used to break seed dormancy. (2 marks)

25. Seed Germination (6 marks)

a) Define seed germination. (2 marks)

b) Describe four major stages involved in seed germination. (4 marks)

26. Types of Germination (4 marks)

Differentiate between epigeal and hypogeal germination under the following headings:

a) Position of cotyledons. (2 marks)

b) Part of the embryonic axis that elongates. (2 marks)

27. Conditions Necessary for Germination (5 marks)

Explain the importance of the following conditions during seed germination:

a) Water. (2 marks)

b) Oxygen. (1 mark)

c) Suitable temperature. (2 marks)

28. Primary and Secondary Growth (5 marks)

a) Define primary growth. (2 marks)

b) State three differences between primary and secondary growth. (3 marks)

29. Measurement of Plant Growth (4 marks)

a) Name two instruments used to measure plant growth. (2 marks)

b) Explain how an auxanometer is used to measure plant growth. (2 marks)

30. Plant Hormones (4 marks)

State one major role of each of the following plant hormones:

a) Auxins. (1 mark)

b) Gibberellins. (1 mark)

c) Cytokinins. (1 mark)

d) Abscisic acid. (1 mark)

31:

A farmer in Narok County purchases Acacia seeds for establishing a tree nursery. After sowing the seeds, only a few germinate despite adequate watering.

a) Explain why some Acacia seeds may fail to germinate under favourable conditions. (2 marks)

b) Suggest two methods the farmer could use to improve germination. (2 marks)

c) Explain how each method suggested in (b) promotes germination. (2 marks)

32:

A Grade 11 Biology learner set up four experiments using equal numbers of viable bean seeds.

Experiment	Water	Oxygen	Temperature
A	Available	Available	Suitable
B	Unavailable	Available	Suitable
C	Available	Unavailable	Suitable
D	Available	Available	Very low

a) Which experiment is expected to show the highest germination? (1 mark)

b) Explain why seeds in experiment B may fail to germinate. (2 marks)

c) Explain why seeds in experiment C may fail to germinate. (2 marks)

d) State the importance of using equal numbers of seeds in the four experiments. (1 mark)

33:

A learner measured the height of a maize plant at different intervals as shown below.

Time (days)	Plant height (cm)

0	4
5	9
10	19
15	34
20	48
25	57
30	60

a) Calculate the increase in height between day 0 and day 20. (2 marks)

b) Calculate the average growth rate between day 0 and day 20. (2 marks)

c) Identify the period during which the plant experienced the greatest increase in height. (1 mark)

d) Explain why the growth rate may decrease as the plant approaches maturity. (2 marks)

34:

A farmer growing tomatoes notices that some plants produce very few lateral branches. The farmer decides to remove the terminal buds.

a) Name the phenomenon responsible for the suppression of lateral bud growth. (1 mark)

b) Identify the plant hormone mainly associated with this phenomenon. (1 mark)

c) Explain why removing the terminal bud encourages lateral branching. (2 marks)

d) State one agricultural advantage of encouraging lateral branching in suitable crops. (1 mark)

35:

A nursery operator notices that lettuce seeds germinate better when exposed to light than when completely covered with soil.

a) Explain this observation. (2 marks)

b) Name the light-sensitive pigment involved in controlling seed germination. (1 mark)

c) State the type of seed response demonstrated by lettuce seeds. (1 mark)

d) Explain one practical implication of this observation when sowing lettuce seeds. (1 mark)

PRACTICAL ACTIVITIES AND INVESTIGATIONS

Activity 1: Investigating the Structure of Monocot and Dicot Seeds

Materials required

- Soaked bean seeds.

- Maize grains.
- Hand lens.
- Dissecting needle.
- Petri dishes.
- Razor blade or scalpel under teacher supervision.

Procedure

1. Obtain a soaked bean seed.
2. Observe its external features.
3. Identify the hilum and micropyle.
4. Carefully remove the seed coat.
5. Separate the two cotyledons.
6. Observe and identify the embryo.
7. Repeat the procedure using a maize grain.
8. Record the similarities and differences observed.

Expected observations

- Bean seeds have two cotyledons.
- Maize grains have one cotyledon called the scutellum.
- Maize has a large endosperm.
- Both contain an embryo with a radicle and plumule.

Questions

1. Why is the bean seed classified as a dicotyledonous seed?
2. What is the function of the scutellum?
3. State two differences between the seeds observed.
4. Which seed has food mainly stored in its cotyledons?

Activity 2: Investigating Conditions Necessary for Germination

Materials required

- Bean seeds.
- Cotton wool.
- Four transparent containers.
- Water.
- Refrigerator or a suitable cool environment, if available.

Procedure

1. Place equal numbers of viable bean seeds in four containers.
2. Provide moisture and suitable temperature in the first container.

3. Keep the second container dry.
4. Completely submerge seeds in water in the third container to restrict oxygen supply.
5. Place the fourth container under unsuitable low-temperature conditions.
6. Observe the seeds over several days.
7. Record the number of seeds that germinate.

Questions

1. Which container is expected to show the highest germination?
2. Explain why seeds in the dry container may fail to germinate.
3. Why is oxygen important during germination?
4. State two precautions that should be observed during the experiment.

Activity 3: Investigating Plant Growth

Materials required

- Young maize seedlings.
- Ruler.
- Watering can.
- Recording book.
- Labels.

Procedure

1. Plant maize seeds in suitable containers.
2. Water the seedlings appropriately.
3. Measure their heights at regular intervals.
4. Record the measurements.
5. Calculate the average growth rate.
6. Plot a graph of plant height against time.

Questions

1. What is a growth curve?
2. Which phase of growth shows the highest growth rate?
3. Why should measurements be taken at regular intervals?
4. State two factors that may affect the growth rate of the seedlings.

STRAND 2: ANATOMY AND PHYSIOLOGY OF PLANTS

SUB-STRAND 2.3: EXCRETION IN PLANTS

1.0 Introduction to excretion in plants

Living organisms carry out various metabolic activities to maintain life. These activities include photosynthesis, respiration, protein synthesis and absorption of mineral salts.

During these metabolic activities, different waste products are formed. Such products may become harmful when they accumulate in excessive quantities within cells and tissues.

Plants, just like animals, eliminate metabolic waste products from their bodies. However, plants use relatively simple methods of excretion because they do not possess specialised excretory organs such as kidneys, lungs and liver.

Excretion in plants involves the removal, storage or elimination of unwanted metabolic products through different structures and processes.

1.1 Meaning of excretion in plants

Excretion is the biological process by which living organisms remove waste products formed during metabolic activities from their bodies.

Excretion in plants refers to the process by which plants eliminate or isolate unwanted metabolic products formed during cellular activities.

Examples of excretory products in plants include:

1. Oxygen – produced during photosynthesis.
2. Carbon dioxide – produced during respiration.
3. Water vapour – lost through transpiration.
4. Excess water – eliminated through guttation.
5. Resins – produced and stored by some trees.
6. Gums – secreted by certain plants.
7. Latex – produced by specialised plant cells and tissues.
8. Tannins – accumulated in certain plant tissues.
9. Essential oils – produced by aromatic plants.
10. Organic acids – produced during metabolic activities.

Important: Not every substance produced by a plant is a waste product. Some substances, such as oxygen, are useful to other organisms, while others may have protective or storage functions within the plant.

1.2 Importance of excretion in plants

Excretion is important because it helps plants maintain normal cellular activities and healthy growth.

The importance of excretion includes:

1. **Prevents accumulation of toxic substances**

- Some metabolic waste products can interfere with normal cellular activities when they accumulate in large quantities.
- Excretion helps remove or isolate such substances, protecting plant cells from damage.

2. **Maintains internal balance**

- Plants need to maintain suitable water and solute concentrations within their cells.

- Removal of excess water and other substances helps maintain osmotic balance.

3. **Prevents cellular damage**
   - Excessive accumulation of certain waste products may interfere with enzyme activities and other metabolic processes.
   - Excretion and storage in less active tissues help reduce possible damage.
4. **Regulates water content**
   - Processes such as transpiration and guttation help regulate water levels within the plant.
   - This is particularly important when water absorption by roots exceeds the amount needed for immediate metabolic activities.
5. **Maintains normal metabolic activities**
   - Removal or isolation of unwanted substances enables cells to continue carrying out essential processes such as respiration and photosynthesis.
6. **Facilitates removal of gaseous wastes**
   - Oxygen and carbon dioxide move out of plant tissues through diffusion.
   - This allows gaseous exchange with the surrounding environment.
7. **Supports plant survival**
   - Efficient elimination and storage of unwanted substances enable plants to survive under different environmental conditions.
8. **Provides useful substances to other organisms**
   - Some substances released by plants, such as oxygen, support the survival of other organisms.

1.3 Reasons why plants lack complex excretory systems

Plants do not possess specialised excretory organs comparable to those found in animals. This is because of their unique structure, lifestyle and metabolic activities.

The reasons include:

1. **Most plant cells are directly exposed to the environment**
   - Plants have extensive surfaces such as leaves, stems and roots.
   - These surfaces allow waste products to be eliminated through diffusion and other simple processes.
2. **Plants produce relatively small quantities of nitrogenous waste**
   - Unlike animals, plants do not break down large quantities of proteins to obtain energy.
   - Therefore, they generally produce less nitrogenous waste such as ammonia and urea.

3. **Many plant waste products are recycled**
   - Some metabolic products can be reused in other metabolic processes.
   - For example, carbon dioxide released during respiration can be used during photosynthesis.

4. **Some waste products are stored in plant tissues**
   - Plants can isolate unwanted substances in vacuoles, old leaves, bark, fruits and other tissues.
   - These substances may later be removed when the tissues are shed.
5. **Plants have a low rate of metabolism compared with many animals**
   - Plants are generally less active in terms of movement and energy expenditure.
   - Their metabolic requirements and waste production patterns differ from those of animals.
6. **Plants eliminate gaseous wastes through diffusion**
   - Oxygen and carbon dioxide can move through stomata, lenticels and other surfaces.
   - This reduces the need for specialised gaseous excretory organs.
7. **Plants lose excess water through transpiration**
   - Water vapour escapes mainly through stomata.
   - This also helps regulate water balance and temperature.
8. **Plants are stationary organisms**
   - They do not need specialised excretory systems to transport wastes to particular organs for elimination in the same way as mobile animals.

1.4 Methods of excretion in plants

Plants eliminate or isolate waste products through several methods. Some waste products leave the plant directly, while others are stored in plant tissues before eventual removal.

The main methods include:

1. Transpiration.
2. Diffusion.
3. Deposition and storage.
4. Organ and tissue fall (shedding).
5. Exudation.
6. Guttation.

A. Transpiration

Meaning of transpiration

Transpiration is the process by which plants lose water in the form of water vapour from their aerial parts, especially through the leaves.

It mainly occurs when water evaporates from the moist surfaces of mesophyll cells into the intercellular air spaces before diffusing out of the plant.

Although transpiration is primarily a process of water loss and water transport, it also provides a means through which excess water is eliminated from plants.

Types of transpiration

There are three main types of transpiration:

1. **Stomatal transpiration**

- This is the loss of water vapour through stomata found mainly on leaves.
- It accounts for the largest proportion of water lost through transpiration in most plants.
- The opening and closing of stomata are controlled by guard cells.
- When guard cells become turgid, the stomata open, allowing water vapour to escape.
- When guard cells become flaccid, the stomata close or narrow, reducing water loss.

2. **Cuticular transpiration**

- This is the loss of water vapour through the cuticle covering the epidermis of leaves and young stems.
- The cuticle is a waxy protective layer that reduces excessive water loss.
- Plants with thin cuticles generally lose more water through this pathway than plants with thick, waxy cuticles.

3. **Lenticular transpiration**

- This is the loss of water vapour through lenticels found on the surfaces of woody stems and some fruits.
- Lenticels are small openings that facilitate gaseous exchange between internal stem tissues and the atmosphere.
- Water vapour escapes through these openings continuously, although the amount is usually small.



Process of transpiration

Transpiration takes place through the following stages:

1. Water is absorbed from the soil by root hair cells through osmosis.
2. Water moves across the root tissues into the xylem vessels.
3. Water is transported upwards through the xylem vessels to the leaves.
4. Water moves from the leaf xylem into the mesophyll cells.
5. Water evaporates from the moist surfaces of mesophyll cells into the intercellular air spaces.
6. Water vapour diffuses through the stomatal pores into the atmosphere.
7. A small proportion of water vapour may also escape through the cuticle and lenticels.

Factors affecting the rate of transpiration

The rate of transpiration is affected by environmental and internal factors.

Environmental factors

1. **Temperature**

- High temperatures increase the rate of evaporation of water from mesophyll cell surfaces.

- This generally increases the rate of transpiration.
- Very high temperatures may cause stomata to close, reducing water loss.

2. **Humidity**
   - High atmospheric humidity reduces the difference in water vapour concentration between the leaf and the surrounding air.
   - This reduces the rate of transpiration.
   - Low humidity increases the rate of transpiration.
3. **Wind**
   - Wind removes moist air surrounding the leaf surface.
   - This maintains a steep water vapour concentration gradient between the leaf and the atmosphere.
   - Consequently, transpiration increases.
   - Extremely strong winds may cause stomatal closure.
4. **Light intensity**
   - Increased light intensity generally causes stomata to open in many plants.
   - This increases the loss of water vapour.
   - In darkness, stomata generally close, reducing transpiration.
5. **Availability of soil water**
   - Adequate soil water allows roots to absorb sufficient water for transpiration.
   - When soil water is limited, plants may close their stomata to reduce water loss.

Internal factors

1. **Leaf surface area**
   - Plants with large leaves generally have a greater surface area for water loss.
   - They may therefore transpire faster than plants with small leaves under similar conditions.
2. **Number and distribution of stomata**
   - Leaves with many stomata may have a higher potential rate of stomatal transpiration.
   - Stomatal distribution also influences water loss.
3. **Thickness of the cuticle**
   - Thick waxy cuticles reduce water loss through the leaf surface.
   - Thin cuticles allow relatively greater cuticular water loss.
4. **Leaf structure**
   - Sunken stomata and rolled leaves reduce exposure of stomata to moving air.
   - These adaptations reduce water loss.

Importance of transpiration in plants

1. **Elimination of excess water**

- Transpiration removes water that is absorbed by roots but is not immediately required for metabolic activities.

2. **Creates transpiration pull**
   - Water loss from leaves creates tension in the xylem.
   - This helps pull water and dissolved mineral salts from the roots to the leaves.
3. **Cools the plant**
   - Evaporation of water from leaf surfaces removes heat.
   - This helps prevent overheating, especially under hot conditions.
4. **Facilitates mineral transport**
   - Mineral salts dissolved in water are transported from the roots to other parts of the plant through the xylem.
5. **Maintains water movement**
   - Transpiration helps maintain a continuous flow of water through the plant.
6. **Supports photosynthesis**
   - Water transported to leaves provides a raw material needed for photosynthesis.
7. **Maintains cell turgidity indirectly**
   - Continuous absorption and transport of water help maintain the water supply needed to keep plant cells turgid.

Adaptations of plants to reduce excessive transpiration

1. Thick waxy cuticle.
2. Sunken stomata.
3. Reduced leaf surface area.
4. Rolled leaves.
5. Hairy leaf surfaces.
6. Reduced number of stomata.
7. Stomata that open mainly at night, as in many CAM plants.
8. Shedding of leaves during dry seasons.

Examples in the Kenyan environment

- Cactus plants in dry regions have reduced leaves and thick waxy stems.
- Acacia trees have relatively small leaflets that reduce exposed leaf surface area.
- Aloe plants have thick, fleshy leaves adapted to water conservation.
- Maize plants may roll their leaves during water stress to reduce water loss.

B. Diffusion

Meaning of diffusion

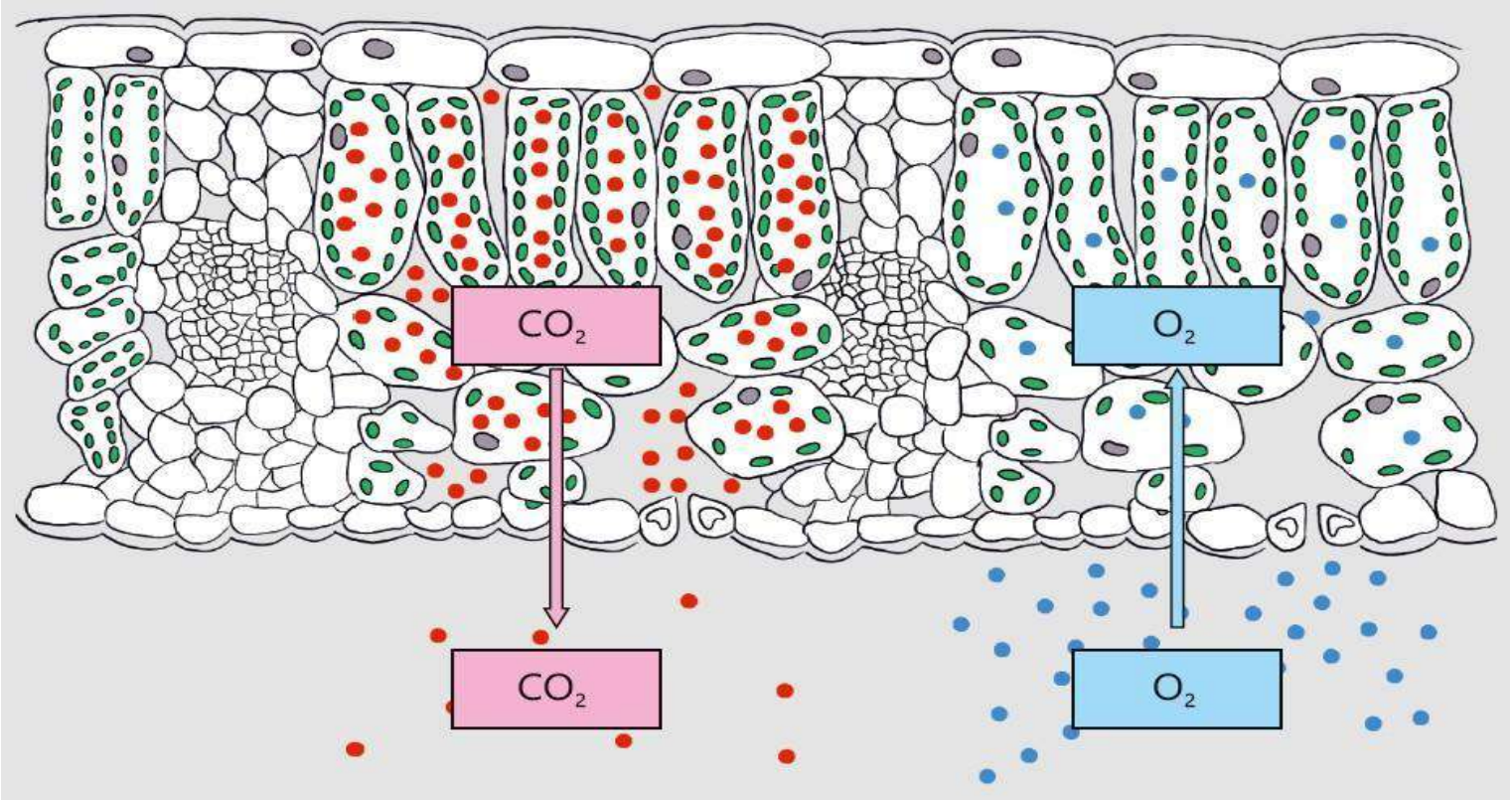
Diffusion is the movement of particles or molecules from a region of higher concentration to a region of lower concentration until they become evenly distributed.

In plants, diffusion enables gaseous waste products such as oxygen and carbon dioxide to move out of cells and tissues into the surrounding environment.

Diffusion is a passive process because it does not require energy from the plant.

How diffusion facilitates excretion in plants

1. During respiration, plant cells produce carbon dioxide as a waste product.
2. Carbon dioxide accumulates within the cells, creating a concentration gradient.
3. Carbon dioxide moves from the cells into the intercellular air spaces.
4. It then moves through stomata or lenticels into the atmosphere.
5. During photosynthesis, oxygen is produced within the chloroplasts.
6. Oxygen moves from the cells into the intercellular spaces.
7. It eventually diffuses out through stomata and other available surfaces.



Examples of waste products eliminated through diffusion

1. Carbon dioxide produced during respiration.
2. Oxygen produced during photosynthesis.
3. Some volatile organic substances produced during plant metabolism.

Factors affecting diffusion in plants

1. **Concentration gradient**

- A greater difference in concentration between two regions increases the rate of diffusion.

2. **Temperature**
   - Higher temperatures increase the kinetic energy of molecules, generally increasing diffusion rate.
3. **Surface area**
   - A larger surface area provides more space for particles to diffuse through.
4. **Diffusion distance**
   - Shorter diffusion distances increase the rate of diffusion.
   - Thin plant surfaces facilitate faster diffusion.
5. **Nature of the diffusing substance**
   - Small molecules generally diffuse more easily than larger molecules.
6. **Availability of diffusion pathways**
   - Open stomata and functional lenticels facilitate gaseous diffusion.

Importance of diffusion in plant excretion

- Removes carbon dioxide produced during respiration.
- Eliminates oxygen produced during photosynthesis.
- Allows some volatile metabolic products to escape.
- Facilitates gaseous exchange between plant tissues and the atmosphere.
- Helps prevent excessive accumulation of gaseous waste products.

C. Deposition and storage of waste products

Meaning of deposition

Deposition in plants is the process by which metabolic waste products are accumulated and stored in particular cells, tissues or organs instead of being immediately eliminated from the plant.

Plants often store substances that are difficult to break down or remove safely.

These substances may be deposited in vacuoles, old tissues, bark, leaves, fruits and other structures.

How deposition takes place

1. Waste products are formed during metabolic activities.
2. Some of these substances are transported to specialised storage cells or tissues.
3. The substances are deposited in vacuoles or other cellular compartments.
4. Some waste products are converted into relatively insoluble substances.
5. They remain isolated from important metabolic processes.
6. Some stored substances are eventually eliminated when the organs containing them are shed.

Examples of substances deposited in plants

1. **Calcium oxalate crystals**
   - These are formed when calcium combines with oxalic acid.

- They may be deposited in plant cells as needle-shaped crystals called raphides or as star-shaped clusters called druses.
- They are commonly found in plants such as the taro plant.

2. **Calcium carbonate**
   - It may be deposited in specialised cells as cystoliths.
   - Cystoliths occur in some plants in the family Acanthaceae.
3. **Tannins**
   - These are complex organic compounds deposited in certain plant tissues.
   - They are common in bark, leaves and fruits.
4. **Resins**
   - These are sticky substances produced by certain plants.
   - They may accumulate in specialised resin ducts.
5. **Latex**
   - This is a milky fluid containing different organic substances.
   - It occurs in specialised cells or tubes called laticifers.

Importance of deposition and storage

1. Prevents harmful substances from interfering with normal cellular activities.
2. Provides a way of isolating substances that cannot easily be eliminated immediately.
3. Some deposited substances help protect plants against herbivores.
4. Some crystals reduce the palatability of plant tissues.
5. Stored substances can be removed when old leaves, bark or fruits are shed.
6. It enables plants to maintain normal metabolic activities.

Examples of plants that store waste products

- Taro stores calcium oxalate crystals in its tissues.
- Tea plants contain tannins in their leaves.
- Pine trees produce and store resin in resin ducts.
- Rubber plants contain latex in specialised laticifer tissues.

D. Organ and tissue fall (shedding)

Meaning of shedding

Shedding is the process by which plants naturally lose old or unwanted organs and tissues, such as leaves, flowers, fruits and bark.

It is also called abscission when referring to the natural separation of plant organs, particularly leaves, flowers and fruits.

Shedding is an important method through which plants eliminate waste products that have accumulated in ageing or unwanted tissues.

How shedding facilitates excretion

1. Metabolic waste products accumulate in ageing leaves and other tissues.
2. The plant transports some waste products to these ageing structures.
3. An abscission layer develops at the base of the organ.
4. Cells within the abscission layer undergo structural changes that weaken the attachment.
5. The organ eventually separates from the plant.
6. Waste products stored in the organ are removed together with it.

Examples of shedding in plants

1. **Falling of leaves**

- Deciduous trees shed their leaves during particular seasons.
- Waste products accumulated in the leaves are removed from the plant.
- Examples include mango trees under certain environmental conditions and temperate trees such as maple.

2. **Shedding of bark**

- Some trees periodically lose their outer bark.
- Waste substances accumulated in the outer tissues may be eliminated together with the bark.
- Examples include eucalyptus and some other woody trees.

3. **Shedding of flowers**

- Flowers may fall after pollination and fertilisation or when they are not successfully fertilised.
- Some unwanted substances stored in these tissues are removed.

4. **Shedding of fruits**

- Mature fruits may detach naturally from the parent plant.
- Waste substances accumulated in fruit tissues are removed with the fallen fruit.

Importance of shedding in plant excretion

- Removes waste products stored in old leaves and tissues.
- Prevents prolonged accumulation of certain unwanted substances.
- Helps plants eliminate dead or damaged tissues.
- Enables plants to replace old structures with new ones.
- Reduces water loss in some plants during dry seasons.
- Helps plants maintain healthy growth.

E. Exudation

Meaning of exudation

Exudation is the process by which plants release substances from their internal tissues to the outside through wounds, specialised structures or natural openings.

The substances released are called exudates.

Some exudates are metabolic products that may serve protective or other functions within the plant.

Examples of substances released through exudation

1. Latex.
2. Gums.
3. Resins.
4. Mucilage.
5. Plant oils and other secretions.

How exudation takes place

1. Certain metabolic substances are produced in specialised plant cells or tissues.
2. The substances accumulate in secretory structures such as resin ducts, laticifers and secretory cavities.
3. When a plant is wounded or when the substances reach an opening, they are released.
4. The substances flow or ooze out of the plant tissues.
5. Some substances harden after exposure to air and form protective coverings over wounds.

Examples of exudation in plants

1. **Latex**
   - Latex is a milky fluid produced by specialised plant cells known as laticifers.
   - It is released when these cells or tissues are cut or damaged.
   - Example: Rubber tree (*Hevea brasiliensis*).
2. **Gums**
   - Gums are sticky substances released by certain plants.
   - They may flow out through damaged areas of the stem and harden after exposure to air.
   - Example: Acacia trees produce gum arabic.
3. **Resins**
   - Resins are sticky organic substances produced by certain trees.
   - They are released from resin ducts, particularly when the bark is damaged.
   - Example: Pine trees.
4. **Mucilage**
   - Mucilage is a slippery, gelatinous substance produced by certain plants.
   - It may be released from specialised cells or tissues.
   - Example: Aloe vera.

Importance of exudation

- Helps remove or release certain metabolic substances.
- Seals wounds and prevents excessive loss of internal fluids.
- Protects plants against invasion by disease-causing microorganisms.
- Some exudates discourage herbivores and insect attacks.
- Provides commercially useful substances to human beings.

F. Guttation

Meaning of guttation

Guttation is the process by which plants lose excess liquid water in the form of droplets through specialised structures called hydathodes, usually found at the tips or margins of leaves.

The water released during guttation contains small quantities of dissolved mineral salts and other substances.

Guttation commonly occurs when the soil is very moist, atmospheric humidity is high and transpiration is low.

Hydathodes

Hydathodes are specialised structures found mainly at the tips and margins of leaves through which liquid water is released.

They are associated with the ends of leaf veins and are connected to the internal vascular tissues through a region of loosely arranged cells called epithem.

Process of guttation

Guttation takes place through the following stages:

1. Plant roots absorb water from the soil through root hair cells.
2. When the soil contains plenty of water, absorption continues even when transpiration is low.
3. Water accumulates in the xylem vessels of the roots.
4. Root pressure develops due to the continued absorption of water and movement of mineral ions.
5. The positive pressure pushes water upwards through the xylem vessels.
6. Water reaches the leaf veins and moves towards the hydathodes.
7. Liquid water is forced out through the hydathodes.
8. Water droplets collect at the tips or margins of the leaves.

Conditions that favour guttation

1. High soil water availability.
2. High atmospheric humidity.
3. Low transpiration rate.
4. Low temperatures, particularly at night.
5. Open stomata or reduced evaporative demand.
6. High root pressure.

Examples of plants that exhibit guttation

- Maize.
- Wheat.
- Rice.
- Grasses.
- Tomato.
- Strawberry.

Difference between guttation and transpiration

Guttation	Transpiration
Involves loss of liquid water.	Involves loss of water vapour.
Occurs through hydathodes.	Occurs mainly through stomata.
Usually occurs at night or early morning.	Commonly occurs during the day.
Favoured by high soil moisture.	Favoured by conditions that increase evaporation.
Driven mainly by root pressure.	Driven mainly by evaporation and transpiration pull.
Water droplets are visible on leaf margins.	Water vapour is generally invisible.
Water contains dissolved mineral salts.	Water vapour contains virtually no dissolved mineral salts.

Importance of guttation

1. Removes excess liquid water from plant tissues.
2. Helps regulate water balance when water absorption is greater than water loss through transpiration.
3. Provides a route through which small quantities of dissolved substances are released.
4. Demonstrates the development and functioning of root pressure.
5. Provides evidence of active water absorption by plant roots.

Limitations of guttation

1. It is not the main method of water loss in most plants.
2. It occurs only under suitable environmental conditions.
3. It may leave mineral deposits on leaf surfaces after the water evaporates.
4. Guttation droplets may contain substances that support microbial growth on leaf surfaces.

Important examination point

Guttation should not be confused with dew formation.

- Guttation water comes from inside the plant and is released through hydathodes.
- Dew forms when atmospheric water vapour condenses on cool plant surfaces.

2.0 Economic importance of plant excretory products

Plants produce various substances that may be considered metabolic waste products or secondary metabolites. Many of these substances have considerable economic value and are used in industries, medicine, agriculture, food production and other commercial activities.

Some plant excretory products are collected directly from living plants, while others are obtained from plant tissues such as leaves, bark, roots, fruits and seeds.

2.1 Latex

Meaning of latex

Latex is a milky or coloured fluid produced by specialised plant cells or tissues known as laticifers.

It contains different substances, including rubber particles, resins, proteins, sugars and other organic compounds.

Economic importance of latex

1. **Manufacture of tyres**
    - Natural rubber obtained from latex is used in the manufacture of motor vehicle, motorcycle, bicycle and aircraft tyres.
2. **Manufacture of footwear**
    - Rubber is used to manufacture shoe soles, sandals, gumboots and other footwear.
3. **Manufacture of medical equipment**
    - Latex is processed to manufacture surgical gloves, examination gloves and some medical devices.
4. **Manufacture of household products**
    - Rubber is used to make rubber bands, mats, hoses and household gloves.
5. **Manufacture of industrial products**
    - It is used in the production of conveyor belts, seals, gaskets and insulation materials.
6. **Employment creation**
    - Latex production supports employment in rubber plantations, processing factories and manufacturing industries.

Example: The rubber tree (*Hevea brasiliensis*) is commercially tapped for natural latex.

2.2 Gums

Meaning of gums

Gums are sticky, water-soluble or water-dispersible substances produced by certain plants. They may be released through damaged plant tissues and harden after exposure to air.

Economic importance of gums

1. **Food industry**
    - Gum arabic is used as a stabiliser and emulsifier in certain food products.
    - It helps prevent ingredients from separating.
2. **Pharmaceutical industry**
    - Some gums are used in the preparation of tablets, syrups and medicinal suspensions.
    - They help bind and stabilise pharmaceutical ingredients.
3. **Paper industry**

- Gums are used in paper coating, binding and adhesive formulations.

4. **Textile industry**
   - Some gums are used in textile printing and finishing processes.
5. **Printing industry**
   - Gum arabic is used in certain printing and lithographic processes.
6. **Cosmetic industry**
   - Some plant gums are used as thickening and stabilising agents in cosmetic products.
7. **Adhesive manufacture**
   - Gums are used in the manufacture of certain adhesives and glues.

Example: Gum arabic is obtained mainly from *Acacia senegal* and *Acacia seyal*, which occur in parts of Africa, including Kenya.

2.3 Resins

Meaning of resins

Resins are sticky organic substances produced by certain plants, particularly coniferous trees. They are usually stored in specialised structures called resin ducts.

They may ooze out when the plant is injured and harden after exposure to air.

Economic importance of resins

1. **Manufacture of varnishes**
   - Resins are used in making varnishes that protect and improve the appearance of wooden surfaces.
2. **Paint industry**
   - Some resins are used in the manufacture of paints and protective coatings.
3. **Adhesive manufacture**
   - Certain resins are used in the production of adhesives.
4. **Paper industry**
   - Resin derivatives are used in paper sizing to improve the resistance of paper to water.
5. **Perfume industry**
   - Some aromatic resins are used in the manufacture of perfumes and incense.
6. **Chemical industry**
   - Pine resin can be processed to produce turpentine and rosin.
7. **Traditional medicine**
   - Some plant resins have been used in traditional preparations, although their safety and effectiveness vary.

Examples:

- Pine trees produce resin.

- Frankincense and myrrh are aromatic plant resins.

2.4 Tannins

Meaning of tannins

Tannins are naturally occurring complex organic compounds found in various plant tissues, especially bark, leaves, fruits and seeds.

They have an astringent taste and can combine with proteins.

Economic importance of tannins

1. **Leather tanning**
   - Tannins are used in processing animal hides and skins into leather.
   - They combine with proteins in the hides, helping to make the leather more durable and resistant to decay.
2. **Dyeing industry**
   - Tannins are used in the preparation of certain dyes and natural colouring materials.
3. **Ink manufacture**
   - Some tannins are used in the production of traditional inks.
4. **Food and beverage industry**
   - Tannins contribute to the taste and astringency of tea, coffee and some fruits.
5. **Traditional medicine**
   - Tannin-containing plant extracts have traditionally been used in preparations for their astringent properties.
6. **Industrial applications**
   - Certain tannins are used in adhesives and other chemical formulations.

Examples: Acacia bark, oak bark, tea leaves and some fruit skins contain tannins.

2.5 Essential oils

Meaning of essential oils

Essential oils are volatile, aromatic substances produced by certain plants. They are responsible for the characteristic smells of many leaves, flowers, fruits and other plant parts.

Economic importance of essential oils

1. **Perfume manufacture**
   - Essential oils are used to produce perfumes, fragrances and scented products.
2. **Soap manufacture**
   - They are added to soaps to provide pleasant scents.
3. **Cosmetic industry**

- They are used in creams, lotions and other personal-care products.

4. **Food flavouring**
   - Certain essential oils are used as flavouring agents in foods and beverages.
5. **Pharmaceutical industry**
   - Some essential oils are used as ingredients in pharmaceutical and medicinal preparations.
6. **Aromatherapy**
   - Selected essential oils are used in aromatherapy products.
7. **Cleaning products**
   - Some are used in air fresheners, detergents and household cleaning formulations.

Examples of plants producing essential oils

- Eucalyptus.
- Lemongrass.
- Peppermint.
- Lavender.
- Rosemary.
- Clove.
- Citrus plants.

2.6 Alkaloids

Meaning of alkaloids

Alkaloids are naturally occurring nitrogen-containing organic compounds produced by plants. Many have strong physiological effects on animals and human beings.

Some alkaloids are toxic, while others are important in medicine.

Economic importance of alkaloids

1. **Medicine production**
   - Some alkaloids are used in the manufacture of medicines.
   - For example, quinine has been used in the treatment of malaria.
2. **Pain management**
   - Morphine, obtained from the opium poppy, is used medically as a strong pain-relieving drug under controlled conditions.
3. **Stimulants**
   - Caffeine, found in coffee and tea, is used in beverages because of its stimulant effect.
4. **Agricultural applications**
   - Some alkaloids have natural insecticidal or pest-deterring properties.
5. **Pharmaceutical research**
   - Plant alkaloids provide important starting materials for the development of medicines.

Examples:

Alkaloid	Plant source

Quinine	Cinchona tree
Caffeine	Coffee and tea plants
Morphine	Opium poppy
Nicotine	Tobacco plant
Atropine	Deadly nightshade

Safety note: Some alkaloids are highly poisonous or addictive. Their use must be controlled and guided by appropriate medical and safety regulations.

2.7 Mucilage

Meaning of mucilage

Mucilage is a thick, slippery, gelatinous substance produced by certain plant cells. It is made mainly of complex carbohydrates that absorb and retain water.

Economic importance of mucilage

1. **Pharmaceutical industry**
   - It is used as a thickening and suspending agent in some medicinal preparations.
2. **Cosmetic industry**
   - It is used in lotions, creams, shampoos and skin-care products.
3. **Food industry**
   - Some plant mucilages are used as natural thickeners and stabilisers.
4. **Textile industry**
   - Certain mucilages are used in textile processing and printing.
5. **Paper industry**
   - Some mucilages are used in paper production and finishing.
6. **Traditional applications**
   - Aloe vera gel and other mucilage-rich plant materials have traditionally been used in skin preparations.

Examples: Aloe vera, okra, cactus and flaxseed.

2.8 Plant waxes

Meaning of plant waxes

Plant waxes are lipid substances deposited on plant surfaces, especially leaves, fruits and stems. They form part of the protective cuticle.



Economic importance of plant waxes

1. Used in the manufacture of polishes for shoes, furniture and vehicles.
2. Used in cosmetics such as lip balms and creams.
3. Used in the production of candles.
4. Used as protective coatings for some fruits.
5. Used in pharmaceutical preparations.
6. Used in waterproofing certain materials.

Example: Carnauba wax is obtained from the leaves of the carnauba palm.

2.9 Plant pigments and colouring substances

Some plants produce coloured substances such as anthocyanins and other natural pigments.

Economic importance

1. Used as natural food colourants.
2. Used in textile dyeing.
3. Used in the manufacture of natural inks.
4. Used in cosmetics.
5. Used in scientific research as biological indicators and staining materials.

Examples:

- Anthocyanins from flowers and fruits.
- Curcumin from turmeric.
- Betalains from beetroot.

3.0 Summary of methods of excretion in plants

Method	Description	Examples
Transpiration	Loss of water as water vapour.	Water vapour through stomata.
Diffusion	Movement of waste molecules down a concentration gradient.	Oxygen and carbon dioxide.

Deposition	Storage or isolation of waste substances in plant tissues.	Calcium oxalate crystals and tannins.
Organ and tissue fall	Removal of stored substances through shedding of old organs.	Falling leaves and bark.
Exudation	Release of substances from plant tissues.	Latex, gums and resins.
Guttation	Loss of liquid water through hydathodes.	Water droplets on maize leaves.

4.0 Important biological concepts to remember

1. Plants do not have specialised excretory organs like kidneys in animals.
2. Diffusion is a passive process that does not require energy.
3. Transpiration involves the loss of water in vapour form.
4. Guttation involves the loss of liquid water through hydathodes.
5. Root pressure plays an important role in guttation.
6. Stomata are the main structures involved in stomatal transpiration and gaseous exchange.
7. Lenticels facilitate gaseous exchange in woody stems.
8. Deposition enables plants to isolate certain unwanted substances.
9. Shedding removes substances stored in old plant organs.
10. Exudation involves the release of substances such as gums, latex and resins.
11. Some plant excretory products have important commercial and industrial applications.
12. Not all substances released by plants are purely metabolic wastes; some have protective and economic functions.

REVISION QUESTIONS

SELF-ASSESSMENT

Section A: Multiple-choice questions

Choose the correct answer from the alternatives provided.

1. What is excretion in plants?

A. The process of manufacturing food.
B. The removal of metabolic waste products.
C. The absorption of mineral salts.
D. The movement of water through xylem.

2. Which of the following is a gaseous waste product of photosynthesis?

A. Nitrogen B. Carbon dioxide C. Oxygen D. Hydrogen

3. The main reason plants lack specialised excretory organs is that:

A. They do not produce waste products.
B. They do not carry out respiration.
C. Most waste products can be removed or stored through simple mechanisms.
D. They do not absorb water.

4. Which structure is responsible for the loss of water vapour during stomatal transpiration?

A. Hydathodes B. Stomata C. Root hairs D. Xylem vessels

5. Loss of water vapour through lenticels is referred to as:

A. Stomatal transpiration B. Cuticular transpiration C. Lenticular transpiration D. Guttation

6. Which of the following is the main driving force for guttation?

A. Transpiration pull B. Root pressure C. Photosynthesis D. Diffusion of oxygen

7. The specialised structures through which guttation occurs are called:

A. Stomata B. Lenticels C. Hydathodes D. Root hairs

8. Which process involves the movement of molecules from a region of higher concentration to a region of lower concentration?

A. Osmosis B. Diffusion C. Active transport D. Translocation

9. Which of the following substances is commonly deposited in plant cells as crystals?

A. Glucose B. Calcium oxalate C. Oxygen D. Starch

10. The natural falling of leaves from plants is known as:

A. Germination B. Abscission C. Pollination D. Translocation

11. Latex is produced by specialised structures called:

A. Hydathodes B. Laticifers C. Lenticels D. Guard cells

12. Which plant product is commercially important in leather tanning?

A. Oxygen B. Tannins C. Glucose D. Water vapour

13. Gum arabic is mainly obtained from:

A. Maize B. Acacia C. Sugarcane D. Wheat

14. Which of the following is an example of a plant that produces commercially important latex?

A. Rubber tree B. Maize C. Wheat D. Rice

15. Which environmental condition favours guttation?

A. Low soil moisture and high transpiration.
B. High soil moisture and high humidity.
C. High wind speed and low humidity.
D. High temperature and low root pressure.

16. Which of the following reduces the rate of transpiration?

A. High temperature B. Strong wind C. Thick waxy cuticle D. Low atmospheric humidity

17. The accumulation of unwanted substances in vacuoles is an example of:

A. Diffusion B. Deposition C. Guttation D. Translocation

18. Which of the following plant products is used in perfume manufacture?

A. Essential oils B. Calcium oxalate C. Carbon dioxide D. Calcium carbonate

19. Which of the following is NOT a type of transpiration?

A. Cuticular transpiration B. Stomatal transpiration C. Lenticular transpiration D. Root transpiration

20. Which statement correctly distinguishes guttation from transpiration?

A. Guttation involves water vapour loss.
B. Transpiration occurs through hydathodes.
C. Guttation involves liquid water loss.
D. Both processes occur exclusively at night.

Section B: Structured questions

21. Excretion in plants

a) Define excretion in plants. (2 marks)

b) State four reasons why plants do not possess complex excretory systems. (4 marks)

c) Identify four waste products produced by plants. (4 marks)

22. Transpiration

a) Define transpiration. (2 marks)

b) Name the three types of transpiration. (3 marks)

c) Explain how water moves from the soil into the atmosphere through a plant during transpiration. (6 marks)

d) Explain four environmental factors that affect the rate of transpiration. (8 marks)

e) State three ways through which plants reduce excessive water loss. (3 marks)

23. Diffusion

a) Define diffusion. (2 marks)

b) Explain how diffusion facilitates the elimination of gaseous waste products in plants. (4 marks)

c) Name two gaseous waste products eliminated through diffusion. (2 marks)

d) State four factors that affect the rate of diffusion. (4 marks)

24. Deposition and storage

a) Explain the meaning of deposition in plants. (2 marks)

b) Name four substances that may be deposited in plant tissues. (4 marks)

c) Explain three advantages of deposition in plants. (6 marks)

d) Identify two plant structures or locations where waste products may be stored. (2 marks)

25. Organ and tissue fall

a) Define shedding in plants. (2 marks)

b) What is meant by abscission? (2 marks)

c) Explain how shedding facilitates excretion in plants. (5 marks)

d) Give three examples of plant organs or tissues that may be shed. (3 marks)

26. Exudation

a) Define exudation. (2 marks)

b) Name four substances that may be released through exudation. (4 marks)

c) Explain three ways in which exudation benefits plants. (6 marks)

d) Name one plant from which each of the following substances is obtained:

i. Latex. (1 mark)

ii. Gum arabic. (1 mark)

iii. Resin. (1 mark)

27. Guttation

a) Define guttation. (2 marks)

b) Name the specialised structures through which guttation occurs. (1 mark)

c) Explain the process of guttation in flowering plants. (6 marks)

d) State four conditions that favour guttation. (4 marks)

e) Give three differences between guttation and transpiration. (6 marks)

28. Economic importance of plant excretory products

a) State the economic importance of the following plant products:

i. Latex. (3 marks)

ii. Gums. (3 marks)

iii. Resins. (3 marks)

iv. Tannins. (3 marks)

v. Essential oils. (3 marks)

b) Name the plant source of each of the following:

i. Quinine. (1 mark)

ii. Caffeine. (1 mark)

iii. Morphine. (1 mark)

iv. Natural rubber. (1 mark)

29.

A learner observed small droplets of water at the tips and margins of maize leaves early in the morning. The learner concluded that the plant was undergoing guttation.

a) Identify the structures responsible for releasing the droplets. (1 mark)

b) Explain why guttation was likely to occur early in the morning. (4 marks)

c) State two differences between the water droplets observed and dew. (4 marks)

d) Explain the role of root pressure in the process. (3 marks)

30.

A learner set up an experiment to investigate the effect of environmental conditions on transpiration using a leafy shoot.

a) Name the apparatus that can be used to measure the rate of water uptake by the shoot. (1 mark)

b) Explain the principle of operation of the apparatus. (3 marks)

c) State four factors that may affect the rate of water uptake. (4 marks)

d) Explain why the cut end of the shoot should be fitted into the apparatus while under water. (2 marks)

e) State two precautions that should be taken when setting up the experiment. (2 marks)

6.0 Practical and learner-centred activities

These activities help learners develop practical skills, critical thinking, observation and scientific investigation competencies.

Activity 1: Investigating guttation

Materials required:

- A healthy maize or grass plant.

- A transparent polythene bag.
- String or rubber band.
- Watering can.

Procedure:

1. Water a potted maize plant thoroughly.
2. Place the plant in a humid environment.
3. Cover a leafy shoot with a transparent polythene bag without damaging the leaves.
4. Secure the bag loosely around the shoot.
5. Observe the plant early the following morning.
6. Examine the leaf tips and margins for water droplets.

Expected observations:

- Water droplets may be observed at the tips and margins of leaves.
- Some water vapour may condense on the inside of the polythene bag.

Questions:

1. What causes water droplets to appear at the tips of maize leaves?
2. Which structures are responsible for guttation?
3. Why is guttation more likely to occur at night or early in the morning?
4. How can you distinguish guttation water from dew?

Activity 2: Investigating transpiration

Materials required:

- Fresh leafy plant.
- Dry blue cobalt chloride paper.
- Glass slides.
- Clips.

Procedure:

1. Obtain a fresh leaf from a healthy plant.
2. Place dry blue cobalt chloride paper on the upper surface of the leaf.
3. Place another piece on the lower surface.
4. Cover each piece with a glass slide.
5. Secure the arrangement using clips.
6. Observe the colour changes in the cobalt chloride papers.

Expected observations:

- Blue cobalt chloride paper changes to pink when exposed to water.
- The paper on the surface with a higher rate of water loss may change colour faster.

Questions:

1. What causes the colour change in cobalt chloride paper?
2. Why may the lower leaf surface show a faster colour change?
3. What does this experiment demonstrate?
4. State two limitations of this experiment.

Safety: Cobalt chloride is hazardous. This experiment should only be conducted under teacher supervision using appropriate protective equipment. An alternative demonstration using a transparent bag over a leafy shoot may be used.

7.0 Key biological terms and definitions

Term	Meaning
Excretion	Removal of metabolic waste products.
Transpiration	Loss of water as vapour from aerial plant parts.
Diffusion	Movement of particles from higher to lower concentration.
Guttation	Loss of liquid water through hydathodes.
Hydathodes	Specialised structures through which guttation occurs.
Lenticels	Openings in woody stems that facilitate gaseous exchange.
Stomata	Small pores on plant surfaces involved in gaseous exchange.
Deposition	Accumulation and storage of substances in plant tissues.
Abscission	Natural separation of an organ from a plant.
Exudation	Release of substances from plant tissues.
Latex	Milky fluid produced by specialised plant tissues.
Resin	Sticky organic substance produced by certain plants.
Tannins	Complex organic compounds found in plant tissues.
Laticifers	Specialised cells or tissues that produce or contain latex.
Root pressure	Positive pressure developed in roots that helps push water upwards through xylem.
Epithem	Loosely arranged tissue associated with hydathodes.

STRAND 3.0: ANATOMY AND PHYSIOLOGY OF ANIMALS

SUB-STRAND 3.1: REPRODUCTION IN ANIMALS

3.1.1 Introduction to reproduction in animals

Meaning of reproduction

Reproduction is the biological process through which living organisms produce new individuals of their own kind. It ensures the continuation of a species from one generation to another.

Reproduction is an essential characteristic of living organisms. Although an individual animal can survive without reproducing, reproduction is necessary for the survival and continuity of its species.

Importance of reproduction in animals

1. **Continuity of species:** Reproduction ensures that animal species do not become extinct through natural death of existing individuals.
2. **Production of offspring:** It enables animals to produce young ones that develop into adults.
3. **Transfer of genetic information:** Parents pass hereditary information (DNA) to their offspring.
4. **Genetic variation:** Sexual reproduction combines genetic materials from two parents, producing offspring with different characteristics.

5. **Population maintenance:** Reproduction helps maintain animal populations in their natural habitats.
6. **Evolution:** Genetic variations arising during sexual reproduction provide material for natural selection and evolution.
7. **Replacement of individuals:** New individuals replace those that die due to old age, predation, diseases or environmental conditions.

3.1.2 Types of reproduction in animals

Animals reproduce mainly through two methods:

A. Asexual reproduction

Asexual reproduction is a process in which a single parent produces offspring without the fusion of male and female gametes.

Characteristics:

- It involves only one parent.
- There is no formation or fusion of gametes.
- Offspring are usually genetically similar to the parent.
- It can occur rapidly under favourable environmental conditions.
- It produces little genetic variation, except through mutations.

Examples:

- Budding in Hydra.
- Binary fission in some unicellular organisms.
- Fragmentation and regeneration in some simple animals.
- Parthenogenesis in some insects, such as honeybees and aphids.

B. Sexual reproduction

Sexual reproduction is a process in which male and female gametes fuse to form a zygote.

Characteristics:

1. It usually involves two parents.
2. Male and female gametes are produced.
3. Fertilization occurs through the fusion of gametes.
4. A diploid zygote is formed.
5. Offspring inherit genetic information from both parents.
6. It promotes genetic variation among offspring.

Examples include reproduction in humans, cattle, goats, sheep, fish, frogs and birds.

Comparison between asexual and sexual reproduction

Asexual reproduction	Sexual reproduction
Usually involves one parent.	Usually involves two parents.
No fusion of gametes.	Involves fusion of gametes.

Offspring are usually genetically similar.	Offspring show genetic variation.
Usually occurs rapidly.	Often involves more complex processes.
Little genetic variation.	Greater genetic variation.

