MINISTRY OF EDUCATION

GHANA ASSOCATION OF SCIENCE TEACHERS

(GAST)

Biology

for Senior High Schools

Year 2

• Caroline Asantewaa Biritwum • Gloria Naa Deedei Nartey
• Jo Ann Naa Dei Neequaye

MINISTRY OF EDUCATION

GHANA ASSOCIATION OF SCIENCE TEACHERS

BIOLOGY

For Senior High Schools

Year 2

Caroline Asantewaa Biritwum
Gloria Naa Deedei Nartey
Jo Ann Naa Dei Neequaye

Ghana Education Service (GES)

(GAST)

WE LIVE TO TEACH

NAGRAT

ISBN:

CONTENTS

FOREWORD

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

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

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

Haruna Iddrisu MP

Minister for Education

SECTION

1 BIOLOGY AS THE SCIENCE OF LIFE

EXPLORING BIOLOGY IN SOCIETY

Biology as the Science of Life

Biology and Entrepreneurship

INTRODUCTION

In this section, we study Rhizopus spp. (a fungus), mosses and ferns, highlighting their unique characteristics and economic significance. Rhizopus thrives in moist environments, playing a crucial role in decomposing organic matter, while mosses, as non-vascular Bryophytes, flourish in damp areas and provide insulation and habitat for small animals. Ferns, or Pteridophytes, adapt to various habitats, contribute to nutrient recycling, and are often used in medicine and landscaping. Understanding basic biological concepts such as photosynthesis, reproduction, and nutrition is essential for improving crop and animal production. For example, understanding mosses and ferns' reproduction can improve plant multiplication techniques, and recognising Rhizopus's role can boost soil fertility. By studying these organisms, learners can discover innovative ideas that promote agriculture, environmental balance, and improved quality of life, ultimately leading to increased productivity and resilience in crops and livestock.

KEY IDEAS

- Farmers practise activities based on biological concepts to satisfy the need to provide healthy nutrition and good conditions to breed plants and animals while protecting them from pests to improve production.
- It has significant economic value, especially in food production and biotechnology.
- **Mosses** are small plants that belong to the group of plants known as bryophytes, which lack true roots, true stems and true leaves. remove space below
- **Reproductive Features**: Unlike many plants, ferns have clusters of sporangia called **sori**. Sporangia produce and release spores.
- **Unique Structure**: Ferns are distinguished by their large, intricately divided leaves known as fronds, and specialised underground rhizomes,

which are horizontal stems that store nutrients and give rise to new fronds and roots.

DISTINCTIVE CHARACTERISTICS, LIFE PROCESSES AND ECONOMIC IMPORTANCE OF RHIZOPUS

Distinctive Characteristics and Structure of the Fungus Rhizopus

Rhizopus is a type of fungus, like the mould you sometimes see on bread, kenkey, or fruits. It loves warm and damp places, especially where there's something organic (made from living things) that is rotting.

When Rhizopus starts growing, it looks white, but as it gets older, it turns greyish and eventually black. The body of the Rhizopus consists of hyphae, which are microscopic branching threads. They are of three types that grow: vertical upward(sporangiophore), horizontal (stolon) and vertical downward (rhizoids).

Rhizopus can be likened to a tiny plant with roots and branches, but its root-like structures are called rhizoids, and its "branches" are called stolon. The rhizoids grow into the food source, like bread, to absorb nutrients for growth and to provide anchorage. The stolon spread out on the surface of the food source. This forms a network of hyphae called a mycelium.

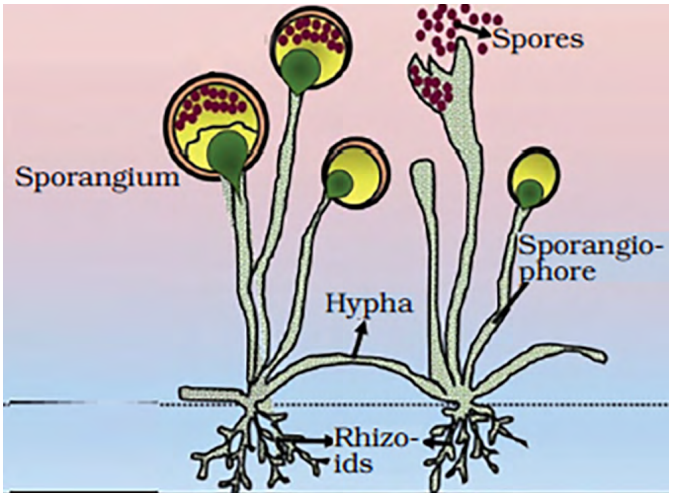
Rhizopus cannot make its food as plants do because it does not have chlorophyll. Instead, it gets its food from dead and decaying organic matter. That is why it is called a saprophyte.

To reproduce, Rhizopus grows special stalks called sporangiophores. These stalks have little balls on top called sporangia, which are like tiny containers full of spores. When the sporangia burst open, the spores spread out and can grow into new Rhizopus.

There are many types of Rhizopus, but a common one is called Rhizopus stolonifer (see **Figure 1.1**). Below is a summary of the functions of the structural components of the Rhizopus

Table 1.1: Functions of the structural components of the Rhizopus.

Structural component	Function
Stolon	Form rhizoids and sporangiophores
Rhizoids	Anchor the mould and extract nutrients
Sporangiophores	Hold the sporangia at their tips
Sporangia	Produce and distribute spores



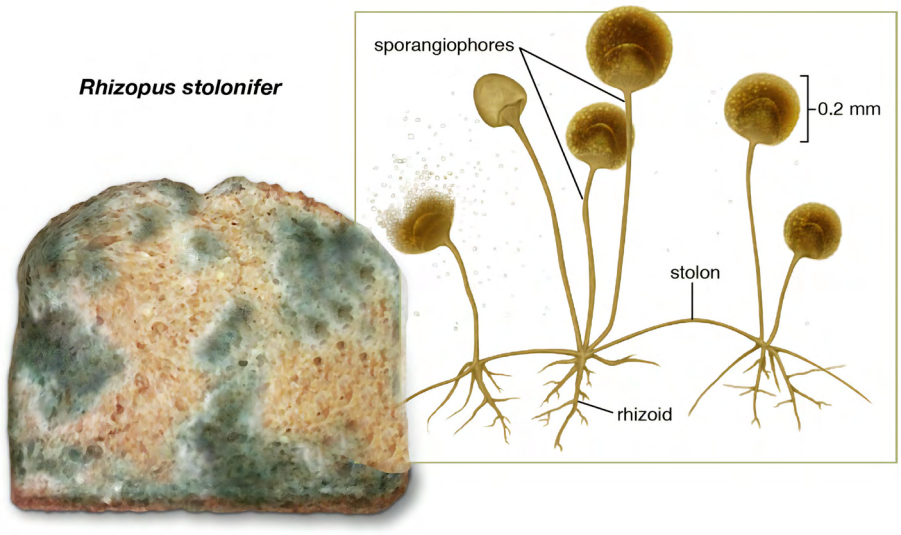


Figure 1.1: Structure of Rhizopus stolonifer

Activity 1.1 Growing Rhizopus in the Classroom

1. Put a slice of moist bread in a transparent polythene bag and keep it in a warm room.
2. Allow it to stay there for five to seven days.
3. Observe periodically and record changes that may occur.
4. After portions of the bread turn black, pick some of the black growth, mount it on a slide and observe it under the microscope. Draw what you see.
5. State four of the structural characteristics observed and describe their functions.

Life Processes of Rhizopus

Rhizopus, the fungus that makes mould on your bread, is alive, just like you! This means it does all the things living things do:

1. **Movement**: It grows by spreading its hyphae. Passively, it also releases spores that float through the air and water like tiny seeds.
2. **Breathing or respiration**: Rhizopus needs oxygen to survive, just like us!
3. **Sensing or irritability**: It responds to the presence of food and to an extent temperature.
4. **Growing:** Rhizopus grows fast when it finds food and the temperature is right.
5. **Reproduction**: It can reproduce in two ways: sexually and asexually. **Asexual reproduction** happens when Rhizopus creates a structure called a sporangium that makes lots of tiny spores. These spores are released and grow into new Rhizopus. **Sexual reproduction** happens when two hyphae of Rhizopus meet and combine their genetic material to create a tough, long-lasting zygospore. This zygospore can survive harsh conditions and will grow into a new Rhizopus when the environment is favourable.

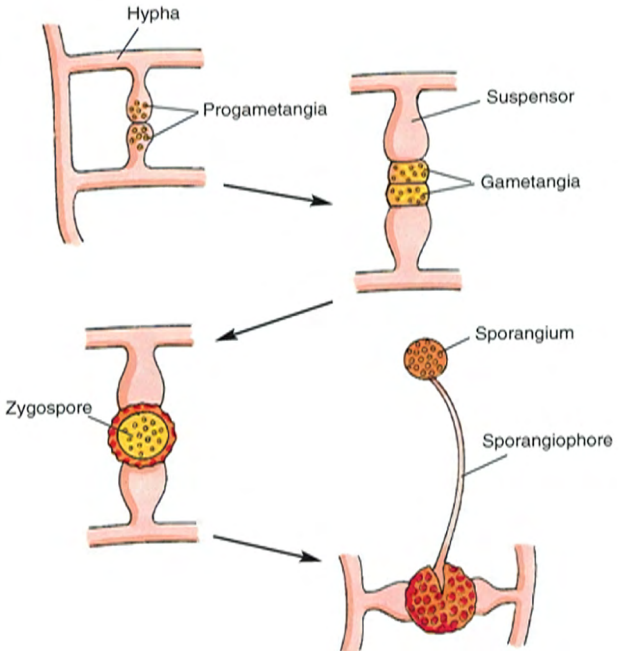


Figure 1.2: Sexual reproduction in the Rhizopus

6. **Excretion**: Rhizopus gets rid of waste materials from its body into its surroundings.
7. **Nutrition or feeding**: Hyphae of Rhizopus release special chemicals (enzymes) that break down its food into a soluble form so it can absorb the nutrients.

Activity 1.2 Life Processes of Rhizopus

1. From **Activity 1.1**, deduce the conditions that were needed for the following life processes.
   - **a.** growth
   - **b.** reproduction
   - **c.** nutrition
2. Share your findings with the class in presentations.

Economic Importance of Rhizopus

While mould might seem unpleasant, it's a living organism with a significant purpose in the natural world:

1. Some species cause diseases (such as mucormycosis, a serious fungal infection which infects immune-compromised individuals).

2. Some Rhizopus species are used in industrial fermentation processes, and the production of traditional foods in some cultures (e.g. Rhizopus oligosporus is used in the production of tempeh, a cooked and fermented soybean dish).
3. Spores of Rhizopus can contribute to indoor air quality problems and trigger allergic reactions.
4. Some species of Rhizopus are used in enzyme production and in the production of organic acids (e.g. lactic acid, fumaric acid).
5. Rhizopus causes post-harvest losses due to the spoilage of fruits and vegetables.
6. Rhizopus causes the decomposition and recycling of organic wastes in the ecosystem.

Activity 1.3 Economic Importance of Rhizopus

1. Carry out some further research from Internet sources on the economic importance of Rhizopus
2. Discuss the pros and cons of the economic importance of Rhizopus.

DISTINCTIVE CHARACTERISTICS AND LIFE PROCESSES OF MOSSES

Distinctive characteristics and structure of moss.

Mosses are small plants that are found growing on damp soil, tree bark and bare surfaces of rocks or concrete. Mosses belong to the group of plants known as Bryophytes. They lack true roots, stems and leaves, which distinguish them from vascular plants. Instead, they have gametophytes, which include rhizoids as well as stem-like and leaf-like structures. The leaves are simple, single-layered and arranged in whorls with no cuticle, stomata and internal air spaces. The gametophytes produce a stalk called a seta, which has a capsule with a cap called a calyptra at its tip. This comprises the sporophyte. As a result of these distinctive features, Mosses are described as being non-vascular. They absorb water and nutrients from the soil through their rhizoids, which also provide anchorage on the substrate on which they grow.

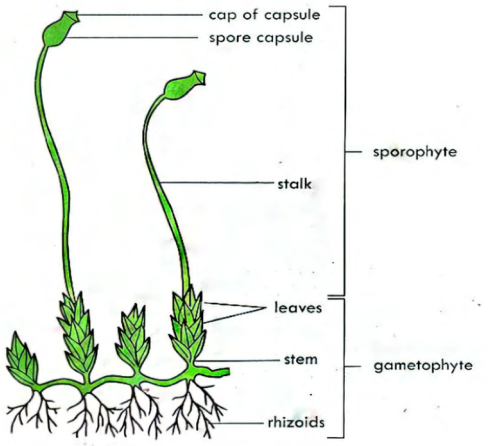


Figure 1.3: Structure of Brachymenium

Figure 1.4: Mosses growing on damp soil

Figure 1.5: Moss growing on a wall

Figure 1.6: Moss growing on a tree trunk

Life Processes of Mosses

1. **Movement**: movement occurs in the protonema, which develops from the spores. It further develops rhizoids, which extend into the substrate.
2. **Respiration:** this occurs aerobically by gaseous exchange, which takes place directly through the thin leaves.
3. **Sensitivity:** mosses respond to environmental stimuli such as water, light, nutrients, humidity and temperature.
4. **Growth**: mosses increase in size through cell division and expansion.
5. **Reproduction**: mosses produce male and female gametes, which fuse to form a zygote (sexual reproduction) and, through spore formation (asexual) to form a sporophyte. These two generations, i.e. sporophyte and gametophyte, alternate with each other.
6. **Excretion**: they do not have specialised excretory structures, but get rid of excess water, oxygen during the day, carbon dioxide at night and ions through the leaves, stems and roots.

7. **Nutrition**: mosses are autotrophic, meaning they can produce their food through photosynthesis.