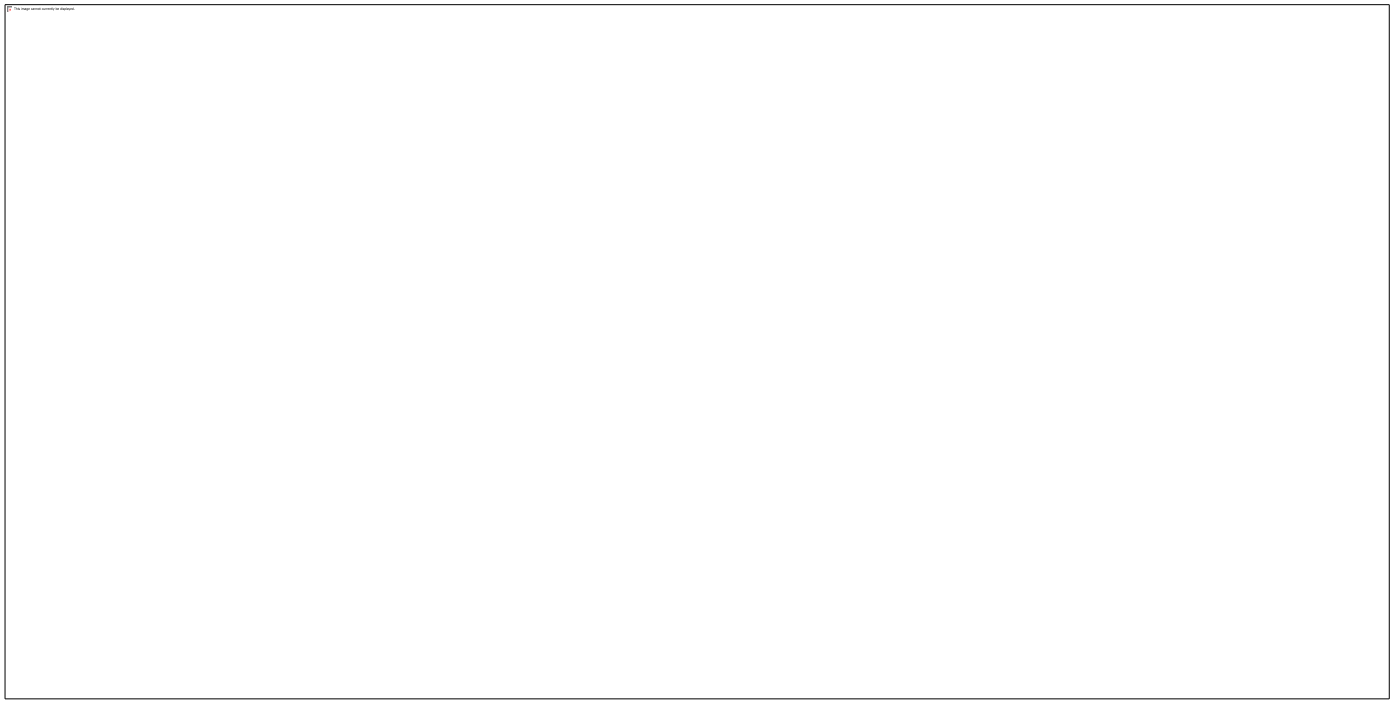
3.1.3 External fertilization in animals

Meaning of external fertilization

External fertilization is the process in which the male and female gametes fuse outside the body of the female animal to form a zygote.

It is common in aquatic animals, especially fish and amphibians.

During external fertilization, the female releases eggs into water while the male releases sperm over or near the eggs. The sperm swim through the water and fuse with the eggs.



A. External fertilization in fish

Most bony fish, such as tilapia, use external fertilization.

Process of fertilization in fish

1. **Egg production:** The female fish produces mature eggs in its ovaries.
2. **Spawning:** The female releases mature eggs into water, usually in a nest or suitable breeding area.
3. **Sperm release:** The male releases milt, which contains millions of sperm, over the eggs.
4. **Movement of sperm:** The sperm move through the surrounding water towards the eggs.
5. **Fusion of gametes:** A sperm penetrates an egg and the male and female nuclei fuse.
6. **Zygote formation:** A diploid zygote is formed.
7. **Embryonic development:** The zygote undergoes repeated mitotic cell divisions to form an embryo.
8. **Hatching:** The embryo develops inside the egg and eventually hatches into a young fish.

Adaptations that make external fertilization successful in fish

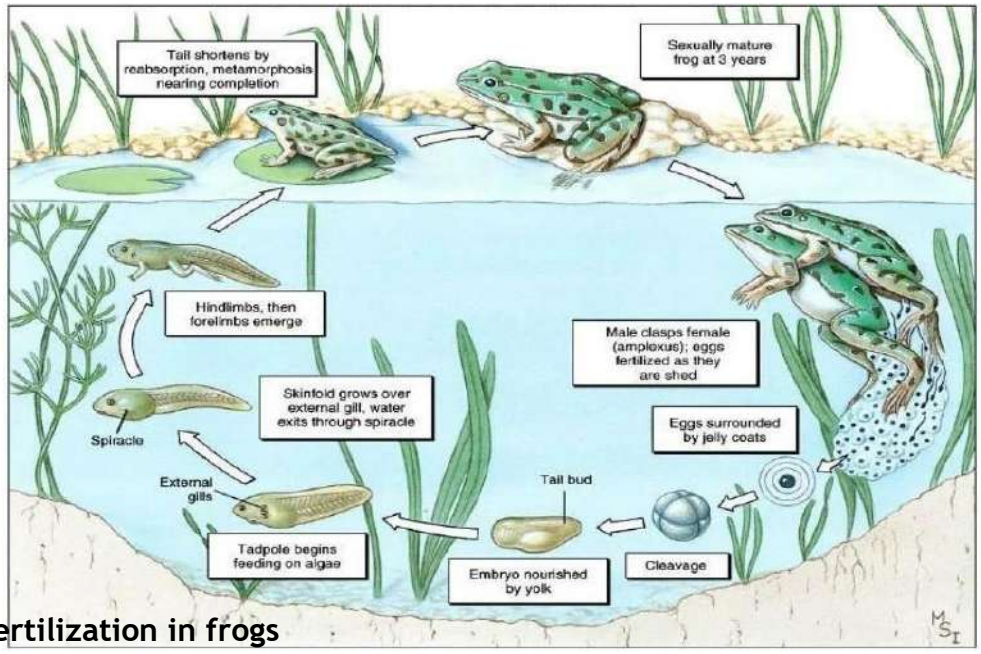
- Production of large numbers of eggs increases the chances of fertilization.
- Production of millions of sperm increases the probability of sperm reaching the eggs.
- Spawning takes place in water, which provides a medium for sperm movement.
- Eggs contain protective coverings that protect the developing embryo.
- Some fish select sheltered breeding grounds to reduce predation and disturbance.

Examples of fish that use external fertilization

- Tilapia.
- Carp.
- Many species of catfish.
- Salmon.
- Goldfish.

B. External fertilization in amphibians

Amphibians such as frogs and toads commonly reproduce through external fertilization.



Process of fertilization in frogs

1. **Breeding season:** Frogs usually reproduce during rainy seasons when water is readily available.
2. **Amplexus:** The male frog clasps the female from behind in a mating position known as amplexus.
3. **Egg release:** The female releases eggs into water through the cloaca.
4. **Sperm release:** As the eggs are released, the male releases sperm over them.
5. **Fertilization:** Sperm swim towards the eggs and one sperm fuses with the nucleus of each successfully fertilized egg.
6. **Zygote formation:** A zygote is formed.
7. **Embryonic development:** The zygote divides repeatedly and develops into an embryo.
8. **Hatching:** The embryo develops into a tadpole.
9. **Metamorphosis:** The tadpole develops hind limbs, forelimbs and lungs, while the tail gradually reduces.
10. **Adult formation:** The young frog develops into an adult frog capable of reproduction.

Adaptations for external fertilization in amphibians

- They reproduce in water or moist environments.

- They produce numerous eggs.
- Their eggs have jelly-like coverings that protect them from mechanical damage.
- The male releases sperm close to the eggs.
- Mating behaviour helps synchronise the release of eggs and sperm.

Advantages of external fertilization

1. Many offspring can be produced at the same time.
2. The process requires fewer specialised reproductive structures than internal fertilization.
3. Fertilization can occur rapidly when many gametes are released together.
4. It allows aquatic animals to reproduce without carrying embryos inside the female body.

Disadvantages of external fertilization

1. Many gametes are wasted because fertilization does not always occur.
2. Eggs and embryos are exposed to predators.
3. Fertilization depends on suitable environmental conditions, especially water.
4. Eggs may be washed away by strong water currents.
5. A large proportion of offspring may die before reaching adulthood.
6. It is less efficient where sperm and eggs are widely dispersed.

3.1.4 Internal fertilization in animals

Meaning of internal fertilization

Internal fertilization is the process in which the male and female gametes fuse inside the reproductive tract of the female to form a zygote.

It occurs in many terrestrial animals and some aquatic animals.

Examples include:

- Humans.
- Cattle.
- Goats.
- Sheep.
- Dogs.
- Cats.
- Chickens.
- Snakes.
- Lizards.
- Sharks.

Process of internal fertilization

1. **Mating:** The male and female animals engage in mating behaviour.

2. **Sperm transfer:** The male transfers sperm into the female reproductive tract, usually through a copulatory organ or other reproductive structures.
3. **Sperm movement:** The sperm swim through the female reproductive tract towards the site of fertilization.
4. **Ovulation:** In females that undergo ovulation, a mature egg is released from the ovary into the oviduct.
5. **Sperm penetration:** A sperm penetrates the egg's protective coverings.
6. **Fusion of nuclei:** The male and female nuclei fuse.
7. **Zygote formation:** A diploid zygote is formed.
8. **Development:** The zygote undergoes mitotic cell divisions and develops into an embryo.

Adaptations that facilitate internal fertilization

1. **Specialised reproductive organs:** Male animals possess structures that transfer sperm into the female reproductive tract.
2. **Production of motile sperm:** Sperm have tails that enable them to swim towards the egg.
3. **Protection of gametes:** Gametes are protected from direct exposure to harsh environmental conditions.
4. **Chemical recognition:** Chemical interactions help sperm recognise and interact with the egg.
5. **Suitable reproductive tract:** The female reproductive tract provides conditions that support sperm movement and fertilization.
6. **Hormonal regulation:** Reproductive hormones coordinate ovulation, sperm production and other reproductive processes.

Advantages of internal fertilization

- Increases the chances of successful fertilization because sperm are deposited close to the egg.
- Protects gametes from drying out.
- Reduces wastage of gametes.
- Allows reproduction in terrestrial environments.
- In animals with internal development, the embryo receives protection from the external environment.
- It may increase the survival rate of offspring.

Disadvantages of internal fertilization

- Requires specialised reproductive structures.
- Usually requires mating or a mechanism for sperm transfer.
- Requires more energy for reproductive activities.
- The number of offspring produced may be relatively small.
- Pregnancy and parental care may place considerable demands on the parents.

3.1.5 Types of animal development based on reproduction

Animals that reproduce sexually can be classified according to where embryos develop and how they obtain nourishment.

The three main categories are:

1. Oviparous animals.
2. Viviparous animals.
3. Ovoviviparous animals.

A. Oviparous animals

Meaning

Oviparous animals are animals that reproduce by laying eggs, with embryonic development taking place outside the mother's body.

The embryo develops inside the egg and obtains nourishment mainly from the yolk.

Characteristics of oviparous animals

1. They lay eggs.
2. Fertilization may be external or internal, depending on the animal.
3. Embryonic development takes place outside the mother's body.
4. The developing embryo obtains nutrients from the yolk.
5. Eggs have protective coverings that reduce mechanical damage and water loss.
6. Some species provide parental care by incubating or guarding their eggs.

Examples

- Birds: chicken, duck, ostrich and eagle.
- Reptiles: crocodiles, turtles and many snakes.
- Amphibians: frogs and toads.
- Fish: tilapia and salmon.
- Insects: butterflies and grasshoppers.

Development in a chicken egg

A typical chicken egg contains the following structures:

1. **Shell:** A hard, porous outer covering that protects the developing embryo and allows gaseous exchange.
2. **Shell membranes:** Two thin membranes beneath the shell that provide additional protection.
3. **Air space:** A space at the broad end of the egg that provides an air supply to the developing chick, especially before hatching.

4. **Albumen:** The egg white, which provides water and proteins and cushions the embryo.
5. **Yolk:** The main food reserve containing fats, proteins, vitamins and minerals.
6. **Germinal disc:** A small region on the yolk where embryonic development begins after fertilization.
7. **Chalaza:** Twisted cords of albumen that help keep the yolk suspended in position.

Advantages of oviparity

- The mother does not have to carry developing embryos throughout pregnancy.
- Several eggs may be produced at once.
- Eggs contain stored food for embryonic development.
- Some eggs have protective coverings that reduce environmental damage.

Disadvantages of oviparity

- Eggs may be eaten by predators.
- Eggs may be destroyed by environmental conditions.
- Embryos may die if eggs are not kept under suitable conditions.
- Some animals must invest considerable energy in incubating and protecting eggs.

B. Viviparous animals

Meaning

Viviparous animals are animals in which the embryo develops inside the mother's reproductive system, and the female gives birth to living young ones.

In most mammals, the developing embryo receives nutrients and oxygen from the mother through the placenta.



Characteristics of viviparous animals

1. Fertilization is internal.
2. The embryo develops inside the mother's reproductive tract, usually the uterus.
3. The developing embryo receives nourishment from the mother, commonly through a placenta in placental mammals.

4. The mother provides protection to the developing embryo.
5. The young ones are born alive.
6. Pregnancy occurs before birth.
7. The mother may provide parental care and lactation after birth.

Examples

- Humans.
- Cattle.
- Goats.
- Sheep.
- Dogs.
- Cats.
- Elephants.
- Horses.

Advantages of viviparity

- The developing embryo is protected inside the mother's body.
- The embryo receives a continuous supply of nutrients in placental mammals.
- The embryo is protected from many external environmental changes.
- The chances of survival may be higher than in animals that lay unprotected eggs.

Disadvantages of viviparity

- Pregnancy requires considerable energy from the mother.
- The mother may experience physical strain during pregnancy and birth.
- Usually fewer offspring are produced at a time.
- The mother's movement may be restricted during advanced pregnancy.
- Complications during pregnancy and birth may threaten the life of the mother or offspring.

C. Ovoviviparous animals

Meaning

Ovoviviparous animals are animals in which fertilized eggs remain inside the mother's body until they hatch. The embryos obtain most of their nourishment from the yolk stored in the eggs rather than directly from the mother through a placenta.

The young ones are released or born alive after hatching inside the mother's reproductive tract.



Characteristics

1. Fertilization is internal.
2. Fertilized eggs are retained inside the mother's reproductive tract.
3. The embryo develops inside an egg with a yolk supply.
4. The embryo receives most of its nutrients from the egg yolk.
5. The eggs hatch inside the mother's body or reproductive tract.
6. The mother releases living young ones.

Examples

- Some sharks.
- Some rays.
- Some snakes, such as certain boas.
- Some lizards.

Advantages

- The eggs are protected from many external predators.
- The developing embryos experience relatively stable environmental conditions.
- The young ones are released after substantial development.

Disadvantages

- The mother carries developing eggs, which requires energy.
- The number of offspring may be limited by the space available inside the reproductive tract.
- The mother may be exposed to increased physical demands during development.

Comparison of oviparous, viviparous and ovoviviparous animals

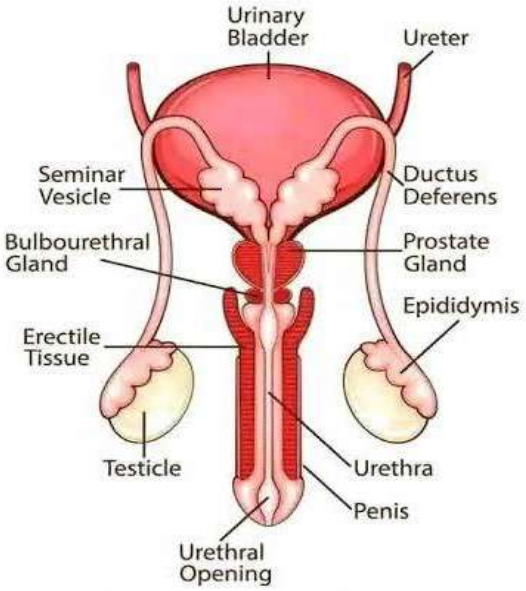
Feature	Oviparous	Viviparous	Ovoviviparous
Egg laying	Yes	No	Usually no
Fertilization	External or internal	Internal	Internal

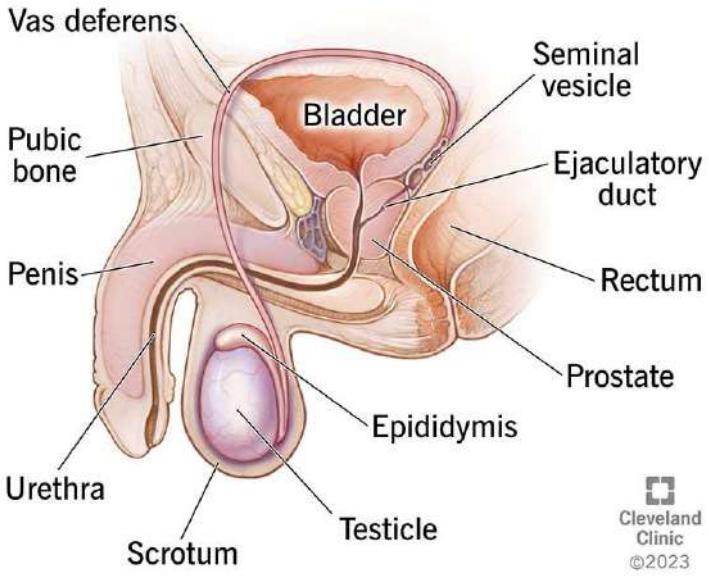
Embryo development	Outside mother	Inside mother	Inside retained egg
Main food source	Egg yolk	Maternal supply	Egg yolk
Birth	Hatching from laid egg	Live birth	Live young after internal hatching
Example	Chicken	Human	Some sharks

Important distinction: Ovoviviparity is different from true viviparity. In ovoviviparity, the embryo depends mainly on yolk stored in the egg. In placental viviparity, the embryo receives nutrients from the mother through specialised maternal and embryonic tissues.

3.1.6 Structure of the human male reproductive system

The male reproductive system consists of organs responsible for producing sperm, secreting male sex hormones and transferring sperm into the female reproductive tract.





Main parts and their functions

1. Testes

The testes are a pair of oval-shaped reproductive organs located in the scrotum.

Functions:

- Produce sperm cells through spermatogenesis.
- Secrete testosterone, the main male sex hormone.
- Contain seminiferous tubules where sperm are produced.
- Contain interstitial (Leydig) cells that produce testosterone.

2. Scrotum

The scrotum is a sac of skin and muscle that holds the testes outside the abdominal cavity.

Functions:

- Holds and protects the testes.
- Regulates the temperature of the testes.
- Maintains a temperature approximately 2–3°C below normal body temperature, which is favourable for sperm production.

3. Epididymis

The epididymis is a long, highly coiled tube attached to the posterior surface of each testis.

Functions:

- Stores sperm temporarily.
- Provides an environment for sperm maturation.
- Allows sperm to acquire the ability to swim and fertilize an egg.

4. Sperm duct (vas deferens)

The vas deferens is a muscular tube that carries sperm from the epididymis towards the ejaculatory duct.

Functions:

- Transports mature sperm.
- Moves sperm through muscular contractions during ejaculation.
- Provides a passage for sperm towards the urethra.

5. Seminal vesicles

These are paired glands located behind the urinary bladder.

Functions:

- Secrete a fluid rich in fructose.
- Provide energy for sperm movement.
- Contribute a large proportion of the fluid in semen.
- Produce substances that support sperm survival and movement.

6. Prostate gland

The prostate gland is located below the urinary bladder and surrounds part of the urethra.

Functions:

- Produces a milky fluid that forms part of semen.
- Provides substances that support sperm function.
- Helps create a suitable chemical environment for sperm.

7. Bulbourethral glands (Cowper's glands)

These are two small glands located below the prostate gland.

Functions:

- Secrete a clear mucus-like fluid before ejaculation.
- Lubricate the urethra.
- Help neutralise traces of acidity in the urethra.

8. Urethra

The urethra is a tube that passes through the penis.

Functions:

- Carries semen out of the male reproductive system during ejaculation.
- Carries urine from the urinary bladder during urination.
- A sphincter mechanism helps prevent urine and semen from passing at the same time.

9. Penis

The penis is the male copulatory organ.

Functions:

- Deposits semen into the female reproductive tract during sexual intercourse.
- Contains erectile tissues that become filled with blood during erection.
- Contains the urethra through which semen is released.

3.1.7 Semen and sperm

Meaning of semen

Semen is a whitish fluid containing sperm cells and secretions from the male reproductive glands.

It consists of sperm mixed with fluids from the seminal vesicles, prostate gland and bulbourethral glands.

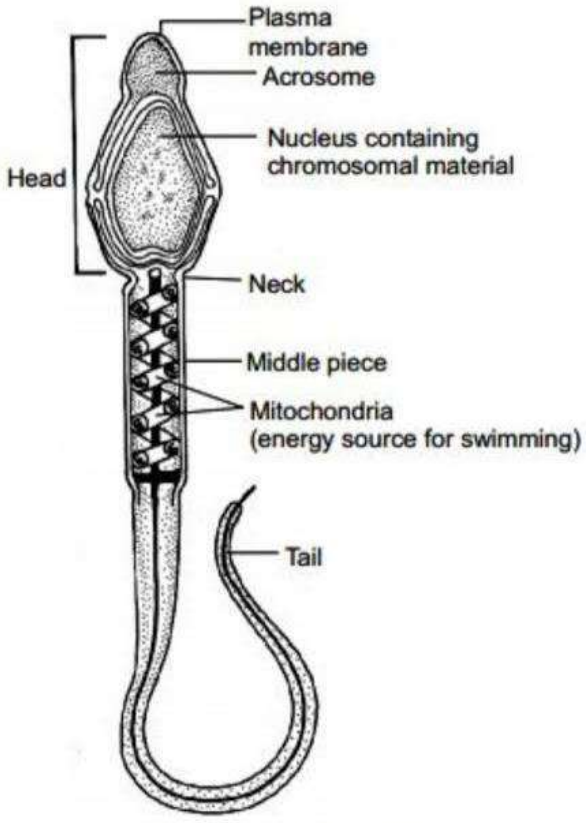
Functions of semen

1. Transports sperm cells.
2. Provides nutrients that support sperm movement.
3. Helps maintain a suitable chemical environment for sperm survival.
4. Lubricates the reproductive passage.
5. Helps sperm move through the female reproductive tract.

Structure of a human sperm cell

A sperm cell is a microscopic male gamete adapted for swimming towards and fertilizing the ovum.

It has four main regions.



1. Head

- Contains the haploid nucleus.
- The nucleus carries 23 chromosomes in humans.
- Contains the acrosome, a cap-like structure at the front of the head.
- The acrosome contains enzymes that help the sperm penetrate the protective coverings of the ovum.

2. Neck

- Connects the head to the middle piece.
- Contains structures associated with the sperm's movement apparatus.
- Provides structural support between the head and middle piece.

3. Middle piece

- Contains numerous mitochondria arranged around the central filament.
- Mitochondria release energy in the form of ATP.
- ATP provides energy needed for movement of the sperm tail.

4. Tail (flagellum)

- A long whip-like structure.
- Produces wave-like movements.
- Propels the sperm through fluid towards the ovum.

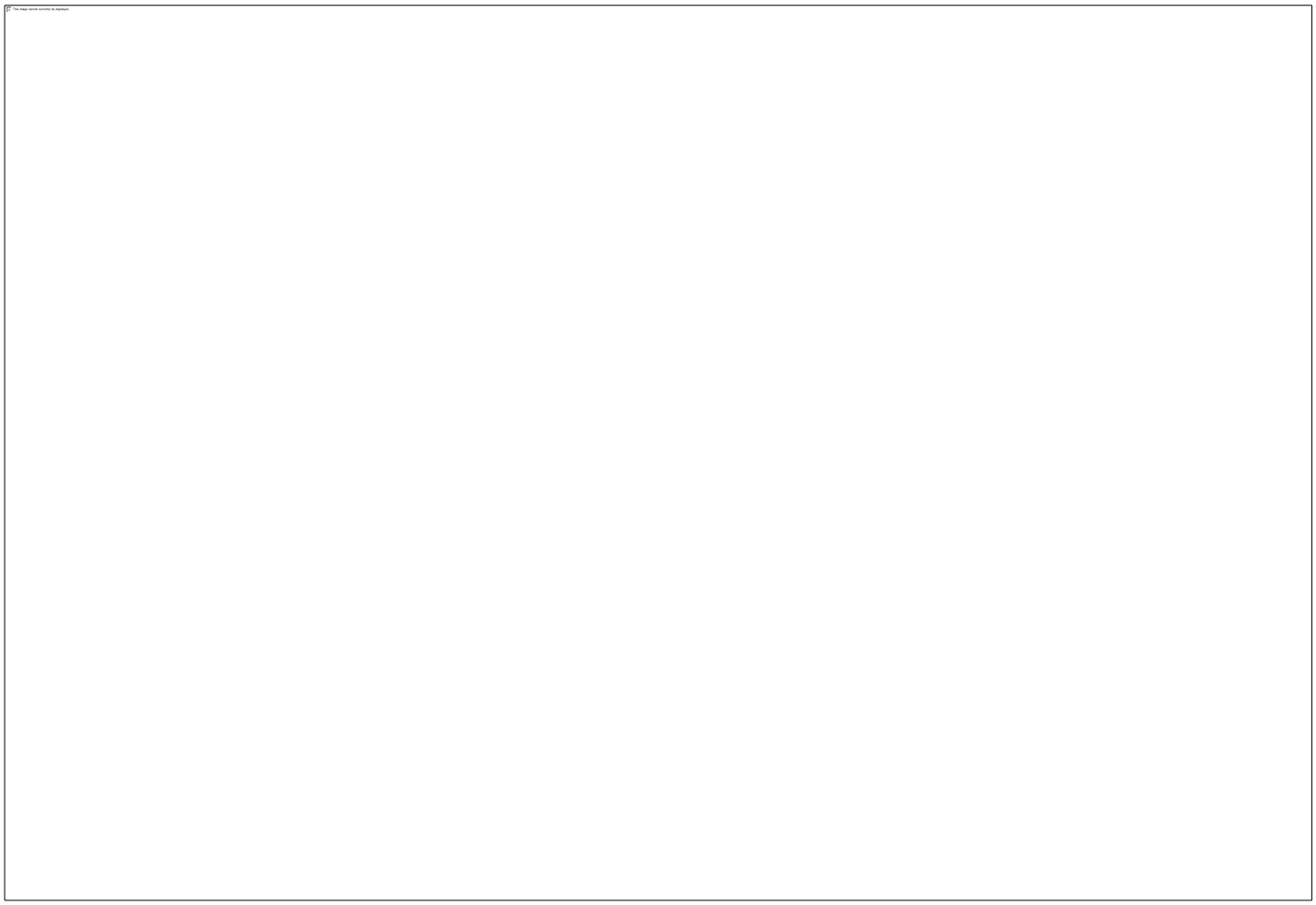
Adaptations of sperm to its functions

1. **Streamlined shape:** Reduces resistance as the sperm moves through fluid.
2. **Flagellum:** Enables movement towards the ovum.
3. **Numerous mitochondria:** Supply ATP for movement.
4. **Acrosome:** Contains enzymes that assist penetration of the egg coverings.
5. **Haploid nucleus:** Contains half the normal human chromosome number, allowing restoration of the diploid number during fertilization.
6. **Small amount of cytoplasm:** Reduces unnecessary bulk and makes the sperm more streamlined.
7. **Specialised membrane receptors:** Help the sperm interact with the egg coverings.

3.1.8 Structure of the human female reproductive system

The female reproductive system consists of organs responsible for producing ova, receiving sperm, providing a site for fertilization, supporting embryonic development, giving birth and producing milk after birth.

Main parts and their functions



1. Ovaries

The ovaries are a pair of small, oval-shaped reproductive organs located on either side of the uterus in the pelvic cavity.

Functions:

- Produce female gametes (ova or egg cells).
- Produce the female sex hormones oestrogen and progesterone.

- Contain ovarian follicles in which ova develop.
- Release mature ova during ovulation.
- Form the corpus luteum after ovulation, which secretes progesterone and some oestrogen.

2. Fallopian tubes (oviducts)

These are narrow muscular tubes that extend from the region of each ovary towards the uterus.

Functions:

- Receive the ovum released during ovulation.
- Provide the usual site of fertilization, particularly the ampulla.
- Transport the ovum or early embryo towards the uterus.
- Provide a suitable environment for fertilization and early embryonic development.

3. Fimbriae

Fimbriae are finger-like projections found at the open end of each fallopian tube near the ovary.

Functions:

- Help guide the released ovum into the fallopian tube.
- Create movements that assist the collection of the ovum.
- Reduce the likelihood of the ovum being lost into the pelvic cavity.

4. Uterus

The uterus is a hollow, muscular, pear-shaped organ located in the pelvic cavity.

Functions:

- Receives the blastocyst during implantation.
- Provides a suitable environment for embryonic and foetal development.
- Protects and supports the developing embryo and foetus.
- Contracts during childbirth to expel the baby.
- Its lining is involved in menstruation when pregnancy does not occur.

Layers of the uterus

The uterine wall has three major layers:

1. **Perimetrium:** The outer protective covering of the uterus.
2. **Myometrium:** The thick middle muscular layer responsible for contractions during menstruation and childbirth.
3. **Endometrium:** The inner lining of the uterus. It thickens during the menstrual cycle and provides the site for implantation.

5. Cervix

The cervix is the narrow lower part of the uterus that opens into the vagina.

Functions:

- Connects the uterus to the vagina.
- Produces cervical mucus that changes during the menstrual cycle.
- Helps protect the uterus against infection.
- Remains relatively closed during pregnancy.
- Dilates during childbirth to allow the baby to pass through.

6. Vagina

The vagina is an elastic muscular canal extending from the cervix to the external genital opening.

Functions:

- Receives the penis during sexual intercourse.
- Receives semen deposited during intercourse.
- Provides a passage for menstrual flow.
- Acts as the birth canal during normal vaginal delivery.

7. Vulva

The vulva refers to the external female genital structures.

It includes:

- Labia majora.
- Labia minora.
- Clitoris.
- Vestibule.
- Openings of the vagina and urethra.

Functions:

- Protects the openings of the reproductive and urinary systems.
- Provides sensory structures involved in sexual response.
- Helps protect the entrance to the vagina.

Adaptations of the female reproductive system

1. The ovaries produce ova and reproductive hormones.
2. The fallopian tubes have cilia and muscular walls that assist in transporting the ovum and early embryo.
3. The uterus has a thick muscular wall that expands during pregnancy.
4. The endometrium has a rich blood supply to support implantation and pregnancy.
5. The cervix produces mucus that changes in consistency during the menstrual cycle.
6. The vagina is elastic and muscular, allowing it to expand during childbirth.

3.1.9 Structure of the human ovum

Meaning of an ovum

An ovum is the female reproductive cell or gamete produced by the ovaries.

It is a large, spherical cell containing a haploid nucleus and nutrient-rich cytoplasm.

In humans, the mature female gamete released during ovulation is technically a secondary oocyte, which completes meiosis II following fertilization.

Main structures of the ovum

1. Corona radiata

- Consists of layers of follicular cells surrounding the ovum.
- Protects the ovum.
- Provides support and nourishment.

2. Zona pellucida

- A thick, transparent glycoprotein layer surrounding the egg cell.
- Protects the ovum.
- Contains receptors involved in sperm recognition and binding.
- Participates in mechanisms that prevent entry of additional sperm after fertilization.

3. Cell membrane (oolemma)

- Forms the outer boundary of the egg cell.
- Regulates movement of substances into and out of the cell.
- Participates in the fusion of the sperm and egg membranes.

4. Cytoplasm (ooplasm)

- Contains nutrients and cellular organelles.
- Provides materials needed for early embryonic development.
- Contains substances involved in controlling early cell division.

5. Nucleus

- Contains the haploid maternal genetic material.
- Has 23 chromosomes in humans.
- Fuses with the male genetic material during fertilization.

6. Cortical granules

- Located beneath the plasma membrane.
- Release their contents following sperm entry.
- Help modify the zona pellucida to prevent polyspermy (entry of more than one sperm).

Adaptations of the ovum to its functions

1. **Large size:** Provides sufficient cytoplasm for early embryonic development.
2. **Nutrient-rich cytoplasm:** Supplies materials required during early cell divisions.
3. **Haploid nucleus:** Contains 23 chromosomes, allowing restoration of the diploid chromosome number after fertilization.

4. **Protective coverings:** The zona pellucida and corona radiata protect the ovum.
5. **Specialised membrane receptors:** Enable recognition and interaction with sperm.
6. **Cortical granules:** Help prevent fertilization by additional sperm.

Differences between sperm and ovum

Feature	Sperm	Ovum
Gamete type	Male	Female
Size	Very small	Large
Shape	Elongated	Spherical
Movement	Motile	Does not actively swim
Cytoplasm	Very little	Abundant
Food reserves	Very limited	Contains materials for early development
Chromosomes	23	23
Production	Testes	Ovaries
Special structure	Flagellum	Protective egg coverings
Main function	Delivers paternal genetic material	Provides maternal genetic material and cytoplasm

3.1.10 Gametogenesis in humans

Gametogenesis is the process through which mature male and female gametes are produced.

There are two types:

1. Spermatogenesis.
2. Oogenesis.

A. Spermatogenesis

Spermatogenesis is the process of formation of mature sperm cells from diploid germ cells in the seminiferous tubules of the testes.

Stages of spermatogenesis

1. **Multiplication phase:** Spermatogonia divide repeatedly by mitosis to maintain the population of germ cells.
2. **Growth phase:** Some spermatogonia grow and develop into primary spermatocytes.
3. **First meiotic division:** Each primary spermatocyte undergoes meiosis I to produce two haploid secondary spermatocytes.
4. **Second meiotic division:** Each secondary spermatocyte undergoes meiosis II to produce two spermatids.
5. **Spermiogenesis:** The spermatids undergo structural changes to become spermatozoa (mature sperm cells).
6. **Sperm release:** Mature sperm cells are released into the lumen of the seminiferous tubules and subsequently transported to the epididymis for maturation.

Products of spermatogenesis

One primary spermatocyte normally produces four haploid spermatids, which develop into four sperm cells.

Importance of spermatogenesis

- Ensures continuous production of male gametes.

- Maintains the haploid chromosome number in sperm.
- Allows transmission of paternal genetic information.
- Supports successful sexual reproduction.

B. Oogenesis

Oogenesis is the process of formation and development of female gametes in the ovaries.

Stages of oogenesis

1. **Multiplication phase:** During foetal development, oogonia multiply through mitosis in the developing ovaries.
2. **Growth phase:** Oogonia develop into primary oocytes, which begin meiosis I and remain arrested in prophase I.
3. **Maturation phase:** From puberty, during reproductive cycles, selected primary oocytes may complete meiosis I to form a large secondary oocyte and a smaller first polar body.
4. **Ovulation:** The secondary oocyte is released from the ovary. It is arrested in metaphase II.
5. **Completion of meiosis II:** If fertilization occurs, the secondary oocyte completes meiosis II, producing the mature ovum and a second polar body.

Products of oogenesis

Oogenesis normally produces one functional large female gamete and small polar bodies, which usually degenerate.

Importance of oogenesis

- Produces female gametes.
- Ensures transmission of maternal genetic information.
- Provides cytoplasm and cellular materials for early embryonic development.
- Contributes to genetic variation through meiosis.

Differences between spermatogenesis and oogenesis

Spermatogenesis	Oogenesis
Occurs in testes.	Occurs in ovaries.
Begins at puberty.	Begins before birth.
Produces four functional sperm cells per primary spermatocyte.	Produces one functional gamete per primary oocyte.
Cytoplasm divides approximately equally.	Cytoplasm divides unequally.
Usually continuous after puberty.	Occurs in cycles during reproductive years.
Produces small motile gametes.	Produces large non-motile gametes.

3.1.11 The human menstrual cycle

Meaning of the menstrual cycle

The menstrual cycle is a series of coordinated physiological and hormonal changes that occur in the female reproductive system, particularly the ovaries and uterus, in preparation for possible pregnancy.

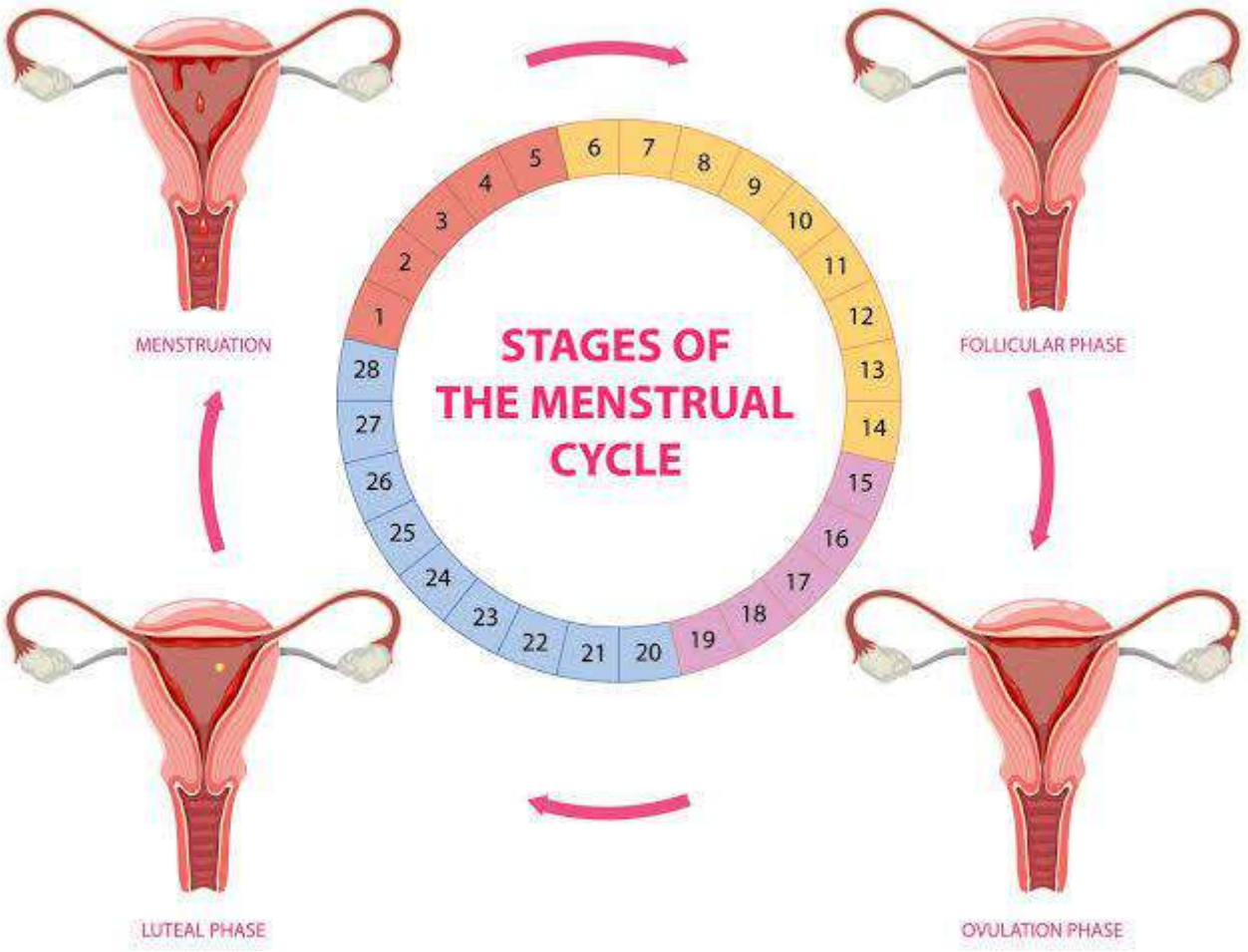
The cycle involves:

- Development and maturation of an ovarian follicle.
- Release of an ovum through ovulation.

- Changes in the uterine lining.
- Changes in reproductive hormone levels.

The average menstrual cycle lasts approximately 28 days, although normal cycles vary considerably among individuals.

Phases of the menstrual cycle



The menstrual cycle can be divided into four main phases.

1. Menstrual phase (approximately days 1–5)

This is the phase during which the functional layer of the endometrium is shed and expelled through the vagina.

Events during menstruation

1. The corpus luteum from the previous cycle degenerates if pregnancy has not occurred.
2. Progesterone and oestrogen levels decrease.
3. The blood supply to the functional layer of the endometrium is reduced.
4. The functional layer breaks down.
5. Blood, mucus and endometrial tissue are discharged through the vagina.

Hormonal changes

- Oestrogen levels are relatively low.
- Progesterone levels are low.
- FSH begins to rise, stimulating the development of ovarian follicles.

Importance of menstruation

- Removes the functional uterine lining when pregnancy has not occurred.
- Allows development of a new endometrial lining for a subsequent cycle.

2. Follicular or proliferative phase (approximately days 1–13)

This phase involves the development of ovarian follicles and rebuilding of the uterine lining.

Events in the ovary

1. FSH stimulates the development of ovarian follicles.
2. One follicle usually becomes dominant.
3. The developing follicle contains a growing oocyte.
4. The follicular cells secrete increasing amounts of oestrogen.

Events in the uterus

1. Oestrogen stimulates repair of the endometrium.
2. The endometrium becomes thicker.
3. Blood vessels develop in the uterine lining.
4. Uterine glands begin to develop.

Importance

The follicular phase prepares an ovum for possible fertilization and restores the uterine lining in preparation for implantation.

3. Ovulation (approximately day 14 in a 28-day cycle)

Ovulation is the process through which a mature secondary oocyte is released from a mature ovarian follicle.

Events during ovulation

1. Oestrogen levels rise significantly as the dominant follicle matures.
2. High oestrogen levels trigger a surge in luteinising hormone (LH).
3. The LH surge causes the mature follicle to rupture.
4. The secondary oocyte is released from the ovary.
5. Fimbriae help guide the oocyte into the fallopian tube.

Importance of ovulation

- Releases the female gamete for possible fertilization.
- Marks the transition from the follicular phase to the luteal phase.

- Provides an opportunity for conception.

4. Luteal or secretory phase (approximately days 15–28)

After ovulation, the ruptured follicle develops into the corpus luteum.

Events in the ovary

1. LH stimulates the development and maintenance of the corpus luteum.
2. The corpus luteum secretes progesterone and some oestrogen.
3. These hormones help maintain the uterine lining.

Events in the uterus

1. The endometrium becomes thicker and more vascular.
2. Uterine glands become more active.
3. The lining becomes suitable for implantation.
4. If fertilization and implantation do not occur, the corpus luteum degenerates.
5. Progesterone and oestrogen levels fall, leading to the next menstruation.

If pregnancy occurs

- The early embryo produces human chorionic gonadotropin (hCG).
- hCG maintains the corpus luteum during early pregnancy.
- Progesterone secretion continues to support the uterine lining.

Summary of the menstrual cycle

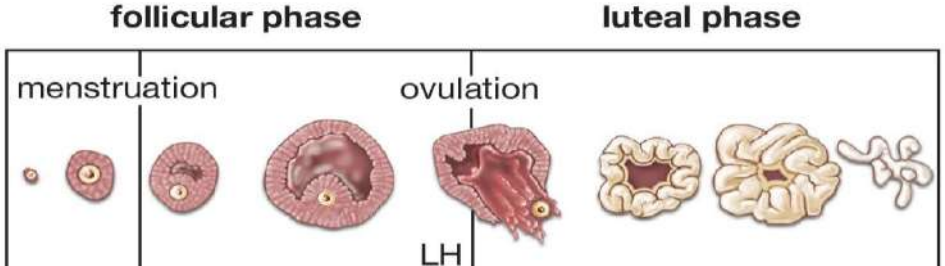
Phase	Approximate days	Main events
Menstrual	1–5	Shedding of uterine lining
Follicular/proliferative	1–13	Follicle development and endometrial repair
Ovulation	Around 14	Release of secondary oocyte
Luteal/secretory	15–28	Corpus luteum formation and maintenance of endometrium

Note: These are approximate timings for a 28-day cycle. Ovulation does not always occur on day 14, and cycle length varies.

3.1.12 Hormonal regulation of human reproduction

Hormones are chemical messengers produced by endocrine glands and specialised tissues. They are transported through the bloodstream to target organs where they regulate physiological activities.

Human reproduction is controlled by hormones produced by the hypothalamus, pituitary gland, testes, ovaries and placenta.



A. Hormones involved in male reproduction

1. Gonadotropin-releasing hormone (GnRH)

Source: Hypothalamus.

Functions:

- Stimulates the anterior pituitary gland to release FSH and LH.
- Regulates reproductive activity in males.
- Controls the hormonal signals responsible for sperm production and testosterone secretion.

2. Follicle-stimulating hormone (FSH)

Source: Anterior pituitary gland.

Functions:

- Acts on Sertoli cells in the seminiferous tubules.
- Stimulates and supports spermatogenesis.
- Promotes the production of substances that support developing sperm cells.
- Works together with testosterone in regulating sperm production.

3. Luteinising hormone (LH)

Source: Anterior pituitary gland.

Functions:

- Stimulates Leydig cells in the testes.
- Promotes the secretion of testosterone.
- Supports the development and maintenance of male reproductive functions.

In males, LH is also commonly referred to as interstitial cell-stimulating hormone (ICSH).

4. Testosterone

Source: Leydig cells of the testes.

Functions:

1. Promotes development of male reproductive organs.
2. Stimulates development of male secondary sexual characteristics.
3. Supports spermatogenesis.
4. Promotes development of facial, pubic and body hair.
5. Deepens the voice during puberty.
6. Promotes growth of muscles and bones.
7. Supports sexual drive (libido).
8. Helps maintain the functioning of male reproductive organs.

5. Inhibin

Source: Sertoli cells of the testes.

Functions:

- Inhibits FSH secretion from the anterior pituitary gland.
- Helps regulate the rate of sperm production.
- Participates in negative feedback control of spermatogenesis.

B. Hormones involved in female reproduction

1. Gonadotropin-releasing hormone (GnRH)

Source: Hypothalamus.

Functions:

- Stimulates the anterior pituitary gland to release FSH and LH.
- Regulates the menstrual cycle.
- Controls hormonal activities involved in ovulation.

2. Follicle-stimulating hormone (FSH)

Source: Anterior pituitary gland.

Functions:

- Stimulates growth and development of ovarian follicles.
- Promotes maturation of the oocyte within the follicle.
- Stimulates the production of oestrogen by developing follicles.

3. Luteinising hormone (LH)

Source: Anterior pituitary gland.

Functions:

- Triggers ovulation.

- Stimulates formation of the corpus luteum.
- Promotes secretion of progesterone by the corpus luteum.

4. Oestrogen

Source: Mainly developing ovarian follicles; also produced by the corpus luteum and placenta during pregnancy.

Functions:

1. Promotes development of female reproductive organs.
2. Stimulates development of female secondary sexual characteristics.
3. Promotes growth and repair of the endometrium.
4. Contributes to breast development.
5. Helps regulate the menstrual cycle.
6. At high levels before ovulation, stimulates the LH surge through positive feedback.

5. Progesterone

Source: Corpus luteum and placenta during pregnancy.

Functions:

- Maintains the endometrium for implantation and pregnancy.
- Stimulates development of uterine glands.
- Reduces excessive uterine contractions during pregnancy.
- Promotes development of breast tissue in preparation for lactation.
- Helps regulate the menstrual cycle.

6. Inhibin

Source: Granulosa cells of the ovaries and corpus luteum.

Functions:

- Inhibits FSH secretion.
- Helps regulate ovarian follicle development.
- Participates in hormonal feedback mechanisms.

C. Hormones involved in pregnancy, childbirth and lactation

1. Human chorionic gonadotropin (hCG)

Source: Developing trophoblast, particularly the syncytiotrophoblast of the implanted embryo.

Functions:

- Maintains the corpus luteum during early pregnancy.
- Stimulates continued progesterone secretion by the corpus luteum.
- Helps maintain the uterine lining.
- Forms the basis of most pregnancy tests.

2. Relaxin

Source: Corpus luteum and placenta.

Functions:

- Helps soften and remodel the cervix.
- Promotes relaxation of pelvic ligaments.
- Contributes to preparation of the birth canal for childbirth.

3. Human placental lactogen (hPL)

Source: Placenta.

Functions:

- Alters maternal metabolism to make more nutrients available to the developing foetus.
- Promotes changes in maternal insulin sensitivity.
- Supports breast development in preparation for lactation.

4. Prolactin

Source: Anterior pituitary gland.

Functions:

- Stimulates milk production in the mammary glands after childbirth.
- Supports continued milk synthesis during breastfeeding.

5. Oxytocin

Source: Produced by the hypothalamus and released by the posterior pituitary gland.

Functions:

- Stimulates powerful uterine contractions during childbirth.
- Causes milk ejection from the mammary glands during breastfeeding.
- Helps strengthen the bond between a mother and her baby.

Summary of reproductive hormones

Hormone	Main source	Main function
GnRH	Hypothalamus	Stimulates release of FSH and LH
FSH	Anterior pituitary	Supports follicle development and sperm production
LH	Anterior pituitary	Triggers ovulation; stimulates testosterone production
Testosterone	Testes	Male reproductive development and sperm production
Oestrogen	Ovaries, placenta	Female characteristics and endometrial growth
Progesterone	Corpus luteum, placenta	Maintains pregnancy and endometrium
Inhibin	Testes and ovaries	Inhibits FSH secretion
hCG	Developing placenta	Maintains corpus luteum in early pregnancy
Relaxin	Corpus luteum and placenta	Helps prepare cervix and pelvic structures

hPL	Placenta	Adjusts maternal metabolism during pregnancy
Prolactin	Anterior pituitary	Stimulates milk production
Oxytocin	Hypothalamus; released by posterior pituitary	Uterine contractions and milk ejection

3.1.13 Effects of undersecretion and oversecretion of reproductive hormones

Hormonal imbalance occurs when the body produces too little or too much of a hormone, or when target organs fail to respond appropriately to it.

Hormonal imbalances can affect puberty, gamete production, fertility, pregnancy, childbirth and lactation.

A. Effects of undersecretion

Undersecretion refers to the production or release of a hormone in amounts below the normal physiological level.