Economic Importance of Mosses

1. Horticulture and landscaping: mosses are used as ornamental plants in gardens, parks and indoor spaces.
2. Erosion control: mosses help stabilise soil and prevent erosion.
3. Medical application: some mosses are believed to have antiseptic and antibacterial properties and are applied in traditional medicine for treatment.
4. Biodiversity and ecological research: mosses are important indicators of environmental health, used in research to monitor air quality and climate change.
5. food: mosses are used as food in some cultures. For example, Icelandic moss is used to make tea and soup.
6. Carbon sequestration: in the long term, mosses can absorb high amounts of carbon from the atmosphere.

Activity 1.4 Exploring the Moss Plant

In this activity, you will be exploring further the structure of the moss plant.

1. Team up with your friends and take a specific aspect of each of the moss plants, e.g. structure, habitat and reproduction.
2. Search online, from articles and other reading materials, for more information on your assigned specific aspect.
3. Together with your friends, create posters or presentations and share them with the rest of the class.

Activity 1.5 Debate on the Economic Importance of Moss

1. In this activity, you will be engaging in a debate on the economic importance and the implications of moss harvesting.
2. Get your views and those of your team members neatly written out on a sheet of paper to be read out in class for the debate.
3. Do you and your team agree with the views of your opponents?
4. Share your reasoning with the class.

Activity 1.6 Moss Plant Life Processes Model

1. Search for videos online for further information on the life processes of the Moss plant.
2. From the video you watched, create a chart highlighting the keynotes of each life process.
3. Compare your chart with that of your friends.
4. Paste the charts in your classroom for quick reference.

DISTINCTIVE CHARACTERISTICS AND LIFE PROCESSES OF FERNS

Distinctive Characteristics and Structure of a Fern

Learners, you learned about mosses in your previous lesson. In this lesson, you will look at ferns. Ferns are unique and fascinating plants that belong to a group known as pteridophytes. They are different from flowering plants and conifers, primarily because they reproduce using spores instead of seeds. You can often find ferns in wet and shady places like forests, swamps, and even on other plants. Understanding the distinctive characteristics and structure of ferns helps us appreciate their diversity and role in various ecosystems.

Some common types of ferns are the bracken fern (Pteridium aquilinum) and the common polypody (Polypodium vulgare).

A fern has three main parts:

1. **Frond:** This is the fern's leaf, which is often divided into smaller sections called pinnae.
2. **Rhizome:** This is a thick stem that grows underground. It helps store food and produces fronds and roots.
3. **Sporangia (singular-sporangium):** These are located on the underside of the pinnae and contain clusters called sori. Sori produces spores for reproduction. The mature frond with the sori is called a **sporophyll**.

The roots of the fern hold it in place and take in nutrients from the soil. Below is a picture of ferns growing on a palm tree.

Figure 1.7: Fern growing on a palm tree

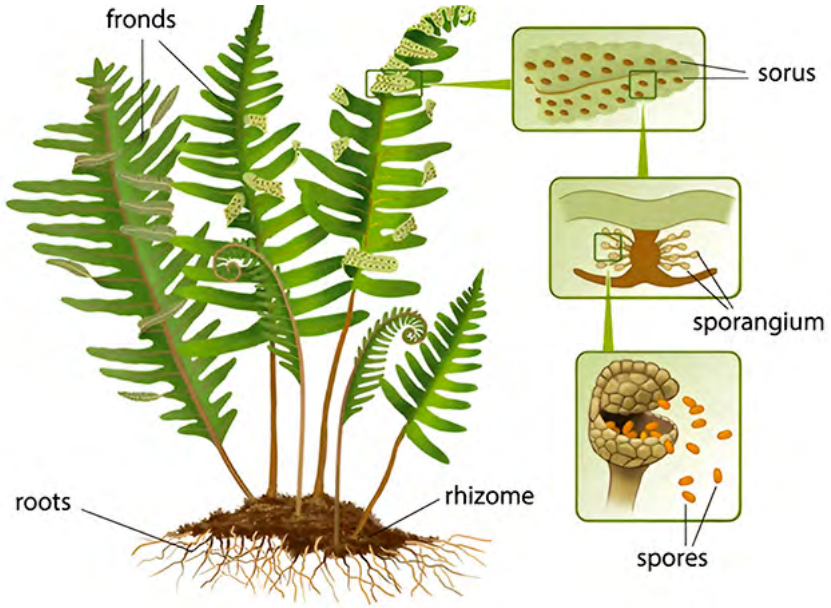


Figure 1.8: Structure of a fern. Image

Life Processes of a Fern

Ferns are fascinating plants that exhibit a variety of life processes, allowing them to thrive in diverse environments. As vascular plants, they possess specialised tissues for transporting water, nutrients, and food. Ferns have a unique life cycle that includes both a haploid stage and a diploid stage, showcasing their adaptability and ability to withstand unfavourable conditions (resilience). Understanding the life processes of ferns provides valuable insights into their ecological roles and importance in the natural world. Below are the life processes:

1. **Nutrition:** Ferns absorb nutrients through their roots and produce food using their leaves, which capture sunlight in a process called photosynthesis.

2. **Reproduction:** Ferns have a special life cycle that alternates between two stages: one stage produces **haploid** spores (the gametophyte), while the other is the **diploid** stage that grows into the actual fern plant itself (the sporophyte).

NOTE

a. *Haploid **(n):** A haploid cell has only one set of chromosomes and is often seen in the stage where spores are produced. For example, when a fern produces spores, those spores are haploid. They have half the number of chromosomes compared to the plant itself.*

*Diploid **(2n):** A diploid cell has two sets of chromosomes, one from each parent, and most of the time, the main fern plant is diploid. This means its cells each contain a full set of chromosomes.*

b. ***How They Work Together***

***Spores** (Haploid): The fern releases haploid spores that can grow into gametophytes.*

***Gametophyte** (Haploid): These spores develop into gametophytes, which can produce male gametes and female gametes.*

***Fertilisation**: When a male gamete from one gametophyte meets a female gamete from another, they combine to form a diploid zygote.*

***Sporophyte** (Diploid): This zygote grows into the diploid fern plant we see.*

3. **Respiration:** Ferns exchange gases through small openings in their leaves known as stomata.

Figure 1.9: Stomata of a fern

4. **Excretion:** Ferns eliminate excess salts and waste through their roots.
5. **Growth:** Ferns grow continuously throughout their lives, starting from spores and developing into mature plants.
6. **Movement:** Ferns can grow towards light, water, and gravity. Male gametes also swim through water to fertilise the female gamete.
7. **Sensitivity:** Ferns can respond to changes in their environment, such as light and moisture.

Economic Importance of Ferns

Ferns play a significant role in various aspects of human life and the economy, extending beyond their beauty as ornamental plants. These versatile plants are utilised in landscaping and interior design, contributing to aesthetic appeal and environmental health. Exploring the economic importance of ferns reveals their multifaceted contributions to both nature and society. Below are some features which are of economic importance.

1. **Decorative Plants:** Many fern species are popular for their attractive appearance and are used to beautify homes and gardens.
2. **Health Benefits:** Certain ferns are known for their medicinal qualities. They can be used to help manage conditions like diabetes and high blood pressure, and they assist in recovery after childbirth.
3. **Culinary Uses:** In some regions, specific ferns are consumed as food. For instance, the tubers of the king fern (Ptisana salicina) are used in traditional dishes in New Zealand and the South Pacific. They are also included in palm nut soup to help mothers who are breastfeeding by boosting milk production in Ghanaian homes.
4. **Environmental Cleanup:** Ferns can play a role in improving soil quality by removing toxic heavy metals, such as arsenic, from the ground.

Activity 1.7 Group Field Study on Ferns and Their Characteristics

1. Embark on a field trip to a local park or botanical garden where ferns are present.
2. Record details such as frond shape, size, and the presence of sori in your notebook, and try to identify your species.
3. Discuss your findings and focus on listening to others as they share their insights in turn.

4. Present your observations to the class, highlighting the importance of teamwork and constructive feedback.

Activity 1.8 Report on Life Processes of Ferns

1. Team up with a friend and select three varying life processes of ferns (e.g. nutrition, reproduction, respiration).
2. Gather information from textbooks, videos, and reliable online resources to create a comprehensive report.
3. Prepare a group presentation that outlines your findings, including visuals like diagrams or models.
4. Develop healthy, respectful relationships by practising supportive feedback during preparation.
5. Share your presentations with the class.

Activity 1.9 Presentation on Ferns Unveiling Their Advantages and Potential Harm

1. Research the benefits of ferns (e.g., ornamental use, medicinal properties) and any harmful effects (e.g., invasive species) from textbooks, scientific journals and reliable online sources.
2. Create a short presentation using slides, posters, or other creative formats.
3. Present your findings to the class on the day of the presentation.
4. Receive constructive feedback and ask questions from friends.

BASIC CONCEPTS IN BIOLOGY AND HOW THESE CAN BE USED TO IMPROVE CROP PRODUCTION

To produce crops, some practices are employed before planting, during the growth of the plants and harvesting. These practices used to raise crops are called **agricultural practices**. The variety of procedures carried out (after planting) at specific points in the growing period of the crop are the **cultural practices,** which include transplanting and weeding. Both practices are important because they involve the application of basic biological concepts when the activities are carried out. Some of the activities carried out include the following:

Soil preparation

At this first stage, the decision to use a particular type of soil will depend on how much is known about the structure of the soil, how much water it can retain and how much air is present in the soil. This knowledge of biology will help to decide on the type of soil to select for the intended crop to be cultivated. Soil preparation activities like weeding, raking, levelling, and ploughing improve the soil air (aeration) and water permeability. These, therefore, improve the fertility of the soil.

Figure 1.10: Raking of soil.

Seed sowing

Farmers at this stage select seeds that are intact, fully matured and can potentially germinate and grow (viable). The seeds are planted manually by hand or mechanically. The seeds can be sown in a row (drill) or scattered (broadcasting).

Figure 1.11: Seed sown in a row.

Fertiliser application

At this stage, fertilisers are added to the soil to improve fertility and crop yield. The fertilisers used are either organic (green manures, composts) or inorganic fertilisers. Green manuring is the mixing or mulching of green crops into the soil with the aim of improving the structure of the soil and its fertility. Composting is the practice of converting organic matter into a nutrient-rich soil known as compost by decaying.

Figure 1.12: Inorganic fertiliser application on a mechanised farm.

Irrigation

The practice of supplying water to crops provides sufficient moisture for plant growth and development. Plants depend on adequate water for photosynthesis, leading to the growth and development of fruits and seeds. Irrigation is done through water supplied in watering cans, water canals, tube wells, reservoirs, and wells.

Figure 1.13: Irrigation using a watering can.

Pruning

This is the practice of selectively removing undesirable parts of a plant, such as branches, buds, or roots, to improve its growth and productivity. This process reduces overcrowding, which prevents competition for resources, disease and pest infestations. It also promotes crop yield due to sufficient sunlight and air reaching the plants.

Grafting

This is the technique where tissues from one plant part with desirable characteristics are inserted into another plant, such that their vascular tissues are joined together. Knowledge in tissue regeneration and genetics promotes this process allowing the development of desirable traits to improve productivity and preservation of varieties in crops.

Pest and disease control methods and strategies

These activities are performed to manage and reduce damage by pests and diseases to crops and livestock. Introduction of a predator to the pest (biological control) and chemical control methods may be used. The practice reduces crop losses, increases crop yield, and enhances crop quality.

Activity 1.10 Agricultural practices on a farm visit

1. Visit a nearby farm or garden with your peer and interact with the owner or workers on the methods used for preparing the land, and planting and harvesting the crops. Ask about good practices used on the farm and record it.
2. Participate in an activity on the farm or garden and identify the biological concept (s) applied during the activity.
3. Write and record a video or an audio of your experience on the farm.
4. Share these experiences and the importance of the activity with your class.

Caution: Be careful with sharp agricultural tools!

SOME BASIC CONCEPTS IN BIOLOGY AND HOW THESE CAN BE USED TO IMPROVE ANIMAL PRODUCTION

Animal Husbandry Practices refer to the day-to-day care, management, production, feeding, and raising of farm animals, resulting in healthy animals leading to an increase in productivity. Some animal husbandry practices include:

1. **Selective breeding**: This is the process of intentionally choosing parent organisms with specific traits to produce offspring with desired characteristics. This results in the production of offspring that have enhanced or desired traits, such as drought and disease resistance. This practice is done in crop production and animal husbandry.

Figure 1.14: Selectively bred chicken.

2. **Supplementary feeding** is the provision of additional nutrients to animals apart from the normal feed given to them. This may be in the form of supplements given to enhance growth and improve reproductive performance, thus resulting in increased productivity.
3. **Flushing** is the technique of increasing the nutrition of breeding female animals before and during the breeding seasons to enhance fertility and reproduction.

Figure 1.15: Increase in reproduction as a result of flushing.

4. **Deworming** is the giving of drugs to animals to get rid of endoparasites. The exercise improves the health of animals, leading to an increase in growth and weight and reduces the spread of disease among livestock.
5. The marketing and selling of products from agriculture is done to earn income for the farmer and to provide food for the population/consumer

Figure 1.16: Farm products on a stall

When biological concepts are integrated into animal and crop production, farmers and farm owners can achieve a higher yield, ensure that there is food security and promote a sustainable environment.

Activity 1.11 Farm Visit

1. Identify and visit a nearby pig, cattle, poultry or any other livestock farm with your peers.
2. Interact with the owner or workers on the daily activities or routine on the farm. Ask about husbandry practices used on the farm and record them.
3. Create a catalogue for the routine activities observed during the visit and share it with the class.
4. Surf the Internet for genetic selection and breeding practices and discuss the findings with the class.