Hormone	Possible effects of undersecretion
GnRH	Delayed or absent puberty, reduced FSH and LH, impaired fertility
FSH in males	Reduced sperm production and possible infertility
FSH in females	Poor follicular development, irregular menstruation and infertility
LH in males	Reduced testosterone production and impaired sperm production
LH in females	Failure of ovulation and menstrual irregularities
Testosterone	Delayed puberty, reduced libido, reduced muscle mass and impaired sperm production
Oestrogen	Delayed puberty, irregular or absent menstruation, reduced bone density and vaginal dryness
Progesterone	Inadequate support of the endometrium and possible difficulty maintaining early pregnancy
Prolactin	Inadequate milk production after childbirth
Oxytocin	Poor milk ejection and potentially inadequate uterine contractions during labour
hCG	May be associated with poor early pregnancy development, although low hCG alone does not establish the cause
Inhibin	Increased FSH due to reduced negative feedback, depending on the underlying condition

B. Effects of oversecretion

Oversecretion refers to the production or release of a hormone in amounts above the normal physiological level.

Hormone	Possible effects of oversecretion
GnRH	Abnormally early activation of reproductive hormone secretion in certain conditions
FSH	Abnormal stimulation of ovarian follicles; can contribute to reproductive disturbances
LH	Increased stimulation of testosterone production or ovarian steroid production, depending on the condition
Testosterone	Acne, excessive androgen effects, reduced testicular size and suppression of sperm production when levels are abnormally high
Oestrogen	Abnormal uterine bleeding, breast tenderness and excessive endometrial stimulation
Progesterone	Menstrual changes, breast tenderness and other hormone-related symptoms
Prolactin	Suppression of GnRH, infertility, menstrual disturbances and sometimes milk production outside pregnancy or breastfeeding

Oxytocin	Excessive uterine contractions when given inappropriately during labour
hCG	Very high levels may occur in certain abnormal pregnancies or hCG-producing tumours
Inhibin	Suppression of FSH, which may interfere with normal gamete development

C. Causes of reproductive hormonal imbalance

1. **Pituitary gland disorders:** Diseases affecting the pituitary gland may interfere with the production of FSH and LH.
2. **Hypothalamic disorders:** Damage or dysfunction of the hypothalamus may alter GnRH secretion.
3. **Ovarian disorders:** Conditions affecting the ovaries may interfere with oestrogen and progesterone production.
4. **Testicular disorders:** Damage to the testes may reduce testosterone production and sperm formation.
5. **Polycystic ovary syndrome (PCOS):** A hormonal and metabolic disorder that can cause irregular ovulation and increased androgen levels.
6. **Premature ovarian insufficiency:** Reduced ovarian function before the age of 40 may lead to low oestrogen levels.
7. **Tumours:** Some pituitary, ovarian or testicular tumours may cause abnormal hormone production.
8. **Severe nutritional deficiencies:** Poor nutrition and very low energy availability may interfere with reproductive hormone regulation.
9. **Certain medications:** Some medicines can affect reproductive hormone levels.

D. General effects of reproductive hormonal imbalance

- Infertility.
- Delayed or early puberty.
- Irregular menstrual cycles.
- Absent menstruation.
- Reduced sperm production.
- Reduced sexual desire.
- Erectile difficulties.
- Abnormal breast development.
- Reduced bone density.
- Difficulty maintaining pregnancy.
- Abnormal milk production.

Note: The effects depend on the particular hormone, the amount produced, the duration of the imbalance and the age and reproductive stage of the individual.

3.1.14 Fertilization in humans

Meaning of fertilization

Fertilization is the process through which a male gamete (sperm) fuses with a female gamete (secondary oocyte) to form a diploid zygote.

In humans, fertilization normally takes place in the ampulla, which is the wider region of the fallopian tube.

Conditions necessary for successful fertilization

1. Production of viable sperm cells.
2. Release of a secondary oocyte during ovulation.
3. Successful deposition of semen in the female reproductive tract.
4. Movement of sperm through the cervix and uterus into the fallopian tube.
5. Survival of the sperm and oocyte until they meet.
6. Successful interaction between sperm and the protective coverings of the oocyte.

Stages of human fertilization

Stage 1: Movement of sperm towards the ovum

- During sexual intercourse, semen is deposited in the vagina.
- Sperm move through the cervix and uterus.
- They enter the fallopian tube.
- Only a small proportion of the sperm deposited reach the region where fertilization normally occurs.

Stage 2: Capacitation

Capacitation is a series of biochemical and structural changes that sperm undergo within the female reproductive tract.

- It prepares sperm for fertilization.
- It changes the sperm membrane.
- It enables the sperm to undergo the acrosome reaction.

Stage 3: Penetration of the corona radiata

- The sperm encounter the outer layer of follicular cells surrounding the secondary oocyte.
- Enzymatic activity and sperm movement help the sperm pass through this layer.

Stage 4: Penetration of the zona pellucida

- The sperm binds to proteins in the zona pellucida.
- The acrosome reaction releases enzymes and exposes proteins that assist penetration.
- A sperm passes through the zona pellucida.

Stage 5: Fusion of sperm and egg membranes

- The sperm membrane fuses with the oocyte plasma membrane.
- The sperm nucleus and other components enter the oocyte.

Stage 6: Prevention of polyspermy

Polyspermy is the entry of more than one sperm into an egg.

- Following sperm entry, cortical granules release their contents.

- The zona pellucida undergoes changes.
- These changes help prevent additional sperm from entering.

Stage 7: Completion of meiosis II

- The secondary oocyte completes its second meiotic division.
- A mature ovum and second polar body are formed.

Stage 8: Fusion of genetic material

- The maternal and paternal genetic materials are brought together.
- The diploid chromosome number is restored.
- A zygote containing 46 chromosomes is formed.

Stage 9: Cleavage

- The zygote begins repeated mitotic divisions.
- It develops into a multicellular structure.
- It moves towards the uterus.

Significance of fertilization

1. Restores the diploid chromosome number.
2. Combines genetic material from both parents.
3. Initiates embryonic development.
4. Introduces genetic variation.
5. Determines the chromosomal sex of the embryo in typical XX/XY chromosomal development.

Sex determination in humans

- An ovum normally carries an X chromosome.
- A sperm may carry either an X or a Y chromosome.
- X-bearing sperm fertilizing an X-bearing ovum usually produces an XX embryo.
- Y-bearing sperm fertilizing an X-bearing ovum usually produces an XY embryo.

Thus, the sperm contributes the chromosome that usually determines chromosomal sex in typical human development.

3.1.15 Development from zygote to embryo

After fertilization, the zygote undergoes a series of developmental changes before implantation.

Stages of early embryonic development

1. Zygote

- The zygote is the single diploid cell formed after fertilization.
- It contains genetic material from both parents.
- It begins mitotic division as it moves along the fallopian tube.

2. Cleavage

Cleavage refers to repeated mitotic divisions of the zygote without a corresponding increase in the overall size of the developing structure.

The divisions produce smaller cells known as blastomeres.

- First cleavage produces two cells.
- Further divisions produce four cells.
- Subsequent divisions produce eight or more cells.

3. Morula

- The morula is a solid ball of cells.
- It usually forms approximately three to four days after fertilization.
- It continues moving towards the uterus.

4. Blastocyst

The blastocyst is a hollow, fluid-filled structure formed after the morula develops further.

It has three important components:

- **Trophoblast:** The outer layer of cells that contributes to formation of the placenta.
- **Inner cell mass (embryoblast):** Develops into the embryo.
- **Blastocoel:** The fluid-filled cavity inside the blastocyst.

5. Implantation

Implantation is the process through which the blastocyst attaches to and becomes embedded in the endometrium.

- It normally begins approximately 6–7 days after fertilization.
- The trophoblast attaches to the uterine lining.
- The trophoblast invades the endometrium.
- Early placental development begins.
- The developing embryo receives support from maternal tissues.

Importance of implantation

1. Establishes the developing embryo in the uterus.
2. Allows development of the placenta.
3. Enables exchange of substances between the mother and developing embryo.
4. Supports continuation of pregnancy.
5. Initiates hormonal changes that help maintain the pregnancy.

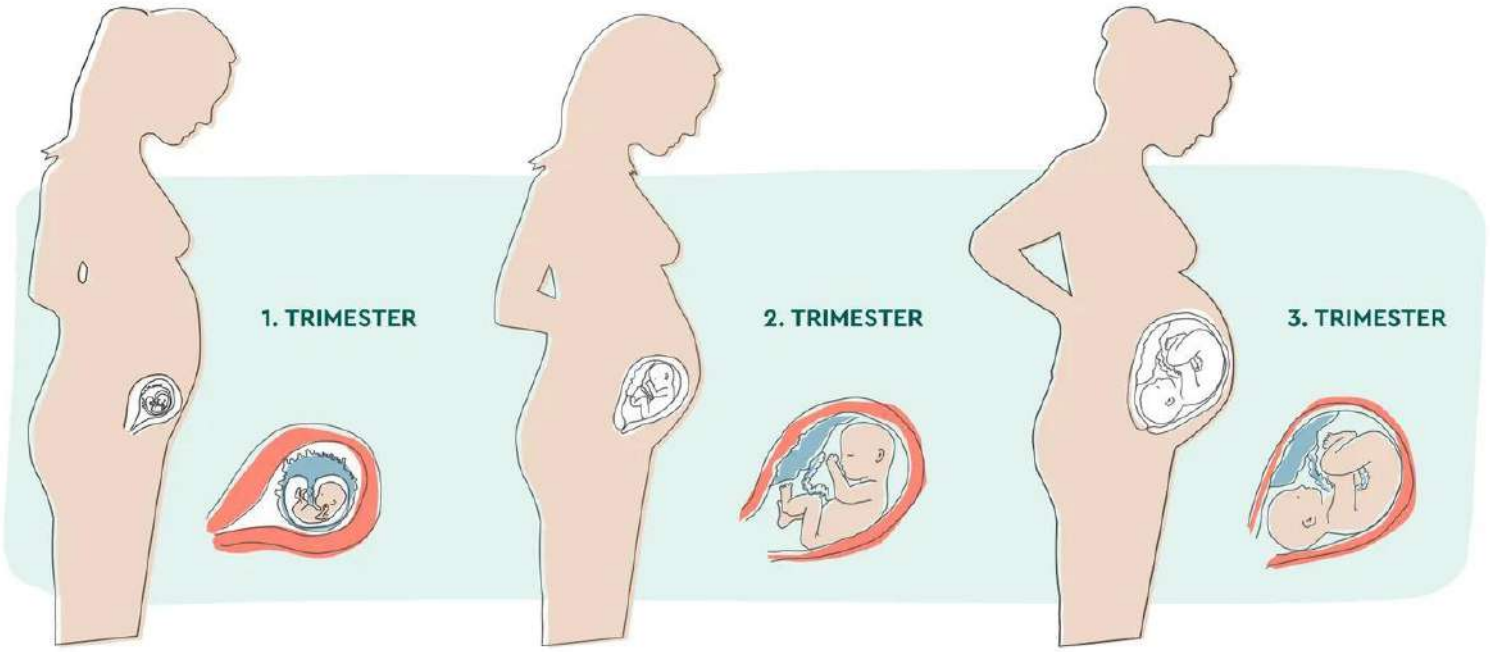
3.1.16 Pregnancy in humans

Meaning of pregnancy

Pregnancy is the physiological condition in which a developing embryo and later a foetus grows inside the uterus following successful fertilization and implantation.

Human pregnancy lasts approximately 38 weeks from fertilization or about 40 weeks from the first day of the last menstrual period.

Pregnancy is divided into three main trimesters.



A. First trimester (weeks 1-12)

This is the early stage of pregnancy, during which the embryo develops its major body structures and organs begin forming.

Major developmental events

1. Fertilization occurs in the fallopian tube.
2. The zygote undergoes cleavage.
3. The blastocyst forms and implants in the endometrium.
4. The placenta begins developing.
5. The embryo develops the neural tube, which forms the brain and spinal cord.
6. The heart begins developing and starts beating early in embryonic development.
7. Limb buds develop.
8. Major organs begin forming through organogenesis.
9. The developing individual is referred to as a foetus from approximately the ninth week after fertilization.

Changes experienced by the mother

- Nausea and vomiting.
- Breast tenderness.
- Increased urination.
- Fatigue.

- Missed menstrual periods.
- Hormonal changes.
- Changes in appetite.

Importance of the first trimester

This period is particularly important because the major organs and body systems begin developing. Exposure to harmful substances can interfere with organ formation.

B. Second trimester (weeks 13-27)

This stage is characterised by rapid growth and further development of the foetus.

Major developmental events

1. The foetus increases in length and mass.
2. Bones become more developed and begin to harden.
3. Muscles become stronger.
4. The external genitalia become more distinguishable.
5. The foetus begins making coordinated movements.
6. The mother may begin feeling foetal movements, known as quickening.
7. Hair begins developing on the scalp.
8. The skin develops a protective covering called vernix caseosa.
9. Hearing structures develop and the foetus begins responding to sounds.
10. The lungs continue developing, although they are not yet fully mature.

Changes experienced by the mother

- The abdomen increases in size.
- Foetal movements become noticeable.
- Nausea may reduce.
- Breast size may increase.
- The mother may experience back discomfort.

C. Third trimester (weeks 28-birth)

This is the final stage of pregnancy, during which the foetus undergoes rapid growth and prepares for life outside the uterus.

Major developmental events

1. The foetus increases rapidly in body mass.
2. The brain develops further.
3. The lungs continue maturing.
4. Fat accumulates beneath the skin.
5. The foetus responds to sounds and light.

6. The bones continue developing, although some skull bones remain unfused.
7. The foetus usually assumes a head-down position before birth.
8. The organs become increasingly prepared for independent functioning.
9. Maternal antibodies are transferred across the placenta, providing some passive immunity.

Changes experienced by the mother

- Increased abdominal size.
- Frequent urination due to pressure on the bladder.
- Backache.
- Difficulty sleeping.
- Increased tiredness.
- Braxton Hicks contractions, which are practice contractions.
- Increased pressure in the pelvic region.

Summary of the three trimesters

Trimester	Period	Major events
First	Weeks 1–12	Implantation and formation of major organs
Second	Weeks 13–27	Rapid growth and noticeable foetal movement
Third	Week 28–birth	Further maturation and preparation for birth

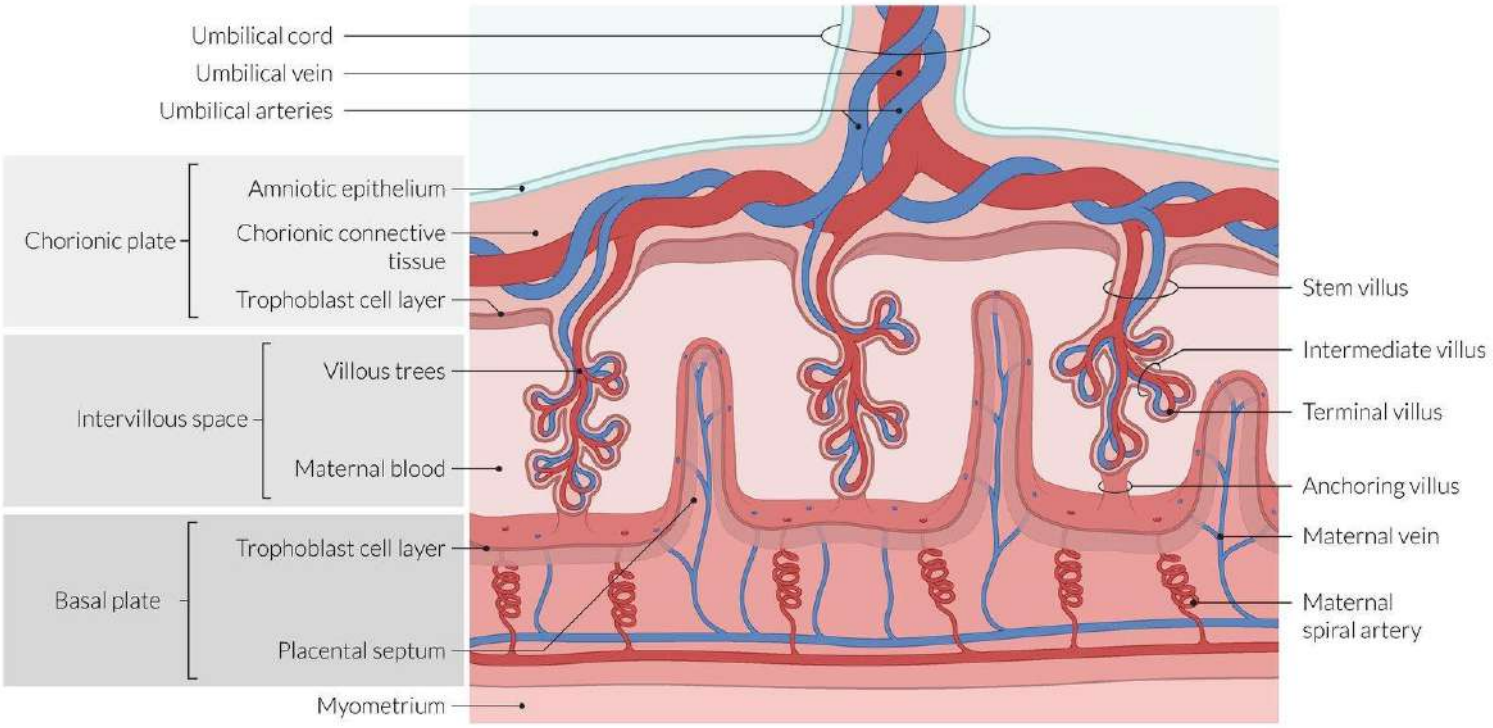
3.1.17 The placenta

Meaning of the placenta

The placenta is a temporary, specialised organ that develops during pregnancy and connects the developing foetus to the mother's uterine wall.

In humans, it is formed from embryonic tissues, particularly the chorion, together with maternal endometrial tissues.

It provides an important exchange surface between maternal and foetal blood.



Structure of the placenta

The placenta consists of several specialised structures.

1. Chorionic villi

- Finger-like projections from the embryonic chorion.
- Contain foetal blood capillaries.
- Increase the surface area available for exchange of substances.
- Project into spaces containing maternal blood.

2. Intervillous spaces

- Spaces surrounding the chorionic villi.
- Contain maternal blood.
- Allow exchange of substances between maternal and foetal blood across the placental barrier.

3. Umbilical cord

The umbilical cord connects the foetus to the placenta.

It normally contains:

- Two umbilical arteries.
- One umbilical vein.
- Wharton's jelly, which protects the blood vessels.

4. Placental membrane (placental barrier)

- Separates maternal blood from foetal blood.
- Allows selected substances to pass between the two circulations.
- Helps prevent direct mixing of maternal and foetal blood under normal conditions.

Functions of the placenta

1. Gaseous exchange

- Oxygen diffuses from maternal blood into foetal blood.
- Carbon dioxide diffuses from foetal blood into maternal blood.
- Carbon dioxide is carried to the mother's lungs for removal.

2. Nutrient supply

- Glucose passes from maternal blood to foetal blood.
- Amino acids are transported to support growth.
- Fatty acids, vitamins, minerals and other nutrients are supplied to the foetus.

3. Removal of metabolic wastes

- Urea passes from foetal blood into maternal blood.
- Other metabolic waste products are transferred to maternal blood.
- The mother's kidneys eliminate these wastes.

4. Hormone production

The placenta produces hormones such as:

- Human chorionic gonadotropin (hCG).
- Progesterone.
- Oestrogens.
- Human placental lactogen (hPL).

These hormones support pregnancy and prepare the mother's body for childbirth and lactation.

5. Protection

- Acts as a selective barrier against some harmful substances.
- Transfers maternal antibodies, particularly IgG, to the foetus.
- Reduces direct exposure of the foetus to certain maternal pathogens.

However, the placenta is not a complete barrier. Some viruses, drugs, toxins and harmful substances can cross it.

6. Attachment and support

- Anchors the developing foetus to the uterine wall through the umbilical cord.
- Supports the exchange of materials between mother and foetus.

Structure and functions of the umbilical cord

The umbilical cord contains three major blood vessels.

A. Two umbilical arteries

- Carry deoxygenated blood from the foetus to the placenta.
- Transport carbon dioxide and metabolic wastes from the foetus.

B. One umbilical vein

- Carries oxygenated, nutrient-rich blood from the placenta to the foetus.

Important distinction: The names of the umbilical arteries and vein are based on the direction of blood flow relative to the foetal heart, not on the oxygen content of the blood.

Differences between maternal and foetal blood circulation

Maternal circulation	Foetal circulation
Supplies oxygen and nutrients to the placenta.	Receives oxygen and nutrients from the placenta.
Receives carbon dioxide and wastes from the placenta.	Sends carbon dioxide and wastes to the placenta.
Blood flows through maternal vessels in the uterine lining.	Blood flows through foetal vessels in the chorionic villi and umbilical cord.

Substances that can cross the placenta

- Oxygen.
- Carbon dioxide.
- Glucose.
- Amino acids.
- Water.
- Mineral salts.
- Some antibodies.
- Some medicines.
- Alcohol.
- Nicotine and harmful substances in tobacco.
- Some infectious agents.

Harmful substances and their effects on the foetus

1. **Alcohol:** Can interfere with brain development and cause foetal alcohol spectrum disorders.
2. **Nicotine:** Can reduce oxygen supply and increase the risk of low birth weight and premature birth.
3. **Certain drugs:** May interfere with normal development and cause birth defects.
4. **Some infectious organisms:** May cause congenital infections and developmental complications.
5. **Environmental toxins:** Certain heavy metals and chemicals can damage the developing nervous system.

Why maternal and foetal blood do not normally mix directly

- The placental barrier separates the two blood circulations.
- Maternal blood flows around chorionic villi.
- Foetal blood flows inside capillaries within the villi.

- Substances move across the barrier through diffusion, facilitated diffusion, active transport and other transport mechanisms.

3.1.18 Birth in humans (parturition)

Meaning of birth

Birth, also known as parturition, is the physiological process through which a fully developed baby is expelled from the mother's uterus at the end of pregnancy.

Human birth normally occurs around 37–42 weeks of gestation, although the timing varies.

Hormonal control of childbirth

Birth is controlled by the interaction of several hormones.

1. Oxytocin

- Released from the posterior pituitary gland.
- Stimulates contractions of the uterine muscles.
- Strengthens uterine contractions through positive feedback.
- Helps expel the baby from the uterus.

2. Prostaglandins

- Produced by tissues in the uterus and foetal membranes.
- Promote uterine contractions.
- Help soften and ripen the cervix.

3. Oestrogen

- Contributes to increased uterine sensitivity to oxytocin.
- Promotes the development of uterine contractions.
- Helps prepare the uterus for labour.

4. Progesterone

- Maintains uterine relaxation during most of pregnancy.
- Near childbirth, its functional influence decreases, allowing uterine activity to increase.

5. Relaxin

- Helps soften and remodel the cervix.
- Contributes to relaxation of pelvic ligaments.

Stages of human childbirth

Human childbirth is generally divided into three main stages.

Stage 1: Dilation stage

This is usually the longest stage of labour.

Events:

1. Regular uterine contractions begin.
2. The cervix gradually softens and thins.

3. The cervix begins to dilate.
4. The amniotic membranes may rupture, resulting in the release of amniotic fluid (breaking of the waters).
5. Contractions become stronger and closer together.
6. The cervix eventually dilates to approximately 10 cm.

Importance of cervical dilation

It creates a sufficiently wide opening through which the baby can pass from the uterus into the birth canal.

Stage 2: Expulsion stage

This is the stage during which the baby is delivered.

Events:

1. Strong uterine contractions continue.
2. The baby's head moves down through the cervix.
3. The baby passes through the vagina.
4. The head is usually delivered first in a head-first presentation.
5. The shoulders and rest of the body follow.
6. The baby is born.

Importance of uterine contractions

They provide the muscular force necessary to move the baby through the birth canal.

Stage 3: Placental stage

This is the final stage of childbirth.

Events:

1. The uterus continues contracting after the baby is delivered.
2. The placenta separates from the uterine wall.
3. The placenta and foetal membranes are expelled through the vagina.
4. The uterus contracts to reduce bleeding from the site where the placenta was attached.

Care immediately after birth

- The baby's breathing and general condition are assessed.
- The baby is dried and kept warm.
- Skin-to-skin contact is encouraged when possible.
- The umbilical cord is clamped and cut using appropriate sterile procedures.
- Breastfeeding is initiated as early as possible.
- The mother is monitored for excessive bleeding and other complications.

Adaptations that facilitate human childbirth

1. The uterus has a thick muscular wall that produces strong contractions.
2. The cervix is capable of dilating.
3. The vagina is elastic and can expand during delivery.
4. The pelvic joints and ligaments allow some flexibility.
5. The baby's skull bones are not fully fused at birth, allowing moulding during passage through the birth canal.

3.1.19 Lactation in humans

Meaning of lactation

Lactation is the physiological process through which the mammary glands produce and release milk to nourish a newborn baby.

Lactation begins during pregnancy through hormonal stimulation, but substantial milk production increases after childbirth.

Structure of the mammary glands

The mammary glands are specialised organs located in the breasts.

Their major structures include:

1. Alveoli

- Small sac-like structures lined with milk-secreting cells.
- Produce and secrete breast milk.

2. Lobules

- Groups of alveoli.
- Contain milk-producing structures.

3. Mammary ducts

- Tubes that transport milk from the alveoli towards the nipple.

4. Lactiferous ducts

- Larger milk-carrying passages that open at the nipple.

5. Nipple

- The external structure through which breast milk is released.

6. Areola

- The pigmented area surrounding the nipple.
- Contains glands that help lubricate and protect the nipple.

Hormonal control of lactation

A. Prolactin – milk production

- Secreted by the anterior pituitary gland.
- Stimulates milk synthesis in the alveolar cells.
- Its secretion increases in response to suckling.

B. Oxytocin – milk ejection

- Released from the posterior pituitary gland.
- Causes contraction of myoepithelial cells surrounding the alveoli.
- Pushes milk into the mammary ducts.
- Causes milk to flow towards the nipple.

Process of lactation

1. After childbirth, the delivery of the placenta causes a rapid decrease in progesterone and oestrogen.
2. This allows prolactin to stimulate increased milk production.
3. The baby suckles at the mother's nipple.
4. Sensory receptors send nerve impulses to the hypothalamus.
5. The hypothalamus stimulates the release of prolactin and oxytocin through pituitary pathways.
6. Prolactin stimulates milk production.
7. Oxytocin causes milk ejection.
8. Continued suckling helps maintain milk production.

Types of breast milk

1. Colostrum

Colostrum is the first milk produced during late pregnancy and the first few days after childbirth.

Characteristics:

- Usually yellowish in colour.
- Rich in antibodies, particularly secretory IgA.
- Contains proteins and immune-protective substances.
- Contains relatively little fat compared with mature milk.
- Helps protect the newborn against infections.

2. Transitional milk

- Produced after the colostrum stage.
- Contains changing proportions of fats, proteins and carbohydrates.
- Supports the increasing nutritional requirements of the baby.

3. Mature milk

- Produced after the transitional stage.
- Contains water, carbohydrates, fats, proteins, vitamins and minerals.
- Provides essential nutrients for infant growth and development.

Importance of breastfeeding

1. Provides balanced nutrients for infant growth.

2. Supplies antibodies that protect against infections.
3. Provides easily digestible nutrients.
4. Promotes bonding between the mother and baby.
5. Reduces the risk of some childhood infections.
6. Supports healthy development of the digestive system.
7. Provides a safe and hygienic source of nutrition.
8. Encourages uterine contractions through oxytocin release, helping the uterus return towards its pre-pregnancy size.

Exclusive breastfeeding

Exclusive breastfeeding means feeding an infant only breast milk, without other foods or liquids, including water, except oral rehydration solution or prescribed medicines and supplements where necessary, for the first six months of life.

3.1.20 Role of biotechnology in human reproduction

Meaning of biotechnology in human reproduction

Biotechnology in human reproduction refers to the application of scientific techniques and technologies to assist, improve, regulate or manage human reproductive processes.

Reproductive biotechnology is used to help individuals and couples experiencing fertility difficulties to achieve pregnancy and have children.

It also supports fertility preservation, reproductive health research and the treatment of certain reproductive disorders.

Major applications of biotechnology in human reproduction

1. Artificial insemination.
2. In vitro fertilization (IVF).
3. Intracytoplasmic sperm injection (ICSI).
4. Surrogacy.
5. Sperm banking.
6. Egg freezing.
7. Embryo freezing.
8. Hormonal fertility treatment.
9. Preimplantation genetic testing.

A. Artificial insemination

Meaning

Artificial insemination is a reproductive technique in which sperm are deliberately introduced into the female reproductive tract using medical procedures rather than through sexual intercourse.

In humans, a common method is intrauterine insemination (IUI), where prepared sperm are placed directly into the uterus.

Procedure

1. The female reproductive cycle is assessed.
2. Ovulation is monitored.
3. A semen sample is collected from the male partner or a donor.
4. The semen is processed to separate and concentrate suitable motile sperm.
5. A thin catheter is inserted through the cervix.
6. The prepared sperm are deposited into the uterus.
7. The sperm may then travel towards the fallopian tube.
8. Fertilization may occur naturally inside the female reproductive tract.

Importance of artificial insemination

- Helps couples experiencing certain fertility problems.
- May assist where sperm movement or sperm delivery is impaired.
- Allows the use of screened donor sperm.
- Can help individuals who need donor sperm to conceive.

B. In vitro fertilization (IVF)

Meaning

In vitro fertilization is an assisted reproductive technology in which an egg is fertilized by sperm outside the human body under controlled laboratory conditions.

The resulting embryo may then be transferred into the uterus.

Stages of IVF

Stage 1: Ovarian stimulation

- The female receives prescribed fertility hormones.
- These hormones stimulate the development of several ovarian follicles.
- The follicles are monitored using ultrasound and sometimes blood tests.

Stage 2: Egg retrieval

- Mature eggs are collected from the ovaries using a specialised needle guided by ultrasound.
- The procedure is usually performed under sedation or anaesthesia.

Stage 3: Sperm collection

- A semen sample is obtained from the male partner or a screened donor.
- The sperm are processed to select suitable sperm cells.

Stage 4: Fertilization

- Eggs and sperm are brought together in a laboratory dish.
- Fertilization may occur through conventional IVF.
- Alternatively, a single sperm may be injected directly into an egg through a procedure known as ICSI.

Stage 5: Embryo development

- Fertilized eggs are cultured in controlled laboratory conditions.
- Embryos are monitored as they divide.
- Suitable embryos may develop to the cleavage stage or blastocyst stage.

Stage 6: Embryo transfer

- A selected embryo is transferred into the uterus using a thin catheter.
- The embryo may implant in the endometrium if successful.

Stage 7: Pregnancy testing

- A pregnancy test is conducted after an appropriate waiting period.
- Blood tests may measure hCG to establish whether implantation has occurred.

Advantages of IVF

1. Helps individuals and couples experiencing infertility.
2. Can help where fallopian tubes are blocked or severely damaged.
3. Can be used in cases of severe male-factor infertility.
4. Allows the use of donor eggs or sperm where appropriate.
5. Allows embryos to be frozen for future use.
6. May enable preimplantation genetic testing for selected genetic conditions.
7. Provides reproductive options to individuals who might otherwise be unable to conceive.

Disadvantages and limitations of IVF

1. It is expensive and may not be accessible to everyone.
2. It involves medical procedures and hormonal treatment.
3. Ovarian stimulation may cause side effects.
4. Egg retrieval involves medical risks.
5. Not every fertilized egg develops into a suitable embryo.
6. Implantation and pregnancy are not guaranteed.
7. Emotional and psychological stress may occur.
8. Multiple pregnancy may occur, especially where more than one embryo is transferred.

C. Intracytoplasmic sperm injection (ICSI)

Meaning

ICSI is an assisted reproductive technique in which a single sperm is injected directly into the cytoplasm of an egg using a specialised microscopic needle.

Procedure

1. Mature eggs are collected from the female.
2. A suitable sperm cell is selected.
3. The egg is held in position using a holding pipette.

4. A microscopic injection needle containing one sperm penetrates the egg membrane.
5. The sperm is injected into the egg cytoplasm.
6. The egg is monitored for fertilization.
7. Developing embryos may be transferred into the uterus.

Importance of ICSI

- Helps overcome severe male-factor infertility.
- Can be useful where sperm count is very low.
- Can assist where sperm movement is poor.
- May be used when sperm must be retrieved surgically.
- Can be used when previous conventional IVF attempts have resulted in poor or failed fertilization.

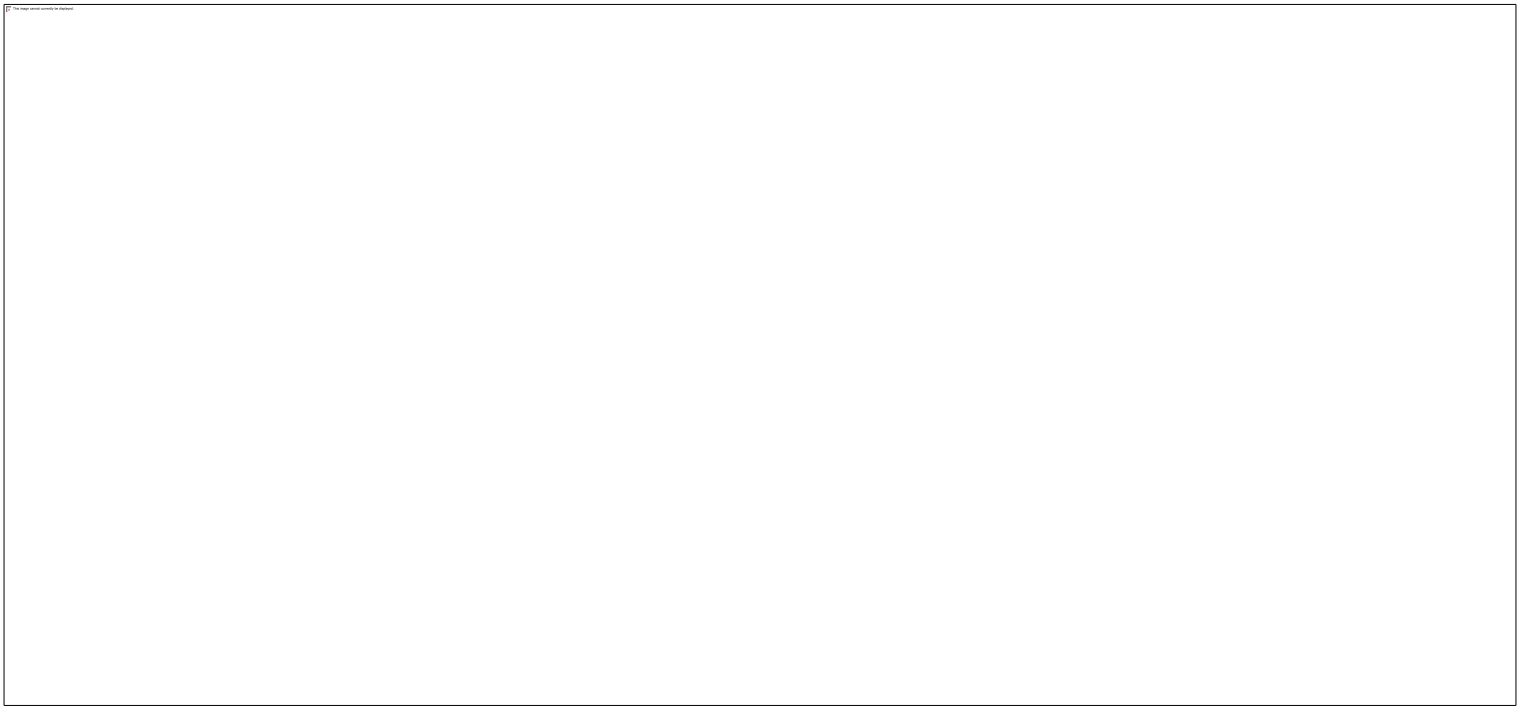
Difference between IVF and ICSI

IVF	ICSI
Eggs and sperm are placed together in a laboratory dish.	One sperm is injected directly into an egg.
Fertilization occurs through natural sperm penetration in the laboratory.	Fertilization is assisted through direct sperm injection.
Several sperm are placed around an egg.	One selected sperm is used for each injected egg.
Used for various fertility problems.	Particularly useful in certain cases of male-factor infertility.

D. Surrogacy

Meaning of surrogacy

Surrogacy is an arrangement in which a woman agrees to carry a pregnancy and give birth to a child for another individual or couple who intend to become the child's parent or parents.



Types of surrogacy

1. Traditional surrogacy

In traditional surrogacy:

- The surrogate mother's own egg is used.
- The egg is fertilized using sperm from the intended father or a donor.
- The surrogate is genetically related to the child.
- Fertilization may be achieved through artificial insemination or another suitable reproductive technique.

2. Gestational surrogacy

In gestational surrogacy:

- An embryo is created through IVF using eggs and sperm from intended parents or donors.
- The embryo is transferred into the surrogate's uterus.
- The surrogate carries the pregnancy.
- The surrogate does not contribute the egg and is therefore not genetically related to the child through the egg.

Reasons for surrogacy

1. Absence of a functional uterus.
2. Severe uterine abnormalities.
3. Medical conditions that make carrying a pregnancy dangerous.
4. Repeated unsuccessful attempts to carry a pregnancy.
5. Certain reproductive disorders that prevent pregnancy from being carried safely.

Advantages of surrogacy

- Provides an opportunity for parenthood to individuals who cannot safely carry a pregnancy.
- Allows the use of intended parents' genetic material in gestational surrogacy.
- May provide an alternative where other fertility treatments have failed.

Challenges associated with surrogacy

- High medical and financial costs.
- Ethical and social disagreements.
- Psychological and emotional challenges.
- Possible pregnancy complications.
- Legal questions concerning parentage, consent and responsibilities.
- Potential exploitation where adequate protection is absent.

Kenyan context: Surrogacy involves important questions of reproductive health, consent, parentage and legal protection. Legal requirements should be checked against current Kenyan law and professional medical guidance before entering into any arrangement.

E. Sperm banking

Meaning

Sperm banking is the process of collecting, screening, processing and preserving sperm cells at very low temperatures for future reproductive use.

The process is also known as sperm cryopreservation.

Procedure involved in sperm banking

1. **Collection:** A semen sample is collected under appropriate clinical conditions.
2. **Screening:** The sample is assessed for sperm count, movement and quality. Relevant infectious disease screening is also conducted.
3. **Processing:** The sperm may be prepared and mixed with a cryoprotectant to reduce damage during freezing.
4. **Freezing:** The sperm are frozen using controlled procedures.
5. **Storage:** The samples are stored in specialised containers, usually in liquid nitrogen at approximately -196°C.
6. **Preservation:** The frozen samples are kept under monitored storage conditions.
7. **Thawing:** When required, the sample is carefully thawed and assessed for reproductive use.

Reasons for sperm banking

- Before cancer treatment that may damage sperm-producing tissues.
- Before certain surgical procedures.
- Before medical treatments that may affect fertility.
- For men with conditions that may cause future infertility.
- To preserve fertility before certain medical or occupational exposures.
- To provide sperm for future assisted reproduction.

Advantages of sperm banking

1. Preserves the possibility of future biological fatherhood.
2. Allows sperm to be stored for long periods under suitable conditions.
3. Provides sperm for IVF and ICSI.
4. Helps individuals preserve fertility before certain medical treatments.
5. Allows screening and documentation before reproductive use.

Limitations of sperm banking

- Some sperm cells may not survive freezing and thawing.
- Storage and medical procedures can be expensive.
- It requires specialised equipment.
- Not all stored samples will result in successful pregnancy.
- Proper consent, confidentiality and storage management are essential.

F. Egg freezing

Egg freezing is a reproductive biotechnology technique in which mature eggs are collected from the ovaries and preserved at very low temperatures for future use.

Procedure

1. Ovarian stimulation is carried out using prescribed hormones.
2. Mature eggs are collected.
3. The eggs are assessed.
4. Suitable mature eggs are frozen, commonly through vitrification.
5. They are stored in specialised cryogenic facilities.
6. When required, they are thawed, fertilized and used in assisted reproduction.

Importance

- Helps preserve fertility before certain cancer treatments.
- Provides reproductive options for individuals who wish to delay childbearing.
- May help individuals with medical conditions that threaten ovarian function.

G. Embryo freezing

Embryo freezing is the preservation of embryos at very low temperatures for possible future reproductive use.

Procedure

1. Eggs are fertilized through IVF.
2. Embryos are cultured in a laboratory.
3. Suitable embryos are selected.
4. Embryos are frozen using cryopreservation techniques.
5. They are stored in specialised facilities.
6. They may later be thawed and transferred into the uterus.

Importance

- Allows embryos from an IVF cycle to be used in future attempts.
- Reduces the need for repeated ovarian stimulation and egg collection.
- Provides an option for fertility preservation.

H. Preimplantation genetic testing (PGT)

Preimplantation genetic testing is a technique used to examine genetic material from embryos produced through IVF before embryo transfer.

Types

1. **PGT-M:** Used to identify specific inherited single-gene disorders.
2. **PGT-SR:** Used to identify certain structural chromosomal rearrangements.
3. **PGT-A:** Used to assess the number of chromosomes in an embryo.

Importance

- May help reduce the risk of transferring embryos affected by certain inherited conditions.
- Provides information about particular genetic or chromosomal abnormalities.
- Supports reproductive decision-making for some families.

Limitation: PGT does not guarantee pregnancy or the birth of a healthy child. Its benefits and limitations depend on the condition being investigated and the clinical circumstances.

3.1.21 Ethical, social and health considerations in reproductive biotechnology

The application of biotechnology in human reproduction raises important ethical, social, medical and legal issues.

Ethical considerations

1. **Informed consent:** All individuals involved should understand and voluntarily agree to the procedures.
2. **Confidentiality:** Donor and patient information should be protected.
3. **Embryo management:** Decisions concerning unused frozen embryos require careful ethical consideration.
4. **Donor rights:** The rights and welfare of egg and sperm donors should be protected.
5. **Surrogate welfare:** Surrogates should receive appropriate medical care, counselling and legal protection.
6. **Access and affordability:** Expensive reproductive technologies may not be available to all individuals.
7. **Genetic selection:** Genetic testing should be used responsibly and ethically.
8. **Child welfare:** The health, rights and welfare of children born through assisted reproduction should be considered.

Social considerations

- Cultural beliefs about assisted reproduction.
- Family relationships and parenthood.
- Religious perspectives.
- Social acceptance of donor conception.
- Possible stigma associated with infertility.
- Financial challenges faced by families seeking treatment.

Health and safety considerations

- Proper screening of donors.
- Prevention of infections.
- Safe handling of gametes and embryos.
- Monitoring of hormonal treatment.
- Management of multiple pregnancies.

- Qualified medical personnel and properly equipped fertility laboratories.

3.1.22 General reproductive health and responsible reproductive practices

Reproductive health refers to a state of physical, mental and social well-being in all matters relating to the reproductive system.

Practices that promote reproductive health

1. Maintaining personal hygiene.
2. Eating a balanced diet.
3. Seeking medical attention when reproductive health problems occur.
4. Avoiding tobacco, alcohol and harmful drugs.
5. Practising responsible sexual behaviour.
6. Seeking appropriate screening and treatment for sexually transmitted infections.
7. Avoiding self-medication with hormonal drugs.
8. Seeking professional advice when experiencing menstrual irregularities.
9. Attending antenatal clinics during pregnancy.
10. Following appropriate medical guidance during childbirth and after delivery.

Common reproductive health challenges

- Infertility.
- Sexually transmitted infections.
- Menstrual disorders.
- Reproductive cancers.
- Pregnancy complications.
- Hormonal disorders.
- Miscarriage.
- Ectopic pregnancy.
- Disorders affecting the testes or ovaries.

STRAND 3.0: ANATOMY AND PHYSIOLOGY OF ANIMALS

SUB-STRAND 3.1: REPRODUCTION IN ANIMALS

SECTION A: MULTIPLE-CHOICE QUESTIONS

Choose the correct answer from the alternatives A, B, C and D.

1. Which statement best describes reproduction in animals?

A. The process through which organisms obtain food.

B. The process through which organisms produce offspring.

C. The process through which organisms remove metabolic wastes.

D. The process through which organisms respond to stimuli.

2. External fertilization is commonly observed in which pair of animals?

A. Cattle and goats.

B. Dogs and cats.

C. Fish and frogs.

D. Humans and elephants.

3. During external fertilization in fish, the substance released by the male fish containing sperm is known as

A. Amnion.

B. Milt.

C. Yolk.

D. Albumen.

4. Which of the following is an adaptation of animals that reproduce through external fertilization?

A. Production of very few gametes.

B. Production of large numbers of gametes.

C. Development of a thick placenta.

D. Retention of eggs inside the uterus.

5. The reproductive behaviour in frogs in which the male clasps the female during fertilization is called

A. Implantation.

B. Amplexus.

C. Ovulation.

D. Gestation.

6. An animal that lays eggs in which embryos develop outside the mother's body is described as

A. Viviparous. B. Ovoviviparous.

C. Oviparous. D. Parthenogenetic.

7. Which of the following correctly describes ovoviviparous reproduction?

A. The embryo develops directly inside the uterus and receives all nutrients through a placenta.

B. Fertilized eggs are retained inside the mother and embryos obtain nourishment mainly from the yolk.

C. Eggs are released into water before fertilization.

D. Embryos develop without fertilization.

8. Which structure in the male reproductive system produces sperm cells?

A. Epididymis.

B. Prostate gland.

C. Seminiferous tubules.

D. Seminal vesicle.

9. The main function of the epididymis is to

A. Produce testosterone.

B. Store and allow maturation of sperm.

C. Produce seminal fluid.

D. Transport urine from the bladder.

10. Which male reproductive structure secretes a fluid rich in fructose that provides energy for sperm?

A. Seminal vesicles.

B. Testes.

C. Scrotum.

D. Urethra.

11. The primary function of the scrotum is to

A. Produce sperm.

B. Regulate the temperature of the testes.

C. Produce testosterone.

D. Store semen.

12. Which part of the sperm contains enzymes that assist in penetrating the protective coverings of the ovum?

A. Middle piece. B. Tail.

C. Acrosome. D. Neck.

13. The middle piece of a sperm cell contains numerous

A. Ribosomes.

B. Mitochondria.

C. Vacuoles.

D. Chloroplasts.

14. Which structure of the female reproductive system is the usual site of fertilization?

A. Uterus.

B. Cervix.

C. Vagina.

D. Ampulla of the fallopian tube.

15. The finger-like projections at the end of the fallopian tube are called

A. Villi.

B. Fimbriae.

C. Alveoli.

D. Chorionic villi.

16. The inner lining of the uterus is known as

A. Myometrium.

B. Perimetrium.

C. Endometrium.

D. Peritoneum.

17. Which structure connects the uterus to the vagina?

A. Ovary.

B. Cervix.

C. Fallopian tube.

D. Fimbriae.

18. The female reproductive hormone responsible for maintaining the uterine lining during pregnancy is

A. Testosterone.

B. Progesterone.

C. Adrenaline.

D. Thyroxine.

19. Ovulation is triggered by a sudden increase in

A. Prolactin.

B. Progesterone.

C. LH.

D. Testosterone.

20. Which hormone stimulates the development of ovarian follicles?

A. FSH. B. Oxytocin.

C. Prolactin. D. Relaxin.

21. The corpus luteum develops from

A. The endometrium.

B. The ruptured ovarian follicle.

C. The fallopian tube.

D. The cervix.

22. Which hormone is responsible for stimulating milk production after childbirth?

A. Oxytocin.

B. Prolactin.

C. Testosterone.

D. LH.

23. The hormone responsible for milk ejection during breastfeeding is

A. Progesterone.

B. Oestrogen.

C. Oxytocin.

D. FSH.

24. Which hormone is produced by the developing placenta and helps maintain the corpus luteum during early pregnancy?

A. hCG.

B. FSH.

C. Testosterone.

D. Inhibin.

25. The main function of the placenta is to

A. Produce sperm cells.

B. Exchange nutrients, gases and wastes between mother and foetus.

C. Produce ova.

D. Prevent all substances from entering the foetus.

26. How many umbilical arteries are normally present in the human umbilical cord?

A. One.

B. Two.

C. Three.

D. Four.

27. Which blood vessel carries oxygenated blood from the placenta to the foetus?

A. Umbilical artery. B. Pulmonary artery.

C. Umbilical vein. D. Aorta.

28. The solid ball of cells formed during early embryonic development is called

A. Blastocyst. B. Morula. C. Placenta. D. Gastrula.

29. Implantation normally involves the attachment of the

A. Sperm to the ovary.

B. Blastocyst to the endometrium.

C. Ovum to the cervix.

D. Zygote to the vagina.

30. Which stage of pregnancy involves the formation of major organs?

A. First trimester.

B. Second trimester.

C. Third trimester.

D. Postnatal stage.

31. The process through which the baby is expelled from the uterus is known as

A. Ovulation.

B. Implantation.

C. Parturition.

D. Lactation.

32. During childbirth, the hormone that stimulates strong uterine contractions is

A. Prolactin. B. Oxytocin. C. Insulin. D. Glucagon.

33. Which structure is responsible for the production of breast milk?

A. Mammary alveoli.

B. Fallopian tubes.

C. Ovarian follicles.

D. Uterine glands.

34. The first milk produced after childbirth is known as

A. Plasma. B. Colostrum. C. Albumen. D. Amniotic fluid.

35. The reproductive technique in which fertilization takes place outside the female body is

A. Natural mating.

B. IVF.

C. Ovulation.

D. Lactation.

36. In ICSI, the reproductive specialist

A. Places sperm into the cervix.

B. Injects one sperm directly into the egg.

C. Transfers an egg into the ovary.

D. Injects an embryo into the fallopian tube.

37. The preservation of sperm cells at very low temperatures for future use is called

A. Implantation.

B. Cryopreservation.

C. Ovulation.

D. Menstruation.

38. A woman who carries a pregnancy for intended parents under a surrogacy arrangement is known as

A. Egg donor.

B. Surrogate mother.

C. Midwife.

D. Genetic counsellor.

39. Which reproductive biotechnology is particularly useful for preserving sperm before cancer treatment?

A. Sperm banking.

B. Ovulation.

C. Menstruation.

D. Parturition.

40. Which hormone inhibits the secretion of FSH through negative feedback?

A. Inhibin.

B. Oxytocin.

C. Prolactin.

D. hCG.

SECTION B: STRUCTURED QUESTIONS

41: REPRODUCTION IN ANIMALS (10 MARKS)

a) Define reproduction. (2 marks)

b) Distinguish between sexual and asexual reproduction in animals. (2 marks)

c) Explain four advantages of sexual reproduction in animals. (4 marks)

d) State two examples of animals that reproduce through external fertilization. (2 marks)

42: EXTERNAL AND INTERNAL FERTILIZATION (10 MARKS)

a) Define external fertilization. (2 marks)

b) Describe the process of fertilization in frogs. (4 marks)

c) State two adaptations of fish that increase the chances of successful external fertilization. (2 marks)

d) Give two advantages of internal fertilization over external fertilization. (2 marks)

43: TYPES OF ANIMAL REPRODUCTION (10 MARKS)

a) Define the following terms:

i. Oviparous animals. (2 marks)

ii. Viviparous animals. (2 marks)

iii. Ovoviviparous animals. (2 marks)

b) Give two examples of oviparous animals. (2 marks)

c) State two differences between viviparous and ovoviviparous reproduction. (2 marks)

44: MALE REPRODUCTIVE SYSTEM (10 MARKS)

a) Name four structures found in the human male reproductive system. (4 marks)

b) Explain the functions of the following:

i. Testes. (2 marks)

ii. Epididymis. (1 mark)

iii. Vas deferens. (1 mark)

iv. Prostate gland. (1 mark)

v. Scrotum. (1 mark)

45: FEMALE REPRODUCTIVE SYSTEM (10 MARKS)

a) Name five structures of the human female reproductive system. (5 marks)

b) Explain the functions of the following:

i. Ovaries. (1 mark)

ii. Fallopian tubes. (1 mark)

iii. Uterus. (1 mark)

iv. Cervix. (1 mark)

v. Vagina. (1 mark)

46: STRUCTURE OF GAMETES (10 MARKS)

a) Draw a well-labelled diagram of a human sperm cell. (4 marks)

b) State the functions of the following sperm structures:

i. Acrosome. (1 mark)

ii. Nucleus. (1 mark)

iii. Middle piece. (1 mark)

c) Explain three adaptations of the ovum to its functions. (3 marks)

47: GAMETOGENESIS (10 MARKS)

a) Define gametogenesis. (2 marks)

b) Describe the process of spermatogenesis. (4 marks)

c) Distinguish between spermatogenesis and oogenesis. (4 marks)

48: MENSTRUAL CYCLE (10 MARKS)

a) Define the menstrual cycle. (2 marks)

b) Name the four major phases of the menstrual cycle. (2 marks)

c) Explain the hormonal changes that occur during ovulation. (3 marks)

d) State three changes that occur in the endometrium during the menstrual cycle. (3 marks)

49: REPRODUCTIVE HORMONES (10 MARKS)

a) Name the glands responsible for producing the following hormones:

i. FSH. (1 mark)

ii. Testosterone. (1 mark)

iii. Oestrogen. (1 mark)

iv. Progesterone. (1 mark)

b) Explain the roles of the following hormones:

i. Prolactin. (1 mark)

ii. Oxytocin. (1 mark)

iii. LH. (1 mark)

iv. hCG. (1 mark)

c) State two effects of undersecretion of testosterone. (2 marks)

50: FERTILIZATION IN HUMANS (10 MARKS)

a) Define fertilization. (2 marks)

b) State the usual site of fertilization in humans. (1 mark)

c) Describe the process of fertilization in humans. (5 marks)

d) Explain the importance of preventing polyspermy. (2 marks)

51: EARLY EMBRYONIC DEVELOPMENT (10 MARKS)

a) Define implantation. (2 marks)

b) Arrange the following developmental stages in their correct sequence:

Morula, zygote, blastocyst, cleavage. (2 marks)

c) Describe the development of the blastocyst. (3 marks)

d) Explain three importance of implantation. (3 marks)

52: PREGNANCY AND PLACENTA (10 MARKS)

a) Define pregnancy. (2 marks)

b) Name the three trimesters of human pregnancy. (3 marks)

c) State three functions of the placenta. (3 marks)

d) Explain the roles of the umbilical arteries and umbilical vein. (2 marks)

53: STAGES OF PREGNANCY (10 MARKS)

a) State two developmental events that occur during the first trimester. (2 marks)

b) Explain three developmental changes that occur during the second trimester. (3 marks)

c) State three developmental changes that occur during the third trimester. (3 marks)

d) Give two reasons why the first trimester is particularly important in human development. (2 marks)

54: BIRTH IN HUMANS (10 MARKS)

a) Define parturition. (2 marks)

b) Name the three stages of childbirth. (3 marks)

c) Explain the role of oxytocin during childbirth. (2 marks)

d) Describe the events that occur during the placental stage of childbirth. (3 marks)

55: LACTATION (10 MARKS)

a) Define lactation. (2 marks)

b) Distinguish between prolactin and oxytocin in lactation. (2 marks)

c) Explain four benefits of breastfeeding to the newborn baby. (4 marks)

d) State two characteristics of colostrum. (2 marks)

56: HORMONAL IMBALANCES (10 MARKS)

a) Define hormonal imbalance. (2 marks)

b) State three effects of undersecretion of oestrogen. (3 marks)

c) State three effects of oversecretion of prolactin. (3 marks)

d) Give two possible causes of reproductive hormonal imbalance. (2 marks)

57: BIOTECHNOLOGY IN HUMAN REPRODUCTION (10 MARKS)

a) Define biotechnology in human reproduction. (2 marks)

b) Explain the process of in vitro fertilization. (4 marks)

c) State two advantages of sperm banking. (2 marks)

d) Distinguish between traditional and gestational surrogacy. (2 marks)

58: ASSISTED REPRODUCTIVE TECHNOLOGIES (10 MARKS)

a) Define artificial insemination. (2 marks)

b) Explain the role of ICSI in human reproduction. (2 marks)

c) State three advantages of reproductive biotechnology. (3 marks)

d) Identify three ethical or social issues associated with reproductive biotechnology. (3 marks)

59:

A farmer observes that tilapia fish release eggs into water while the male releases milt over the eggs. After some time, young fish emerge from the eggs.

a) Identify the type of fertilization taking place. (1 mark)

b) Explain how fertilization takes place in tilapia. (3 marks)

c) Explain three reasons why many eggs are produced during reproduction in fish. (3 marks)

d) State three environmental conditions that favour successful fertilization and development in fish. (3 marks)

60:

A couple has experienced difficulties conceiving. Medical investigations reveal that the female has blocked fallopian tubes while the male produces healthy sperm.

a) Identify an appropriate assisted reproductive technology that may help the couple. (1 mark)

b) Explain the procedure involved in the technology identified. (4 marks)

c) State three advantages of the technology. (3 marks)

d) Give two possible limitations of the procedure. (2 marks)

61:

A female learner studies the menstrual cycle and observes that ovulation usually occurs around the middle of a 28-day cycle.

a) Define ovulation. (2 marks)

b) Identify the hormone responsible for triggering ovulation. (1 mark)

c) Explain how the hormone is involved in ovulation. (3 marks)

d) Describe what happens to the corpus luteum when fertilization and implantation do not occur. (2 marks)

e) State two functions of progesterone during the menstrual cycle. (2 marks)

62.