EXTENDED READING

https://www.lifepersona.com/the-5-most-important-applications-of-biology-in-agriculture

ADDITIONAL READING MATERIALS

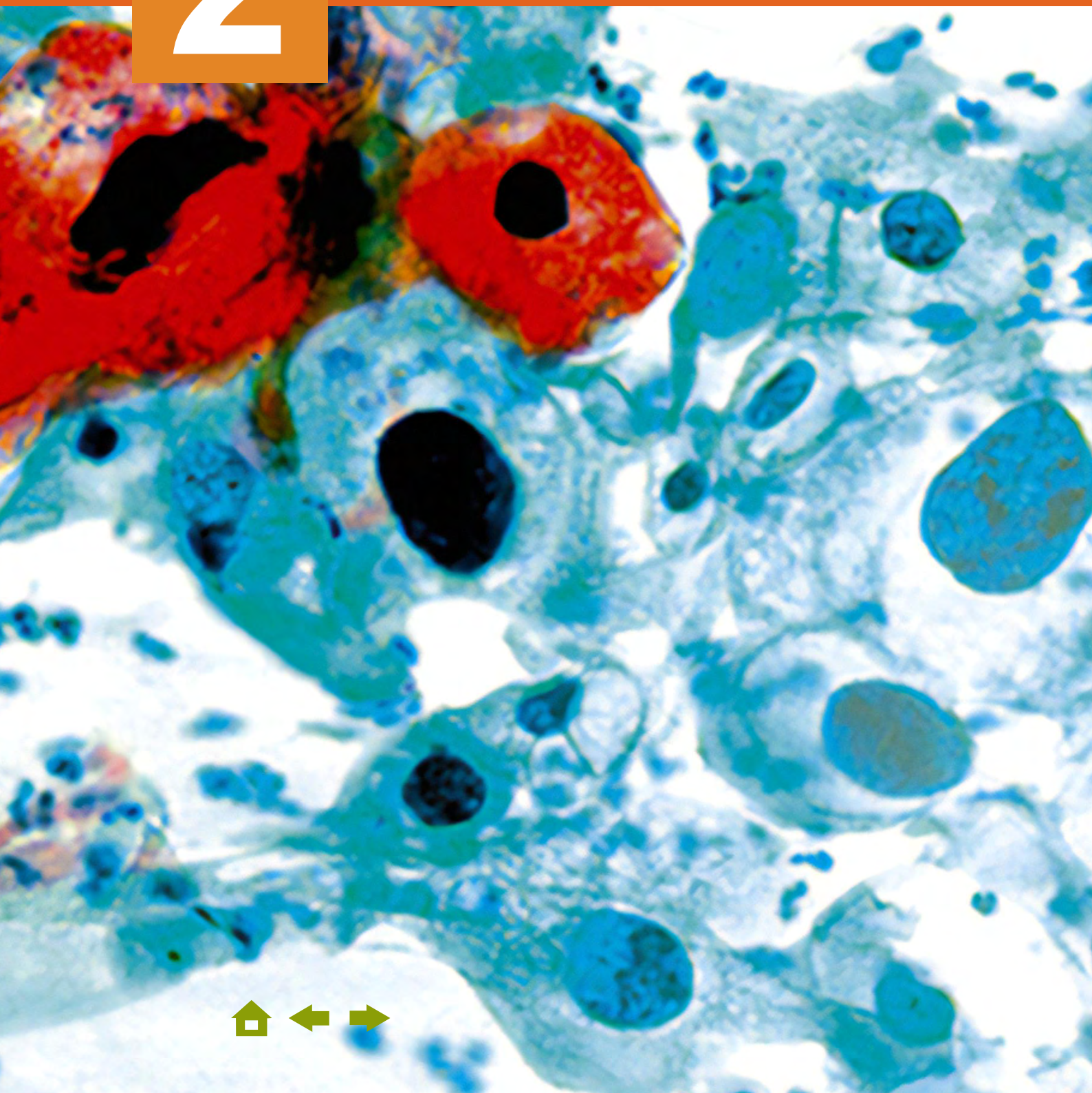
- Biology GAST
- College Biology
- Online Biology Resources

REVIEW QUESTIONS

1. What are the structural characteristics of Rhizopus?
2. How do the hyphae of Rhizopus relate to its position on the substrate?
3. What are the key life processes of Rhizopus?
4. How does the presence of Rhizopus affect our everyday lives?
5. What are the key structures of a moss plant?
6. What are the benefits of having mosses in the ecosystem?
7. What are the distinctive features that identify a fern plant?
8. What are the ecological impacts of having many ferns in an environment?
9. Name some cultural practices used in crop production.
10. What biological concepts are associated with crop production?
11. How can cultural and farming practices be implemented to enhance crop production?
12. What are the four effects of cultural practices on crop production?
13. Define the term, Animal Husbandry?
14. What are the basic biological principles of animal husbandry?
15. What are the most common farm animals raised in animal husbandry?

SECTION

2 CYTOLOGY



LIFE IN THE FUNDAMENTAL UNIT

Cell Structure and Function

INTRODUCTION

Cytology is the study of cells, which are tiny building blocks that make up every living thing. You have already learned about the different parts of a cell, but now we are going deeper.

We will explore how cells transport things in bulk, such as tiny packages moving in and out. Discussions on the structure of the DNA will be done, the Watson - Crick Model of DNA will be examined in terms of its essential components and then followed with the importance of the DNA to living things. We will also learn about DNA and RNA, being the blueprints of life that control how cells build proteins.

The study of cells is important because it helps us understand how our bodies work and can even lead to breakthroughs in things like healthcare and farming

KEY IDEAS

- The study of the cell is guided by the **cell theory,** which has three components.
- Some cells have developed adaptations to perform specific functions. Based on these functions or roles, they are referred to as **specialised cells**.
- **Active transport** involves the movement of molecules or ions across a cell membrane from an area of lower concentration to an area of higher concentration using energy from the cell.
- **DNA and RNA** are the two main types of nucleic acids which are biopolymers that carry genetic information from living organisms to their offspring.
- **A nucleotide** is made up of a five-carbon sugar, called a pentose sugar, a nitrogenous base: adenine (A), thymine (T), cytosine (C), guanine (G), or uracil, (U), and a phosphate group.

- **DNA replication** is essential for cell division, ensuring that each new cell receives a copy of the organism's genetic material and occasionally, errors occur during the replication leading to mutations.
- DNA replication ensures that genetic information is passed from parents to their offspring during reproduction.
- **RNA** is a single–stranded nucleic acid found in the cytoplasm and the nucleus of living organisms and is in three types (mRNA, tRNA and rRNA), each with specific functions.
- **Transcription** is the process by which a molecule of RNA is formed using a strand of DNA as a template.
- The **genetic code** refers to the set of rules by which the sequence of nucleotides in DNA or RNA is translated into an amino acid sequence of proteins in living cells.

CELL THEORY AND CELL STRUCTURES IN RELATION TO THEIR FUNCTIONS

The Cell Theory

Cells are tiny building blocks that make up all living things. Some living things are made of just one cell, while others, like plants and animals, are made of many cells.

This lesson will look at two types of cells:

1. **Prokaryotic cells:** These are simple cells, like bacteria, without a nucleus.
2. **Eukaryotic cells:** These are more complex cells, like plant and animal cells, with a nucleus and other tiny parts called organelles.

The Cell Theory tells us three very important facts:

a. Everything alive is made of cells
b. Cells are the basic building blocks of life
c. Cells come from other cells

No matter how big or small an organism is, if it is alive, it is made of cells. Just as a house is built with bricks, all living things are built with cells and new cells are made when old cells divide. Understanding the Cell Theory helps scientists learn

more about how living things work, and that helps us develop new medicines and ways to improve our lives.

Cell Structure

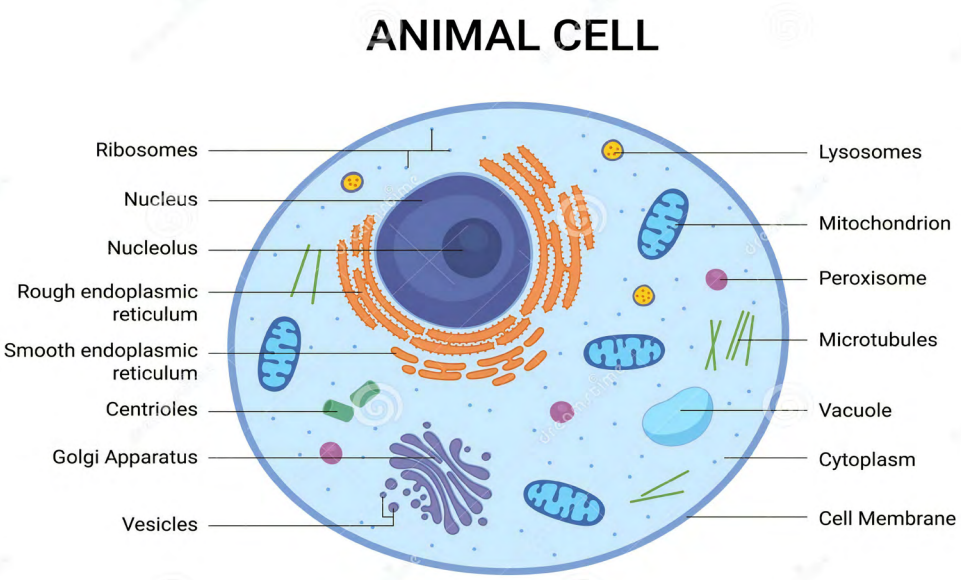


Figure 2.1: Structure of an Animal Cell

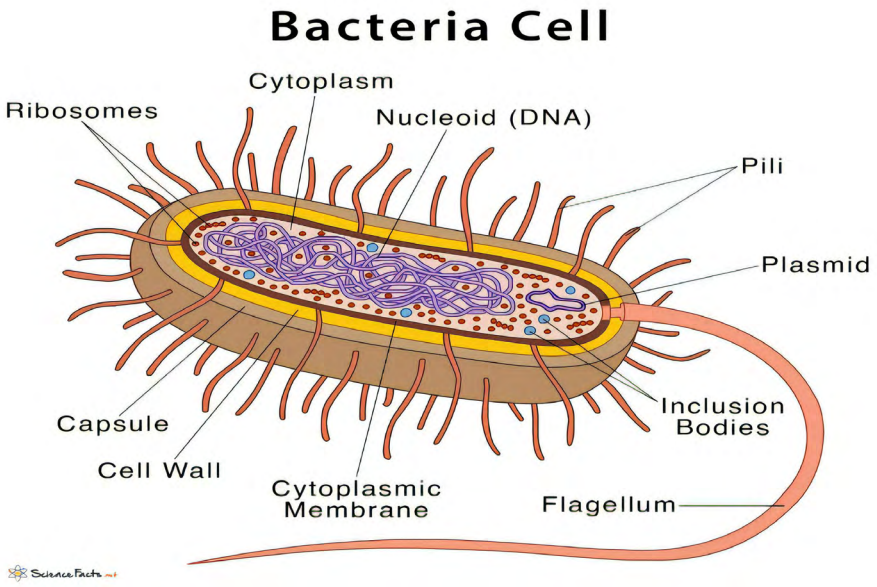


Figure 2.2: Structure of a bacterial cell

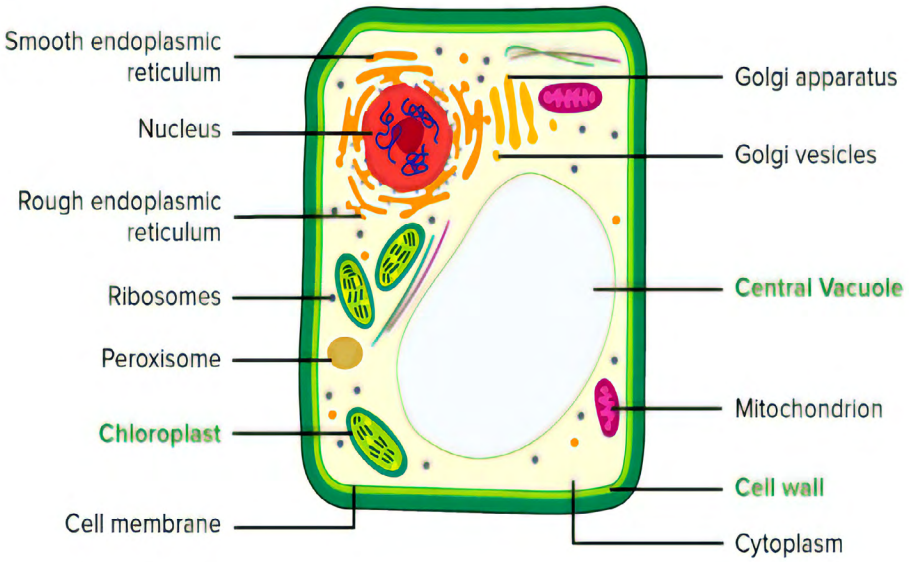


Figure 2.3: Structure of a Plant Cell

One of the key distinctions between plant and animal cells lies in their structure and the organelles they possess. Plant cells, typically more rigid, have a sturdy cell wall made of cellulose that provides structural support and gives the cell a fixed shape. Additionally, they contain chloroplasts, which contain chlorophyll used for trapping sunlight for the process of photosynthesis. Many plant cells have a permanent large central vacuole used to store water, pigments and nutrients. On the other hand, animal cells lack a cell wall, chloroplasts, and a central vacuole as prominent as that found in plant cells. Animal cells have lysosomes that contain enzymes responsible for the digestion of macromolecules, old cell parts, and microorganisms.

Organelles found in both plants and animal cells are mitochondrion, golgi apparatus, smooth and rough endoplasmic reticulum, ribosomes and peroxisomes.

Activity 2.1 Build a Cell City

Imagine a cell as the community you live in. This community has many parts or areas, and they work together for its progress or development, just as the different parts within the cell.