A pregnant woman attends an antenatal clinic. The healthcare worker explains that the placenta provides nutrients and oxygen to the developing baby.

a) Explain how oxygen moves from maternal blood to foetal blood. (2 marks)

b) State the role of chorionic villi. (2 marks)

c) Explain why maternal and foetal blood do not normally mix directly. (2 marks)

d) State two substances that may cross the placenta and harm the developing foetus. (2 marks)

e) Explain the role of the umbilical vein. (2 marks)

63: HUMAN REPRODUCTIVE SYSTEM (10 MARKS)

Study a labelled diagram of the human male reproductive system.

a) Identify the reproductive organ responsible for sperm production. (1 mark)

b) Name the structure where sperm mature. (1 mark)

c) State the function of the seminal vesicles. (2 marks)

d) Identify the structure responsible for temperature regulation of the testes. (1 mark)

e) Explain the function of the vas deferens. (2 marks)

f) State three adaptations of the male reproductive system for its functions. (3 marks)

64: FEMALE REPRODUCTIVE SYSTEM (10 MARKS)

a) Identify the site of fertilization. (1 mark)

b) Name the structure that releases the ovum. (1 mark)

c) State the function of the endometrium. (2 marks)

d) Explain the role of fimbriae. (2 marks)

e) Describe two functions of the uterus. (2 marks)

f) Explain the role of the cervix during childbirth. (2 marks)

65: PLACENTA AND FOETAL DEVELOPMENT (10 MARKS)

a) Identify the temporary organ responsible for exchange between mother and foetus. (1 mark)

b) Name the structures that increase the surface area for exchange. (1 mark)

c) State two functions of the umbilical cord. (2 marks)

d) Explain two ways in which the placenta protects the developing foetus. (2 marks)

e) Describe three functions of the placenta. (3 marks)

f) State one hormone produced by the placenta. (1 mark)

66: GAMETE STRUCTURE (10 MARKS)

a) Identify the male gamete. (1 mark)

b) State the function of the acrosome. (2 marks)

c) Explain the role of mitochondria in sperm. (2 marks)

d) State two functions of the ovum's cytoplasm. (2 marks)

e) Explain the importance of the haploid chromosome number in both gametes. (3 marks)

Answer the following questions in well-organised paragraphs.

67. Discuss the reproductive processes in fish and amphibians, explaining how external fertilization occurs and the adaptations that increase its success.

68. Describe the structure and functions of the human male reproductive system.

69. Describe the structure and functions of the human female reproductive system.

70. Explain the hormonal control of the menstrual cycle, clearly showing the roles of FSH, LH, oestrogen and progesterone.

71. Discuss the process of human fertilization from sperm deposition to zygote formation.

72. Explain the stages of human embryonic development from zygote formation to implantation.

73. Discuss the development of the embryo and foetus during the three trimesters of pregnancy.

74. Describe the structure of the human placenta and explain its roles in pregnancy.

75. Explain the hormonal control and three stages of human childbirth.

76. Discuss the process of lactation and explain the importance of breastfeeding to the newborn.

77. Explain the effects of undersecretion and oversecretion of reproductive hormones in males and females.

78. Discuss the applications, advantages, limitations and ethical considerations of biotechnology in human reproduction.

KEY BIOLOGY TERMINOLOGY

Term	Meaning
Reproduction	Production of new individuals of the same species
Fertilization	Fusion of male and female gametes
External fertilization	Fusion of gametes outside the female body
Internal fertilization	Fusion of gametes inside the female reproductive tract

Gamete	A reproductive cell with a haploid chromosome number
Sperm	Male reproductive cell
Ovum	Female reproductive cell
Zygote	Diploid cell formed after fertilization
Spermatogenesis	Formation of sperm cells
Oogenesis	Formation of female gametes
Ovulation	Release of a secondary oocyte from an ovary
Menstruation	Shedding of the functional uterine lining
Implantation	Attachment and embedding of a blastocyst in the endometrium
Gestation	Period of development of an embryo and foetus inside the mother
Placenta	Temporary organ for exchange between mother and foetus
Parturition	Process of childbirth
Lactation	Production and release of breast milk
Colostrum	First milk produced around childbirth
Cryopreservation	Preservation of biological material at very low temperatures
IVF	Fertilization of eggs outside the body
ICSI	Injection of a single sperm directly into an egg
Surrogacy	Arrangement in which a woman carries a pregnancy for intended parents
Sperm banking	Collection and preservation of sperm for future use
Morula	Solid ball of cells formed during early embryonic development
Blastocyst	Hollow, fluid-filled early embryonic structure
Corpus luteum	Hormone-secreting structure formed from the ruptured ovarian follicle
Polyspermy	Entry of more than one sperm into an egg
Parturition	Expulsion of the baby from the uterus

STRAND 3.0: ANATOMY AND PHYSIOLOGY OF ANIMALS

SUBSTRAND 3.2: GROWTH AND DEVELOPMENT IN ANIMALS

3.2 GROWTH AND DEVELOPMENT IN ANIMALS

3.2.1 Introduction to Growth and Development in Animals

Animals undergo various changes throughout their lives. These changes include an increase in body size, mass, complexity and the development of specialised structures that enable them to perform different functions.

Growth and development are important biological processes that enable animals to attain maturity, reproduce and maintain their populations.

Growth refers to a permanent and irreversible increase in the size, dry mass, volume or number of cells in an organism.

Development refers to the progressive changes in the structure, form and functioning of an organism as it grows from an early stage to maturity.

Differences Between Growth and Development

Growth	Development
Involves an increase in size and mass.	Involves changes in structure and function.
Mainly involves an increase in cell number and	Involves cell differentiation and specialisation.

cell size.	
Can be measured using length, height and mass.	Observed through changes in body organisation and abilities.
May occur without major changes in body form.	May involve significant changes in body form.

Examples of growth and development in animals

1. A young goat increases in body size and mass as it grows into an adult.
2. A tadpole develops legs and lungs as it transforms into a frog.
3. A caterpillar develops into a butterfly through metamorphosis.
4. A human baby develops into an adult through gradual growth and maturation.

3.2.2 METAMORPHOSIS IN INSECTS



Meaning of Metamorphosis

Metamorphosis is the process through which an animal undergoes a series of distinct changes in body form and structure during its development from an immature stage to an adult.

In insects, metamorphosis involves changes in body organisation, feeding habits, movement and sometimes habitat.

The immature stages of insects may differ considerably from the adult stages in appearance, feeding habits and ecological roles.

Examples of insects that undergo metamorphosis include:

- Butterflies.
- Moths.
- Houseflies.
- Mosquitoes.
- Beetles.
- Grasshoppers.
- Cockroaches.

- Termites.

Types of Metamorphosis in Insects

There are two main types of metamorphosis in insects:

1. Complete metamorphosis.
2. Incomplete metamorphosis.

A. Complete Metamorphosis in Insects



Meaning of Complete Metamorphosis

Complete metamorphosis is a type of insect development in which an insect passes through four distinct developmental stages: egg, larva, pupa and adult.

The larval stage differs greatly from the adult stage in body structure, appearance, feeding habits and often habitat.

Stages of Complete Metamorphosis

1. Egg Stage

- Development begins when a female insect lays fertilised eggs.
- Eggs contain an embryo that develops into a young insect.
- The eggs are laid in suitable places where the developing embryos can survive.
- The eggs may be laid on leaves, in soil, in water or in other protected locations depending on the insect species.
- The embryo obtains nutrients from the yolk stored inside the egg.
- Under favourable conditions, the eggs hatch to release larvae.

Example: A female butterfly lays eggs on suitable host plant leaves.

2. Larval Stage

- The larva is the active feeding and growing stage of complete metamorphosis.
- It usually has a body structure that differs considerably from that of the adult.
- It feeds actively to obtain nutrients needed for rapid growth.

- It increases in size and mass through repeated moulting.
- Moulting involves shedding the old outer covering (exoskeleton) to allow the body to grow.
- The larva stores energy and nutrients that are required during the pupal stage.
- In butterflies and moths, the larva is commonly called a caterpillar.
- In houseflies, the larva is called a maggot.

Example: A caterpillar feeds on leaves and increases in size before changing into a pupa.

3. Pupal Stage

- The pupa is the stage between the larva and the adult.
- During this stage, the insect undergoes extensive internal and external structural changes.
- The larval tissues are reorganised to form adult body structures.
- Adult structures such as wings, compound eyes, legs and reproductive organs develop.
- The insect is generally inactive in terms of feeding.
- In butterflies, the pupa is called a chrysalis.
- In many moths, the pupa is enclosed in a protective silk cocoon.
- The adult insect eventually emerges from the pupal covering.

Example: A butterfly develops inside a chrysalis before emerging as an adult.

4. Adult Stage

- The adult insect emerges from the pupal stage.
- It possesses the characteristic body structures of the species.
- It develops functional wings in winged insects.
- It becomes capable of reproduction.
- Its main biological role is usually dispersal and reproduction.
- In many species, adults feed on different types of food from the larvae.
- Adult insects mate and females lay eggs to begin another generation.

Example: An adult butterfly feeds on nectar and reproduces by laying eggs.

Summary of Complete Metamorphosis

Stage	Main characteristics
Egg	Embryo develops inside the egg.
Larva	Active feeding and rapid growth.
Pupa	Extensive transformation into adult form.
Adult	Fully developed reproductive stage.

Examples of insects that undergo complete metamorphosis

1. Butterflies.
2. Moths.

3. Houseflies.
4. Mosquitoes.
5. Beetles.
6. Bees.
7. Wasps.
8. Fleas.

Advantages of Complete Metamorphosis

1. **Reduced competition for food:** Larvae and adults often feed on different food sources, reducing competition within the same species.

2. **Reduced competition for habitat:** Immature and adult stages may occupy different habitats.

3. **Specialisation of developmental stages:** The larval stage is adapted mainly for feeding and growth, while the adult stage is adapted mainly for reproduction and dispersal.

4. **Protection during development:** The pupal stage provides an opportunity for extensive body reorganisation within a protective covering.

5. **Efficient resource utilisation:** Different stages can exploit different environmental resources.

6. **Improved survival:** Different developmental stages may survive under different environmental conditions.

B. Incomplete Metamorphosis in Insects

Meaning of Incomplete Metamorphosis

Incomplete metamorphosis is a type of insect development in which an insect passes through three main developmental stages: egg, nymph and adult.

The immature stage is called a nymph.

Unlike complete metamorphosis, incomplete metamorphosis does not involve a pupal stage.

The nymph resembles the adult in general body structure but is smaller, sexually immature and usually lacks fully developed wings.

Stages of Incomplete Metamorphosis

1. Egg Stage

- Development begins when the female insect lays eggs.
- The eggs contain developing embryos.
- The embryos obtain nutrients from the yolk.
- The eggs are deposited in suitable places such as soil, plant tissues or protected surfaces.
- Under favourable conditions, the eggs hatch into nymphs.

Example: A female grasshopper lays eggs in the soil.

2. Nymph Stage

- The nymph is the immature stage of an insect undergoing incomplete metamorphosis.
- It resembles the adult in general body organisation.
- It is usually smaller than the adult.
- Its wings, where present in the adult, are either absent or represented by developing wing pads.
- It is usually sexually immature.
- It feeds actively and increases in size.
- It undergoes repeated moulting to allow body growth.
- Each period between successive moults is called an instar.
- During successive moults, the nymph becomes progressively larger and develops adult characteristics.
- After the final moult, it becomes a sexually mature adult.

Example: A young grasshopper resembles the adult grasshopper but lacks fully developed wings and reproductive organs.

3. Adult Stage

- The adult emerges after the final moult.
- It has fully developed body structures.
- Its wings are fully developed in winged species.
- Its reproductive organs become functional.
- It becomes sexually mature and capable of reproduction.
- Adults mate and females lay eggs to begin another generation.

Summary of Incomplete Metamorphosis

Stage	**Main characteristics**
Egg	Embryo develops inside the egg.
Nymph	Resembles the adult but is smaller and immature.
Adult	Fully developed and reproductively mature.

Examples of Insects That Undergo Incomplete Metamorphosis

1. Grasshoppers.
2. Cockroaches.
3. Termites.
4. Praying mantises.
5. Dragonflies.
6. Crickets.

7. Locusts.
8. Bedbugs.

Advantages of Incomplete Metamorphosis

1. **No pupal stage:** The insect does not require a separate pupal stage.
2. **Continuous feeding:** Nymphs can feed actively throughout their development.
3. **Early exploitation of resources:** Nymphs can utilise food sources before reaching adulthood.
4. **Gradual development:** Changes occur progressively through successive moults.
5. **Similarity in feeding habits:** Nymphs and adults often use similar food resources.

C. Differences Between Complete and Incomplete Metamorphosis

Complete metamorphosis	Incomplete metamorphosis
Has four developmental stages.	Has three developmental stages.
Stages are egg, larva, pupa and adult.	Stages are egg, nymph and adult.
Has a pupal stage.	Has no pupal stage.
Immature stage is called a larva.	Immature stage is called a nymph.
Larva looks very different from adult.	Nymph resembles the adult.
Larvae and adults often have different feeding habits.	Nymphs and adults often have similar feeding habits.
Body transformation is extensive during pupation.	Body changes occur gradually through moulting.
Examples include butterflies and houseflies.	Examples include grasshoppers and cockroaches.

Similarities Between Complete and Incomplete Metamorphosis

1. Both involve changes in body structure during development.
2. Both begin with an egg stage.
3. Both involve growth and development.
4. Both involve moulting in their immature stages.
5. Both eventually produce sexually mature adults.
6. Both are regulated by hormones.
7. Both ensure continuation of the insect species through reproduction.

3.2.3 ROLE OF GROWTH HORMONES IN INSECTS

Meaning of Hormones

Hormones are chemical substances produced by specialised endocrine glands or cells and transported to target tissues, where they regulate various physiological processes.

In insects, hormones regulate growth, moulting, metamorphosis, reproduction and other developmental activities.

Insect growth and metamorphosis are mainly controlled by two important hormones:

1. Ecdysone.
2. Juvenile hormone.

The hormones work together to regulate the timing and nature of moulting and metamorphosis.

A. Ecdysone (Moulting Hormone)

Meaning of Ecdysone

Ecdysone is a steroid hormone produced by the prothoracic glands in insects. It stimulates moulting and initiates the developmental changes associated with the formation of a new exoskeleton.

Functions of Ecdysone

1. **Stimulates moulting:** It initiates the process through which an insect sheds its old exoskeleton.

2. **Promotes formation of a new exoskeleton:** It stimulates processes involved in the development of a new outer covering beneath the old one.

3. **Regulates growth:** By triggering moulting, it allows insects with rigid exoskeletons to increase in body size.

4. **Promotes metamorphosis:** It participates in the developmental changes that transform larvae into pupae and pupae into adults.

5. **Controls developmental transitions:** It helps coordinate changes from one developmental stage to another.

6. **Promotes tissue changes:** It activates developmental processes involved in the reorganisation and differentiation of tissues during metamorphosis.

How Ecdysone Works

- As an insect grows, its old exoskeleton becomes restrictive.
- The insect's endocrine system releases ecdysone.
- Ecdysone stimulates the moulting process.
- A new exoskeleton develops beneath the old one.
- The old exoskeleton is shed.
- The insect expands its body before the new exoskeleton hardens.

B. Juvenile Hormone (JH)

Meaning of Juvenile Hormone

Juvenile hormone is a hormone produced by a pair of endocrine glands called the corpora allata.

It maintains juvenile characteristics during insect development and regulates the nature of the developmental changes that occur during moulting.

Functions of Juvenile Hormone

1. **Maintains juvenile characteristics:** It prevents premature transformation into the adult form.

2. **Regulates metamorphosis:** It determines whether moulting results in another immature stage or a transition to a more advanced developmental stage.

3. **Controls larval development:** High levels of juvenile hormone during larval development promote another larval stage after moulting.

4. **Regulates pupation:** A decline in juvenile hormone levels allows the larva to develop into a pupa in insects that undergo complete metamorphosis.

5. **Promotes adult development:** Very low or absent juvenile hormone during the final developmental transition allows adult characteristics to develop.

6. **Influences reproduction:** In some insects, juvenile hormone also regulates reproductive development and reproductive activities.

C. Interaction Between Ecdysone and Juvenile Hormone

The two hormones work together to control insect development.

- Ecdysone initiates moulting.
- Juvenile hormone determines the developmental nature of the moult.

The effect of ecdysone depends partly on the concentration of juvenile hormone present.

Hormonal Control of Insect Development

Ecdysone activity	Juvenile hormone level	Developmental outcome
Moulting stimulated	High	Larva moults into another larva.
Moulting stimulated	Low	Larva develops into a pupa.
Moulting stimulated	Very low or absent	Pupa develops into an adult.

Importance of Insect Growth Hormones

1. They regulate normal insect growth and development.
2. They control moulting and replacement of the exoskeleton.
3. They regulate the transition from one developmental stage to another.
4. They ensure that adult structures develop at the appropriate stage.
5. They regulate the timing of metamorphosis.
6. They contribute to reproductive development.
7. They maintain proper coordination of developmental processes.

Application of Knowledge of Insect Hormones in Agriculture

Knowledge of insect hormones is useful in controlling agricultural pests.

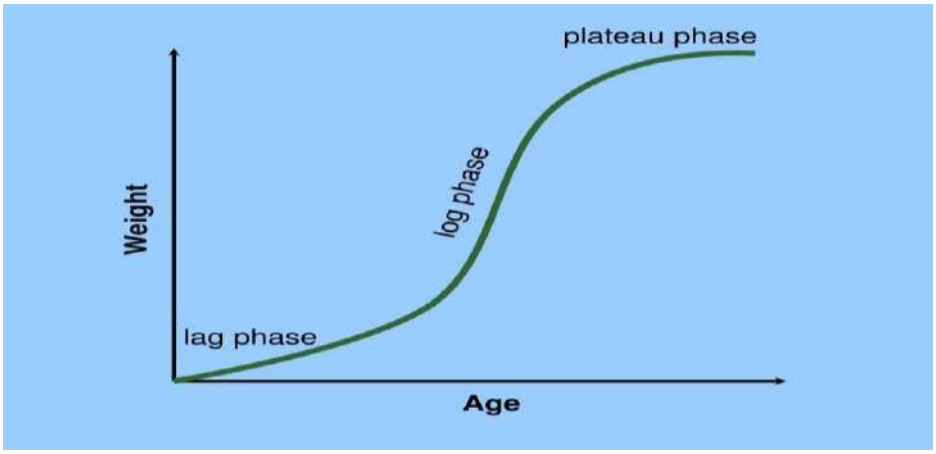
Insect growth regulators (IGRs) are substances used to interfere with normal insect growth and development.

Examples of their applications include:

- Preventing immature insects from developing into reproductive adults.
- Disrupting normal moulting.
- Interfering with the action of juvenile hormone.
- Reducing the ability of insect pests to reproduce.
- Controlling certain agricultural and public-health insect pests.

Example: Some insect growth regulators interfere with juvenile hormone activity, preventing normal development into reproductive adults.

3.2.4 GROWTH CURVES IN ANIMALS



Meaning of a Growth Curve

A growth curve is a graphical representation showing how the size, mass, length or another measurable characteristic of an organism changes over a given period.

In animals, growth curves are used to show changes in body mass, height, length or other physical measurements as an animal develops.

A growth curve is obtained by measuring an animal's growth at regular intervals and plotting the measurements against time.

Characteristics of Growth Curves

1. They show the pattern of growth over time.
2. They help identify periods of rapid and slow growth.
3. They can be used to compare the growth rates of different animals.
4. They help determine the age at which animals attain maturity.
5. They provide information about the effects of nutrition and environmental conditions on growth.

A. Sigmoid (S-shaped) Growth Curve

A sigmoid growth curve is a growth pattern in which growth begins slowly, becomes rapid and eventually slows down as the organism approaches maturity.

It is commonly associated with continuous growth in many animals.

Phases of a Sigmoid Growth Curve

1. Lag Phase

- This is the initial stage of growth.
- Growth occurs slowly.
- The organism is adapting to its environment.
- Cells are undergoing active metabolic activities.
- The increase in body size or mass is relatively small.

Example: A young mammal experiences relatively slow growth during the early stages of development.

2. Exponential or Rapid Growth Phase

- Growth occurs at a very high rate.
- There is a rapid increase in body size and mass.

- Cell division and enlargement occur actively.
- Nutrients and energy are utilised rapidly.
- The organism develops rapidly towards maturity.

Example: A young calf increases rapidly in body mass when provided with adequate food and favourable environmental conditions.

3. Decelerating Growth Phase

- The rate of growth begins to decrease.
- The animal approaches physical maturity.
- Cell division and enlargement become slower.
- The body develops towards its mature size and structure.

4. Stationary or Maturity Phase

- Growth in body size becomes very slow or almost stops.
- The animal has attained or is approaching its maximum adult size.
- Body mass may continue to fluctuate due to feeding, reproduction and changes in body reserves.
- The animal maintains its body tissues through metabolic activities.

Importance of the Sigmoid Growth Curve

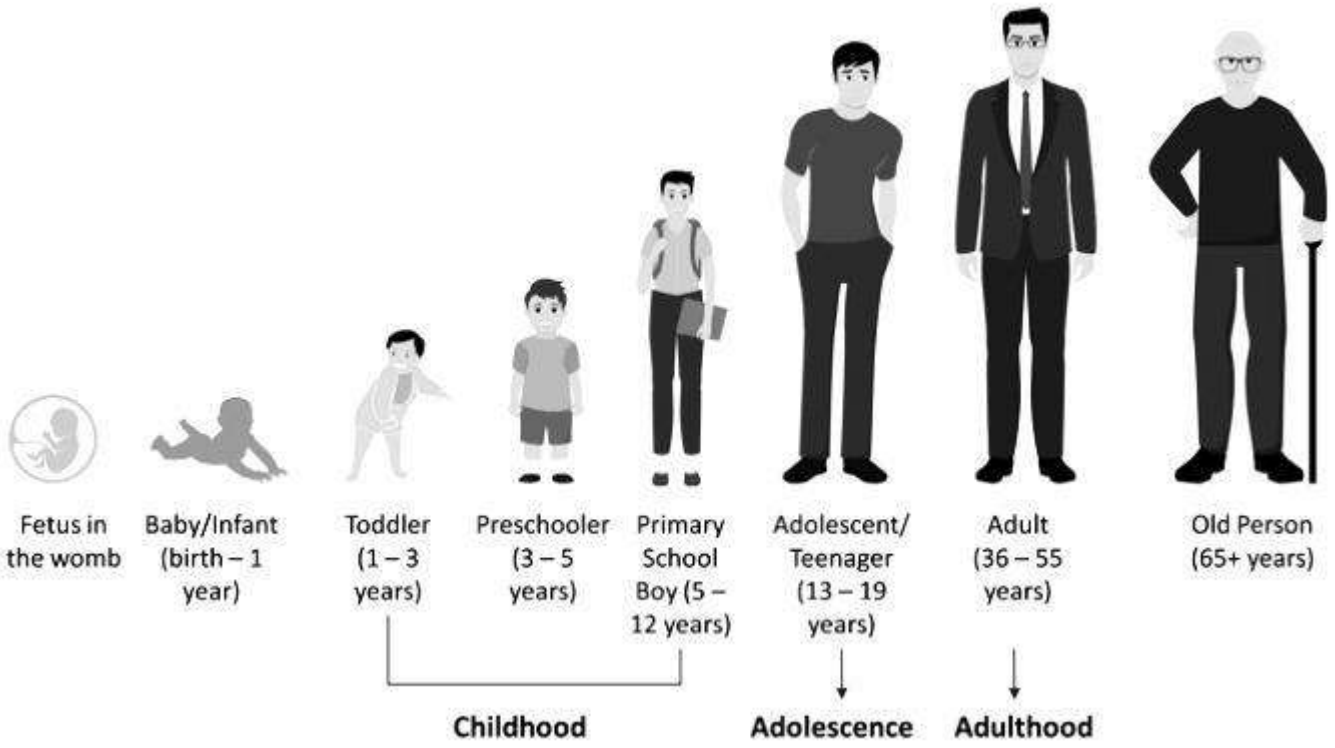
1. It helps identify different stages of animal growth.
2. It helps farmers determine appropriate feeding programmes.
3. It helps identify the age at which animals attain maturity.
4. It assists in determining the appropriate time for marketing livestock.
5. It helps assess the health and nutritional status of animals.
6. It enables comparison of growth performance among animals.

3.2.5 TYPES OF GROWTH IN ANIMALS

Animal growth can be classified into two main types based on the pattern in which growth occurs:

1. Continuous growth.
2. Intermittent growth.

A. Continuous Growth



Meaning of Continuous Growth

Continuous growth is a type of growth in which an animal increases gradually in size and mass over time without distinct periods of complete interruption caused by the shedding of a rigid exoskeleton.

It is common in vertebrates such as mammals, birds, reptiles and amphibians.

Animals with an internal skeleton can generally increase in body size as their bones and other tissues grow.

Characteristics of Continuous Growth

1. Growth occurs gradually over time.
2. There are no distinct moulting stages associated with body-size increase.
3. Body size increases through cell division and cell enlargement.
4. Bones, muscles and other tissues increase in size.
5. Growth may be rapid during certain developmental periods and slow during others.
6. Growth usually slows down when the animal approaches maturity.
7. It is common in animals with an internal skeleton.

Examples of Continuous Growth

1. Human beings.
2. Cattle.
3. Goats.
4. Sheep.
5. Dogs.
6. Cats.

7. Birds.

Factors Affecting Continuous Growth

1. Nutrition

- Adequate nutrients are necessary for proper growth.
- Proteins are required for tissue formation and repair.
- Carbohydrates and fats provide energy.
- Minerals such as calcium and phosphorus are important for bone development.
- Vitamins regulate metabolic processes.

2. Hormones

- Growth hormones stimulate body growth.
- Thyroid hormones regulate metabolism and normal development.
- Sex hormones influence growth during puberty and adolescence.

3. Genetic Factors

- Genes influence the maximum size and growth potential of an animal.
- Different breeds have different growth rates and mature body sizes.

4. Environmental Conditions

- Temperature affects metabolic activities.
- Adequate water supports physiological processes.
- Proper housing and management promote healthy growth.

5. Disease and Parasites

- Diseases interfere with normal body functioning.
- Parasites may reduce nutrient availability.
- Severe infections may reduce growth rates.

B. Intermittent Growth

Meaning of Intermittent Growth

Intermittent growth is a type of growth in which an animal increases in size in distinct stages separated by periods during which little or no increase in body size occurs.

It is commonly observed in arthropods such as insects, spiders and crustaceans.

These animals possess a rigid external skeleton called an exoskeleton, which does not expand continuously with the growth of the body.

As a result, they must shed the old exoskeleton through a process called moulting or ecdysis to allow an increase in body size.

Why Intermittent Growth Occurs in Insects

1. Insects possess a rigid exoskeleton made mainly of chitin and associated proteins.

2. The exoskeleton provides support and protection.
3. The rigid exoskeleton cannot expand continuously as the insect's internal body tissues grow.
4. The old exoskeleton eventually becomes restrictive.
5. The insect develops a new exoskeleton beneath the old one.
6. The old exoskeleton is shed during moulting.
7. The insect expands its body before the new exoskeleton hardens.
8. The insect then continues growing until the next moult.

Stages of Intermittent Growth

1. Growth between moults

- The insect feeds actively.
- Body tissues increase in size and mass.
- The exoskeleton remains relatively rigid.
- The internal body may increase in size until the old exoskeleton becomes restrictive.

2. Preparation for moulting

- Hormonal changes initiate the moulting process.
- A new exoskeleton begins developing beneath the old one.
- The insect prepares to shed the old covering.

3. Ecdysis (shedding of the old exoskeleton)

- The old exoskeleton splits at specific points.
- The insect gradually emerges from the old covering.
- The newly formed exoskeleton is initially soft and flexible.

4. Expansion of the body

- The insect takes in air or water, depending on the species.
- The body expands before the new exoskeleton hardens.
- This allows the insect to attain a larger body size.

5. Hardening of the new exoskeleton

- The new exoskeleton hardens through a process called sclerotisation.
- The insect becomes protected by its new outer covering.
- Growth in body size becomes restricted again until the next moult.

Characteristics of Intermittent Growth

1. Growth occurs in distinct stages.
2. It involves repeated moulting.
3. It is common in animals with rigid exoskeletons.
4. There are periods of rapid size increase after moulting.

5. There are periods of little or no external size increase between moults.
6. The exoskeleton is replaced during growth.
7. Growth may involve several moulting stages before maturity.

Examples of Animals That Show Intermittent Growth

- Grasshoppers.
- Cockroaches.
- Butterflies.
- Crabs.
- Lobsters.
- Spiders.
- Shrimp.

Advantages of Intermittent Growth

1. It enables animals with rigid exoskeletons to increase in body size.
2. It allows replacement of damaged or worn-out external coverings.
3. It provides opportunities for development of new body structures.
4. It allows insects to progress from one developmental stage to another.

Disadvantages of Intermittent Growth

1. Animals are vulnerable to predators during moulting.
2. The new exoskeleton is initially soft and offers limited protection.
3. Moulting requires energy.
4. Environmental stress may interfere with successful moulting.
5. Failure to moult properly may result in injury or death.

C. Differences Between Continuous and Intermittent Growth

Continuous growth	Intermittent growth
Growth occurs gradually.	Growth occurs in distinct stages.
No periodic shedding of a rigid exoskeleton is required.	Requires periodic moulting.
Common in vertebrates.	Common in arthropods.
Body size increases progressively.	Body size increases significantly after moulting.
There are no distinct moulting-related growth interruptions.	Growth in body size is restricted between moults.
Examples include cattle, goats and humans.	Examples include grasshoppers, crabs and spiders.

Comparison of Continuous and Intermittent Growth Curves

Interpretation of the graphs

- The continuous growth curve shows a gradual increase in body size over time.

- The intermittent growth curve shows periods of little or no increase in external body size followed by sudden increases after moulting.
- The step-like pattern in intermittent growth is associated with the rigid exoskeleton of arthropods.

3.2.6 IMPORTANCE OF GROWTH IN ANIMALS

Growth is an essential biological process that enables animals to increase in size, develop body structures and attain reproductive maturity.

Importance of Growth in Animals

1. Enables animals to attain maturity

- Growth allows young animals to develop into adults.
- As animals grow, their body structures and organs become more developed.
- They eventually attain physical and reproductive maturity.

2. Enables reproduction

- Growth allows animals to develop functional reproductive organs.
- Sexually mature animals can reproduce and produce offspring.
- This ensures continuity of the species.

3. Increases body size and strength

- Growth results in increased body size and muscle development.
- Larger and stronger animals may be better able to move, defend themselves and obtain food.

4. Promotes development of specialised structures

- Growth is accompanied by differentiation and development of specialised tissues and organs.
- These structures enable animals to perform different physiological functions efficiently.

5. Improves survival

- As animals grow, they may develop better defence mechanisms, improved movement and greater ability to obtain food.
- Increased body size may reduce vulnerability to some predators.

6. Enhances reproductive success

- Growth enables animals to attain the appropriate body condition for reproduction.
- Well-developed animals are generally better prepared for reproductive activities.

7. Supports adaptation to the environment

- Growth and development allow animals to develop structures and abilities suited to their environment.
- Metamorphosis enables some insects to exploit different habitats and food resources during different developmental stages.

8. Enables replacement and repair of tissues

- Growth involves cell division and the production of new cells.

- These processes support the replacement of worn-out or damaged cells and the repair of tissues.

9. Increases productivity in livestock

- Growth increases the body mass of farm animals.
- This contributes to the production of meat, milk and other animal products.
- Farmers monitor growth to assess livestock performance.

10. Promotes development of movement and coordination

- Growth supports the development of muscles, bones and the nervous system.
- This improves locomotion, coordination and other body activities.

11. Enables animals to compete effectively

- Growth may increase body size and physical strength.
- This can improve an animal's ability to compete for food, shelter, mates and other resources.

12. Supports population continuity

- Growth enables animals to reach reproductive age.
- Mature individuals produce offspring, ensuring the continuation of animal populations.

3.2.7 APPLICATION OF KNOWLEDGE OF ANIMAL GROWTH IN AGRICULTURE

Understanding animal growth and development is important in livestock production and animal management in Kenya.

1. Selection of Fast-Growing Animals

Farmers select animals with desirable growth characteristics for breeding.

Example: Selecting fast-growing broiler chickens for commercial meat production.

2. Preparation of Appropriate Feeding Programmes

- Young animals require adequate nutrients for rapid growth.
- Farmers formulate balanced rations according to the animal's age and production stage.
- This improves growth performance and productivity.

3. Determination of Market Age

- Monitoring growth helps farmers identify when animals have attained suitable market weight.
- This reduces unnecessary feeding costs.

Example: Monitoring the growth of broiler chickens to determine when they are ready for sale.

4. Monitoring Animal Health

- Sudden reductions in growth may indicate disease, parasite infestation or poor nutrition.
- Farmers can identify problems early and take corrective measures.

5. Breeding Management

- Knowledge of growth and maturity helps farmers determine appropriate breeding ages.

- Animals should attain adequate physical development before breeding.

6. Pest Control

- Knowledge of insect metamorphosis and hormonal regulation helps in selecting appropriate pest-control methods.
- Insect growth regulators can interfere with normal insect development.

3.2.8 SUMMARY OF KEY BIOLOGY TERMS

Term	Meaning
Growth	Permanent increase in size, mass or number of cells.
Development	Progressive changes in structure and function.
Metamorphosis	Transformation in body form during development.
Larva	Immature stage in complete metamorphosis.
Nymph	Immature stage in incomplete metamorphosis.
Pupa	Transitional stage between larva and adult.
Moulting	Shedding of an old exoskeleton.
Ecdysis	Actual shedding of the old exoskeleton.
Ecdysone	Hormone that stimulates moulting.
Juvenile hormone	Hormone that maintains juvenile characteristics.
Instar	Developmental period between two successive moults.
Exoskeleton	Rigid external supporting and protective covering.
Continuous growth	Gradual increase in body size over time.
Intermittent growth	Growth occurring in distinct stages separated by periods of little or no external size increase.
Growth curve	Graph showing changes in size or mass over time.
Sigmoid curve	S-shaped growth curve.
Sclerotisation	Process through which the new insect exoskeleton hardens.

REVISION QUESTIONS

SUB-STRAND 3.2: GROWTH AND DEVELOPMENT IN ANIMALS

SECTION A: MULTIPLE-CHOICE QUESTIONS

1. Which of the following best describes growth in animals?

A. A permanent increase in body size and mass.

B. A temporary increase in body temperature.

C. A change in the behaviour of an animal.

D. The removal of metabolic waste products.

2. Development in animals refers to

A. An increase in the amount of food consumed.

B. Progressive changes in an organism's structure and functions.

C. An increase in body weight only.

D. The movement of an animal from one habitat to another.

3. Which of the following is the basic unit responsible for growth in multicellular animals?

A. Tissue.

B. Organ.

C. Cell.

D. Organ system.

4. An increase in the number of cells in an animal's body is known as

A. Hypertrophy.

B. Hyperplasia.

C. Differentiation.

D. Metamorphosis.

5. An increase in the size of existing cells is referred to as

A. Hyperplasia.

B. Hypertrophy.

C. Fertilization.

D. Regeneration.

6. Which process involves the development of specialised cells from unspecialised cells?

A. Differentiation.

B. Respiration.

C. Excretion.

D. Transpiration.

7. Which of the following is NOT a major factor influencing growth and development in animals?

A. Genetic composition.

B. Availability of nutrients.

C. Hormonal regulation.

D. Colour of the surrounding soil.

8. Which nutrient is particularly important for the growth and repair of body tissues in animals?

A. Proteins.

B. Vitamins only.

C. Water only.

D. Mineral salts only.

9. Which hormone is mainly responsible for stimulating body growth in humans?

A. Insulin.

B. Growth hormone.

C. Adrenaline.

D. Thyroxine.

10. Growth hormone in humans is secreted by the

A. Thyroid gland.

B. Adrenal gland.

C. Anterior pituitary gland.

D. Pancreas.

11. Excessive secretion of growth hormone during childhood may lead to

A. Dwarfism.

B. Gigantism.

C. Diabetes insipidus.

D. Goitre.

12. Undersecretion of growth hormone during childhood may result in

A. Gigantism.

B. Acromegaly.

C. Pituitary dwarfism.

D. Hyperthyroidism.

13. Which hormone is essential for normal growth and development and is produced by the thyroid gland?

A. Thyroxine. B. Insulin.

C. Oxytocin. D. Progesterone.

14. Metamorphosis is best described as

A. A gradual increase in body mass without changes in body form.

B. A series of developmental changes in body form during the life cycle.

C. The production of gametes by reproductive organs.

D. The breakdown of complex food substances.

15. Which of the following animals undergoes complete metamorphosis?

A. Grasshopper.

B. Cockroach.

C. Butterfly.

D. Termite.

16. The correct sequence of stages in complete metamorphosis in a butterfly is

A. Egg → Nymph → Adult.

B. Egg → Larva → Pupa → Adult.

C. Egg → Pupa → Nymph → Adult.

D. Larva → Egg → Adult → Pupa.

17. Which stage of complete metamorphosis is characterised by extensive internal reorganisation of the body?

A. Egg.

B. Larva.

C. Pupa.

D. Adult.

18. In incomplete metamorphosis, the young stage that resembles the adult but lacks fully developed wings and reproductive organs is called

A. Pupa.

B. Larva.

C. Nymph.

D. Maggot.

19. Which of the following animals undergoes incomplete metamorphosis?

A. Butterfly. B. Housefly.

C. Grasshopper. D. Mosquito.

20. Which hormone promotes moulting in insects?

A. Insulin. B. Ecdysone.

C. Testosterone. D. Adrenaline.

21. The insect hormone responsible for maintaining juvenile characteristics is

A. Juvenile hormone.

B. Thyroxine.

C. Oestrogen.

D. Progesterone.

22. What is the main function of moulting in insects?

A. To increase the number of body segments.

B. To allow growth by shedding the rigid exoskeleton.

C. To facilitate internal fertilization.

D. To produce reproductive cells.

23. Which of the following best describes regeneration in animals?

A. Formation of gametes through meiosis.

B. Replacement or regrowth of lost or damaged body parts.

C. Formation of a protective external covering.

D. The conversion of food into energy.

24. Which of the following animals has a high capacity for regenerating lost body parts?

A. Planaria.

B. Domestic cat.

C. Cow.

D. Human.

25. In amphibians such as frogs, the transformation from tadpole to adult is mainly controlled by

A. Insulin.

B. Thyroxine.

C. Testosterone.

D. Adrenaline.

26. During the development of a frog, which structure disappears as the tadpole develops into an adult?

A. Hind limbs. B. Forelimbs.

C. Tail. D. Eyes.

27. Which of the following changes occurs during frog metamorphosis?

A. Development of gills into lungs and other respiratory adaptations.

B. Development of feathers.

C. Formation of an external skeleton.

D. Conversion of the body into a pupa.

28. Which of the following factors is likely to slow down growth and development in young animals?

A. Adequate nutrition.

B. Suitable environmental temperature.

C. Prolonged malnutrition.

D. Proper hormonal balance.

29. Why is growth in insects limited by the presence of a rigid exoskeleton?

A. It prevents the insect from feeding.

B. It cannot expand continuously with the growing body.

C. It prevents respiration completely.

D. It stops the production of hormones.

30. A learner observes that a young grasshopper resembles the adult but is smaller and has undeveloped wings. Which developmental process does this observation demonstrate?

A. Complete metamorphosis.

B. Incomplete metamorphosis.

C. Direct development.

D. Regeneration.

SECTION B: SHORT-ANSWER QUESTIONS

1. Define the term growth as used in biology.
2. Explain the meaning of development in animals.
3. Distinguish between growth and development.
4. Define metamorphosis.
5. State the two main types of metamorphosis in insects.
6. Name the four stages of complete metamorphosis.
7. Identify the immature stage of an insect undergoing incomplete metamorphosis.
8. State the stage that is absent in incomplete metamorphosis.
9. Give four examples of insects that undergo complete metamorphosis.
10. Give four examples of insects that undergo incomplete metamorphosis.
11. State three characteristics of the larval stage.
12. Explain the meaning of the pupal stage.
13. State three characteristics of a nymph.
14. Name the hormone responsible for stimulating moulting in insects.
15. Identify the glands that produce juvenile hormone.
16. State four functions of ecdysone in insects.
17. Explain the role of juvenile hormone in insect development.
18. What is an insect growth regulator?
19. Define a growth curve.
20. Name the phases of a sigmoid growth curve.
21. Explain the meaning of continuous growth.
22. Explain the meaning of intermittent growth.
23. State four characteristics of intermittent growth.
24. Explain why insects undergo moulting.
25. State five factors that influence growth in animals.

SECTION C: STRUCTURED QUESTIONS

1. Metamorphosis in Insects

a) Define metamorphosis. (2 marks)

b) Explain the four stages of complete metamorphosis in a butterfly. (8 marks)

c) Describe incomplete metamorphosis in a grasshopper. (5 marks)

d) Give five differences between complete and incomplete metamorphosis. (5 marks)

2. Hormonal Control of Insect Growth

a) Name the two hormones responsible for controlling insect moulting and metamorphosis. (2 marks)

b) Explain four functions of ecdysone. (4 marks)

c) Describe the role of juvenile hormone in insect development. (4 marks)

d) Explain how the interaction between ecdysone and juvenile hormone regulates metamorphosis. (4 marks)

3. Growth Curves in Animals

a) Define a growth curve. (2 marks)

b) Describe the four phases of a sigmoid growth curve. (8 marks)

c) State five ways in which growth curves are important in livestock production. (5 marks)

4. Types of Growth

a) Distinguish between continuous and intermittent growth. (4 marks)

b) Explain why insects exhibit intermittent growth. (5 marks)

c) Describe the process of moulting in insects. (6 marks)

d) State five disadvantages of intermittent growth. (5 marks)

5. Importance of Growth

a) Explain eight ways in which growth is important in animals. (8 marks)

b) Explain four ways in which knowledge of animal growth is useful to livestock farmers in Kenya. (8 marks)

6.

A learner observed a butterfly laying eggs on a green leaf. After some days, small caterpillars emerged and began feeding on the leaves. Later, the caterpillars formed protective coverings from which adult butterflies eventually emerged.

a) Identify the type of metamorphosis described. (1 mark)

b) Name the four developmental stages involved. (4 marks)

c) Explain why the caterpillar feeds actively. (2 marks)

d) Describe the changes that occur during the pupal stage. (3 marks)

7.

A farmer noticed that some insect pests were unable to develop into reproductive adults after being exposed to a particular insect growth regulator.

a) Explain what an insect growth regulator is. (2 marks)

b) Identify the hormone whose activity may be mimicked by the growth regulator. (1 mark)

c) Explain how juvenile hormone affects insect development. (3 marks)

d) State three advantages of using insect growth regulators in pest management. (3 marks)

8.

A livestock farmer recorded the body mass of a calf at regular intervals. Initially, the calf gained mass slowly. Later, its mass increased rapidly before the rate of growth gradually decreased as it approached maturity.

a) Identify the type of growth curve described. (1 mark)

b) Name the phase during which the calf gained mass rapidly. (1 mark)

c) Explain why growth becomes slower as an animal approaches maturity. (3 marks)

d) State five factors that may influence the growth rate of the calf. (5 marks)

9.

A learner observed a grasshopper shedding its outer covering. Immediately after shedding, the grasshopper appeared larger than before.

a) Name the process observed. (1 mark)

b) Explain why the grasshopper sheds its outer covering. (3 marks)

c) Describe what happens immediately after the old exoskeleton is shed. (3 marks)

d) Explain three disadvantages of moulting to the grasshopper. (3 marks)

3.2.10 PRACTICAL LEARNING ACTIVITIES

The following activities can be undertaken by learners to strengthen their understanding of animal growth and development.

Activity 1: Investigating Complete Metamorphosis

Materials:

- Pictures of butterfly developmental stages.
- Biology textbooks.
- Charts.

Procedure:

1. Observe pictures showing the developmental stages of a butterfly.
2. Identify each developmental stage.

3. Arrange the stages in their correct sequence.
4. Discuss the changes that occur at each stage.
5. Draw and label the butterfly life cycle.

Expected learning outcome: Ability to explain complete metamorphosis and identify its developmental stages.

Activity 2: Comparing Complete and Incomplete Metamorphosis

Materials:

- Pictures of butterflies.
- Pictures of grasshoppers.
- Charts or digital learning resources.

Procedure:

1. Observe the life cycle of a butterfly.
2. Observe the life cycle of a grasshopper.
3. Identify similarities and differences.
4. Discuss why the grasshopper does not have a pupal stage.
5. Prepare a comparison table.

Expected learning outcome: Ability to distinguish between complete and incomplete metamorphosis.

Activity 3: Investigating Growth Curves

Materials:

- Animal growth records.
- Graph paper.
- Ruler.
- Pencil.

Procedure:

1. Obtain body mass records of a growing animal.
2. Record the age of the animal against its body mass.
3. Plot age on the horizontal axis.
4. Plot body mass on the vertical axis.
5. Join the plotted points using a smooth curve.
6. Identify periods of slow and rapid growth.
7. Explain the growth pattern observed.

Expected learning outcome: Ability to construct and interpret animal growth curves.

Activity 4: Investigating Intermittent Growth

Materials:

- Pictures of grasshopper moulting.
- Pictures of crab moulting.
- Biology textbooks.

Procedure:

1. Observe the pictures showing moulting.
2. Identify the old exoskeleton.
3. Identify the newly emerged animal.
4. Discuss why moulting is necessary.
5. Explain why animals with rigid exoskeletons cannot grow continuously in external body size.

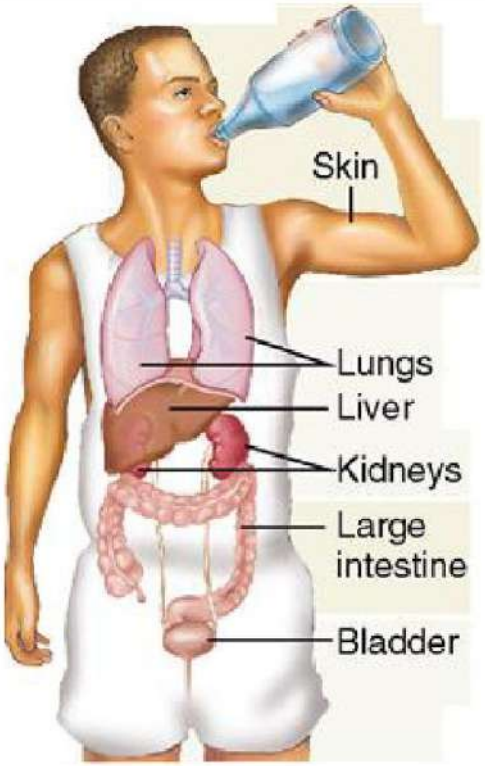
Expected learning outcome: Ability to explain intermittent growth and the importance of moulting.

KEY TAKEAWAYS

1. Growth involves a permanent increase in the size and mass of an animal.
2. Development involves progressive structural and functional changes.
3. Metamorphosis is the transformation of an animal during development.
4. Complete metamorphosis involves egg, larva, pupa and adult stages.
5. Incomplete metamorphosis involves egg, nymph and adult stages.
6. Ecdysone stimulates moulting.
7. Juvenile hormone maintains juvenile characteristics and regulates metamorphosis.
8. A sigmoid growth curve shows slow, rapid and declining growth.
9. Continuous growth occurs gradually, while intermittent growth occurs in distinct stages.
10. Growth enables animals to attain maturity, reproduce and survive.

STRAND 3.0: ANATOMY AND PHYSIOLOGY OF ANIMALS

SUBSTRAND 3.3: EXCRETION AND HOMEOSTASIS IN ANIMALS



SYSTEM	ORGAN	EXCRETION
Urinary	Kidney	Nitrogen compounds Toxins Water Electrolytes
Integumentary	Skin-sweat glands	Nitrogen compounds Electrolytes Water
Respiratory	Lung	Carbon dioxide Water
Digestive	Intestine	Digestive wastes Bile pigments Salts of heavy metals

3.3.1 INTRODUCTION TO EXCRETION

Meaning of Excretion

Excretion is the biological process through which living organisms eliminate metabolic waste products and excess substances from their bodies.

Metabolic waste products are substances formed during chemical reactions that take place within living cells.

These waste products must be removed because their accumulation may interfere with normal body functioning and become toxic to cells.

Examples of metabolic waste products include:

Carbon dioxide: Produced during cellular respiration and eliminated mainly through the lungs.

Urea: Produced in the liver during the breakdown of excess amino acids and eliminated mainly through the kidneys.

Ammonia: Produced during protein metabolism and eliminated by many aquatic animals.

Uric acid: A nitrogenous waste product eliminated by birds, reptiles and insects.

Excess water: Removed through urine, sweat and other routes.

Excess mineral salts: Eliminated through urine, sweat and specialised excretory structures.

Bile pigments: Such as bilirubin, formed during the breakdown of haemoglobin and eliminated through bile.

Importance of Excretion in Animals

Excretion is important because it:

1. **Prevents accumulation of toxic substances:** Removes harmful metabolic waste products that could damage cells and tissues.

2. **Maintains water balance:** Eliminates excess water and helps prevent excessive accumulation of water in body tissues.

3. **Regulates mineral salt concentration:** Maintains appropriate concentrations of ions such as sodium, potassium and chloride in body fluids.

4. **Maintains blood pH:** Helps regulate the acid-base balance by eliminating excess hydrogen ions and conserving bicarbonate ions.

5. **Maintains a stable internal environment:** Helps maintain suitable conditions for normal cellular activities.

6. **Prevents poisoning of body cells:** Removes harmful nitrogenous wastes such as ammonia.

7. **Supports normal enzyme functioning:** Maintains suitable chemical conditions for enzymes to function effectively.

8. **Maintains osmotic balance:** Regulates the concentration of dissolved substances in body fluids.

9. **Supports normal organ functioning:** Prevents disturbances that could interfere with the functioning of the kidneys, brain, heart and other organs.

10. **Maintains homeostasis:** Works together with other physiological processes to keep internal body conditions relatively constant.

Difference Between Excretion and Egestion

These two processes should not be confused.

Excretion	Egestion
Removal of metabolic waste products from the body.	Removal of undigested and unabsorbed food materials from the alimentary canal.
Involves organs such as kidneys, lungs, skin and liver.	Mainly involves the large intestine and anus.
Removes substances such as urea and carbon dioxide.	Removes faeces.
Waste products are formed through metabolic activities.	Materials are mainly derived from food that was not digested or absorbed.

3.3.2 EXCRETORY ORGANS IN ANIMALS

Different animals possess different excretory structures depending on their habitats, body organisation and methods of regulating water and salt balance.

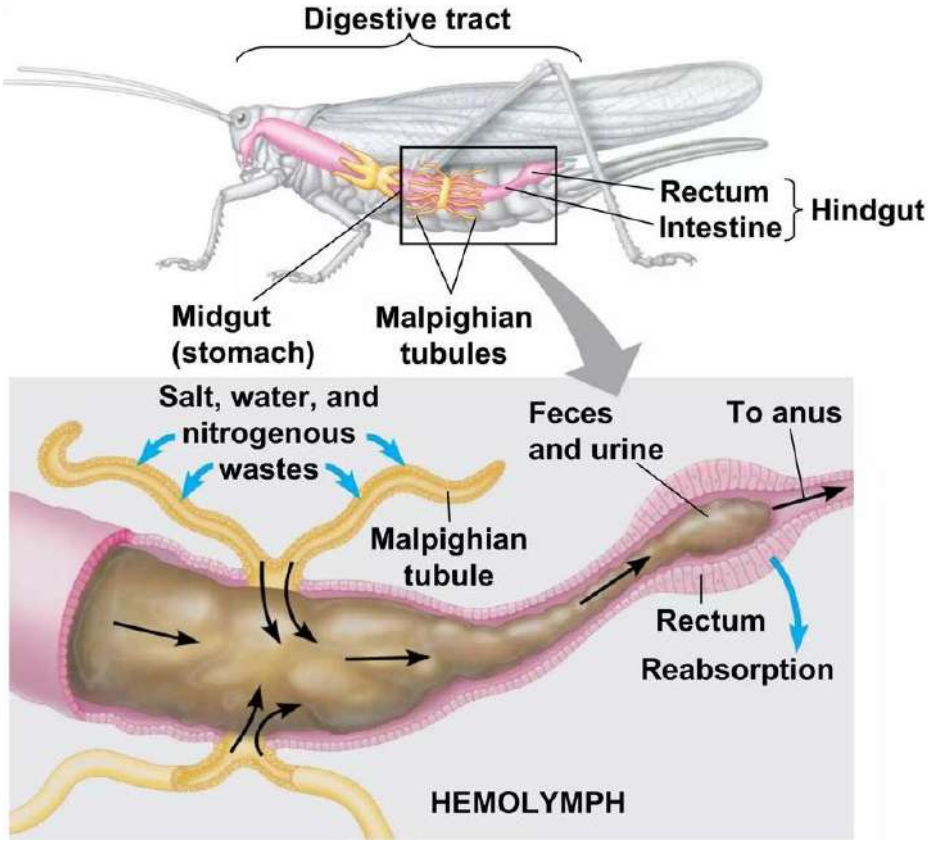
Some animals have specialised excretory organs, while others eliminate wastes through general body surfaces.

A. EXCRETION IN INSECTS

Insects possess specialised excretory structures called **Malpighian tubules**.

These are slender, elongated, blind-ended tubes that are attached to the alimentary canal at the junction between the midgut and hindgut.

They remove nitrogenous wastes from the haemolymph and help regulate water and mineral salt balance.



Structure of Malpighian Tubules

The Malpighian tubules have the following structural features:

They are numerous, thin and elongated tubular structures.

They are blind-ended at one end.

Their free ends lie within the haemolymph in the body cavity.

Their other ends open into the alimentary canal at the junction of the midgut and hindgut.

Their walls consist of a single layer of specialised epithelial cells.

They are surrounded by haemolymph, which supplies them with metabolic waste products.

Their epithelial cells possess transport mechanisms that move ions and other substances into the tubules.

Functions of Malpighian Tubules

1. **Removal of nitrogenous wastes:** They absorb nitrogenous waste products from the haemolymph and transfer them into the tubules for elimination.

2. **Osmoregulation:** They regulate the concentration of water and dissolved salts in the insect's body fluids.

3. **Removal of excess salts:** They help eliminate excess mineral ions from the haemolymph.

4. **Water conservation:** They work together with the hindgut and rectum to conserve water.

5. **Maintenance of internal balance:** They help maintain suitable concentrations of ions and other substances in the haemolymph.

6. **Elimination of harmful substances:** They assist in removing certain unwanted substances from body fluids.

Process of Excretion in Insects

Excretion in insects occurs through the following stages:

Nitrogenous wastes and other dissolved substances are present in the haemolymph.

The Malpighian tubules take up potassium ions, sodium ions and other waste substances from the haemolymph.

Water follows the ions into the tubules through osmosis.

Nitrogenous waste products, mainly in the form of uric acid or urate salts, enter the tubules.

The fluid containing wastes moves towards the hindgut.

As the fluid passes through the hindgut and rectum, most of the water and useful salts are reabsorbed into the haemolymph.

Uric acid and other undigested materials are eliminated together with faecal matter through the anus.

Nitrogenous Excretory Product in Insects

Most terrestrial insects eliminate nitrogenous wastes mainly as **uric acid**.

Importance of Uric Acid in Insects

It is relatively non-toxic and can be stored temporarily without causing serious harm.

It requires very little water for elimination.

It can be eliminated in a semi-solid or solid form.

It enables insects to conserve water in dry environments.

It reduces the amount of water lost during excretion.

It is suitable for insects living in terrestrial habitats where water may be limited.

Examples of insects: Grasshoppers, cockroaches, houseflies, mosquitoes, butterflies and beetles.

B. EXCRETION IN BIRDS

Birds possess specialised excretory organs that enable them to remove nitrogenous wastes while conserving water.

The main excretory organs in birds include:

Kidneys.

Ureters.

Cloaca.

1. Kidneys

Birds possess a pair of kidneys located in the posterior region of the abdominal cavity.

The kidneys contain numerous nephrons that filter blood and regulate water and salt balance.

They remove nitrogenous wastes from the blood.

They produce urine containing mainly uric acid and other dissolved substances.

2. Ureters

These are narrow tubes that transport urine from the kidneys to the cloaca.

They allow the movement of urinary wastes towards the exit of the digestive and urinary tracts.

3. Cloaca

The cloaca is a common chamber through which the digestive, urinary and reproductive systems open.

Urinary wastes from the ureters enter the cloaca.

The wastes are eliminated through the cloacal opening.

Main Nitrogenous Excretory Product in Birds

Birds are mainly **uricotelic animals** because they eliminate nitrogenous wastes predominantly in the form of uric acid.

Uric acid is usually eliminated as a whitish semi-solid paste together with faecal material.

Why Birds Excrete Uric Acid

1. **Conservation of water:** Uric acid requires very little water for elimination.

2. **Reduced body weight:** Birds do not need to carry large quantities of liquid urine in a urinary bladder, reducing the weight they carry during flight.

3. **Low toxicity:** Uric acid is less toxic than ammonia and can be temporarily stored in the body.

4. **Adaptation to terrestrial environments:** It enables birds to survive in environments where water availability may be limited.

5. **Protection of developing embryos:** In birds, uric acid accumulates inside the egg without reaching toxic concentrations easily, making it suitable for embryonic development.

Adaptations of Birds to Excretion

They possess efficient kidneys for filtering blood.

Their nephrons help regulate water and mineral salt balance.

They eliminate nitrogenous wastes mainly as uric acid.

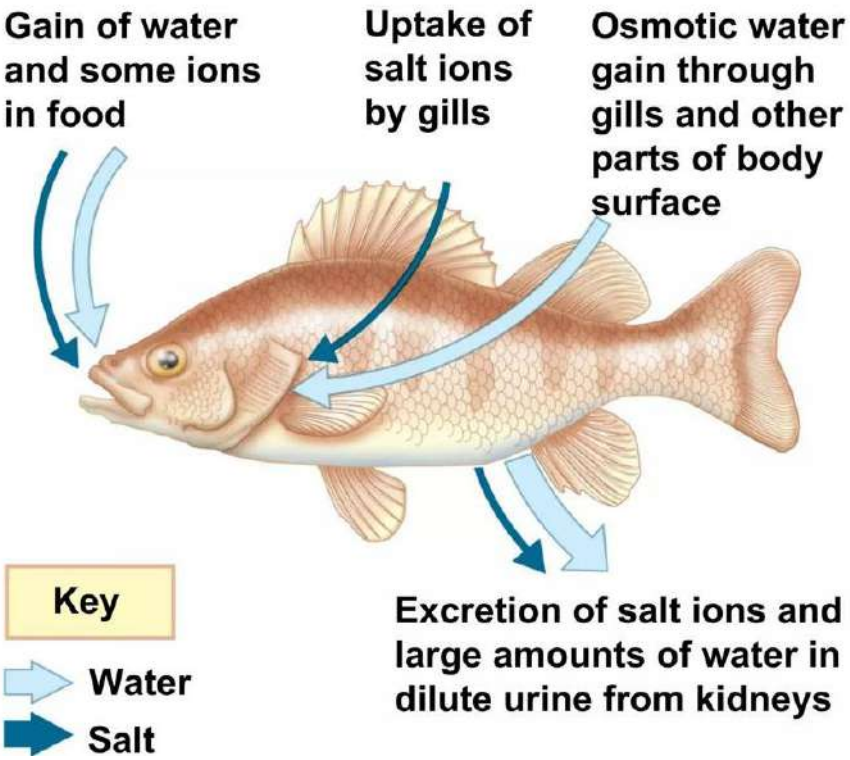
Their urinary system conserves water.

Their cloaca provides a common exit for urinary and digestive wastes.

They generally lack a urinary bladder, reducing unnecessary weight.

C. EXCRETION IN FRESHWATER FISH

(b) Osmoregulation in a freshwater fish



Freshwater fish live in environments where the surrounding water has a lower concentration of dissolved salts than their body fluids.

As a result, water continuously enters their bodies through osmosis, mainly across the gills and other permeable body surfaces.

At the same time, dissolved salts tend to diffuse out of their bodies into the surrounding water.

Main Excretory Structures in Freshwater Fish

Kidneys: Filter blood and produce large quantities of dilute urine.

Gills: Remove ammonia and assist in regulating salt balance.

Skin: Allows limited exchange of water and dissolved substances.

Intestine: Participates in water and ion absorption.

Excretory Product in Freshwater Fish

Most freshwater bony fish are ammonotelic because they eliminate nitrogenous wastes mainly as ammonia.

Ammonia is highly toxic but can be eliminated safely when sufficient water is available.

Osmoregulatory Adaptations of Freshwater Fish

1. **Production of large quantities of dilute urine:** Their kidneys eliminate excess water without losing excessive amounts of mineral salts.

2. **Active absorption of salts through the gills:** Specialised cells in the gills absorb sodium and chloride ions from the surrounding water.

3. **Reduced drinking of water:** They rarely drink water because water enters their bodies continuously through osmosis.

4. **Efficient kidney functioning:** Their kidneys help regulate the concentration of salts and water in body fluids.

5. **Ammonia elimination through gills:** They eliminate much of their ammonia directly through the gills by diffusion.

Why Freshwater Fish Produce Large Quantities of Dilute Urine

Their body fluids are more concentrated than the surrounding freshwater.

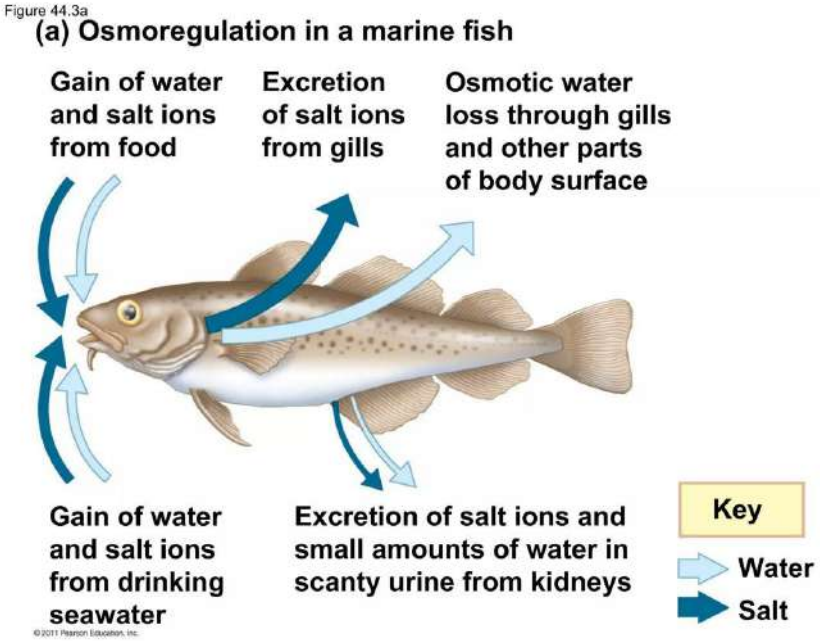
Water enters their bodies through osmosis.

Excess water accumulates in body fluids.

Their kidneys remove the excess water.

The urine produced is dilute because useful salts are conserved.

D. EXCRETION IN MARINE FISH



Marine bony fish live in seawater, which has a higher concentration of dissolved salts than their body fluids.

As a result, they continuously lose water through osmosis and gain excess salts from their surroundings.

They possess specialised adaptations that enable them to maintain water and salt balance.

Main Excretory Structures

Kidneys.

Gills.

Intestine.

Skin.

Excretory Products in Marine Fish

Most marine bony fish eliminate nitrogenous wastes mainly as ammonia.

Excess salts are eliminated mainly through specialised cells in the gills and, to some extent, through the kidneys.

Osmoregulatory Adaptations of Marine Bony Fish

1. **Drinking seawater:** They drink seawater to replace water lost through osmosis.

2. **Salt elimination through gills:** Specialised chloride cells in the gills actively transport excess sodium and chloride ions out of the body.

3. **Production of small quantities of urine:** Their kidneys conserve water by producing relatively small amounts of urine.

4. **Efficient kidney functioning:** Their kidneys regulate the concentration of certain dissolved substances in the blood.

5. **Intestinal water absorption:** Water is absorbed from the seawater consumed through the intestine.

6. **Ammonia elimination:** Ammonia diffuses out of the blood through the gills into the surrounding seawater.

Differences Between Freshwater and Marine Bony Fish

Freshwater fish	**Marine bony fish**
Live in water with a lower salt concentration than their body fluids.	Live in water with a higher salt concentration than their body fluids.
Gain water through osmosis.	Lose water through osmosis.
Lose salts through diffusion.	Gain excess salts from seawater.
Rarely drink water.	Drink seawater.
Produce large quantities of dilute urine.	Produce small quantities of urine.
Actively absorb salts through their gills.	Actively eliminate excess salts through their gills.
Conserve salts.	Conserve water.

3.3.3 COMPARISON OF NITROGENOUS EXCRETORY PRODUCTS IN ANIMALS

Animals eliminate nitrogenous waste products in different forms depending on their habitats, water availability and physiological adaptations.

The three major nitrogenous excretory products are ammonia, urea and uric acid.

A. Ammonia

Ammonia is a highly toxic nitrogenous waste product formed during the metabolism of proteins and amino acids.

Characteristics of Ammonia

- It is highly soluble in water.
- It is highly toxic to body cells.
- It requires large quantities of water for elimination.
- It is easily transported in solution.
- It must be removed quickly to prevent toxic accumulation.

Animals that eliminate ammonia

Most freshwater bony fish.

Many aquatic invertebrates.

Larval amphibians.

Some other aquatic animals.

Such animals are described as **ammonotelic animals**.

B. Urea

Urea is a nitrogenous waste product formed mainly in the liver through the urea cycle.

It is produced when ammonia, which is highly toxic, is converted into a less toxic substance.

Characteristics of Urea

It is less toxic than ammonia.

It is soluble in water.

It requires less water for elimination than ammonia.

It is transported in the blood to the kidneys.

It is eliminated mainly through urine.

It can be stored temporarily in body fluids without causing severe toxicity at normal concentrations.

Animals that eliminate urea

Mammals, including humans.

Adult amphibians.

Sharks and many other cartilaginous fish.

Such animals are described as **ureotelic animals**.

C. Uric Acid

Uric acid is a nitrogenous waste product that is relatively insoluble in water and can be eliminated in a semi-solid or solid form.

Characteristics of Uric Acid

It is relatively non-toxic compared with ammonia.

It requires very little water for elimination.

It is poorly soluble in water.

It can be eliminated as a semi-solid paste.

It is suitable for animals living in dry environments.

It enables developing embryos to store nitrogenous wastes safely inside eggs.

Animals that eliminate uric acid

Birds.

Reptiles.

Most terrestrial insects.

Some land snails.

Such animals are described as **uricotelic animals**.

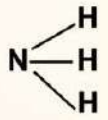
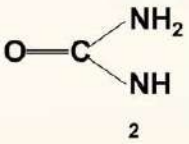
Comparison of the Three Nitrogenous Excretory Products

Feature	Ammonia	Urea	Uric acid
Toxicity	Highly toxic	Less toxic	Relatively low toxicity
Solubility	Highly soluble	Soluble	Poorly soluble
Water required	Very high	Moderate	Very little
Form eliminated	Dissolved in water	Dissolved in urine	Semi-solid or solid
Energy requirement for synthesis	Low	Moderate	Relatively high
Common animals	Aquatic animals	Mammals and adult amphibians	Birds, reptiles and insects

Types of Animals Based on Nitrogenous Excretion

Type	Main waste product	Examples
Ammonotelic	Ammonia	Most bony fish
Ureotelic	Urea	Mammals, adult amphibians
Uricotelic	Uric acid	Birds, reptiles, insects

The use of these three forms of nitrogenous wastes follows a pattern in animals

AMMONIA	UREA	URIC ACID
NH_3	$CO(NH_2)_2$	$C_5H_4O_3N_4$
		
Highly toxic	Moderately toxic	Not very toxic
Highly soluble	Moderately soluble	Insoluble
Excreted mainly by aquatic invertebrates, osteichthyes (bony fish) and tadpoles	Excreted by chondricthyes (sharks and rays), terrestrial amphibians and mammals	Excreted by insects, most reptiles and all birds



3.3.4 INTERNAL STRUCTURE OF THE MAMMALIAN KIDNEY



Meaning of a Kidney

A kidney is a bean-shaped excretory organ responsible for filtering blood, removing metabolic wastes and regulating water, mineral salts and acid-base balance in mammals.

Humans possess two kidneys located towards the back of the abdominal cavity, one on either side of the vertebral column.

The kidneys play an important role in maintaining homeostasis.

External Structure of the Kidney

The mammalian kidney has the following external features:

1. **Renal capsule:** A tough fibrous covering that protects the kidney against mechanical injury and infection.

2. **Renal artery:** A blood vessel that carries oxygenated blood containing metabolic wastes from the aorta into the kidney.

3. **Renal vein:** A blood vessel that carries filtered blood away from the kidney into the inferior vena cava.

4. **Ureter:** A muscular tube that transports urine from the kidney to the urinary bladder.

5. **Hilum:** An indentation on the medial side of the kidney through which the renal artery, renal vein, nerves and ureter pass.

Internal Structure of the Kidney

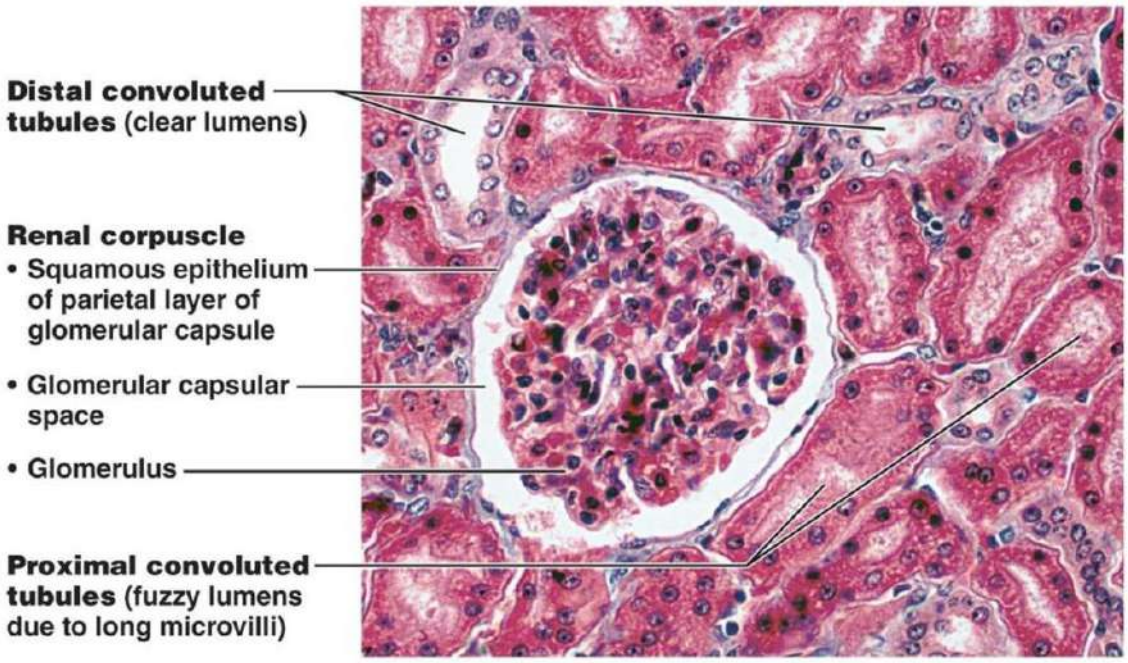
When the kidney is cut longitudinally, three main internal regions can be observed:

Renal cortex.

Renal medulla.

Renal pelvis.

A. RENAL CORTEX



The renal cortex is the outer, dark reddish-brown region of the kidney located immediately beneath the renal capsule.

It contains numerous renal corpuscles and convoluted tubules.

Structures Found in the Renal Cortex

1. **Glomeruli:** Networks of capillaries where ultrafiltration of blood takes place.

2. **Bowman's capsules:** Cup-shaped structures that surround the glomeruli and collect glomerular filtrate.

3. **Proximal convoluted tubules:** Tubular structures where most selective reabsorption takes place.

4. **Distal convoluted tubules:** Structures involved in regulating mineral salts, water and pH.

5. **Blood capillaries:** Supply blood to the nephrons and receive reabsorbed substances.

Functions of the Renal Cortex

1. **Ultrafiltration:** Contains glomeruli where blood is filtered under pressure to form glomerular filtrate.

2. **Selective reabsorption:** Contains proximal convoluted tubules where useful substances such as glucose, amino acids, mineral salts and water are reabsorbed.

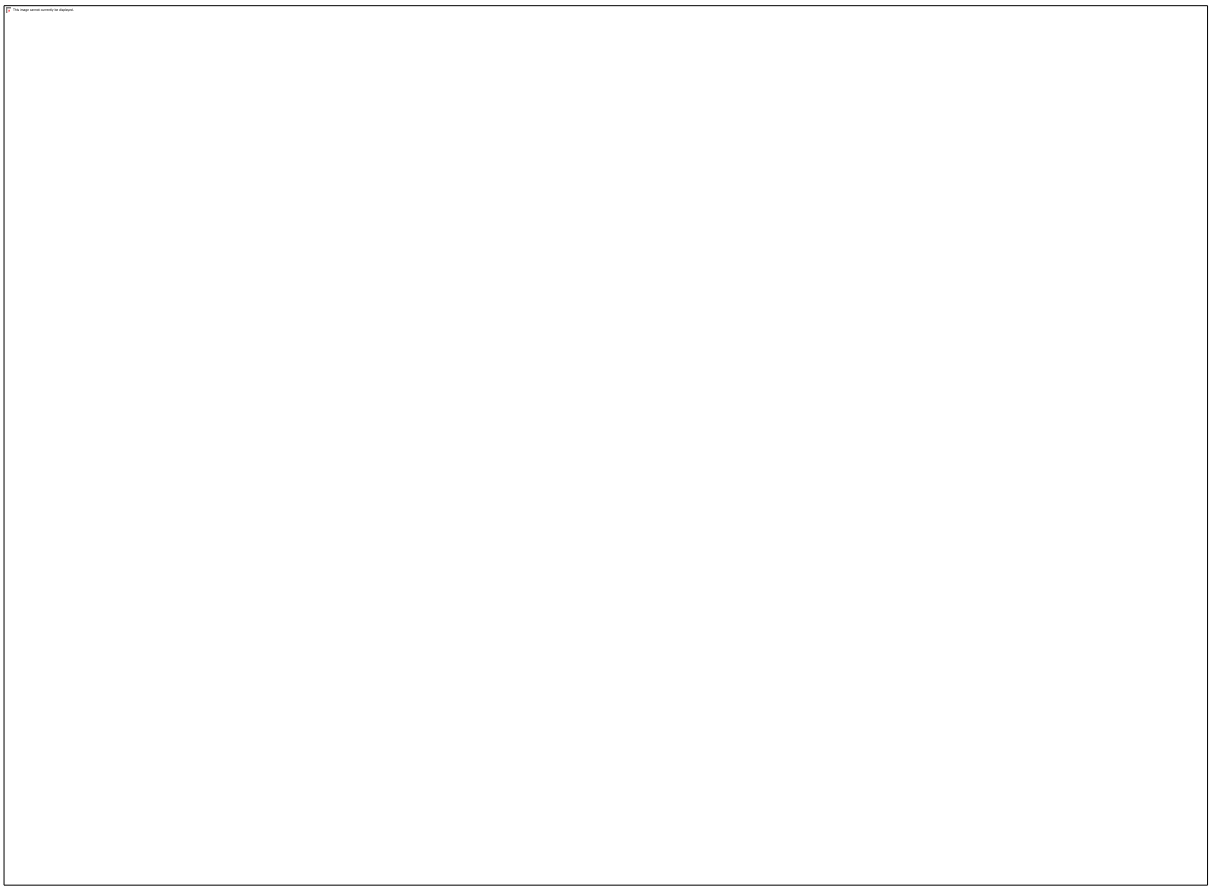
3. **Tubular secretion:** Contains parts of the nephron involved in transferring certain substances from the blood into the renal tubules.

4. **Regulation of blood composition:** Helps regulate the concentration of dissolved substances in blood.

5. **Regulation of pH:** Participates in the regulation of blood acidity through the handling of hydrogen and bicarbonate ions.

6. **Formation of urine:** Contains structures that participate in the initial stages of urine formation.

B. RENAL MEDULLA



The renal medulla is the inner region of the kidney located beneath the cortex.

It is usually lighter in colour and consists of cone-shaped structures called renal pyramids.

Structures Found in the Renal Medulla

1. **Renal pyramids:** Cone-shaped structures containing collecting ducts and loops of Henle.

2. **Loops of Henle:** U-shaped portions of nephrons involved in establishing the concentration gradient required for urine concentration.

3. **Collecting ducts:** Tubes that collect urine from several nephrons and transport it towards the renal papillae.

4. **Vasa recta:** Specialised blood capillaries that run alongside the loops of Henle in the medulla of juxtamedullary nephrons.

5. **Renal papillae:** Tips of the renal pyramids through which urine drains into the minor calyces.

Functions of the Renal Medulla

1. **Concentration of urine:** Establishes an osmotic gradient that enables the kidneys to produce concentrated urine.

2. **Water reabsorption:** Allows water to move from collecting ducts into surrounding tissues, especially under the influence of ADH.

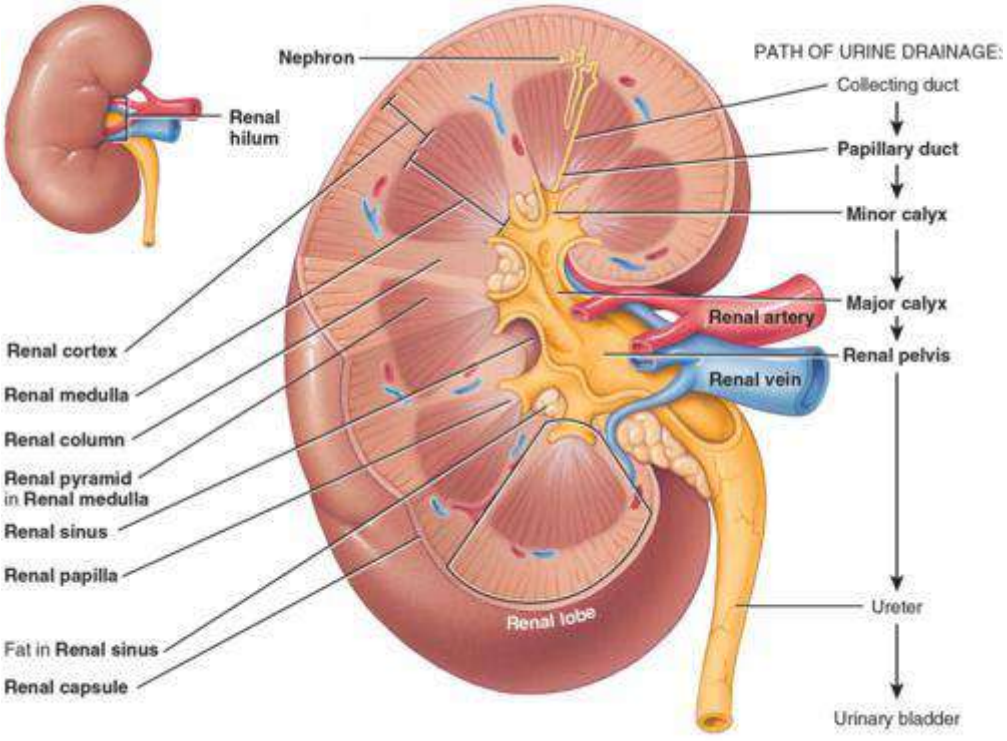
3. **Salt regulation:** Participates in the movement and regulation of sodium and chloride ions.

4. **Formation of concentrated urine:** The loops of Henle establish a concentration gradient that helps conserve water.

5. **Transport of urine:** Collecting ducts carry urine towards the renal papillae.

6. **Maintenance of osmotic balance:** Helps regulate the concentration of body fluids by controlling water and solute movement.

C. RENAL PELVIS



(a) Anterior view of dissection of right kidney

The renal pelvis is a funnel-shaped cavity located in the central part of the kidney.

It receives urine from the major calyces and directs it into the ureter.

Functions of the Renal Pelvis

Collects urine from the renal calyces.

Channels urine towards the ureter.

Provides a temporary space for urine collection before it enters the ureter.

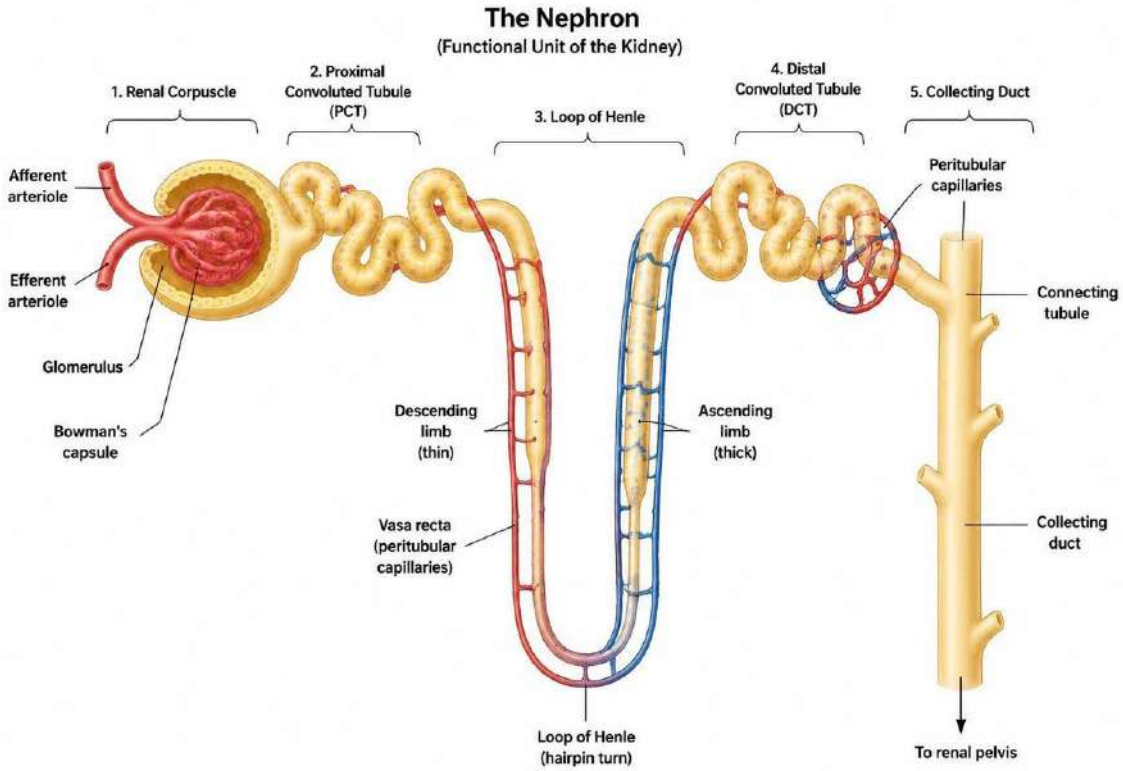
Helps direct urine out of the kidney.

Connects the kidney to the urinary drainage system.

Summary of the Main Internal Regions of the Kidney

Region	Location	Main functions
Renal cortex	Outer region	Ultrafiltration and selective reabsorption
Renal medulla	Inner region	Concentration of urine and water conservation
Renal pelvis	Central cavity	Collection and drainage of urine

3.3.5 STRUCTURE AND FUNCTIONS OF THE NEPHRON



Meaning of a Nephron

A nephron is the structural and functional unit of the mammalian kidney responsible for filtering blood, reabsorbing useful substances, secreting additional wastes and forming urine.

Each human kidney contains approximately one million nephrons.

Nephrons are responsible for maintaining the chemical composition and water balance of blood.

Main Parts of a Nephron

A typical nephron consists of:

- Bowman's capsule.
- Glomerulus.
- Proximal convoluted tubule.
- Loop of Henle.
- Distal convoluted tubule.
- Collecting duct.

The nephron is also associated with blood vessels that supply and drain the renal tissues.

A. BOWMAN'S CAPSULE

Bowman's capsule is a cup-shaped, double-walled structure located in the renal cortex.

It surrounds the glomerulus and collects the fluid filtered from blood.

Structure of Bowman's Capsule

It has an outer parietal layer consisting of simple squamous epithelial cells.

Its inner visceral layer consists of specialised cells called podocytes.

Podocytes possess finger-like extensions called foot processes.

Filtration slits occur between the foot processes.

The space between the two layers is called the capsular space.

The capsular space receives glomerular filtrate.

Functions of Bowman's Capsule

Surrounds and protects the glomerulus.

Receives glomerular filtrate.

Directs filtrate into the proximal convoluted tubule.

Forms part of the filtration barrier through its podocytes.

Prevents large blood components from entering the filtrate under normal conditions.

B. GLOMERULUS

The glomerulus is a network of numerous tiny blood capillaries found inside Bowman's capsule.

It receives blood through the afferent arteriole and drains blood through the efferent arteriole.

Adaptations of the Glomerulus to Its Functions

1. **Numerous capillaries:** Provide a large surface area for filtration.

2. **Thin capillary walls:** Consist of a single layer of endothelial cells, allowing water and small dissolved substances to pass through.

3. **Fenestrated endothelium:** Contains tiny pores that facilitate filtration while retaining blood cells.

4. **High blood pressure:** The afferent arteriole is generally wider than the efferent arteriole, helping maintain high hydrostatic pressure in the glomerulus.

5. **Close association with Bowman's capsule:** Allows filtered substances to enter the capsular space efficiently.

Functions of the Glomerulus

Filters blood under pressure.

Allows water and small dissolved substances to pass into Bowman's capsule.

Retains blood cells and most plasma proteins in the bloodstream.

Initiates urine formation through ultrafiltration.

C. PROXIMAL CONVOLUTED TUBULE (PCT)

The proximal convoluted tubule is a highly coiled section of the nephron located in the renal cortex immediately after Bowman's capsule.

It is the main site of selective reabsorption.

Structural Adaptations of the PCT

1. **Numerous microvilli:** Increase the surface area available for reabsorption.

2. **Numerous mitochondria:** Provide ATP required for active transport of substances.

3. **Thin epithelial walls:** Allow rapid movement of substances between the tubule and surrounding blood capillaries.

4. **Highly coiled structure:** Provides a large surface area and sufficient time for reabsorption.

5. **Numerous surrounding blood capillaries:** Receive substances reabsorbed from the filtrate.

Functions of the PCT

Reabsorbs all or nearly all glucose under normal conditions.

Reabsorbs amino acids.

Reabsorbs most filtered sodium and chloride ions.

Reabsorbs a large proportion of filtered water.

Reabsorbs bicarbonate ions.

Reabsorbs other useful substances such as phosphate.

Secretes hydrogen ions and certain unwanted substances into the filtrate.

Helps regulate the acid-base balance of blood.

D. LOOP OF HENLE



The loop of Henle is a U-shaped section of the nephron that extends from the renal cortex into the renal medulla and then returns towards the cortex.

It consists of:

Descending limb.

Ascending limb.

1. Descending Limb

The descending limb extends downwards into the renal medulla.

Structural and Functional Features

It is highly permeable to water.

Water moves out of the tubule through osmosis into the surrounding medullary tissues.

The filtrate becomes increasingly concentrated as it moves downwards.

The thin descending section has a relatively simple epithelial lining.

Functions

Reabsorbs water from the filtrate.

Increases the concentration of filtrate.

Helps maintain the osmotic gradient in the renal medulla.

Contributes to the formation of concentrated urine.

2. Ascending Limb

The ascending limb moves upwards from the medulla towards the cortex.

Structural and Functional Features

It is relatively impermeable to water.

Sodium and chloride ions move out of the filtrate.

The thick ascending limb uses active transport to move salts out of the tubule.

The filtrate becomes increasingly dilute as it moves upwards.

Functions

Reabsorbs sodium and chloride ions.

Helps establish the osmotic gradient in the renal medulla.

Contributes to the dilution of filtrate.

Supports water conservation through the countercurrent multiplication mechanism.

Importance of the Loop of Henle

Helps produce concentrated urine.

Enables the kidneys to conserve water.

Establishes the osmotic gradient in the renal medulla.

Regulates the concentration of salts in body fluids.

Works together with the collecting duct in regulating water reabsorption.

E. DISTAL CONVOLUTED TUBULE (DCT)

The distal convoluted tubule is a coiled section of the nephron located in the renal cortex after the loop of Henle.

It is involved in the fine regulation of mineral salts, water and blood pH.

Functions of the DCT

Reabsorbs sodium ions under the influence of aldosterone.

Reabsorbs calcium ions under the influence of parathyroid hormone.

Participates in potassium ion secretion.

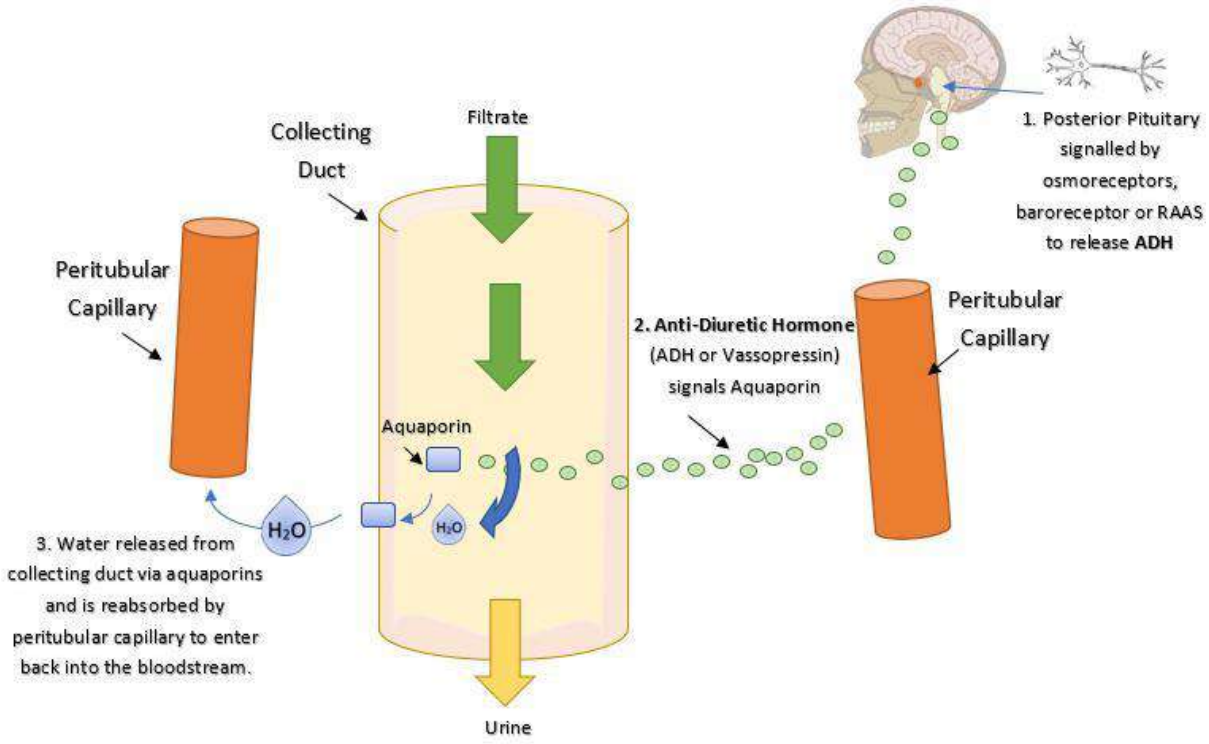
Secretes hydrogen ions to help regulate blood pH.

Reabsorbs bicarbonate ions under appropriate physiological conditions.

Participates in water reabsorption, particularly under the influence of ADH in the late distal tubule.

Helps maintain the balance of dissolved substances in blood.

F. COLLECTING DUCT



The collecting duct is a tube that receives filtrate from several distal convoluted tubules and transports it through the renal medulla towards the renal pelvis.

Functions of the Collecting Duct

Collects filtrate from several nephrons.

Reabsorbs water under the influence of ADH.

Helps regulate the concentration and volume of urine.

Allows some urea to move into the renal medulla, contributing to the osmotic gradient.

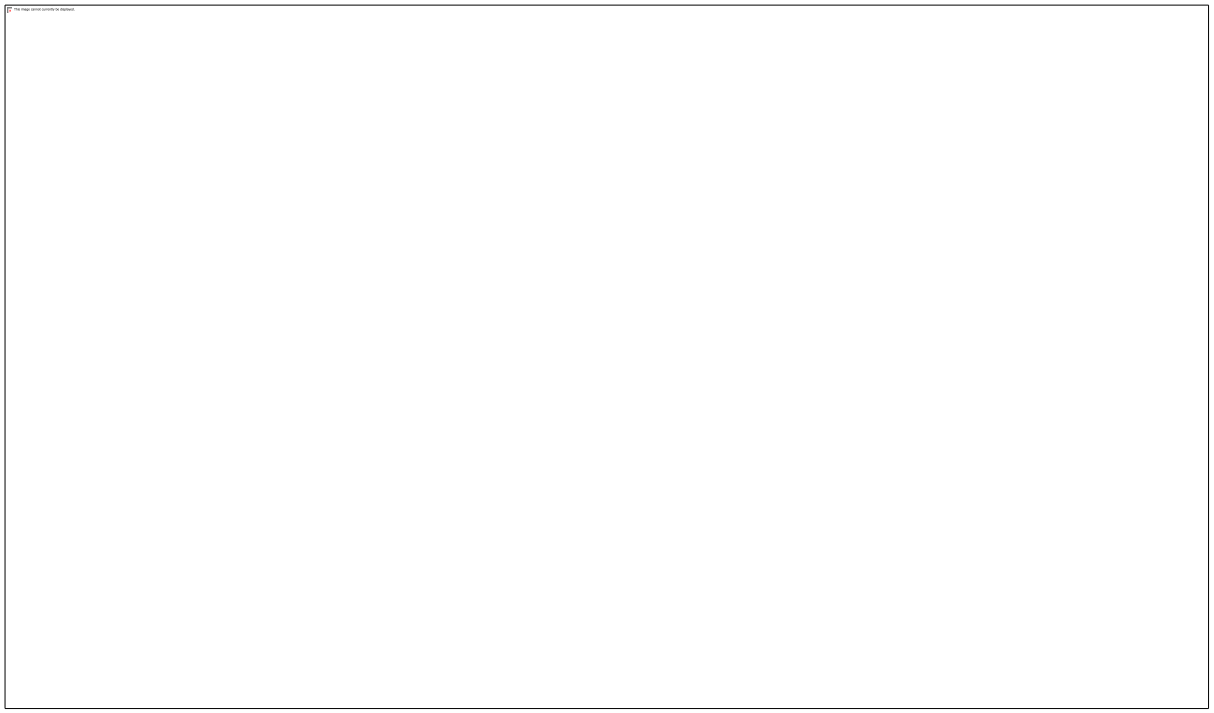
Transports urine towards the renal papillae.