What you need:

- Big paper or cardboard
- Markers, crayons, or pencils
- Old magazines (optional)

Let us do it

1. Think like a city planner: As a class, let us name different parts of our community (such as the Chief's palace, the library, a power station, roads, and the post office).

2. Cell City Match Up: Now, let's imagine those city parts are like parts inside a cell:

   a. Chief's palace: This is like the nucleus, the boss of the cell.

   b. Library: This is like DNA, holding important information for the cell.

   c. Power Station: This is like the mitochondria, giving the cell energy.

   d. Roads: These are like the endoplasmic reticulum, moving things around the cell.

   e. Post Office: This is like the Golgi apparatus for transporting, modifying, and packaging proteins and lipids into vesicles for delivery to targeted destinations.

3. Teamwork Time: Split into groups. Each group gets a different cell part.
4. Get Creative: Each group will draw and colour their cell part on their paper or cardboard.
5. Show and Tell: Each group will show their "Cell City" part to the class and explain what makes it a part of it and its role.

The Big Idea:

- Just as our community needs all its parts to work, a cell also needs all its parts to work.
- Each tiny part of the cell has a big job to do to keep it alive.
- Everything alive, from tiny ants to tall trees, is made of cells.

This activity helps you see how amazing cells are, even though they are microscopic.

Specialised Eukaryotic Cells and Their Adaptations

Some cells have specific adaptations for performing specific functions or roles. These are called specialised cells.

Let us look at some specialised plant cells:

1. **Epidermal cells:** These cells are from the outer protective layer (epidermis) of the plant, acting like skin. They help prevent water loss and protect against pathogens.
2. **Palisade mesophyll cells:** Located just beneath the epidermis, these cells are rich in chloroplasts. They absorb sunlight to carry out photosynthesis, producing food for the plant.
3. **Spongy mesophyll cells:** Found below the palisade layer, these cells have spaces between them that allow for gas exchange. They help the plant take in carbon dioxide and release oxygen.

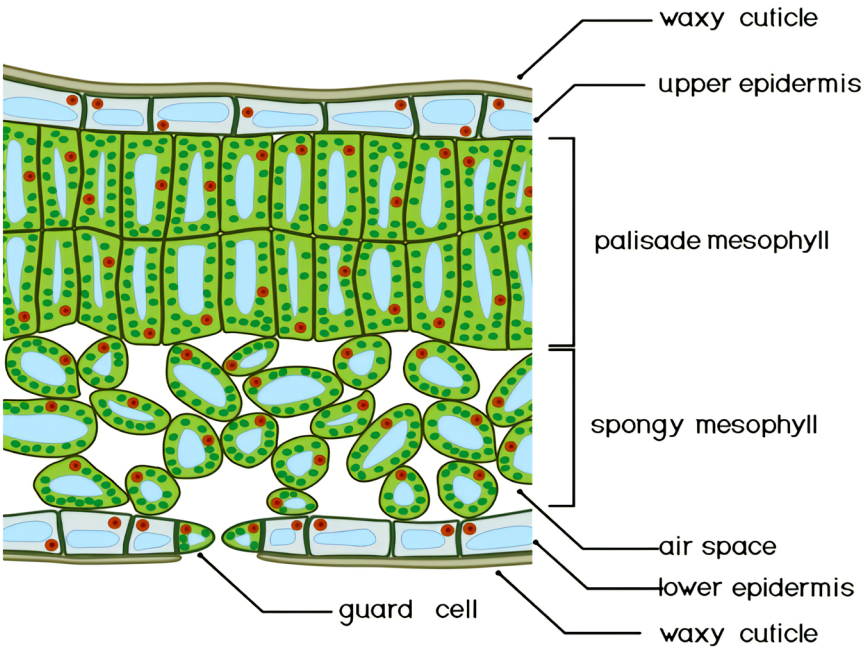


Figure 2.4: Specialised cells in the leaf

4. **Root hair cells:** These specialised cells extend from root surfaces and increase the surface area for absorption. They are crucial for taking in water and nutrients from the soil.
5. **Root tip cells:** These cells are located at the growing tips of roots. They are actively dividing, allowing the roots to grow longer and spread out through the soil, resulting in a large surface area for the absorption of water and minerals.

6. **Guard cells:** These cells surround the stomata (small openings on the leaf surface). They control the opening and closing of these stomata, regulating gas exchange and water loss.

Each type of cell plays a unique role in helping the plant function effectively, from protecting it to facilitating essential processes like photosynthesis and mineral absorption.

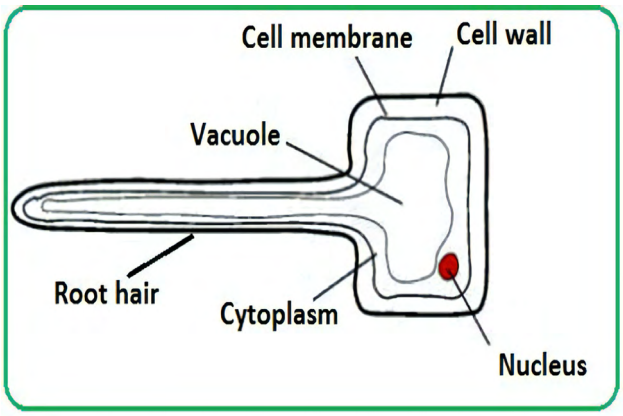


Figure 2.5: Root Hair Cell

Now, let's look at some specialised animal cells:

1. **Muscle cells**: These cells are specialised for contraction and movement. There are three types: skeletal (voluntary movement), cardiac (heart muscle), and smooth (involuntary movement in organs). They help the body move and maintain posture.
2. **Sperm cells:** These are male reproductive cells. They are designed for mobility with a tail (flagellum) that allows them to swim towards the egg for fertilisation.
3. **Egg cell:** These are female reproductive cells. They are larger than sperm and contain nutrients to support the early development of an embryo after fertilisation.
4. **Red blood cells:** These cells transport oxygen from the lungs to the rest of the body and carry carbon dioxide back to the lungs for exhalation. They contain haemoglobin which gives blood in mammals its red colour. The haemoglobin binds to oxygen and carries it to the cells where they are released for use by the cells in respiration.
5. **White blood cells:** These cells are part of the immune system. They help protect the body against infections and foreign invaders. There are several types of white blood cells, each with a specific role in fighting off diseases.

Each type of cell has a specialised function that contributes to the overall health and functioning of the body, from movement and reproduction to oxygen transport and immune defence.