Participates in acid-base regulation through specialised cells.

Summary of Nephron Structure and Function

Nephron part	Main function
Bowman's capsule	Collects glomerular filtrate
Glomerulus	Filters blood
Proximal convoluted tubule	Major site of selective reabsorption
Descending limb	Reabsorbs water
Ascending limb	Reabsorbs salts and is relatively impermeable to water
Distal convoluted tubule	Regulates ions, pH and water
Collecting duct	Regulates final urine concentration and transports urine

3.3.6 PROCESS OF URINE FORMATION IN MAMMALS



Meaning of Urine Formation

Urine formation is the process through which the kidneys remove metabolic wastes and excess substances from blood while retaining useful substances needed by the body.

It takes place in the nephrons.

Urine formation involves three main processes:

- Ultrafiltration.
- Selective reabsorption.
- Tubular secretion.

A. ULTRAFILTRATION

Meaning of Ultrafiltration

Ultrafiltration is the process through which water and small dissolved substances are forced out of the blood in the glomerulus into Bowman's capsule under high hydrostatic pressure.

It takes place in the renal corpuscle, which consists of the glomerulus and Bowman's capsule.

How Ultrafiltration Takes Place

Blood enters the glomerulus through the afferent arteriole.

The afferent arteriole has a wider diameter than the efferent arteriole under normal conditions.

This arrangement helps create high hydrostatic pressure inside the glomerular capillaries.

The high pressure forces water and small dissolved substances through the filtration barrier.

The substances pass through the fenestrated capillary endothelium, basement membrane and filtration slits between podocytes.

The filtered fluid enters the capsular space of Bowman's capsule.

The fluid formed is called glomerular filtrate.

Blood cells and most large plasma proteins remain in the bloodstream.

Substances Found in Glomerular Filtrate

Water.

Glucose.

Amino acids.

Mineral salts.

Urea.

Uric acid.

Small dissolved molecules.

Substances Normally Retained in the Blood

Red blood cells.

White blood cells.

Platelets.

Most plasma proteins.

Other large molecules that cannot pass through the filtration barrier.

Importance of Ultrafiltration

Removes small waste products from blood.

Initiates urine formation.

Allows excess water to enter the renal tubules.

Removes dissolved metabolic wastes such as urea.

Provides filtrate for selective reabsorption.

B. SELECTIVE REABSORPTION

Meaning of Selective Reabsorption

Selective reabsorption is the process through which useful substances are removed from the glomerular filtrate and returned to the bloodstream.

It occurs mainly in the proximal convoluted tubule, although further reabsorption takes place in other parts of the nephron.

Substances Reabsorbed

- Glucose.
- Amino acids.
- Water.
- Sodium ions.
- Chloride ions.
- Bicarbonate ions.
- Calcium ions.
- Phosphate ions.

How Selective Reabsorption Takes Place

- Glomerular filtrate enters the proximal convoluted tubule.
- Useful substances such as glucose and amino acids are transported across the epithelial cells.
- Some substances move by active transport, while others move through facilitated diffusion or other transport mechanisms.
- Sodium ions are actively transported out of the tubule cells into surrounding tissues.
- Water follows dissolved substances by osmosis.
- Useful substances enter the surrounding blood capillaries.
- The blood carries the reabsorbed substances back to other body tissues.
- The remaining filtrate continues along the nephron.

Importance of Selective Reabsorption

- Prevents the loss of essential nutrients.
- Maintains normal blood glucose concentration.
- Conserves amino acids.
- Maintains water balance.
- Regulates mineral salt concentration.
- Helps maintain blood volume.
- Prevents excessive loss of useful substances through urine.

C. TUBULAR SECRETION

Meaning of Tubular Secretion

Tubular secretion is the process through which certain substances are actively or passively transferred from the blood surrounding the renal tubules into the tubular fluid.

It occurs mainly in the proximal and distal convoluted tubules and collecting ducts.

Substances Secreted into the Renal Tubules

- Hydrogen ions.
- Potassium ions.
- Ammonium ions.
- Creatinine.
- Certain drugs and their metabolites.
- Other unwanted organic substances.

Importance of Tubular Secretion

- Removes additional metabolic wastes from blood.
- Helps regulate blood pH.
- Helps regulate potassium concentration.
- Eliminates certain drugs and toxic substances.
- Complements ultrafiltration in removing unwanted substances.

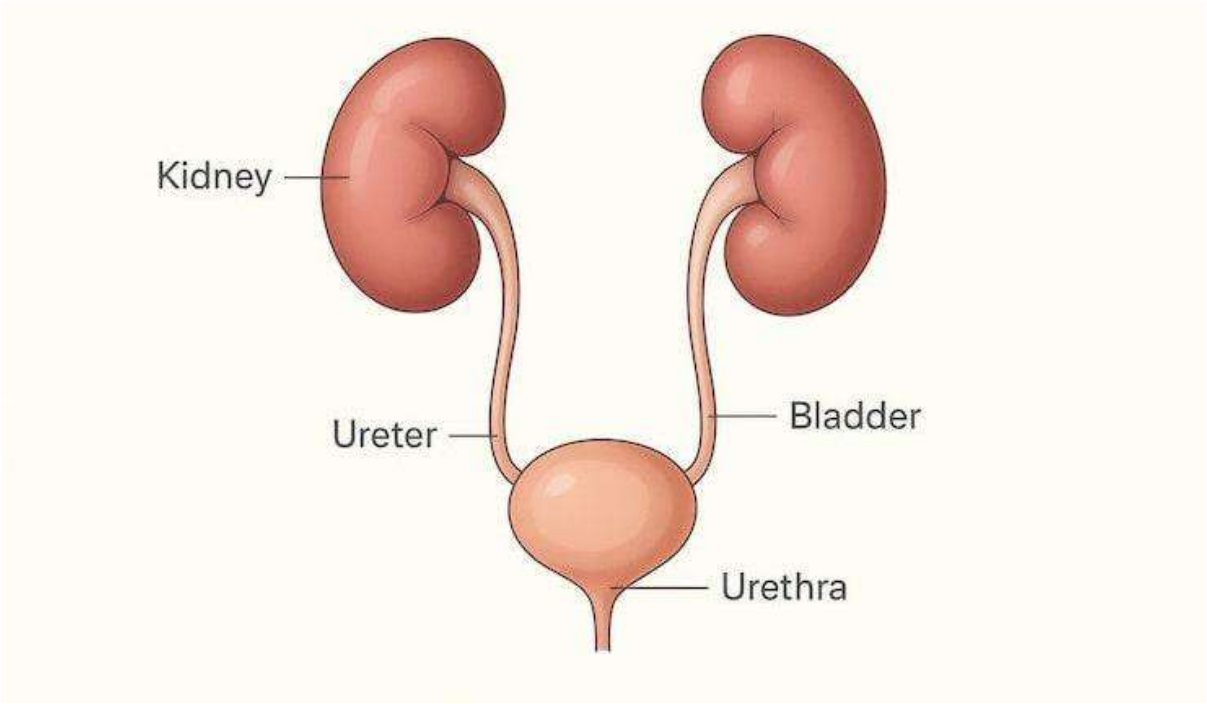
Summary of the Three Processes of Urine Formation

Process	Location	Main function
Ultrafiltration	Glomerulus and Bowman's capsule	Filters blood to form filtrate
Selective reabsorption	Mainly proximal convoluted tubule	Returns useful substances to blood
Tubular secretion	Mainly proximal and distal tubules	Transfers additional wastes into filtrate

Pathway of Urine from the Kidney to Outside the Body

Urine follows this pathway:

Collecting ducts → Renal papillae → Minor calyces → Major calyces → Renal pelvis → Ureter → Urinary bladder → Urethra → Outside the body.



Factors Affecting the Volume of Urine Produced

1. **Water intake:** Drinking large amounts of water increases urine volume, while low water intake reduces urine production.

2. **Environmental temperature:** High temperatures may increase sweating, reducing the amount of water available for urine production.

3. **Physical activity:** Vigorous exercise increases water loss through sweating and may reduce urine volume.

4. **ADH concentration:** Increased ADH promotes water reabsorption and reduces urine volume.

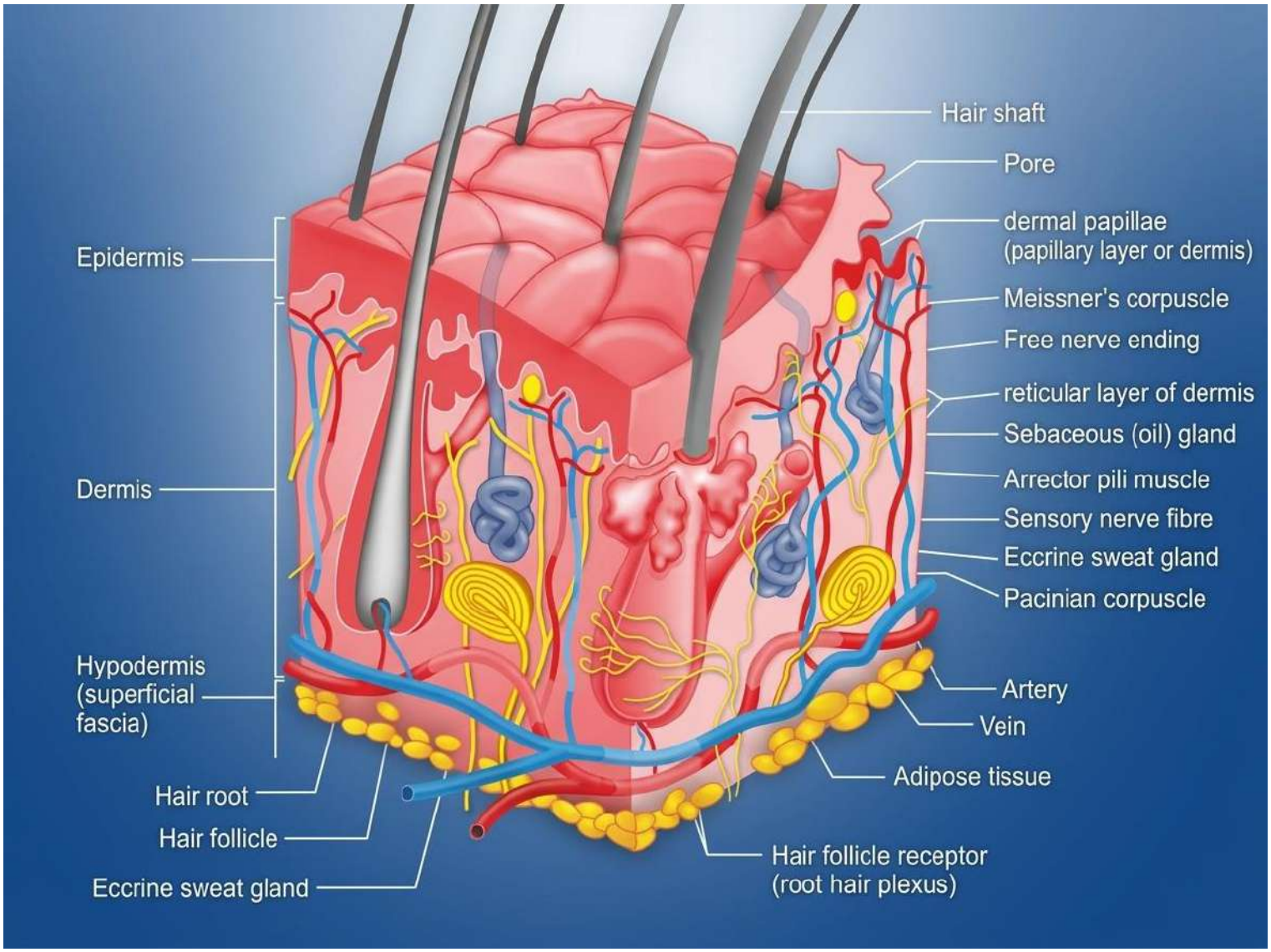
5. **Salt intake:** High salt intake affects osmotic balance and may influence water retention and urine production.

6. **Alcohol consumption:** Alcohol can inhibit ADH release, causing increased urine production.

7. **Caffeine intake:** Caffeine may increase urine production in some circumstances.

8. **Kidney health:** Kidney disorders may interfere with normal filtration and urine formation.

3.3.7 INTERNAL STRUCTURE OF THE MAMMALIAN SKIN



Meaning of Skin

The skin is the external protective covering of the mammalian body.

It is the largest organ of the human body and performs several functions, including protection, temperature regulation, sensation and limited excretion.

The skin contributes to excretion through the production and elimination of sweat.

Main Layers of Mammalian Skin

The mammalian skin consists of three main regions:

Epidermis.

Dermis.

Hypodermis or subcutaneous layer.

A. EPIDERMIS

The epidermis is the outermost layer of the skin.

It consists of several layers of epithelial cells and does not contain blood vessels.

Structure of the Epidermis

It consists mainly of closely packed epithelial cells.

Its outermost cells are dead and filled with keratin.

New cells are produced through cell division in the deeper layers.

It contains melanocytes that produce melanin.

It forms a protective barrier against microorganisms and harmful substances.

Functions of the Epidermis

Protects the body against mechanical injury.

Prevents excessive water loss.

Protects against entry of disease-causing microorganisms.

Provides protection against harmful ultraviolet radiation through melanin.

Continuously replaces worn-out and damaged cells.

Forms a physical barrier against environmental substances.

B. DERMIS

The dermis is the thicker layer of skin located beneath the epidermis.

It consists mainly of connective tissue containing collagen and elastic fibres.

Structures Found in the Dermis

Blood capillaries.

Sweat glands.

Sebaceous glands.

Hair follicles.

Sensory receptors.

Nerve endings.

Arrector pili muscles.

Lymphatic vessels.

Functions of the Dermis

Supports and nourishes the epidermis.

Contains sweat glands that produce sweat.

Contains blood vessels involved in thermoregulation.

Contains sensory receptors for touch, pressure, pain and temperature.

Contains sebaceous glands that produce sebum.

Provides elasticity and strength to the skin.

Contains hair follicles responsible for hair growth.

Helps regulate body temperature through changes in blood flow.

C. HYPODERMIS OR SUBCUTANEOUS LAYER

The hypodermis is the layer of tissue beneath the dermis.

It consists mainly of loose connective tissue and adipose tissue.

Functions

Stores fat as an energy reserve.

Insulates the body against excessive heat loss.

Cushions internal tissues against mechanical injury.

Attaches the skin to underlying muscles and other structures.

Provides a pathway for larger blood vessels and nerves.

3.3.8 ROLE OF THE SKIN IN EXCRETION

The skin contributes to excretion through the activity of sweat glands.

Sweat Glands



Sweat glands are specialised structures located mainly in the dermis.

They produce sweat, which is released onto the skin surface through sweat ducts.

There are two main types of sweat glands:

Eccrine sweat glands.

Apocrine sweat glands.

A. Eccrine Sweat Glands

They are distributed over most parts of the body.

They produce watery sweat.

They play an important role in thermoregulation.

Their secretions contain water, mineral salts and small quantities of urea and other substances.

They release sweat directly onto the skin surface.

B. Apocrine Sweat Glands

They are mainly found in areas such as the armpits and groin.

They release their secretions into hair follicles.

Their secretions contain water, salts, lipids and proteins.

Bacterial action on their secretions contributes to body odour.

Their activity increases after puberty.

Composition of Sweat

Sweat consists mainly of:

Water.

Sodium chloride.

Small quantities of urea.

Small quantities of ammonia.

Lactic acid.

Other dissolved substances.

Functions of Sweat Glands

Remove small quantities of nitrogenous wastes.

Eliminate excess water.

Eliminate some mineral salts.

Assist in regulating body temperature.

Help maintain water and salt balance.

Contribute to the maintenance of a stable internal environment.

How Sweating Helps in Thermoregulation

When body temperature rises, the hypothalamus detects the increase.

Nerve impulses stimulate sweat glands.

Sweat is produced and released onto the skin surface.

Sweat evaporates using heat energy from the skin.

Heat is removed from the body.

Body temperature decreases towards its normal level.

Role of Sebaceous Glands

Sebaceous glands are oil-producing glands located in the dermis, usually associated with hair follicles.

They produce an oily substance called sebum.

Functions of Sebaceous Glands

Lubricate the skin.

Prevent excessive drying of the skin.

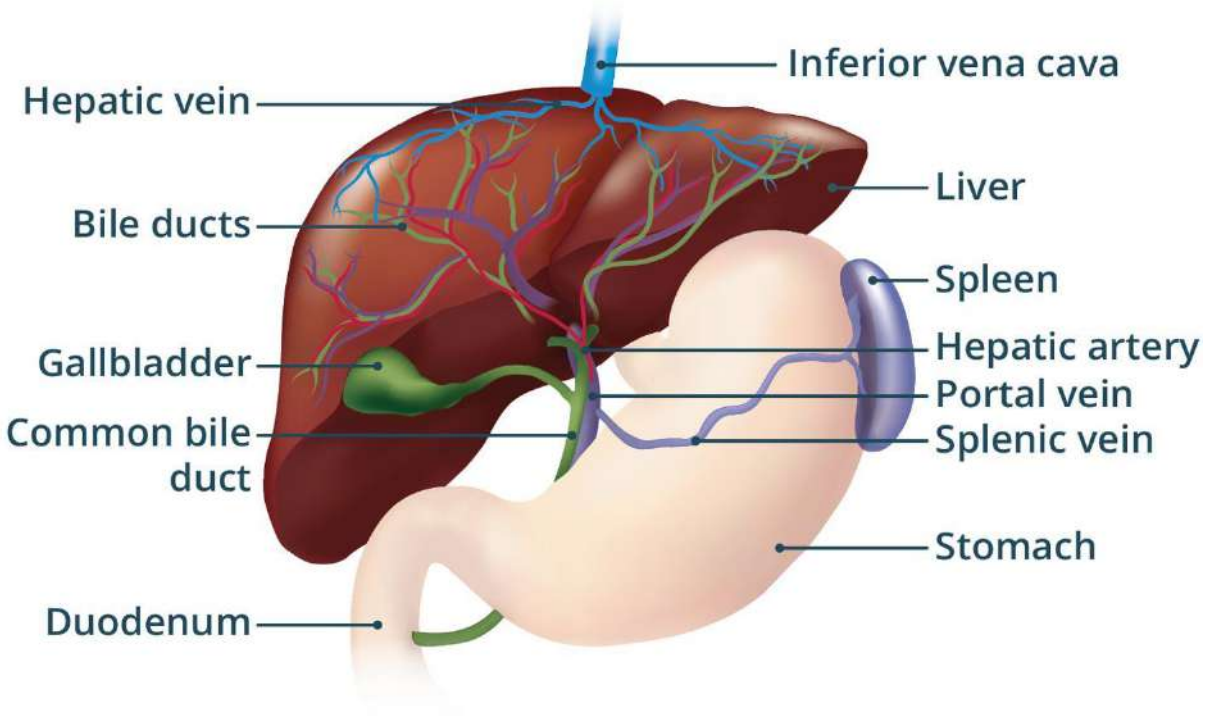
Keep hair soft and flexible.

Provide some protection against microorganisms.

Reduce water loss from the skin surface.

Important distinction: Sweat glands contribute directly to excretion, whereas sebaceous glands mainly contribute to lubrication and protection.

3.3.9 ROLE OF THE LIVER IN EXCRETION



Meaning of the Liver

The liver is a large reddish-brown organ located in the upper right region of the abdominal cavity, just below the diaphragm.

It is one of the most important organs involved in metabolism, detoxification, storage and excretion.

The liver plays an important role in eliminating harmful substances and converting toxic metabolic products into less harmful substances.

Major Excretory Functions of the Liver

A. Deamination of Excess Amino Acids

Meaning of Deamination

Deamination is the process through which the amino group is removed from excess amino acids, mainly in the liver.

Excess amino acids cannot be stored in the body in the same way as carbohydrates and fats.

They are therefore broken down when present in quantities exceeding the body's requirements.

Process of Deamination

Excess amino acids are transported to the liver through the bloodstream.

The amino group is removed from the amino acid.

The amino group is converted into ammonia through metabolic reactions.

Ammonia is highly toxic to body cells.

The liver converts ammonia into urea through the urea cycle.

Urea enters the bloodstream.

Blood transports urea to the kidneys.

The kidneys filter urea from the blood.

Urea is eliminated from the body through urine.

Importance of Deamination

Prevents accumulation of excess amino acids.

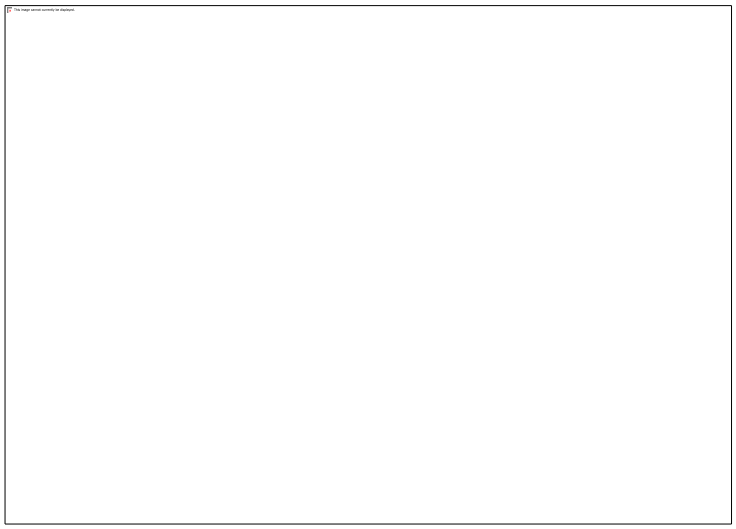
Prevents accumulation of toxic ammonia.

Enables the body to utilise the remaining carbon skeletons for energy production.

Provides substances that can be used in glucose formation or energy metabolism.

Supports nitrogen waste elimination.

B. Conversion of Ammonia into Urea



The liver converts highly toxic ammonia into less toxic urea through a series of chemical reactions called the urea cycle.

Process

Ammonia is produced during amino acid metabolism.

Ammonia enters the urea cycle in liver cells.

Carbon dioxide is used in the formation of nitrogen-containing intermediates.

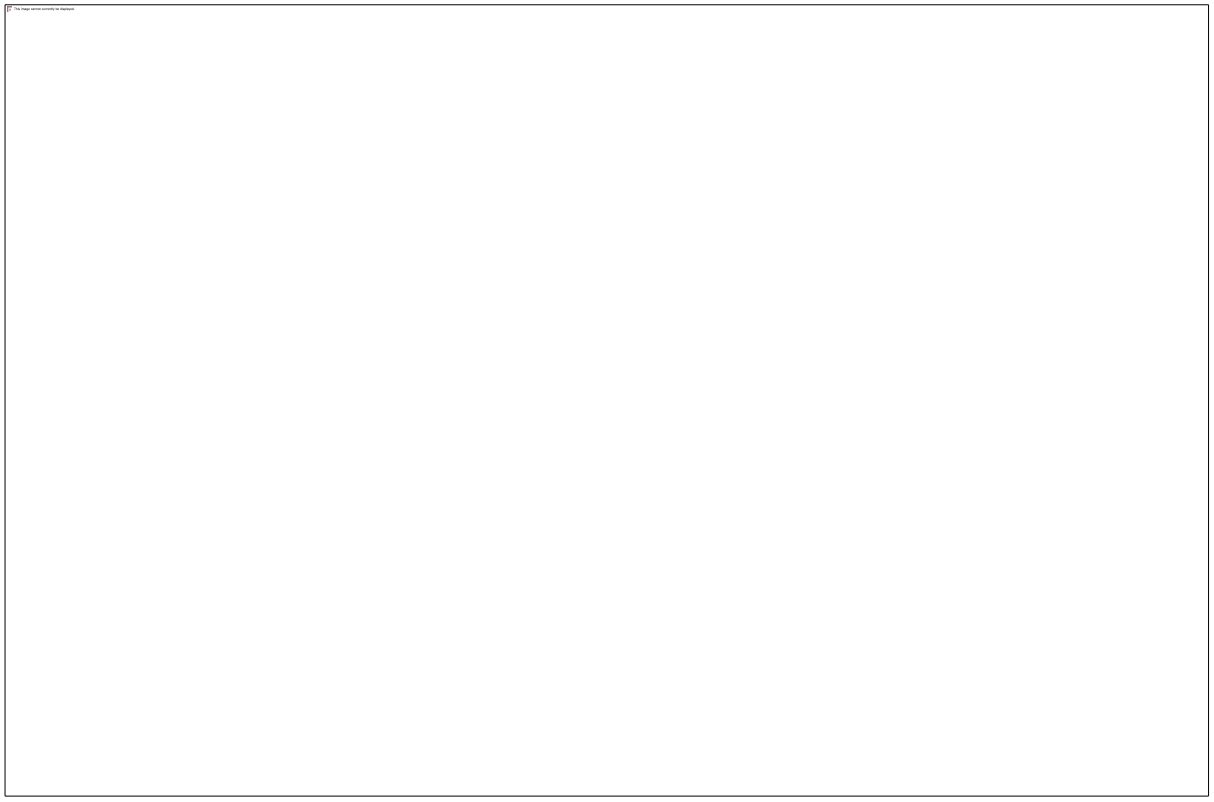
Through a series of enzyme-controlled reactions, nitrogen is incorporated into urea.

Urea is released into the bloodstream.

It is transported to the kidneys for elimination.

Importance: Conversion of ammonia into urea prevents toxic accumulation of ammonia in the blood and tissues.

C. Breakdown of Haemoglobin



Old and damaged red blood cells are broken down mainly by macrophages in the spleen and liver.

Haemoglobin from these cells is separated into globin and haem components.

Process

Old red blood cells are destroyed by macrophages.

Haemoglobin is released and broken down.

Globin is broken down into amino acids.

Haem is separated from the globin.

Iron is recovered and recycled for the production of new haemoglobin.

The remaining haem component is converted into biliverdin.

Biliverdin is converted into bilirubin.

Bilirubin is transported to the liver.

The liver processes bilirubin and secretes it into bile.

Bile carries bilirubin into the small intestine.

Intestinal bacteria convert bilirubin into other pigments.

Some of these pigments are eliminated through faeces, giving faeces their characteristic brown colour.

Importance of Haemoglobin Breakdown

Enables recycling of iron.

Prevents accumulation of old red blood cells.

Provides materials for the formation of new blood cells.

Enables elimination of bile pigments.

Helps maintain normal blood composition.

D. Detoxification of Harmful Substances

The liver modifies potentially harmful substances to make them less toxic or easier to eliminate.

Examples include:

Alcohol.

Certain drugs.

Environmental chemicals.

Some metabolic waste products.

Hormones present in excess.

Importance of Detoxification

Protects body cells from toxic substances.

Prevents harmful accumulation of certain chemicals.

Makes some substances easier to eliminate through urine or bile.

Supports normal metabolic activities.

E. Elimination of Cholesterol and Other Substances

The liver uses cholesterol in the production of bile acids.

Some cholesterol and its derivatives are eliminated through bile.

Certain waste products are secreted into bile.

Bile carries these substances into the intestine for elimination.

Other Functions of the Liver Apart from Excretion

1. **Glycogenesis:** Converts excess glucose into glycogen for storage.
2. **Glycogenolysis:** Breaks down glycogen into glucose when blood glucose levels decrease.

3. **Gluconeogenesis:** Produces glucose from non-carbohydrate substances.

4. **Plasma protein synthesis:** Produces albumin and many blood-clotting proteins.

5. **Bile production:** Produces bile, which helps in the digestion and absorption of fats.

6. **Vitamin storage:** Stores vitamins A, D, E, K and B12.

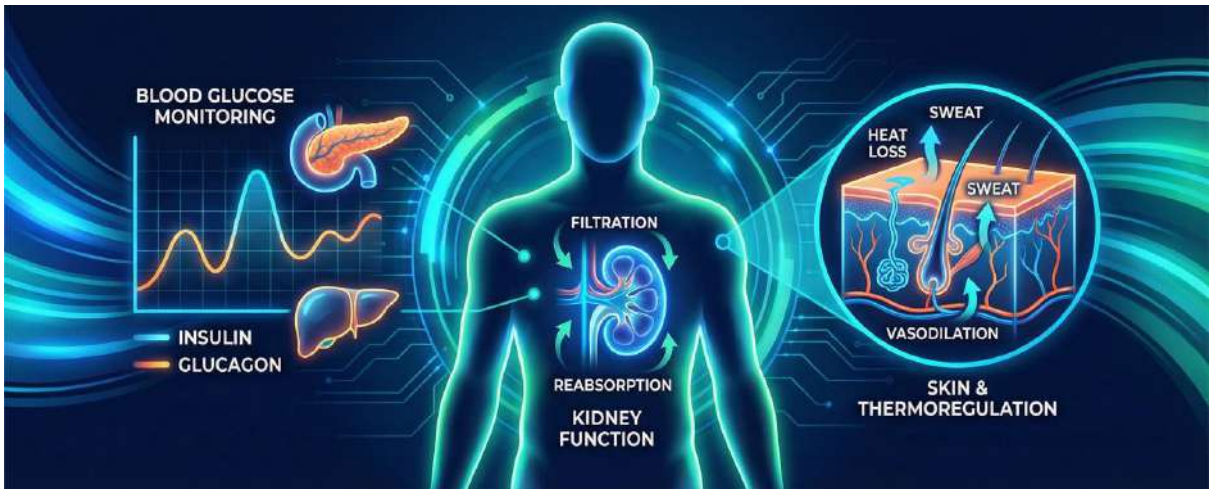
7. **Mineral storage:** Stores minerals such as iron and copper.

8. **Fat metabolism:** Participates in the breakdown and synthesis of fats.

9. **Protein metabolism:** Participates in the metabolism of amino acids and proteins.

10. **Blood glucose regulation:** Helps maintain relatively stable blood glucose concentration.

3.3.10 HOMEOSTASIS IN ANIMALS



Meaning of Homeostasis

Homeostasis is the process through which an organism maintains a relatively stable internal environment despite changes in the external environment.

It involves the regulation of conditions such as:

Body temperature.

Blood glucose concentration.

Water content of body fluids.

Mineral salt concentration.

Blood pH.

Blood pressure.

Carbon dioxide concentration.

Homeostasis is essential because body cells require suitable internal conditions for normal functioning.

Importance of Homeostasis

1. **Maintains optimum enzyme activity:** Enzymes work effectively within suitable temperature and pH ranges.

2. **Maintains stable body temperature:** Prevents excessive heating or cooling that could interfere with cellular activities.

3. **Regulates blood glucose:** Ensures cells receive a continuous supply of glucose for respiration.

4. **Maintains water balance:** Prevents excessive loss or accumulation of water in body tissues.

5. **Maintains mineral salt balance:** Ensures appropriate concentrations of ions such as sodium, potassium and calcium.

6. **Maintains blood pH:** Provides suitable conditions for normal metabolic reactions.

7. **Supports normal organ functioning:** Enables organs such as the heart, brain and kidneys to operate effectively.

8. **Prevents cell damage:** Prevents excessive water movement into or out of cells.

9. **Maintains normal nerve functioning:** Regulates the concentration of ions required for nerve impulse transmission.

10. **Supports survival:** Enables organisms to function effectively under changing environmental conditions.

3.3.11 MECHANISM OF HOMEOSTATIC REGULATION

Most homeostatic processes are controlled through negative feedback mechanisms.

Meaning of Negative Feedback

Negative feedback is a regulatory mechanism in which a change in a particular internal condition triggers responses that oppose the original change and restore the condition towards its normal level.

For example, when body temperature rises above normal, mechanisms such as sweating and vasodilation are activated to lower it.

Components of a Negative Feedback Mechanism



1. **Stimulus:** A change in an internal condition that moves it away from the normal range.

2. **Receptor:** Detects the change and sends information to the control centre.

3. **Control centre:** Processes the information and coordinates an appropriate response.

4. **Effector:** An organ, tissue or gland that carries out the response.

5. **Response:** The action that opposes the original change and restores the internal condition towards normal.

Example: Regulation of Body Temperature

Body temperature rises above normal.

Temperature receptors detect the increase.

Information is sent to the hypothalamus.

The hypothalamus activates sweat glands and promotes vasodilation.

More heat is lost from the body.

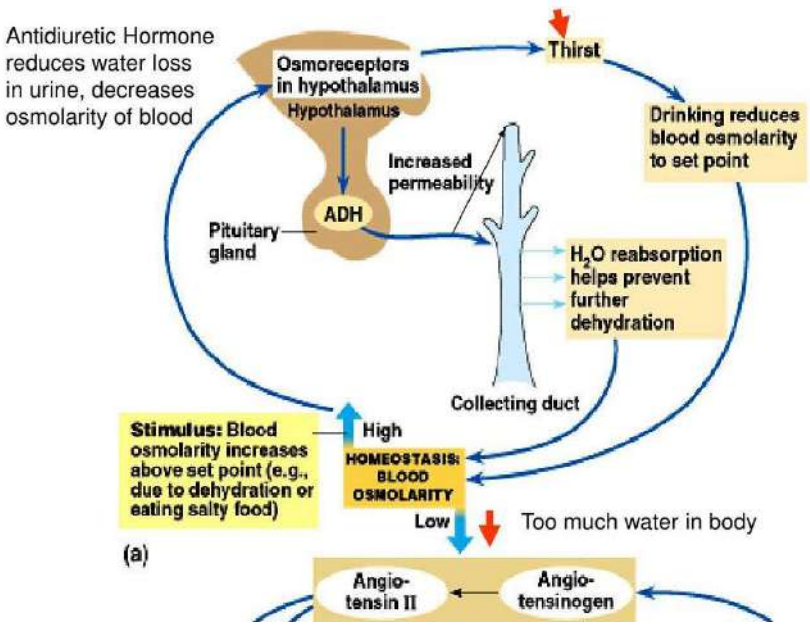
Body temperature falls towards normal.

Difference Between Negative and Positive Feedback

Negative feedback	**Positive feedback**
Opposes the initial change.	Amplifies the initial change.
Helps maintain homeostasis.	Usually drives a process towards a specific endpoint.
Common in temperature regulation.	Common during childbirth.
Restores a variable towards its normal range.	Increases the response until a terminating event occurs.

Example of positive feedback: During childbirth, stretching of the cervix stimulates the release of oxytocin, which increases uterine contractions. Stronger contractions cause further cervical stretching until the baby is delivered.

3.3.12 OSMOREGULATION IN HUMANS



Meaning of Osmoregulation

Osmoregulation is the process through which the body maintains the appropriate concentration of water and dissolved substances in body fluids.

It involves regulating:

- Water content of blood.
- Concentration of mineral salts.
- Osmotic pressure of body fluids.
- Water movement into and out of cells.

The kidneys are the main organs involved in osmoregulation in humans.

The hypothalamus and pituitary gland also play important roles.

Importance of Osmoregulation

- Maintains normal water content in body cells.
- Prevents excessive swelling of cells.
- Prevents excessive shrinking of cells.
- Maintains blood volume.
- Helps regulate blood pressure.
- Maintains appropriate concentrations of mineral salts.
- Supports normal kidney functioning.
- Maintains suitable conditions for enzyme activities.
- Supports normal nerve and muscle functioning.
- Prevents dehydration and excessive water retention.

Role of the Kidneys in Osmoregulation

The kidneys regulate water and salt balance by adjusting the volume and concentration of urine produced.

A. When the Body Has Excess Water

This may occur after drinking large amounts of water.

Process

- Excess water enters the bloodstream.
- The blood becomes more dilute.
- Osmoreceptors in the hypothalamus detect the decrease in blood osmolarity.
- The hypothalamus reduces stimulation of ADH release.
- Less ADH is released into the blood from the posterior pituitary gland.
- The collecting ducts become less permeable to water.
- Less water is reabsorbed into the blood.
- More water remains in the renal tubules.
- A large volume of dilute urine is produced.
- Blood osmolarity gradually returns towards normal.

B. When the Body Has Insufficient Water

This may occur during excessive sweating, diarrhoea, vomiting or inadequate water intake.

Process

The body loses water.

Blood becomes more concentrated.

Osmoreceptors in the hypothalamus detect the increase in blood osmolarity.

The hypothalamus stimulates the release of ADH from the posterior pituitary gland.

ADH is transported through the blood to the kidneys.

ADH increases the permeability of collecting ducts to water by promoting the insertion of aquaporin water channels.

More water is reabsorbed into the bloodstream.

A small volume of concentrated urine is produced.

Water conservation helps restore normal blood osmolarity.

Role of Antidiuretic Hormone (ADH)

ADH is a hormone produced by specialised nerve cells in the hypothalamus and stored and released by the posterior pituitary gland.

It is also called vasopressin.

Functions of ADH

Increases water reabsorption in the collecting ducts.

Helps reduce the volume of urine produced.

Increases urine concentration.

Maintains blood water content.

Helps maintain blood osmolarity.

At higher concentrations, causes vasoconstriction and may help maintain blood pressure.

Role of Aldosterone in Osmoregulation

Aldosterone is a steroid hormone produced by the adrenal cortex.

It helps regulate sodium and potassium concentrations in the body.

Functions of Aldosterone

Increases sodium ion reabsorption in the distal nephron.

Promotes potassium ion secretion into the renal tubules.

Encourages water retention indirectly because water follows sodium.

Helps maintain blood volume.

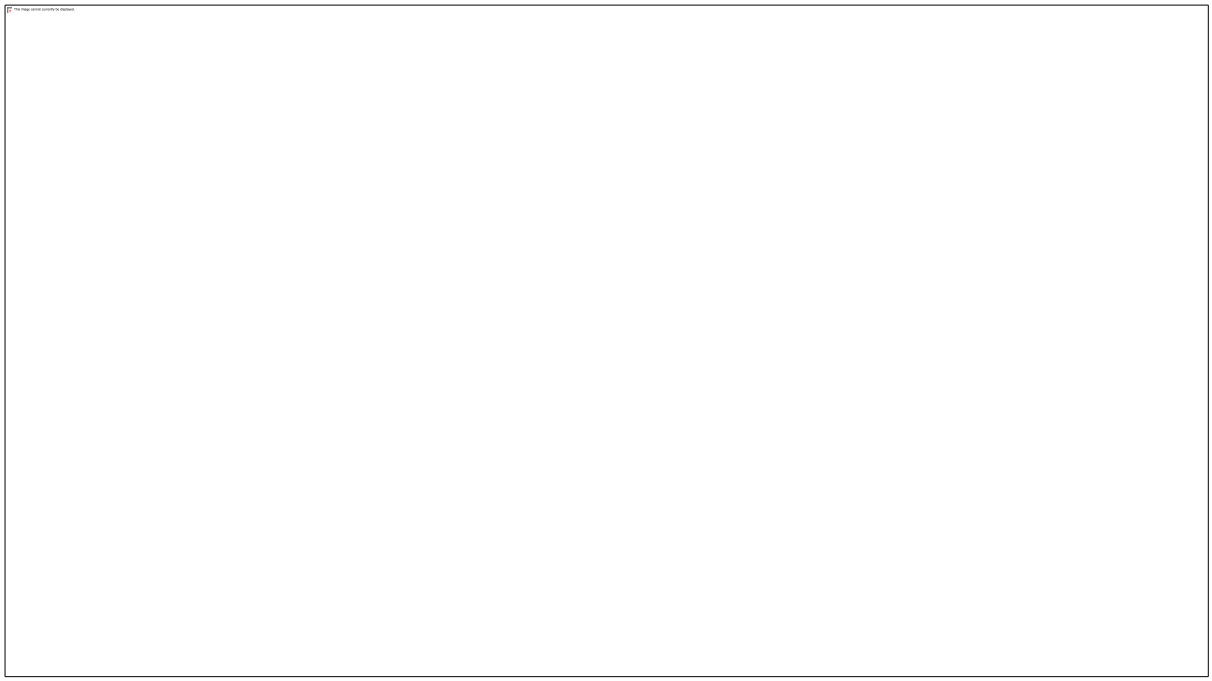
Contributes to the regulation of blood pressure.

Helps maintain electrolyte balance.

Differences Between ADH and Aldosterone

ADH	Aldosterone
Produced in the hypothalamus and released by the posterior pituitary.	Produced by the adrenal cortex.
Mainly regulates water reabsorption.	Mainly regulates sodium reabsorption and potassium secretion.
Acts on the collecting ducts and late distal tubules.	Acts mainly on the distal nephron.
Reduces urine volume.	Promotes sodium retention and indirectly supports water retention.

3.3.13 THERMOREGULATION IN HUMANS



Meaning of Thermoregulation

Thermoregulation is the process through which an organism maintains its body temperature within a suitable range despite changes in environmental temperature.

Humans are endothermic animals because they generate much of their body heat through metabolic activities.

The normal internal body temperature of a healthy adult is approximately 37°C, although it varies slightly with time, activity and individual differences.

Importance of Thermoregulation

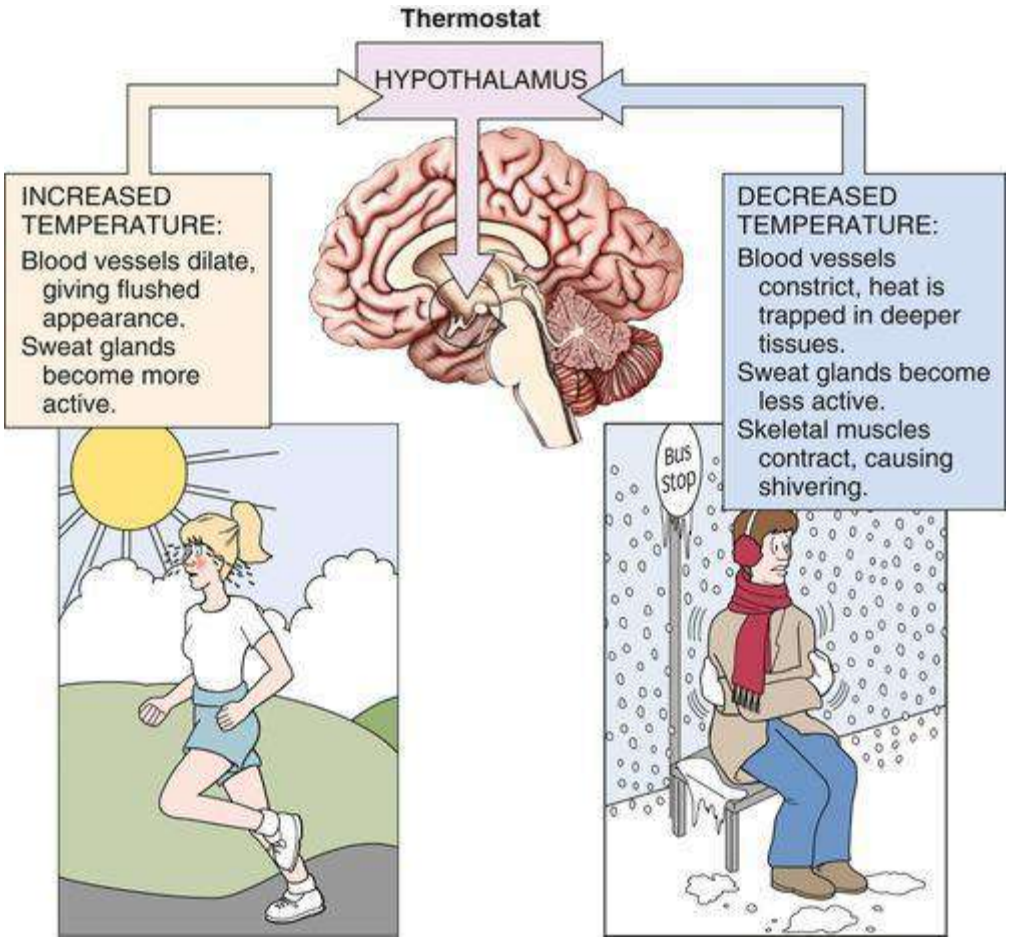
- Maintains optimum enzyme activity.
- Prevents overheating of body cells.
- Prevents excessive cooling of body tissues.
- Maintains normal metabolic reactions.
- Supports normal functioning of the nervous system.

Maintains normal muscular activity.

Prevents damage to sensitive organs such as the brain.

Supports survival under different environmental conditions.

The Hypothalamus and Temperature Regulation



The hypothalamus is the main control centre for thermoregulation.

It receives information from:

Temperature receptors in the skin.

Temperature-sensitive cells within the hypothalamus.

Other internal temperature-sensitive structures.

It coordinates responses that increase or decrease heat loss and heat production.

A. Regulation When Body Temperature Rises

When body temperature rises above the normal range, the body activates cooling mechanisms.

1. Sweating Increases

The hypothalamus stimulates sweat glands.

Sweat is released onto the skin surface.

Sweat evaporates using heat from the skin.

Heat is lost to the environment.

Body temperature decreases.

2. Vasodilation Occurs

Arterioles supplying the skin widen.

More blood flows through superficial blood vessels.

More heat is transferred from the blood to the skin.

Heat is lost to the environment through radiation and convection.

Body temperature falls.

3. Hairs Lie Flat

Arrector pili muscles relax.

Hairs lie flat against the skin.

Less insulating air is trapped around the body.

More heat is lost to the environment.

4. Metabolic Heat Production Decreases

Some heat-producing metabolic activities decrease.

Less internal heat is generated.

Body temperature moves towards normal.

5. Behavioural Responses Occur

A person may:

Move into the shade.

Remove excess clothing.

Drink water.

Reduce physical activity.

Use fans or ventilation.

B. Regulation When Body Temperature Falls

When body temperature falls below the normal range, the body activates heat-conserving and heat-producing mechanisms.

1. Vasoconstriction Occurs

Skin arterioles become narrower.

Less blood flows through superficial blood vessels.

Less heat is lost from the skin.

Body heat is conserved.

2. Sweating Decreases

Sweat gland activity is reduced.

Less water evaporates from the skin.

Heat loss through evaporation decreases.

3. Shivering Occurs

Skeletal muscles contract and relax rapidly and involuntarily.

These contractions require energy.

Heat is produced during muscular activity.

Body temperature increases.

4. Hairs Stand Erect

Arrector pili muscles contract.

Hairs stand upright.

A layer of air may become trapped near the skin.

Heat loss is reduced slightly.

This response is more effective in furry mammals than in humans.

5. Metabolic Rate Increases

Hormonal and nervous mechanisms can increase heat production.

More energy is released through cellular metabolism.

Body temperature rises.

6. Behavioural Responses Occur

A person may:

Wear warm clothing.

Move into a warmer environment.

Curl up to reduce exposed body surface.

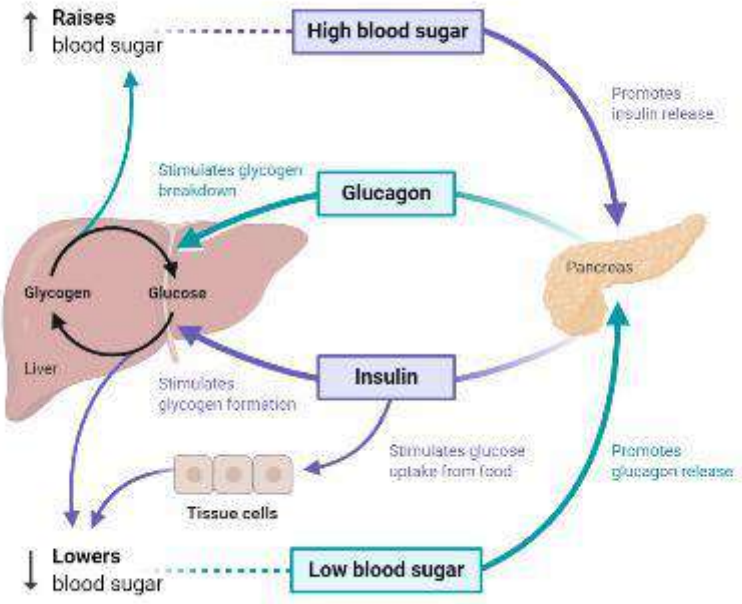
Engage in physical activity.

Seek shelter from cold winds.

Comparison of Thermoregulatory Responses

When body temperature rises	When body temperature falls
Vasodilation	Vasoconstriction
Increased sweating	Reduced sweating
Hairs lie flat	Hairs stand erect
Reduced heat production	Increased heat production
Increased heat loss	Reduced heat loss

3.3.14 BLOOD GLUCOSE REGULATION IN HUMANS



Meaning of Blood Glucose Regulation

Blood glucose regulation is the process through which the body maintains blood glucose concentration within a relatively stable range.

Glucose is an important respiratory substrate used by cells to release energy through cellular respiration.

The pancreas plays a major role in blood glucose regulation by producing two important hormones:

Insulin.

Glucagon.

These hormones work together to regulate blood glucose concentration.

A. INSULIN

Meaning of Insulin

Insulin is a hormone produced by the beta cells of the islets of Langerhans in the pancreas.

It lowers blood glucose concentration when it rises above the normal range.

Functions of Insulin

Stimulates the uptake of glucose by skeletal muscle and adipose tissue.

Stimulates glycogenesis in the liver and skeletal muscles.

Promotes the conversion of excess glucose into glycogen.

Promotes the conversion of excess nutrients into fat for storage.

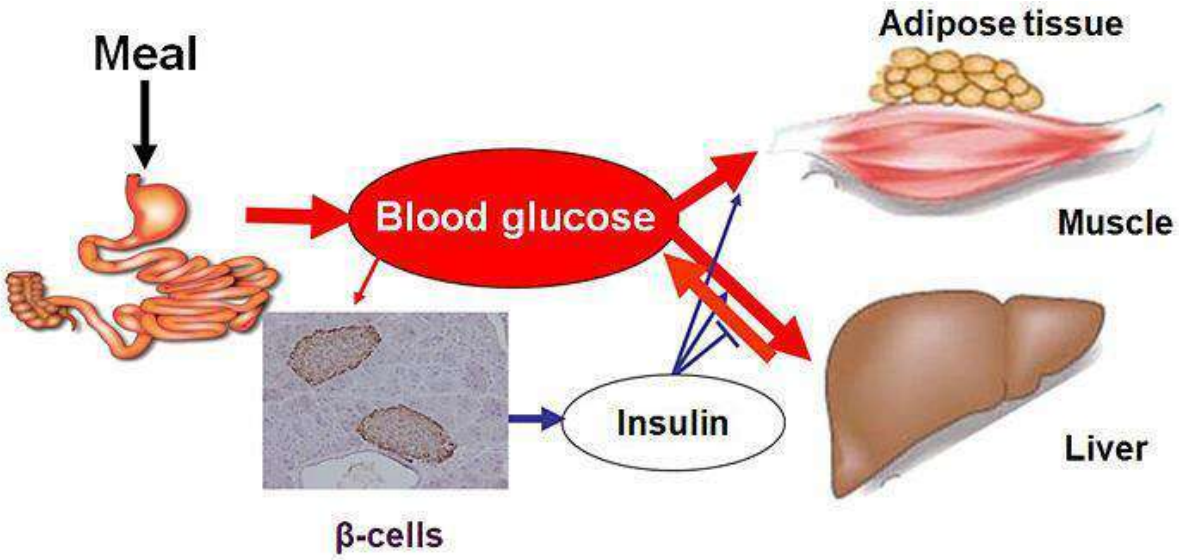
Inhibits glycogen breakdown.

Reduces glucose production by the liver.

Promotes protein synthesis.

Helps maintain normal blood glucose concentration.

How Insulin Regulates Blood Glucose After a Meal



When blood glucose levels rise after a meal, insulin in secreted from β-cells in the pancreas, thereafter acts upon muscle, adipose tissue and the liver to return blood glucose to the normal level. It has been believed that diabetes is caused by a combination of decreased insulin secretion and its impaired action.

A person eats a carbohydrate-rich meal.

Carbohydrates are digested into simple sugars, mainly glucose.

Glucose is absorbed into the bloodstream from the small intestine.

Blood glucose concentration increases.

Beta cells in the pancreas detect the increase.

The pancreas releases insulin into the bloodstream.

Insulin stimulates glucose uptake by skeletal muscle and adipose tissue.

Insulin stimulates the liver and muscles to convert glucose into glycogen.

The liver reduces glucose production and release.

Blood glucose concentration decreases towards normal.

B. GLUCAGON

Meaning of Glucagon

Glucagon is a hormone produced by the alpha cells of the islets of Langerhans in the pancreas.

It increases blood glucose concentration when it falls below the normal range.

Functions of Glucagon

Stimulates glycogenolysis in the liver.

Promotes the breakdown of glycogen into glucose.

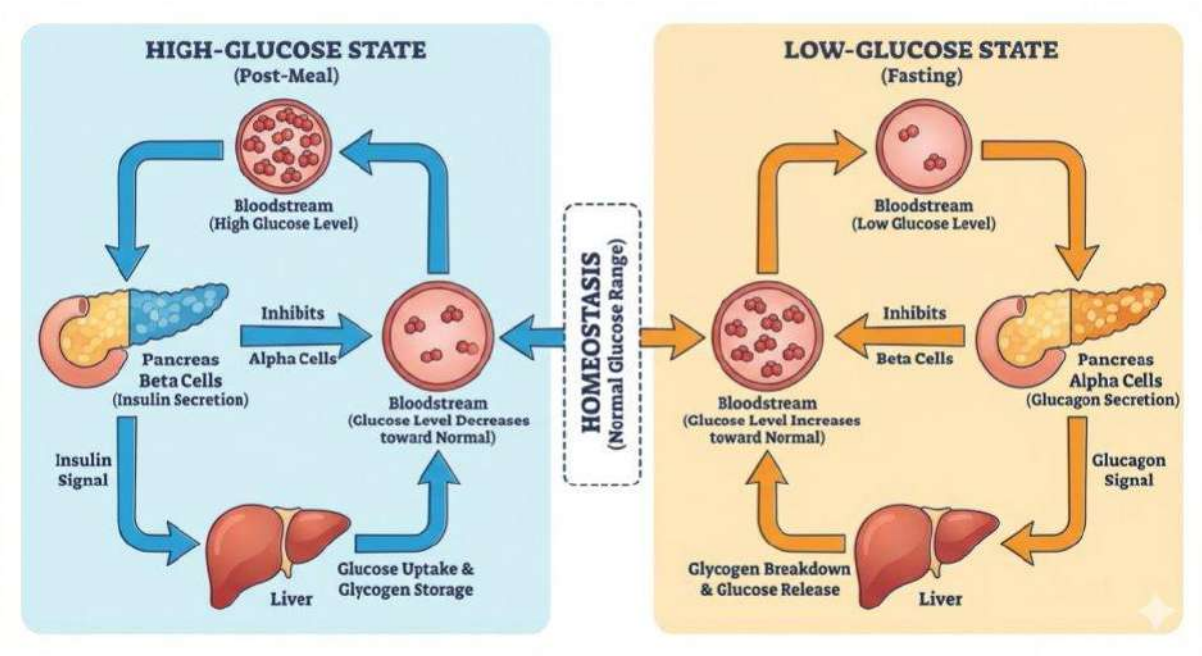
Stimulates gluconeogenesis in the liver.

Encourages the release of glucose into the bloodstream.

Helps prevent blood glucose concentration from falling excessively.

Supports the maintenance of blood glucose during fasting.

How Glucagon Regulates Blood Glucose During Fasting



A person goes for several hours without eating.

Blood glucose concentration begins to decrease.

Alpha cells in the pancreas detect the decrease.

The pancreas releases glucagon into the bloodstream.

Glucagon acts mainly on the liver.

The liver breaks down stored glycogen into glucose.

Glucose is released into the bloodstream.

Glucagon also stimulates the formation of glucose from non-carbohydrate substances.

Blood glucose concentration rises towards normal.

Differences Between Insulin and Glucagon

Insulin	**Glucagon**
Produced by pancreatic beta cells.	Produced by pancreatic alpha cells.
Lowers blood glucose.	Raises blood glucose.
Promotes glycogenesis.	Promotes glycogenolysis.
Promotes glucose uptake by muscle and adipose tissue.	Acts mainly on the liver to increase glucose availability.
Released when blood glucose rises.	Released when blood glucose falls.

Important Processes in Blood Glucose Regulation

1. Glycogenesis

The conversion of excess glucose into glycogen for storage, mainly in the liver and skeletal muscles.

2. Glycogenolysis

The breakdown of stored glycogen into glucose-related products. In the liver, glucose can be released into the blood.

3. Gluconeogenesis

The formation of glucose from non-carbohydrate substances such as lactate, glycerol and certain amino acids.

4. Cellular Respiration

The process through which cells break down glucose to release energy in the form of ATP.

HORMONES INVOLVED IN HOMEOSTASIS

1.0 Meaning of Hormones

Hormones are chemical messenger substances produced by endocrine glands and released directly into the bloodstream. They are transported to specific target organs or tissues, where they regulate and coordinate various body activities.

Hormones play an important role in maintaining a relatively constant internal environment in animals.

This regulation is called **homeostasis**.

Examples of internal conditions controlled by hormones include:

Blood glucose concentration.

Water and salt balance.

Calcium concentration in blood.

Metabolic rate.

Body growth and development.

Reproductive activities.

Blood pressure and blood volume.

2.0 Meaning of Endocrine Glands

Endocrine glands are ductless glands that produce and release hormones directly into the bloodstream.

Unlike exocrine glands, endocrine glands do not use ducts to transport their secretions.

Examples of endocrine glands involved in homeostasis include:

Pancreas.

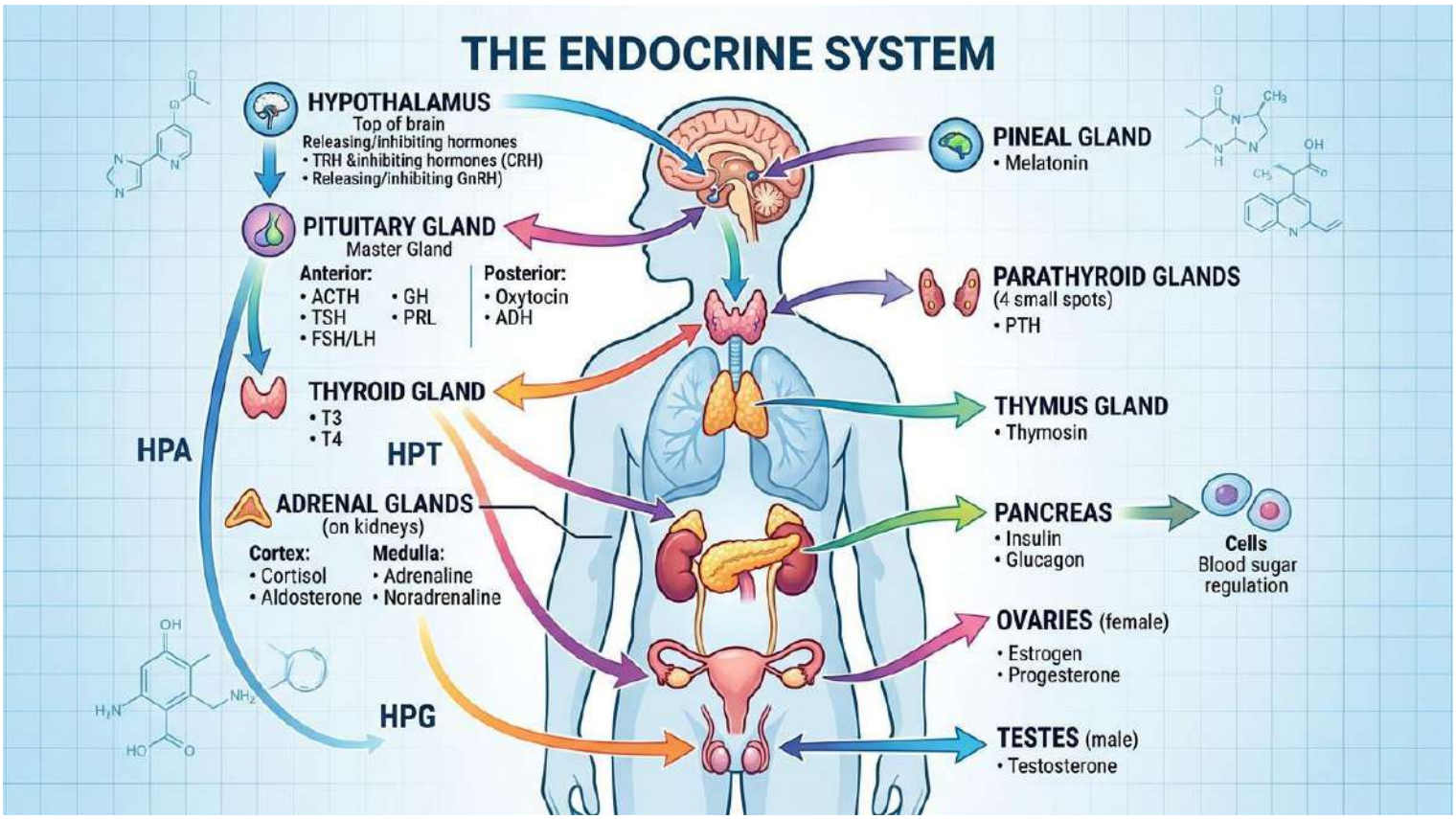
Pituitary gland.

Thyroid gland.

Adrenal glands.

Parathyroid glands.

Hypothalamus.



3.0 Major Hormones Involved in Homeostasis

3.1 Insulin

Source: Beta cells of the Islets of Langerhans in the pancreas.

Main function: Reduces blood glucose concentration when it rises above the normal level.

Actions of insulin:

Stimulates body cells, especially muscle and adipose cells, to take up glucose from the blood.

Stimulates the liver and skeletal muscles to convert excess glucose into glycogen. This process is called glycogenesis.

Inhibits the breakdown of glycogen into glucose in the liver.

Reduces the production of new glucose by the liver.

Promotes conversion of excess glucose into fats for storage.

Helps maintain normal blood glucose concentration.

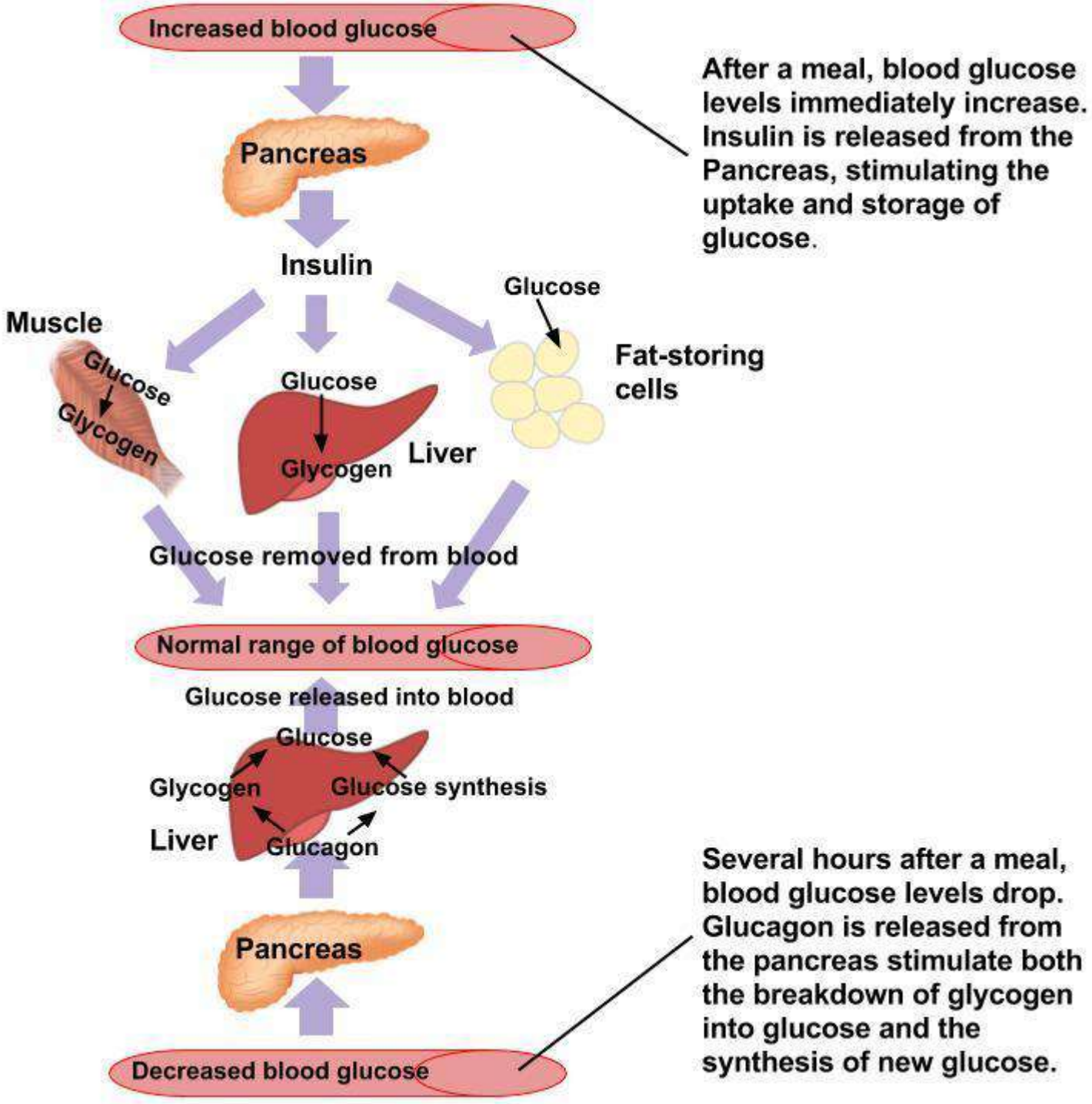
When is insulin released?

After eating carbohydrate-rich foods such as rice, potatoes, ugali, bread and fruits.

When blood glucose concentration rises above the normal range.

Example:

After eating a meal containing ugali and beans, digestion and absorption increase blood glucose concentration. The pancreas releases insulin, which helps body cells take up glucose and encourages the liver to store excess glucose as glycogen.



3.2 Glucagon

Source: Alpha cells of the Islets of Langerhans in the pancreas.

Main function: Increases blood glucose concentration when it falls below the normal level.

Actions of glucagon:

Stimulates the liver to break down stored glycogen into glucose. This process is called glycogenolysis.

Stimulates the liver to produce glucose from non-carbohydrate substances such as amino acids and glycerol. This process is called gluconeogenesis.

Encourages the release of glucose from the liver into the bloodstream.

Helps restore blood glucose concentration to normal levels.

When is glucagon released?

During fasting.

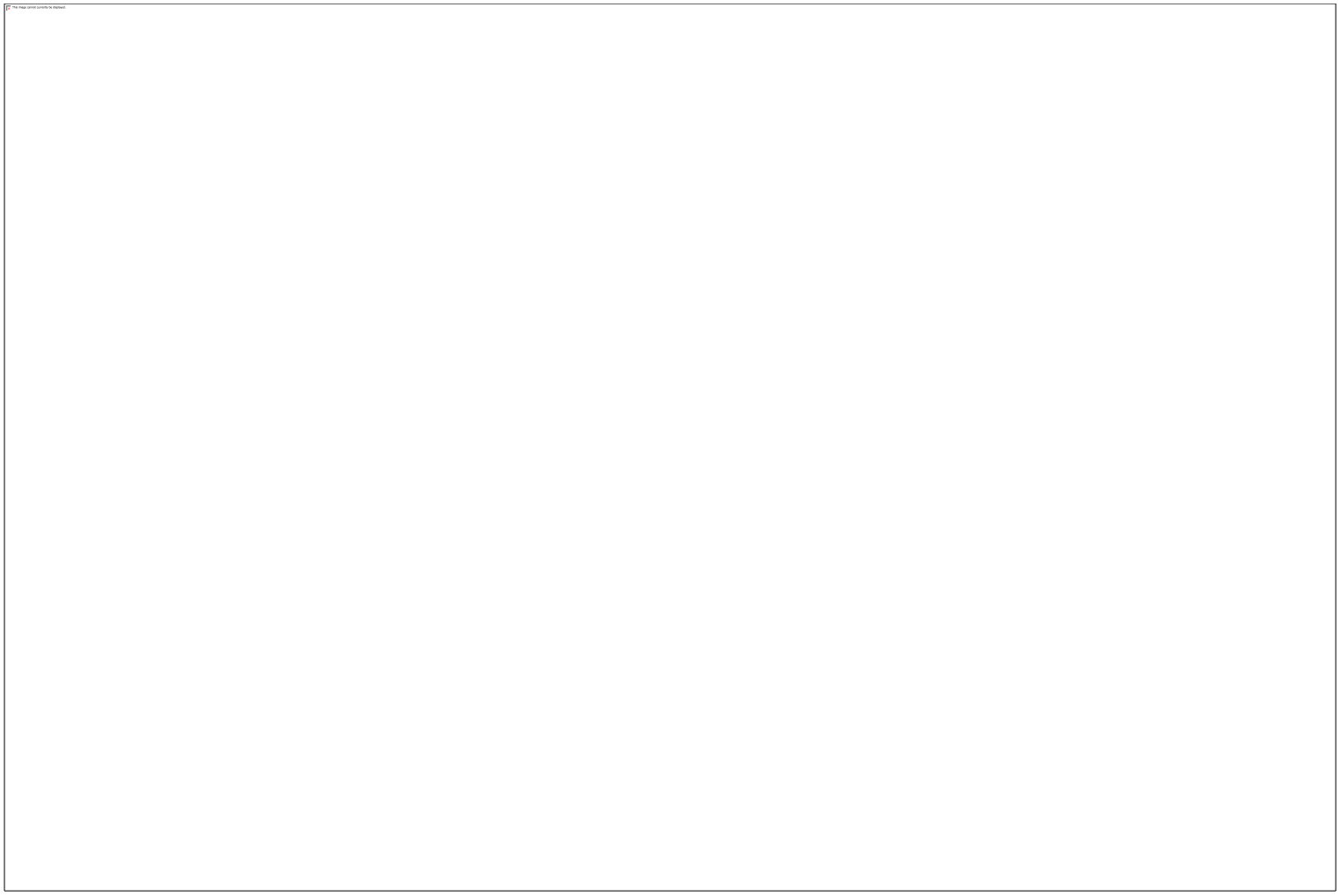
Between meals.

During prolonged physical activity.

When blood glucose concentration falls.

Example:

When a learner skips breakfast and blood glucose concentration begins to fall, the pancreas releases glucagon. The hormone stimulates the liver to release glucose into the blood, providing energy for body activities.



Comparison Between Insulin and Glucagon

Insulin	Glucagon
Produced by beta cells of pancreas.	Produced by alpha cells of pancreas.
Lowers blood glucose concentration.	Raises blood glucose concentration.
Released when blood glucose is high.	Released when blood glucose is low.
Promotes glycogenesis.	Promotes glycogenolysis.
Promotes glucose uptake by certain body cells.	Promotes glucose release from the liver.
Inhibits glucose production by the liver.	Stimulates glucose production by the liver.

Important: Insulin and glucagon work antagonistically to maintain blood glucose concentration within a suitable range.

3.3 Antidiuretic Hormone (ADH)

Other name: Vasopressin.

Source: ADH is synthesised in the hypothalamus and stored and released into the bloodstream by the posterior pituitary gland.

Main function: Regulates water balance in the body by controlling the amount of water reabsorbed by the kidneys.

Actions of ADH:

Increases the permeability of the collecting ducts to water.

Promotes the insertion of water-channel proteins called aquaporins into collecting duct cell membranes.

Increases water reabsorption from the kidney filtrate into the blood.

Reduces the volume of urine produced.

Makes urine more concentrated.

Helps maintain the water concentration and osmotic balance of body fluids.

When is ADH released in large amounts?

When the body loses a lot of water through sweating.

During dehydration.

When blood becomes more concentrated.

When blood osmolarity increases.

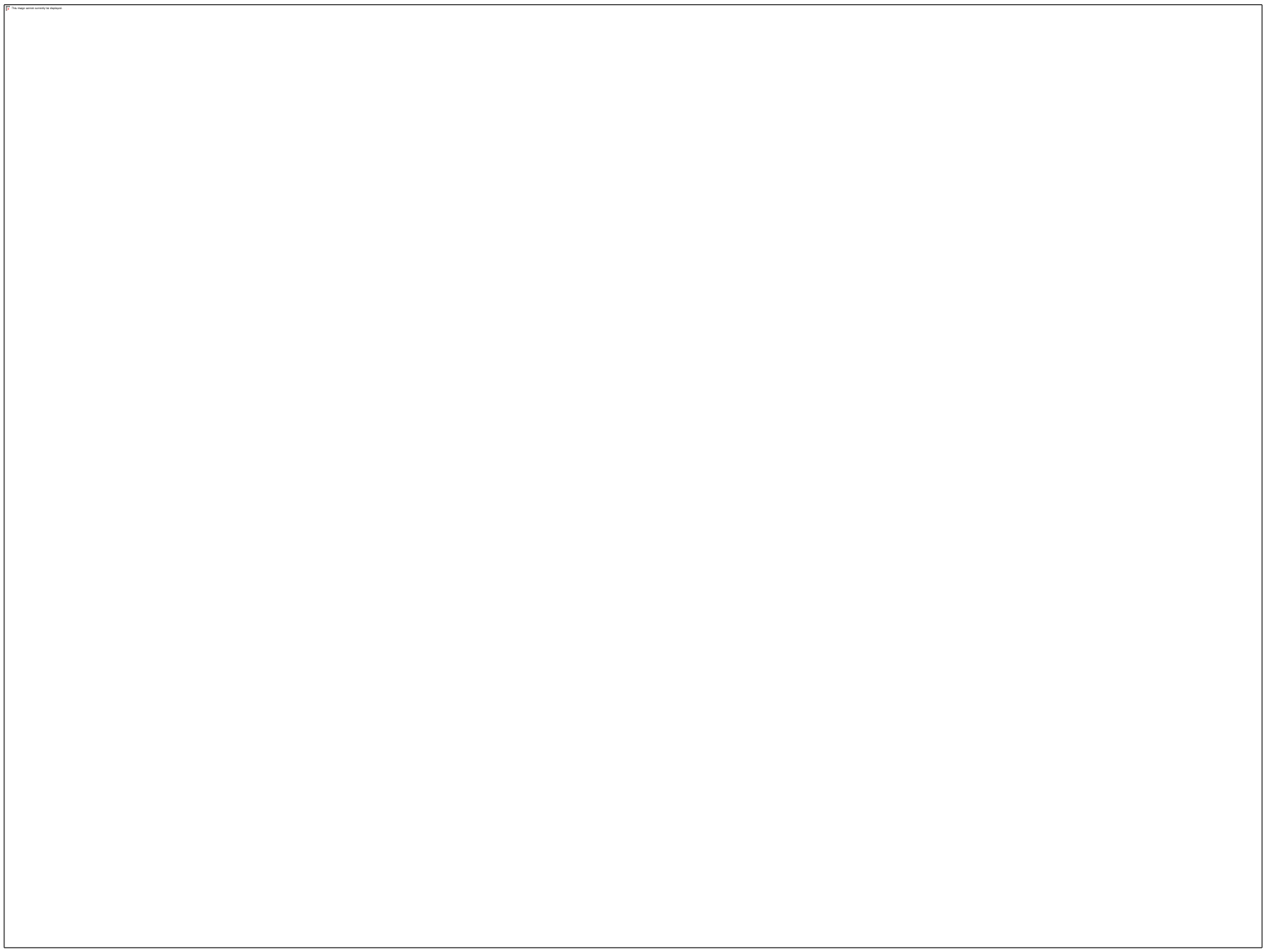
When ADH secretion decreases:

When a person drinks large quantities of water.

When blood becomes more dilute.

When the body has excess water.

This results in reduced water reabsorption and production of a large volume of dilute urine.



Example:

During a football match in a hot environment, a learner loses water through sweating. The blood becomes more concentrated, stimulating increased ADH release. The kidneys reabsorb more water, reducing urine volume and conserving body water.

3.4 Aldosterone

Source: Adrenal cortex (outer part of the adrenal glands).

Main function: Regulates sodium and potassium balance and indirectly helps control blood volume and blood pressure.

Actions of aldosterone:

Increases sodium ion reabsorption in the distal convoluted tubules and collecting ducts of the kidneys.

Promotes potassium ion secretion into the kidney filtrate.

Causes water to be retained because water follows reabsorbed sodium when conditions allow.

Helps maintain blood volume.

Contributes to the regulation of blood pressure.

Helps maintain electrolyte balance in body fluids.

When is aldosterone released?

When blood volume or blood pressure falls.

When blood sodium concentration is low.

When blood potassium concentration is high.

Example:

When a person loses large amounts of salt and water through sweating, aldosterone helps the kidneys conserve sodium. This supports the maintenance of blood volume and electrolyte balance.

3.5 Thyroxine

Source: Thyroid gland.

Main function: Regulates the body's metabolic rate.

Thyroxine is also known as tetraiodothyronine (T4). It is converted in many tissues into the more active hormone triiodothyronine (T3).

Actions of thyroxine:

Increases the rate of cellular respiration.

Regulates the rate at which cells use energy.

Influences body heat production.

Supports normal growth and development.

Regulates the metabolism of carbohydrates, proteins and fats.

Helps maintain normal functioning of body organs.

Importance in homeostasis:

Thyroxine helps regulate energy use and heat production, contributing to the maintenance of normal body temperature and metabolic activities.

3.6 Parathyroid Hormone (PTH)

Source: Parathyroid glands.

Main function: Increases calcium concentration in the blood when it falls below the normal level.

Actions of PTH:

Stimulates the release of calcium from bones into the bloodstream.

Increases calcium reabsorption in the kidneys.

Stimulates the activation of vitamin D in the kidneys.

Activated vitamin D increases calcium absorption from the small intestine.

Helps maintain normal calcium concentration in body fluids.

Importance of calcium regulation:

Calcium is required for:

Formation and maintenance of bones and teeth.

Muscle contraction.

Transmission of nerve impulses.

Normal blood clotting.

Proper functioning of cells.

3.7 Calcitonin

Source: Parafollicular cells (C cells) of the thyroid gland.

Main function: Helps lower blood calcium concentration when it rises.

Actions of calcitonin:

Inhibits the activity of osteoclasts, which break down bone tissue.

Reduces the release of calcium from bones.

Can increase calcium loss through the kidneys.

Helps reduce excessive calcium concentration in the blood.

Importance:

Calcitonin works in opposition to parathyroid hormone in regulating blood calcium levels. However, its role in normal calcium regulation in adult humans is relatively small compared with that of PTH and vitamin D.

3.8 Adrenaline

Source: Adrenal medulla (inner part of the adrenal glands).

Main function: Prepares the body for emergency situations through the fight-or-flight response.

Actions of adrenaline:

Increases heart rate.

Increases the force of heart contraction.

Increases blood glucose concentration by stimulating glycogen breakdown, especially in the liver.

Dilates airways to increase airflow into the lungs.

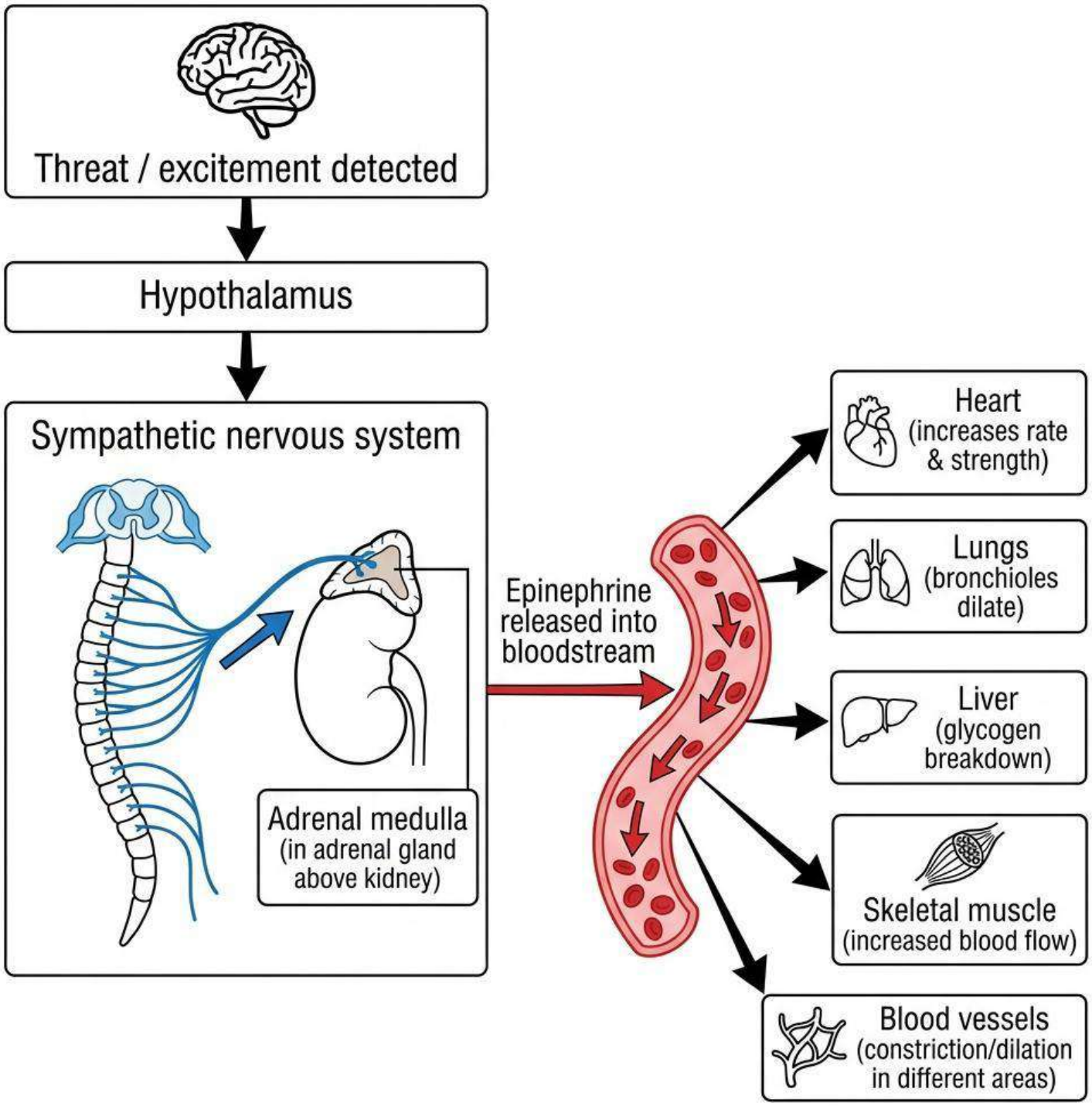
Redirects blood flow towards skeletal muscles.

Increases the rate of cellular respiration in active tissues.

Prepares the body for rapid physical activity.

Importance in homeostasis:

Adrenaline helps the body respond quickly to danger, fear, excitement or intense physical activity.

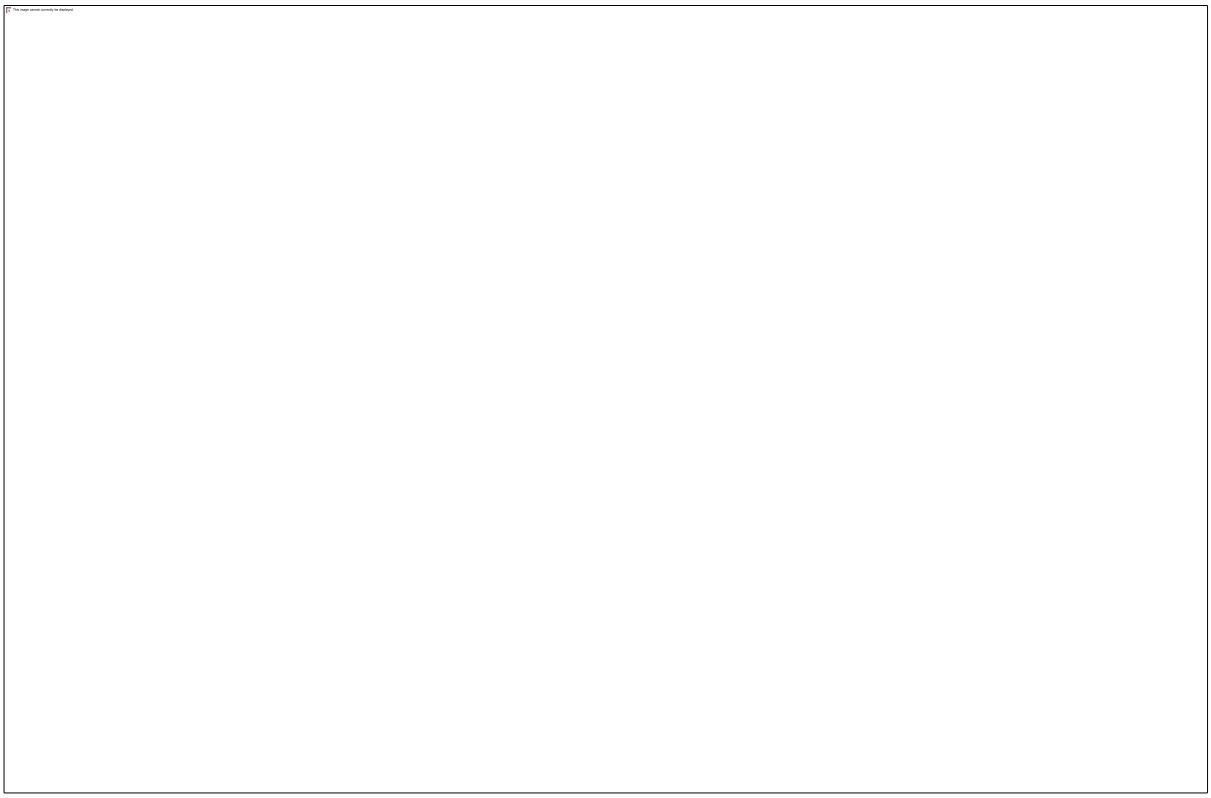


4.0 Summary of Hormones Involved in Homeostasis

Hormone	Source	Main homeostatic function
Insulin	Pancreas (beta cells)	Lowers blood glucose.
Glucagon	Pancreas (alpha cells)	Raises blood glucose.
ADH	Hypothalamus; released by posterior pituitary	Increases water reabsorption by kidneys.
Aldosterone	Adrenal cortex	Increases sodium reabsorption and potassium secretion.
Thyroxine	Thyroid gland	Regulates metabolic rate.
Parathyroid hormone	Parathyroid glands	Raises blood calcium.
Calcitonin	Thyroid gland	Helps lower blood calcium.
Adrenaline	Adrenal medulla	Prepares the body for emergencies.

3.3.15 DISEASES AND DISORDERS ASSOCIATED WITH HOMEOSTASIS

A. DIABETES MELLITUS



Meaning of Diabetes Mellitus

Diabetes mellitus is a metabolic disorder characterised by persistently elevated blood glucose concentration due to inadequate insulin production, impaired insulin action or a combination of both.

Insulin is either insufficient or does not function effectively in regulating blood glucose concentration.

Types of Diabetes Mellitus

There are three major clinical categories:

Type 1 diabetes mellitus.

Type 2 diabetes mellitus.

Gestational diabetes mellitus.

1. Type 1 Diabetes Mellitus

Type 1 diabetes mellitus is a condition in which the body's immune system destroys the insulin-producing beta cells of the pancreas.

As a result, the pancreas produces little or no insulin.

Causes and Risk Factors

Autoimmune destruction of pancreatic beta cells.

Genetic susceptibility.

Environmental factors that may contribute to triggering the autoimmune process.

Characteristics

Often develops during childhood or adolescence, although it can occur at any age.

The body produces little or no insulin.

Individuals require insulin treatment.

It is not caused simply by eating too much sugar.

2. Type 2 Diabetes Mellitus

Type 2 diabetes mellitus is a condition in which body cells become resistant to insulin, while the pancreas may gradually fail to produce enough insulin to meet the body's requirements.

Risk Factors

Overweight and obesity.

Physical inactivity.

Family history of diabetes.

Increasing age.

Insulin resistance.

Unhealthy dietary patterns.

Previous gestational diabetes.

Certain metabolic and hormonal conditions.

Characteristics

More common in adults, although it increasingly occurs in younger people.

The body initially produces insulin but does not respond to it effectively.

Insulin production may decrease as the disease progresses.

It may be managed through lifestyle changes and prescribed medication.

3. Gestational Diabetes Mellitus

This is a type of diabetes that develops during pregnancy when the body cannot produce or use sufficient insulin to meet increased metabolic demands.

It may increase the risk of complications for both the mother and baby.

Women who develop gestational diabetes have an increased risk of developing type 2 diabetes later in life.

Signs and Symptoms of Diabetes Mellitus



1. **Polyuria:** Passing unusually large quantities of urine due to excess glucose in the filtrate causing osmotic diuresis.
2. **Polydipsia:** Excessive thirst resulting from water loss through frequent urination.
3. **Polyphagia:** Increased hunger because the body cannot use glucose effectively.
4. **Unexplained weight loss:** The body may break down fats and proteins for energy.
5. **Fatigue:** Cells may not utilise glucose effectively, resulting in reduced energy availability.
6. **Blurred vision:** Changes in blood glucose concentration can affect the fluid balance of the eye lens.
7. **Slow wound healing:** High blood glucose can impair normal immune and tissue-repair processes.
8. **Frequent infections:** Poorly controlled diabetes can increase susceptibility to certain infections.
9. **Numbness or tingling:** Long-term high blood glucose may damage peripheral nerves.

Complications of Poorly Controlled Diabetes Mellitus

Kidney damage.

Cardiovascular diseases.

Stroke.

Nerve damage.

Eye damage and possible blindness.

Poor wound healing.

Foot ulcers.

Increased risk of serious infections.

Management and Prevention of Type 2 Diabetes

Maintain a healthy body weight.

Participate in regular physical activity.

Eat a balanced diet.

Reduce excessive consumption of sugary drinks.

Monitor blood glucose as advised by healthcare professionals.

Take prescribed medication.

Avoid smoking.

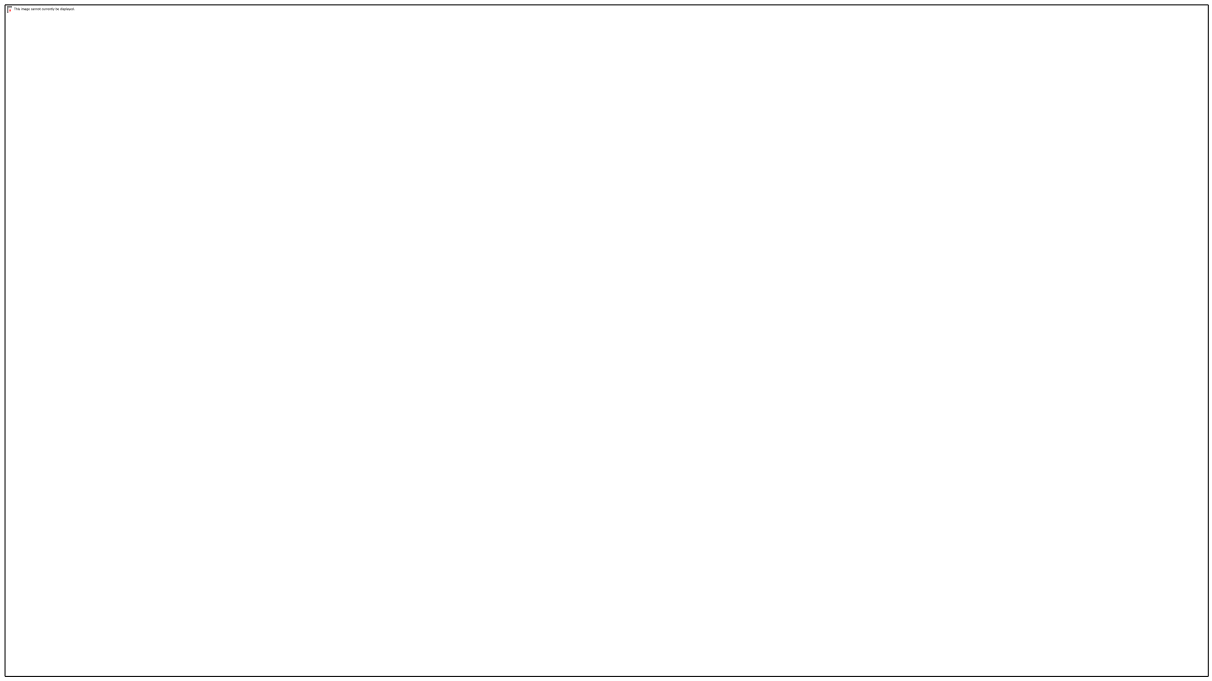
Attend regular medical check-ups.

Manage blood pressure and blood cholesterol.

Follow professional medical advice.

Type 1 diabetes cannot currently be prevented through ordinary lifestyle changes. People with type 1 diabetes require insulin treatment.

B. DIABETES INSIPIDUS



Meaning of Diabetes Insipidus

Diabetes insipidus is a disorder of water balance characterised by the production of unusually large quantities of dilute urine because the body cannot conserve water effectively.

It is associated with insufficient production of antidiuretic hormone (ADH), or reduced response of the kidneys to ADH.

Unlike diabetes mellitus, diabetes insipidus does not result from elevated blood glucose concentration.

Types of Diabetes Insipidus

1. Central Diabetes Insipidus

Occurs when the hypothalamus or posterior pituitary system fails to produce or release sufficient ADH.

As a result, the kidneys receive insufficient hormonal stimulation to reabsorb water.

Large quantities of dilute urine are produced.

2. Nephrogenic Diabetes Insipidus

Occurs when the kidneys fail to respond properly to ADH.

ADH may be present in normal or high concentrations.

The collecting ducts do not respond adequately to the hormone.

Excessive water is lost through urine.

3. Gestational Diabetes Insipidus

Occurs during pregnancy.

It is associated with increased breakdown of ADH by enzymes produced by the placenta.

It is relatively uncommon.

Causes of Diabetes Insipidus

Damage to the hypothalamus.

Damage to the posterior pituitary system.

Certain brain injuries.

Brain surgery affecting ADH production or release.

Kidney disorders that interfere with ADH response.

Certain medicines, particularly lithium.

Some inherited conditions.

Signs and Symptoms

Excessive production of dilute urine.

Frequent urination.

Excessive thirst.

Increased need to drink water, including at night.

Dehydration.

Dry mouth.

Weakness and fatigue.

Disturbed sleep due to frequent urination.

Effects of Diabetes Insipidus

Excessive loss of body water.

Dehydration.

Increased blood sodium concentration if water loss is not replaced.

Disturbance of osmotic balance.

Reduced blood volume in severe cases.

Reduced ability of the kidneys to conserve water.

Management

Treatment depends on the underlying cause.

Central diabetes insipidus may be treated using prescribed desmopressin.

Nephrogenic diabetes insipidus requires management of the underlying cause and may involve dietary and prescribed medical interventions.

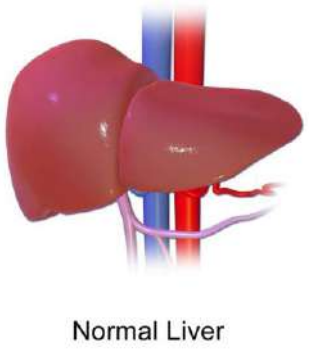
Adequate water intake is essential.

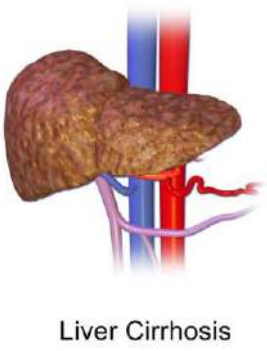
Regular monitoring of fluid balance and blood electrolytes may be necessary.

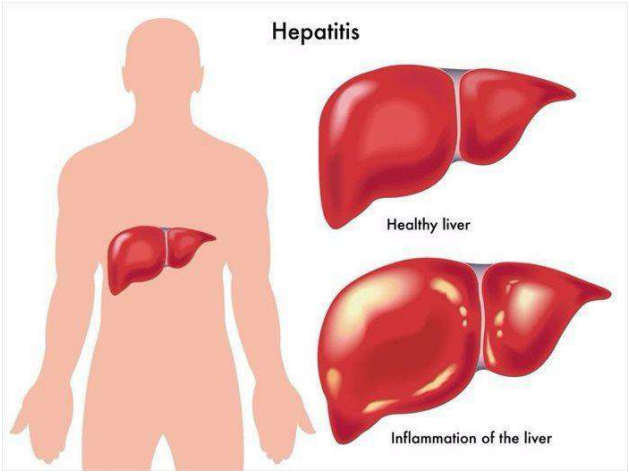
Differences Between Diabetes Mellitus and Diabetes Insipidus

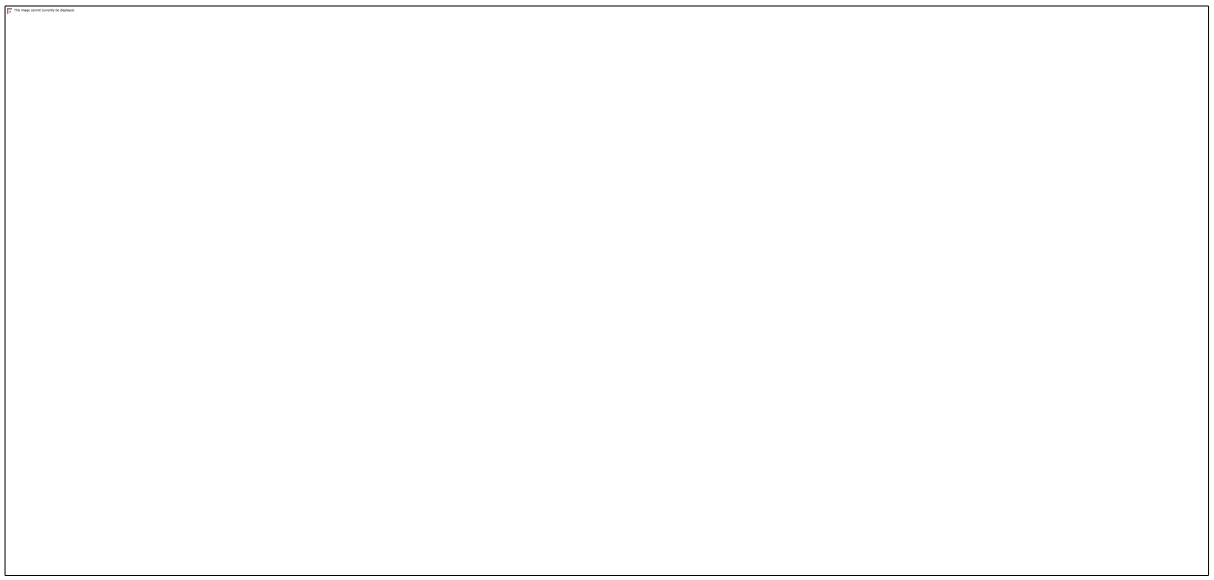
Diabetes mellitus	**Diabetes insipidus**
Mainly involves abnormal regulation of blood glucose.	Mainly involves abnormal regulation of water balance.
Associated with insulin deficiency or insulin resistance.	Associated with ADH deficiency or reduced kidney response to ADH.
Blood glucose is abnormally high.	Blood glucose is generally not elevated because of the disorder.
Glucose may be present in urine when blood glucose exceeds the renal threshold.	Urine is characteristically dilute and contains no excess glucose due to the disorder.
May cause excessive thirst and urination.	Causes excessive thirst and production of large quantities of dilute urine.
Managed through glucose control, lifestyle measures and medication.	Managed through water-balance treatment and appropriate hormone or kidney-directed therapy.

3.3.16 LIVER DISEASES AND DISORDERS









The liver performs several important functions, including detoxification, metabolism, storage of nutrients, production of bile and conversion of ammonia into urea.

However, the liver may be damaged by infections, excessive alcohol consumption, accumulation of fat, certain medicines, toxins and metabolic disorders.

Major liver diseases and disorders include:

Liver cirrhosis.

Hepatitis.

Fatty liver disease.

A. LIVER CIRRHOSIS

Meaning of Liver Cirrhosis

Liver cirrhosis is a chronic liver disease characterised by extensive scarring of liver tissue and the formation of regenerative nodules as a result of long-term liver injury.

Normal liver tissue is gradually replaced by scar tissue, interfering with the normal structure and functioning of the liver.

Causes of Liver Cirrhosis

1. **Chronic alcohol consumption:** Excessive long-term alcohol consumption damages liver cells, causing inflammation and scarring.

2. **Chronic viral hepatitis:** Long-term infection with hepatitis B or C viruses may cause persistent inflammation and liver scarring.

3. **Fatty liver disease:** Continued fat accumulation and inflammation may cause fibrosis and eventually cirrhosis.

4. **Certain medicines and toxic substances:** Some medicines and chemicals may cause chronic liver injury.

5. **Genetic disorders:** Conditions such as haemochromatosis and Wilson disease may cause harmful accumulation of iron or copper in the liver.

Signs and Symptoms of Liver Cirrhosis

1. **Jaundice:** Yellowing of the skin and eyes due to increased bilirubin in the blood.
2. **Abdominal swelling:** Fluid may accumulate in the abdominal cavity, a condition called ascites.
3. **Swelling of legs:** Fluid may accumulate in the lower limbs.
4. **Fatigue:** The individual experiences persistent tiredness and weakness.
5. **Loss of appetite:** The individual may have reduced interest in food.
6. **Nausea and vomiting:** Digestive discomfort may occur.
7. **Easy bruising and bleeding:** The damaged liver may produce insufficient blood-clotting proteins.
8. **Itchy skin:** Bile-related substances may accumulate in the body.
9. **Muscle wasting:** Reduced nutritional intake and altered metabolism may cause loss of muscle mass.
10. **Confusion:** Accumulation of toxins such as ammonia may affect brain functioning, causing hepatic encephalopathy.

Effects of Liver Cirrhosis on Body Functioning

- ✓ Reduces the liver's ability to detoxify harmful substances.
- ✓ Interferes with the conversion of ammonia into urea.
- ✓ Reduces the production of plasma proteins such as albumin.
- ✓ Reduces the production of blood-clotting factors.
- ✓ Interferes with bile production and secretion.
- ✓ Reduces the liver's ability to regulate blood glucose.
- ✓ Interferes with metabolism of fats, carbohydrates and proteins.
- ✓ May cause increased pressure in the portal vein, a condition called portal hypertension.

Prevention of Liver Cirrhosis

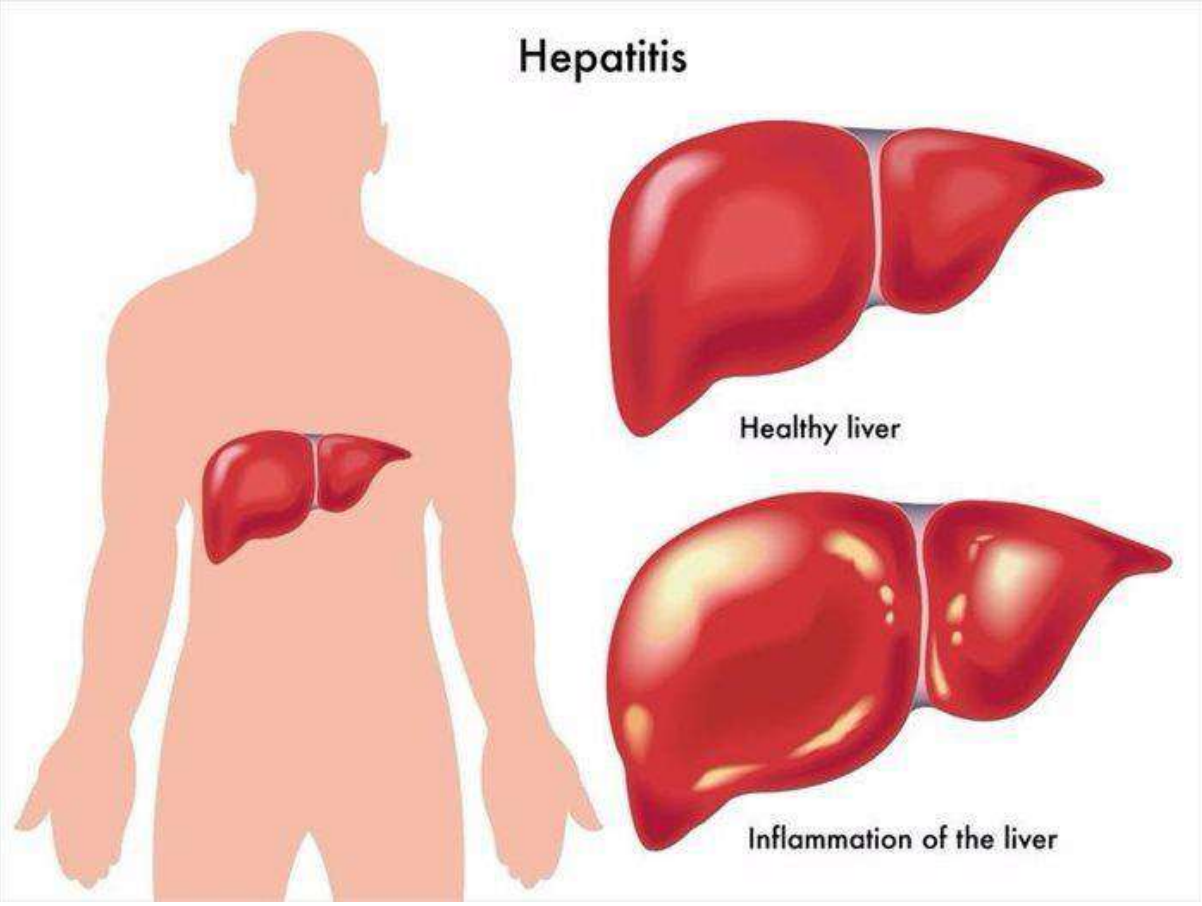
- ✓ Avoid excessive alcohol consumption.
- ✓ Get vaccinated against hepatitis B.
- ✓ Practise safe injection procedures.
- ✓ Avoid sharing needles and sharp instruments.
- ✓ Avoid unnecessary use of medicines.
- ✓ Seek medical treatment for liver infections.
- ✓ Maintain a healthy body weight.
- ✓ Eat a balanced diet.
- ✓ Manage diabetes and other metabolic conditions.
- ✓ Avoid exposure to harmful chemicals and toxins.

Management of Liver Cirrhosis

- ✓ Treat the underlying cause.
- ✓ Stop alcohol consumption where alcohol is responsible.
- ✓ Use prescribed medication to manage complications.
- ✓ Maintain appropriate nutrition.
- ✓ Monitor liver function.
- ✓ Manage fluid accumulation.
- ✓ Treat complications such as portal hypertension.
- ✓ Liver transplantation may be considered in advanced cases.

Important: Established cirrhotic scarring is generally not reversible, although treating the underlying cause can slow or stop further damage and improve outcomes.

B. HEPATITIS



Meaning of Hepatitis

Hepatitis is the inflammation of the liver, commonly caused by viral infections, alcohol, certain medicines, toxins or autoimmune conditions.

Inflammation damages liver cells and interferes with normal liver functioning.

Types of Viral Hepatitis

The major types of viral hepatitis are:

- ✓ Hepatitis A.

- ✓ Hepatitis B.
- ✓ Hepatitis C.
- ✓ Hepatitis D.
- ✓ Hepatitis E.

1. Hepatitis A

Hepatitis A is a viral liver infection caused by the hepatitis A virus (HAV).

Mode of Transmission

- ✓ Consumption of contaminated water.
- ✓ Consumption of contaminated food.
- ✓ Poor sanitation.
- ✓ Poor handwashing practices.
- ✓ Person-to-person transmission through the faecal-oral route.

Signs and Symptoms

- ✓ Fever.
- ✓ Fatigue.
- ✓ Nausea.
- ✓ Vomiting.
- ✓ Abdominal discomfort.
- ✓ Loss of appetite.
- ✓ Dark-coloured urine.
- ✓ Pale stools.
- ✓ Jaundice.

Prevention

- ✓ Proper handwashing.
- ✓ Drinking safe and treated water.
- ✓ Proper disposal of human waste.
- ✓ Washing fruits and vegetables.
- ✓ Eating properly prepared food.
- ✓ Hepatitis A vaccination.

Hepatitis A usually causes an acute infection and does not normally develop into chronic hepatitis.

2. Hepatitis B

Hepatitis B is a viral liver infection caused by the hepatitis B virus (HBV).

Mode of Transmission

- ✓ Contact with infected blood.
- ✓ Unprotected sexual contact with an infected person.
- ✓ Sharing contaminated needles.
- ✓ Use of unsterilised tattooing or piercing equipment.
- ✓ Transmission from an infected mother to her baby during childbirth.
- ✓ Sharing sharp instruments contaminated with infected blood.

Signs and Symptoms

- ✓ Jaundice.
- ✓ Fatigue.
- ✓ Abdominal pain.
- ✓ Nausea.
- ✓ Vomiting.
- ✓ Dark urine.
- ✓ Loss of appetite.
- ✓ Joint pain.

Some infected people may have no obvious symptoms.

Complications

- ✓ Chronic hepatitis.
- ✓ Liver cirrhosis.
- ✓ Liver failure.
- ✓ Liver cancer.

Prevention

- ✓ Hepatitis B vaccination.
- ✓ Screening of donated blood.
- ✓ Avoiding the sharing of needles.
- ✓ Using sterile medical equipment.
- ✓ Practising safer sex.
- ✓ Screening pregnant women and providing appropriate prevention measures for newborns.

3. Hepatitis C

Hepatitis C is a viral infection caused by the hepatitis C virus (HCV).

Mode of Transmission

- ✓ Contact with infected blood.
- ✓ Sharing contaminated needles.
- ✓ Unsafe medical procedures.

- ✓ Poorly sterilised equipment.
- ✓ Less commonly, sexual transmission or transmission during childbirth.

Signs and Symptoms

- ✓ Fatigue.
- ✓ Nausea.
- ✓ Abdominal discomfort.
- ✓ Jaundice.
- ✓ Loss of appetite.
- ✓ Dark urine.
- ✓ Joint pain.

Many people do not develop symptoms during the early stages.

Complications

- ✓ Chronic liver inflammation.
- ✓ Liver fibrosis.
- ✓ Cirrhosis.
- ✓ Liver failure.
- ✓ Liver cancer.

Prevention

- ✓ Avoid sharing needles.
- ✓ Use sterile medical equipment.
- ✓ Screen donated blood.
- ✓ Practise infection prevention.
- ✓ Avoid unregulated body-piercing and tattooing procedures.

There is currently no widely available vaccine for hepatitis C, but effective antiviral medicines can cure most infections.

4. Hepatitis D

- ✓ It is caused by the hepatitis D virus.
- ✓ It occurs only in people who are infected with hepatitis B because it requires the hepatitis B virus to complete its life cycle.
- ✓ It is transmitted through contact with infected blood and body fluids.
- ✓ It may cause severe liver damage.

Prevention: Hepatitis B vaccination prevents hepatitis D infection in people who are not already infected with hepatitis B.

5. Hepatitis E

- ✓ It is caused by the hepatitis E virus.

- ✓ It is commonly transmitted through contaminated water.
- ✓ It may also be transmitted through contaminated food.
- ✓ It usually causes an acute infection.
- ✓ It can be particularly dangerous during pregnancy.

Prevention

- ✓ Drinking safe water.
- ✓ Proper sanitation.
- ✓ Proper food preparation.
- ✓ Washing hands.
- ✓ Avoiding contaminated food and water.

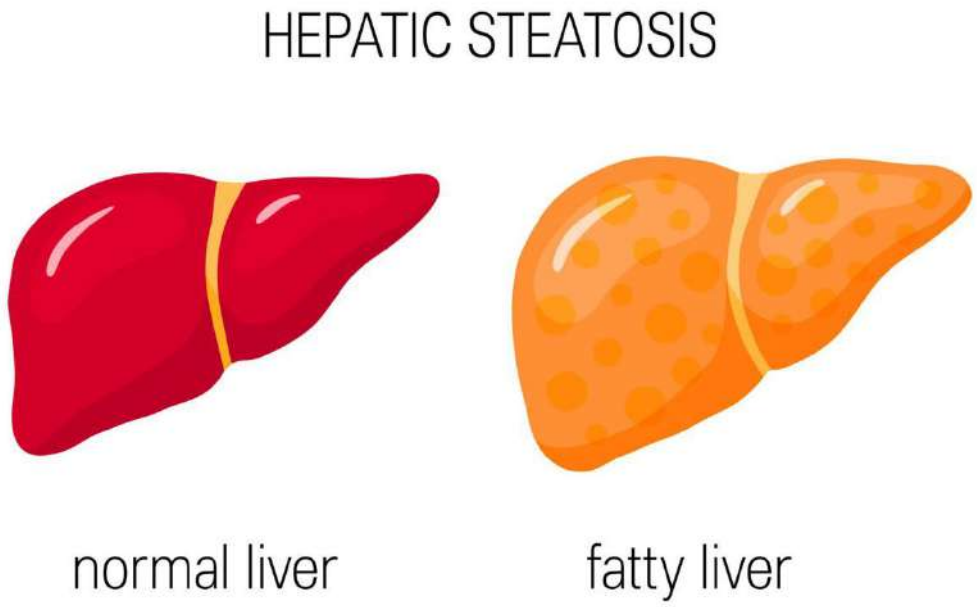
Comparison of Hepatitis Types

Type	Main transmission route	Important prevention
Hepatitis A	Contaminated food and water	Sanitation and vaccination
Hepatitis B	Blood and body fluids	Vaccination and safe practices
Hepatitis C	Mainly infected blood	Sterile equipment and blood screening
Hepatitis D	Blood and body fluids; requires HBV	Hepatitis B vaccination
Hepatitis E	Mainly contaminated water and food	Safe water and sanitation

Effects of Hepatitis on Liver Functioning

- ✓ Damages liver cells.
- ✓ Interferes with normal metabolism.
- ✓ May reduce the ability to process bilirubin.
- ✓ May interfere with the production of plasma proteins.
- ✓ May reduce normal bile secretion.
- ✓ May interfere with detoxification.
- ✓ Severe or chronic infection may cause liver cirrhosis.
- ✓ May increase the risk of liver cancer, particularly in chronic hepatitis B and C.

C. FATTY LIVER DISEASE



Meaning of Fatty Liver Disease

Fatty liver disease is a condition characterised by excessive accumulation of fat, mainly triglycerides, within liver cells.

Small quantities of fat are normally present in the liver. However, excessive accumulation may interfere with normal liver functioning and, in some individuals, cause inflammation and scarring.

Fatty liver disease is also known as hepatic steatosis.

Types of Fatty Liver Disease

There are two major broad categories:

1. Alcohol-Associated Fatty Liver Disease

This occurs when excessive alcohol consumption causes fat to accumulate in liver cells.

2. Metabolic Dysfunction-Associated Steatotic Liver Disease (MASLD)

This occurs when fat accumulates in the liver in association with metabolic risk factors.

It was previously commonly referred to as non-alcoholic fatty liver disease (NAFLD).

Causes and Risk Factors

- Excessive alcohol consumption.
- Obesity, especially abdominal obesity.
- Type 2 diabetes mellitus.
- Insulin resistance.
- High blood triglyceride levels.
- Unhealthy dietary patterns.
- Physical inactivity.
- Metabolic syndrome.

Certain medicines.

Rapid weight loss in some circumstances.

Signs and Symptoms

Many people with fatty liver disease do not experience noticeable symptoms.

When symptoms occur, they may include:

Fatigue.

General weakness.

Discomfort in the upper right side of the abdomen.

Enlarged liver.

Abdominal discomfort.

Reduced appetite in some individuals.

If inflammation and advanced liver damage develop, additional signs may include jaundice, abdominal swelling and leg swelling.

How Fatty Liver Disease Develops

Excess fat accumulates in liver cells.

The liver becomes enlarged in some individuals.

Continued metabolic stress may cause inflammation.

Liver cells may become damaged.

Repeated damage may lead to fibrosis.

Severe fibrosis may eventually develop into cirrhosis.

Effects of Fatty Liver Disease

Interferes with normal liver metabolism.

May cause inflammation of liver tissues.

May reduce normal liver functioning in advanced cases.

May increase the risk of liver fibrosis.

May eventually result in cirrhosis.

May increase the risk of liver cancer in advanced disease.

Prevention and Management

Maintain a healthy body weight.

Engage in regular physical exercise.

Eat a balanced diet.

Reduce excessive intake of foods high in added sugars.

Avoid or minimise alcohol consumption.

Manage blood glucose levels.

Control blood cholesterol and triglyceride levels.

Seek medical assessment when liver disease is suspected.

Avoid unnecessary use of medicines and herbal products.

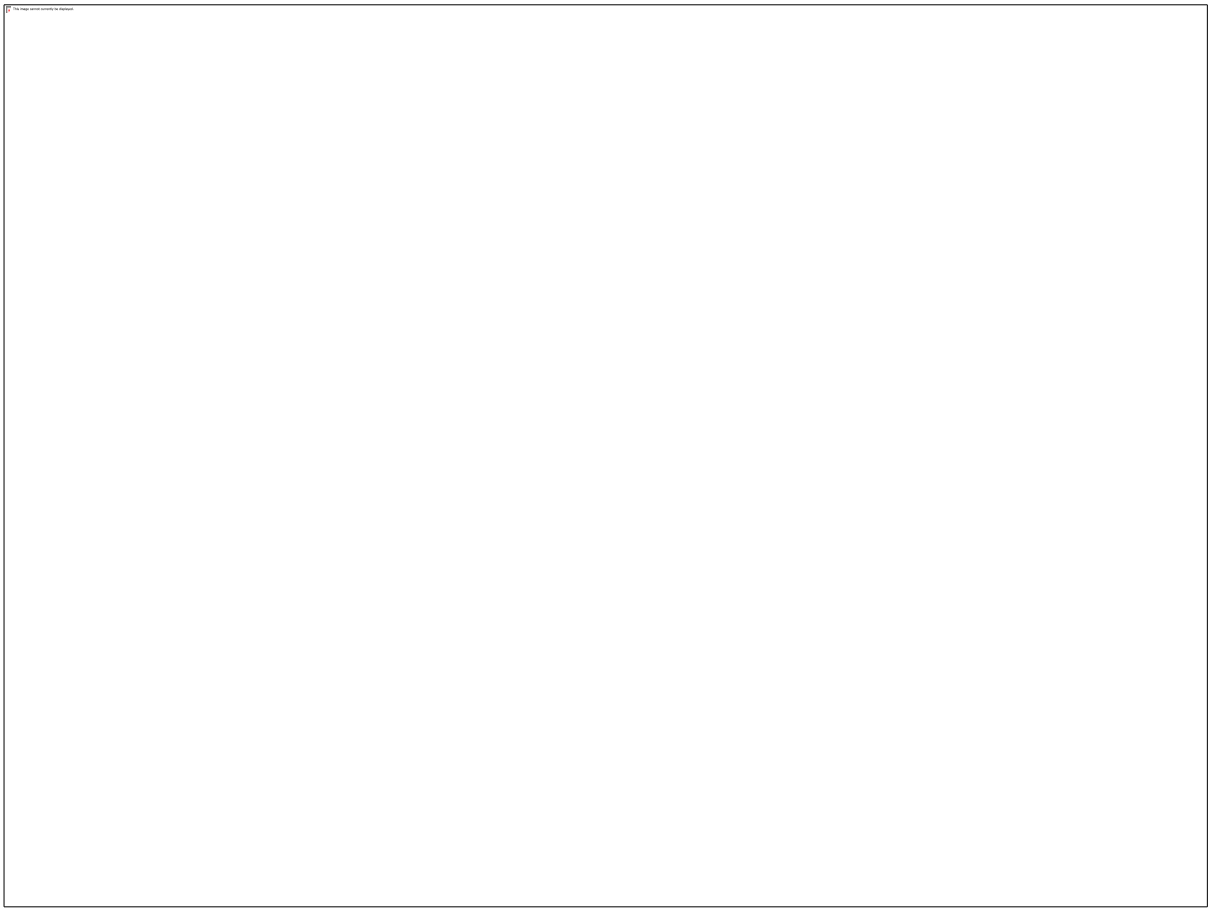
Follow medical advice on gradual and sustainable weight reduction.

Differences Between Cirrhosis, Hepatitis and Fatty Liver Disease

Cirrhosis	Hepatitis	Fatty liver disease
Characterised by extensive scarring and nodular changes.	Characterised by inflammation of the liver.	Characterised by excessive fat accumulation in liver cells.
Commonly develops after prolonged liver damage.	May be caused by viruses, alcohol, toxins or autoimmune conditions.	Associated with alcohol or metabolic risk factors.
May be irreversible.	May be acute or chronic.	May improve when the underlying cause is addressed.
Interferes with liver architecture and function.	Damages and inflames liver cells.	May progress to inflammation, fibrosis and cirrhosis.

3.3.17 OTHER DISORDERS RELATED TO EXCRETION AND HOMEOSTASIS

A. KIDNEY STONES



Meaning

Kidney stones are hard deposits of minerals and salts that form inside the kidneys.

Causes and Risk Factors

Inadequate water intake.

High concentrations of certain minerals in urine.

Excessive urinary calcium or oxalate in susceptible individuals.

Certain metabolic disorders.

Recurrent urinary tract infections in some types of stones.

Signs and Symptoms

Severe pain in the side or back.

Pain during urination.

Blood in urine.

Nausea and vomiting.

Frequent urination.

Difficulty passing urine in some cases.

Prevention and Management

Drink adequate water.

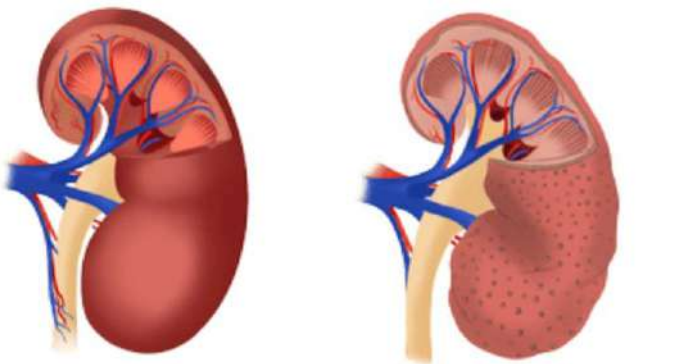
Follow dietary advice according to the type of stone.

Seek medical assessment.

Use prescribed medication.

Undergo procedures to remove or break large stones when necessary.

B. KIDNEY FAILURE



Normal Kidney Chronic Kidney Disease Kidney

Meaning

Kidney failure is a condition in which the kidneys lose their ability to filter blood and regulate body fluids adequately.

Causes

Diabetes mellitus.

High blood pressure.

Severe kidney infections.

Kidney inflammation.

Certain toxic substances and medicines.

Severe dehydration or reduced blood supply to the kidneys.

Effects

Accumulation of urea and other metabolic wastes.

Accumulation of excess water.

Electrolyte imbalance.

Disturbance of blood pH.

Increased blood pressure.

Anaemia due to reduced erythropoietin production.

Bone and mineral disorders.

Management

Treating the underlying cause.

Controlling blood pressure and blood glucose.

Dietary and fluid management.

Prescribed medication.

Dialysis in appropriate cases.

Kidney transplantation in selected patients.

C. GOUT



Meaning

Gout is an inflammatory form of arthritis caused by the accumulation of urate crystals in joints and surrounding tissues.

Causes and Risk Factors

High uric acid concentration in blood.

Reduced elimination of uric acid by the kidneys.

Genetic factors.

Certain medicines.

Excessive alcohol consumption.

Some dietary patterns.

Obesity and metabolic disorders.

Signs and Symptoms

Sudden severe joint pain.

Swelling of affected joints.

Redness.

Warmth around the joint.

Tenderness.

The big toe is commonly affected, although other joints can also be involved.

Management

Appropriate medical treatment.

Adequate hydration.

Dietary adjustments.

Maintaining a healthy body weight.

Medication to lower uric acid when indicated.

3.3.18 SUMMARY OF IMPORTANT BIOLOGICAL CONCEPTS

Concept	Meaning / Main function
Excretion	Removal of metabolic waste products.
Egestion	Removal of undigested food materials.
Homeostasis	Maintenance of a stable internal environment.
Osmoregulation	Regulation of water and dissolved salts.
Thermoregulation	Regulation of body temperature.
Ultrafiltration	Filtration of blood under pressure in the glomerulus.
Selective reabsorption	Returning useful substances to the blood.
Tubular secretion	Movement of additional wastes from blood into renal tubules.
Nephron	Structural and functional unit of the kidney.
Urea	Nitrogenous waste formed in the liver.
Ammonia	Highly toxic nitrogenous waste.
Uric acid	Nitrogenous waste requiring little water for elimination.
ADH	Hormone regulating water reabsorption in the kidneys.
Aldosterone	Hormone regulating sodium reabsorption and potassium secretion.

Insulin	Hormone that lowers blood glucose.
Glucagon	Hormone that raises blood glucose.
Deamination	Removal of amino groups from excess amino acids.
Glycogenesis	Formation of glycogen from glucose.
Glycogenolysis	Breakdown of glycogen into glucose.
Gluconeogenesis	Formation of glucose from non-carbohydrate substances.
Cirrhosis	Chronic liver scarring and structural damage.
Hepatitis	Inflammation of the liver.
Fatty liver	Excessive accumulation of fat in liver cells.
Diabetes mellitus	Disorder involving abnormal blood glucose regulation.
Diabetes insipidus	Disorder involving impaired water conservation and excessive dilute urine production.
Vasodilation	Widening of blood vessels.
Vasoconstriction	Narrowing of blood vessels.
Ascites	Accumulation of fluid in the abdominal cavity.
Jaundice	Yellowing of the skin and eyes due to increased bilirubin.

REVISION QUESTIONS

STRAND 3.0: ANATOMY AND PHYSIOLOGY OF ANIMALS

SUBSTRAND 3.3: EXCRETION AND HOMEOSTASIS IN ANIMALS

SECTION A: MULTIPLE-CHOICE QUESTIONS

1. Which of the following nitrogenous waste products is the most toxic and requires the largest amount of water for its elimination?

A. Urea
B. Ammonia
C. Uric acid
D. Creatinine

2. Animals that mainly excrete nitrogenous waste in the form of uric acid are referred to as:

A. Ammonotelic
B. Ureotelic
C. Uricotelic
D. Osmoregulatory

3. Which part of the mammalian kidney is responsible for filtering blood to form glomerular filtrate?

A. Renal pelvis
B. Glomerulus
C. Collecting duct
D. Loop of Henle

4. The main function of the Bowman's capsule is to:

A. Store urine temporarily
B. Filter blood and collect glomerular filtrate
C. Produce urine pigments
D. Transport urine to the ureter

5. Which process involves the movement of water and small dissolved substances from the glomerular capillaries into Bowman's capsule?

A. Selective reabsorption
B. Tubular secretion
C. Ultrafiltration
D. Osmoregulation

6. Which part of the nephron is mainly responsible for the selective reabsorption of glucose, amino acids and most useful salts?

A. Proximal convoluted tubule
B. Collecting duct
C. Renal pelvis
D. Ureter

7. The hormone that increases water reabsorption in the collecting ducts of the kidneys is:

A. Insulin
B. Glucagon
C. Antidiuretic hormone
D. Adrenaline

8. When a person drinks a large amount of water, the expected response is:

A. Increased secretion of ADH
B. Production of a large volume of dilute urine

C. Reduced urine production
D. Increased water reabsorption in collecting ducts

9. Which part of the brain regulates body temperature and plays a major role in maintaining homeostasis?

A. Cerebellum
B. Medulla oblongata
C. Hypothalamus
D. Cerebrum

10. During exposure to very high environmental temperatures, the skin responds by:

A. Vasoconstriction and reduced sweating
B. Vasodilation and increased sweating
C. Shivering and hair erection
D. Reduced blood flow to the skin

11. Which of the following is the main nitrogenous waste product formed in the liver through deamination and the urea cycle?

A. Ammonia
B. Urea
C. Uric acid
D. Glycogen

12. The liver converts excess amino acid nitrogen into urea mainly because:

A. Urea is more toxic than ammonia
B. Urea is less toxic than ammonia
C. Urea cannot dissolve in water
D. Urea is used to produce red blood cells

13. Which hormone lowers blood glucose concentration by promoting glucose uptake and glycogen formation?

A. Glucagon
B. Insulin
C. ADH
D. Thyroxine

14. When blood glucose concentration falls below the normal level, the pancreas responds by releasing:

A. Insulin B. ADH
C. Glucagon D. Oestrogen

15. A person who produces large quantities of dilute urine, experiences excessive thirst and has normal blood glucose levels may be suffering from:

A. Diabetes mellitus
B. Diabetes insipidus
C. Cirrhosis
D. Gout

16. Which of the following is a common symptom of diabetes mellitus?

A. Excessive urination and thirst
B. Reduced blood glucose at all times
C. Complete absence of urine
D. Increased production of bile

17. The accumulation of uric acid crystals in joints may lead to a condition known as:

A. Hepatitis
B. Gout
C. Diabetes insipidus
D. Kidney stones

18. Which of the following is a major function of the skin in excretion and homeostasis?

A. Production of insulin
B. Removal of carbon dioxide from the blood
C. Elimination of small amounts of water and salts through sweat
D. Formation of urea from amino acids

19. Which of the following conditions results from long-term damage and scarring of liver tissue?

A. Cirrhosis
B. Gout
C. Diabetes insipidus
D. Kidney stones

20. A person working in a hot environment begins sweating heavily. The main biological importance of sweating is to:

A. Increase blood glucose concentration
B. Cool the body through evaporation
C. Increase the production of urea
D. Reduce the amount of oxygen in the blood

21. Which cells of the pancreas produce insulin?

A. Alpha cells
B. Beta cells
C. Delta cells
D. Acinar cells

22. Which hormone stimulates the liver to break down glycogen into glucose when blood glucose concentration is low?

A. Insulin
B. Aldosterone
C. Glucagon
D. Thyroxine

23. ADH is synthesised in the hypothalamus and released into the blood by which structure?

A. Anterior pituitary gland
B. Thyroid gland
C. Adrenal cortex
D. Posterior pituitary gland

24. Which hormone increases sodium ion reabsorption and potassium ion secretion in the kidney tubules?

A. Aldosterone
B. Insulin
C. Calcitonin
D. Adrenaline

25. Which gland produces thyroxine, a hormone that helps regulate metabolic rate?

A. Pancreas
B. Thyroid gland
C. Parathyroid glands
D. Adrenal glands

26. Which hormone raises blood calcium concentration by stimulating calcium release from bones and increasing calcium reabsorption in the kidneys?

A. Calcitonin
B. Insulin
C. Parathyroid hormone
D. ADH

27. Adrenaline is released mainly from which part of the adrenal gland?

A. Adrenal cortex
B. Renal cortex
C. Pancreatic cortex
D. Adrenal medulla

28. Which process describes the conversion of excess glucose into glycogen for storage?

A. Glycogenesis
B. Glycogenolysis
C. Gluconeogenesis
D. Deamination

29. Which hormone helps prepare the body for an emergency by increasing heart rate and widening the airways?

A. Aldosterone
B. Adrenaline
C. Insulin
D. Calcitonin

30. Which statement best explains why insulin and glucagon are described as antagonistic hormones?

A. They are produced by the same pancreatic cells.
B. They both increase blood glucose concentration.
C. They have opposite effects on blood glucose concentration.
D. They are both released only during fasting.

SECTION B: SHORT-ANSWER QUESTIONS

Excretion and Excretory Organs

1. Define excretion.
2. Differentiate between excretion and egestion.
3. State six importance of excretion in animals.
4. Name the main excretory organ in insects.
5. Describe the location of Malpighian tubules in insects.
6. State five functions of Malpighian tubules.
7. Name the main nitrogenous excretory product in insects.
8. Explain why uric acid is suitable for terrestrial insects.
9. Name three excretory organs found in birds.
10. Identify the main nitrogenous excretory product in birds.
11. Explain why birds eliminate nitrogenous wastes mainly as uric acid.
12. Name three structures involved in excretion in freshwater fish.
13. Identify the main nitrogenous excretory product in freshwater bony fish.
14. Explain why freshwater fish produce large quantities of dilute urine.
15. State four osmoregulatory adaptations of freshwater fish.
16. Explain why marine bony fish drink seawater.
17. State four osmoregulatory adaptations of marine bony fish.
18. Distinguish between ammonotelic, ureotelic and uricotelic animals.
19. Give four examples of ureotelic animals.
20. Explain why ammonia requires large quantities of water for elimination.

B. Kidney Structure and Nephron

21. Define a kidney.
22. Name the three main internal regions of the mammalian kidney.
23. State four functions of the renal cortex.
24. State four functions of the renal medulla.
25. Explain the function of the renal pelvis.
26. State the functions of the renal artery and renal vein.
27. What is the function of the ureter?
28. Define a nephron.
29. Name the six main parts of a typical nephron.
30. Describe the structure of Bowman's capsule.
31. Explain the function of the glomerulus.
32. Differentiate between the afferent and efferent arterioles.
33. State five adaptations of the proximal convoluted tubule to its functions.

34. Explain the role of the descending limb of the loop of Henle.
35. Explain the role of the ascending limb of the loop of Henle.
36. State four functions of the distal convoluted tubule.
37. Explain the role of the collecting duct in urine formation.
38. State three functions of the vasa recta.

C. Urine Formation

39. Define urine formation.
40. Name the three main processes involved in urine formation.
41. Explain the process of ultrafiltration.
42. State five substances found in glomerular filtrate.
43. Name four substances that are normally retained in the blood during ultrafiltration.
44. Define selective reabsorption.
45. Explain why glucose is normally absent from the urine of a healthy person.
46. State five substances reabsorbed in the proximal convoluted tubule.
47. Define tubular secretion.
48. State four substances that may be secreted into the renal tubules.
49. Explain the importance of tubular secretion.
50. Describe the pathway followed by urine from the collecting ducts to the outside of the body.
51. State five factors affecting the volume of urine produced.
52. Explain the role of ADH in regulating urine concentration.

D. Skin and Liver

53. Name the three main layers of mammalian skin.
54. Describe the structure of the epidermis.
55. State five functions of the dermis.
56. Explain the role of sweat glands in excretion.
57. Name four substances found in sweat.
58. State four functions of sebaceous glands.
59. Define deamination.
60. Explain how the liver converts ammonia into urea.
61. Describe how bilirubin is formed and eliminated.
62. State six excretory functions of the liver.
63. Explain the role of the liver in detoxification.
64. State six other functions of the liver apart from excretion.

E. Homeostasis and Osmoregulation

65. Define homeostasis.
66. State eight importance of homeostasis in humans.
67. Explain the meaning of negative feedback.
68. Name the main components of a negative feedback mechanism.
69. Differentiate between negative feedback and positive feedback.
70. Define osmoregulation.
71. Explain the role of ADH in osmoregulation.
72. State four functions of aldosterone.
73. Explain what happens when the body has excess water.
74. Explain what happens when the body is dehydrated.

F. Thermoregulation

75. Define thermoregulation.
76. Identify the main control centre for thermoregulation.
77. Explain five ways in which the human body loses heat.
78. Describe the responses of the body when temperature rises above normal.
79. Describe the responses of the body when temperature falls below normal.
80. Explain the role of the hypothalamus in thermoregulation.

SECTION B: SHORT-ANSWER QUESTIONS

G. Hormones and Their Roles in Homeostasis

81. Define the term hormone.
82. What is an endocrine gland?
83. State four characteristics of hormones.
84. Name the gland responsible for producing insulin.
85. Identify the cells of the pancreas that produce glucagon.
86. State three functions of insulin.
87. Explain how glucagon increases blood glucose concentration.
88. Differentiate between glycogenesis and glycogenolysis.
89. State the source and function of ADH.
90. Explain how ADH helps prevent dehydration.
91. State three functions of aldosterone.
92. Identify the gland that produces thyroxine.
93. Explain the role of thyroxine in regulating metabolism.
94. State the function of parathyroid hormone.
95. Differentiate between the actions of PTH and calcitonin.

96. State four effects of adrenaline on the body.
97. Explain why insulin and glucagon are described as antagonistic hormones.
98. Name two hormones involved in regulating blood glucose.
99. Identify the hormone involved in sodium and potassium balance.
100. Explain how hormones contribute to homeostasis.

H. Blood Glucose Regulation and Diseases

101. Define blood glucose regulation.
102. Name the two main hormones involved in blood glucose regulation.
103. State the functions of insulin.
104. State the functions of glucagon.
105. Name the pancreatic cells that produce insulin.
106. Name the pancreatic cells that produce glucagon.
107. Define diabetes mellitus.
108. Differentiate between type 1 and type 2 diabetes mellitus.
109. State six signs and symptoms of diabetes mellitus.
110. Give five complications of poorly controlled diabetes mellitus.
111. Define diabetes insipidus.
112. Explain the role of ADH in the development of diabetes insipidus.
113. Differentiate between diabetes mellitus and diabetes insipidus.
114. State four signs and symptoms of diabetes insipidus.
115. Define liver cirrhosis.
116. State six causes of liver cirrhosis.
117. Explain six effects of cirrhosis on normal body functioning.
118. Define hepatitis.
119. Name the five major types of viral hepatitis.
120. Explain the modes of transmission of hepatitis A, B and C.
121. State five ways of preventing hepatitis B.
122. Define fatty liver disease.
123. State six risk factors associated with fatty liver disease.
124. Explain how fatty liver disease can progress to cirrhosis.
125. Differentiate between cirrhosis, hepatitis and fatty liver disease.

3.3.20 STRUCTURED QUESTIONS

QUESTION 1: EXCRETION IN ANIMALS (15 MARKS)

a) Define excretion. (2 marks)

b) Explain five functions of the Malpighian tubules in insects. (5 marks)

c) Explain why birds excrete nitrogenous wastes mainly as uric acid. (4 marks)

d) Differentiate between excretion in freshwater fish and marine bony fish. (4 marks)

QUESTION 2: MAMMALIAN KIDNEY (20 MARKS)

a) Draw a well-labelled longitudinal section of a mammalian kidney. (6 marks)

b) Describe the structure and functions of the renal cortex. (4 marks)

c) Explain four functions of the renal medulla. (4 marks)

d) State three functions of the renal pelvis. (3 marks)

e) Explain the functions of the renal artery, renal vein and ureter. (3 marks)

QUESTION 3: STRUCTURE OF THE NEPHRON (20 MARKS)

a) Define a nephron. (2 marks)

b) Draw and label a typical mammalian nephron. (6 marks)

c) Describe the structure and functions of the following:

i. Bowman's capsule. (3 marks)

ii. Glomerulus. (3 marks)

iii. Proximal convoluted tubule. (3 marks)

iv. Loop of Henle. (3 marks)

QUESTION 4: URINE FORMATION (20 MARKS)

a) Name the three processes involved in urine formation. (3 marks)

b) Describe the process of ultrafiltration. (6 marks)

c) Explain selective reabsorption in the proximal convoluted tubule. (5 marks)

d) Explain the importance of tubular secretion. (3 marks)

e) State three factors that influence urine production. (3 marks)

QUESTION 5: SKIN AND EXCRETION (15 MARKS)

a) Draw a well-labelled cross-section of mammalian skin. (6 marks)

b) Describe the functions of the epidermis and dermis. (4 marks)

c) Explain how the skin contributes to excretion. (3 marks)

d) State two functions of sebaceous glands. (2 marks)

QUESTION 6: ROLE OF THE LIVER IN EXCRETION (15 MARKS)

a) Define deamination. (2 marks)

b) Explain how the liver converts excess amino acids into urea. (5 marks)

c) Describe the breakdown of haemoglobin and the elimination of bilirubin. (5 marks)

d) State three substances that the liver detoxifies or metabolises. (3 marks)

QUESTION 7: OSMOREGULATION (15 MARKS)

a) Define osmoregulation. (2 marks)

b) Explain how ADH regulates water balance when a person is dehydrated. (6 marks)

c) Explain what happens when a person drinks excessive amounts of water. (4 marks)

d) State three functions of aldosterone. (3 marks)

QUESTION 8: THERMOREGULATION (20 MARKS)

a) Define thermoregulation. (2 marks)

b) Identify the organ that controls body temperature. (1 mark)

c) Explain six responses of the body when the environmental temperature is very high. (9 marks)

d) Describe four responses of the body when environmental temperature is very low. (8 marks)

QUESTION 9: BLOOD GLUCOSE REGULATION (15 MARKS)

a) Name the two hormones involved in regulating blood glucose concentration. (2 marks)

b) Explain how insulin regulates blood glucose concentration after a carbohydrate-rich meal. (5 marks)

c) Describe how glucagon regulates blood glucose concentration during fasting. (5 marks)

d) State three importance of blood glucose regulation. (3 marks)

QUESTION 10: DIABETES MELLITUS AND DIABETES INSIPIDUS (20 MARKS)

a) Define diabetes mellitus. (2 marks)

b) Explain the differences between type 1 and type 2 diabetes mellitus. (6 marks)

c) State five signs and symptoms of diabetes mellitus. (5 marks)

d) Define diabetes insipidus. (2 marks)

e) Explain the difference between diabetes mellitus and diabetes insipidus. (5 marks)

QUESTION 11: LIVER DISEASES (20 MARKS)

a) Define the following:

i. Cirrhosis. (2 marks)

ii. Hepatitis. (2 marks)

iii. Fatty liver disease. (2 marks)

b) Explain five causes of liver cirrhosis. (5 marks)

c) Describe five signs and symptoms of liver disease. (5 marks)

d) Explain four ways of preventing liver diseases. (4 marks)

3.3.21 COMPETENCY-BASED APPLICATION QUESTIONS

QUESTION 1: EXCRETION IN ANIMALS

A Biology learner visited a poultry farm and observed that chickens eliminated a whitish semi-solid substance together with their faecal waste. The learner also observed that the birds did not have a urinary bladder.

a) Identify the main nitrogenous excretory product in birds. (1 mark)

b) Explain why this substance is suitable for birds. (3 marks)

c) Name the organs through which urinary waste passes before elimination. (3 marks)

d) Explain two advantages of eliminating nitrogenous waste in semi-solid form. (2 marks)

QUESTION 2: FRESHWATER AND MARINE FISH

Two groups of fish were kept in separate aquaria. Group A consisted of freshwater fish, while Group B consisted of marine bony fish.

a) Explain why Group A continuously gains water through osmosis. (2 marks)

b) Describe three ways in which Group A maintains its water and salt balance. (3 marks)

c) Explain why Group B loses water through osmosis. (2 marks)

d) Describe three adaptations that enable Group B to survive in seawater. (3 marks)

QUESTION 3: KIDNEY FUNCTION

A patient underwent laboratory investigations that revealed an abnormal accumulation of urea in the blood.

a) Identify the organ mainly responsible for removing urea from blood. (1 mark)

b) Explain how urea is normally removed from the blood. (4 marks)

c) Name the functional unit of the organ identified in (a). (1 mark)

d) Explain three possible consequences of kidney failure. (3 marks)

e) State one medical procedure that can assist a patient whose kidneys have failed. (1 mark)

QUESTION 4: WATER BALANCE

A learner participated in a long-distance athletics competition on a hot afternoon. After the race, the learner had lost considerable amounts of water through sweating.

a) Explain why the learner's blood became more concentrated. (2 marks)

b) Identify the hormone responsible for increasing water reabsorption in the kidneys. (1 mark)

c) Describe how this hormone helps restore normal water balance. (4 marks)

d) State three signs that may indicate dehydration. (3 marks)

QUESTION 5: TEMPERATURE REGULATION

A person moved from a cool environment into a very hot room. After some time, the person started sweating profusely.

a) Identify the part of the brain responsible for coordinating temperature regulation. (1 mark)

b) Explain why sweating increases under these conditions. (3 marks)

c) Describe three other physiological responses that help lower body temperature. (3 marks)

d) Explain the importance of maintaining a relatively constant body temperature. (3 marks)

QUESTION 6: BLOOD GLUCOSE REGULATION

A person consumed a meal containing rice, potatoes and fruit. After digestion and absorption, the person's blood glucose concentration increased.

a) Name the hormone released to lower blood glucose concentration. (1 mark)

b) Identify the cells responsible for producing this hormone. (1 mark)

c) Explain how the hormone lowers blood glucose concentration. (4 marks)

d) Name the process through which glucose is converted into glycogen. (1 mark)

e) State three possible consequences of failure to regulate blood glucose concentration. (3 marks)

QUESTION 7: DIABETES MELLITUS

A middle-aged Kenyan adult frequently experiences excessive thirst, frequent urination, tiredness and slow healing of wounds. Medical investigations reveal persistently high blood glucose concentration.

a) Identify the likely disorder. (1 mark)

b) Explain why excessive urination occurs. (3 marks)

c) State four possible risk factors for type 2 diabetes mellitus. (4 marks)

d) Give four management measures for the condition. (4 marks)

QUESTION 8: LIVER FUNCTION

A farmer was advised to reduce alcohol consumption after medical investigations indicated damage to the liver.

a) Identify the disease that may develop following prolonged alcohol-related liver injury. (1 mark)

b) Explain how excessive alcohol consumption damages liver tissue. (3 marks)

c) State four functions of the liver that may be affected by severe liver damage. (4 marks)

d) Give two ways of preventing alcohol-related liver disease. (2 marks)

QUESTION 9: HEPATITIS AND PUBLIC HEALTH

A community health officer noticed an increase in cases of hepatitis following a period of inadequate sanitation and consumption of untreated water.

a) Identify the type of hepatitis most commonly associated with this mode of transmission. (1 mark)

b) Name the virus responsible. (1 mark)

c) Explain three ways of preventing the spread of the infection. (3 marks)

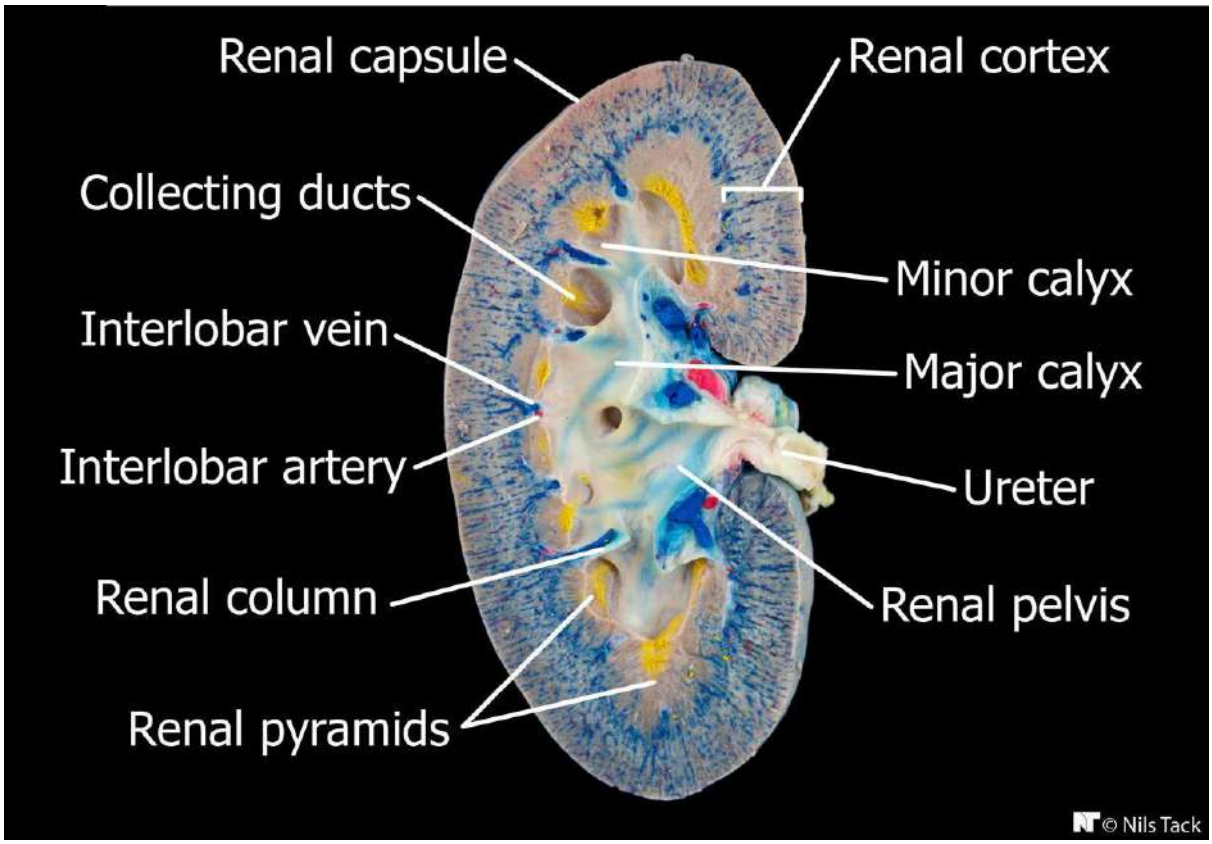
d) State three signs and symptoms of hepatitis. (3 marks)

e) Explain why access to safe drinking water is important in preventing hepatitis A and E. (2 marks)

PRACTICAL ACTIVITIES

These activities help learners develop scientific investigation, observation, communication, collaboration and problem-solving competencies.

ACTIVITY 1: OBSERVING THE INTERNAL STRUCTURE OF A MAMMALIAN KIDNEY



Materials

- ✓ A fresh mammalian kidney obtained from an approved butcher or abattoir.
- ✓ Dissecting tray.
- ✓ Suitable dissection equipment.
- ✓ Gloves.
- ✓ Hand lens.
- ✓ Labels.

Procedure

- ✓ Place the kidney on a dissecting tray.
- ✓ Observe its external appearance.
- ✓ Identify the renal capsule.
- ✓ Identify the renal artery, renal vein and ureter where visible.
- ✓ Cut the kidney longitudinally.
- ✓ Observe the cortex, medulla and renal pelvis.
- ✓ Draw and label the internal structure.
- ✓ Discuss the functions of the identified structures.

Safety precautions

- ✓ Wear protective gloves.
- ✓ Use sharp instruments under teacher supervision.

- ✓ Do not taste or directly inhale biological specimens.
- ✓ Dispose of specimens appropriately.
- ✓ Wash hands and disinfect the working area after the activity.

ACTIVITY 2: CONSTRUCTING A NEPHRON MODEL

Materials

- ✓ Modelling clay.
- ✓ Coloured strings.
- ✓ Cardboard.
- ✓ Labels.
- ✓ Markers.

Procedure

- ✓ Construct a model of Bowman's capsule.
- ✓ Use small strings to represent glomerular capillaries.
- ✓ Construct the proximal convoluted tubule.
- ✓ Construct the loop of Henle.
- ✓ Add the distal convoluted tubule.
- ✓ Add the collecting duct.
- ✓ Label all structures.
- ✓ Explain the function of each part.

Expected outcome: Learners demonstrate an understanding of nephron structure and function.

ACTIVITY 3: INVESTIGATING TEMPERATURE REGULATION

Materials

1. Thermometer.
2. Stopwatch.
3. Water.
4. Exercise space.

Procedure

1. Measure the resting body temperature of a volunteer using an appropriate thermometer.
2. Record the reading.
3. Allow the volunteer to undertake moderate physical activity under teacher supervision.
4. Observe changes in sweating.
5. Record body temperature again.
6. Discuss how the body regulates temperature during exercise.

Expected outcome: Learners explain the importance of thermoregulation.

ACTIVITY 4: INVESTIGATING LIVER HEALTH

Materials

1. Biology textbooks.
2. Health education posters.
3. Charts showing healthy and diseased livers.
4. Internet resources where available.

Procedure

1. Observe images of a healthy liver.
2. Compare it with images showing cirrhosis, hepatitis and fatty liver.
3. Identify visible differences.
4. Research the causes and prevention of liver diseases.
5. Prepare a health-awareness poster for the school community.

Expected outcome: Learners develop awareness of liver health and disease prevention.