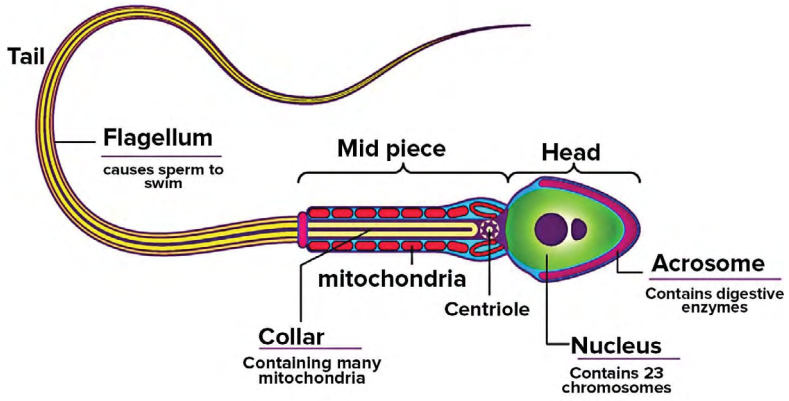
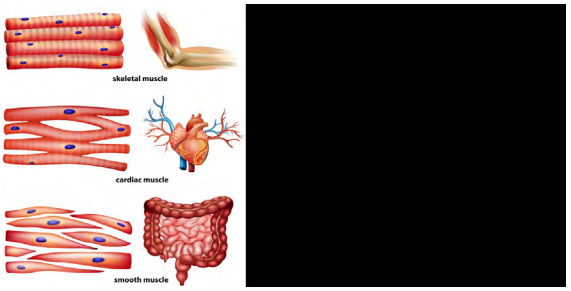


Figure 2.6: Sperm Cell



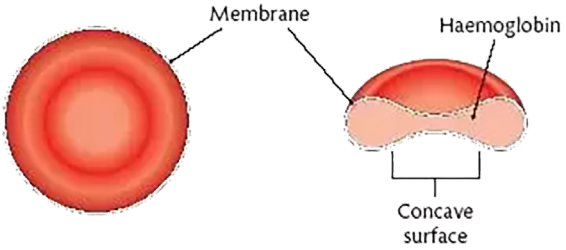


Figure 2.7: Red blood cell

Figure 2.8: Types of muscle cells

Activity 2.2 Specialised cells and adaptations

1. Pick an elbow friend or partner.
2. Each of you should write about two specialised cells of plants along with their adaptations.
3. Each of you should write about two specialised cells of animals along with their adaptations.
4. Take turns to discuss with your colleague what you wrote.

Note

Write each other's responses and submit them to your teacher.

APPLICATION OF ACTIVE TRANSPORT PROCESSES, ENDOCYTOSIS AND EXOCYTOSIS (BULK TRANSPORT PROCESSES)

Active Transport

In JHS, you studied diffusion and osmosis, which are passive ways by which substances such as water and ions move in and out of cells. Another mechanism by which substances move into and out of cells is by **active transport**. This is the movement of molecules or ions from an area of lower concentration to an area of higher concentration across a cell membrane with the use of energy provided by the cell. In this process, substances move against a concentration gradient into cells. This means, instead of substances moving from a high to a low concentrated region, movement rather occurs from a low to a high concentrated region. This movement requires energy in the form of ATP.

Typical examples of active transport in animals include the sodium- potassium pump that moves ions in nerve cells, the proton pump that moves ions in the stomach lining, selective reabsorption in the kidney tubules and the secretion of enzymes, hormones and antibodies from cells.

In plants, a typical example of active transport is the uptake of water and mineral salts from the soil by the root hair cells, the proton pump to regulate pH and solute transport in phloem cells.

Endocytosis

This is the process by which cells take in substances from outside the cell by engulfing them with a portion of their cell membrane. The steps involved in endocytosis are:

1. Recognition- the cell identifies a substance outside of it
2. Invagination- the cell membrane folds inwards, forming a pocket structure with the substance within.

3. Vesicle formation- the cell membrane surrounding the substance breaks off into the cytoplasm.
4. Internalisation or vesicle transport – vesicle(endosome) into the cell with substance in it, and is transported to various parts of the cell.

Endocytosis helps the cell to:

a. Absorb nutrients and proteins
b. Regulate the action of the cell surface
c. Defend against pathogens and toxins
d. Maintain cell membrane recycling.

Types of Endocytosis

1. **Phagocytosis** involves taking in or engulfing large particles such as bacteria and dead cells and transporting them into its inner space. For example, macrophages (white blood cells) engulf bacteria and other foreign bodies and digest them. Phagocytosis is also called "cell eating" because of the solid nature of the substance engulfed by the cell.
2. **Pinocytosis**, also known as 'cell drinking', involves the uptake of small molecules or fluids. An example is the absorption of nutrients from fluids passing through the kidney tubules.

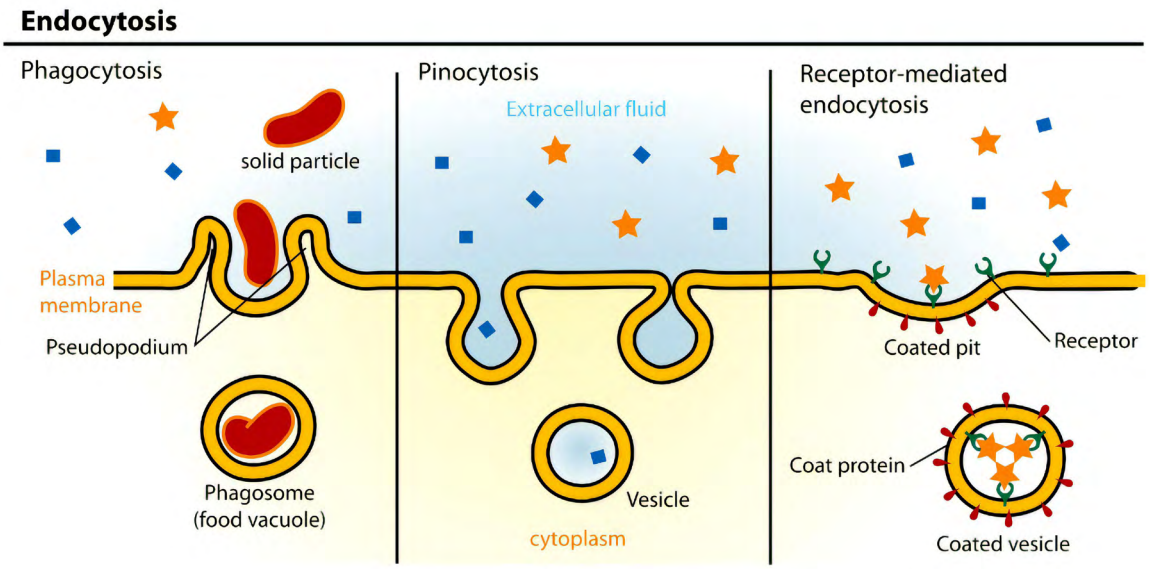


Figure 2.9: Types of Endocytosis

Exocytosis

This is the process by which cells release substances from within them to the outside. The processes involved in exocytosis include:

1. Vesicle Transport: Vesicles with the materials to be expelled move to the cell membrane.
2. Docking: Vesicles align and bind to the cell membrane.
3. Fusion: Vesicles merge with the cell membrane to release contents.
4. Release: molecules are released outside the cell.

Exocytosis is important in:

1. hormone secretion (e.g. insulin release from pancreatic cells)
2. neurotransmitter release from neurons.
3. waste removal
4. cell signalling
5. immune response (release of antibodies)

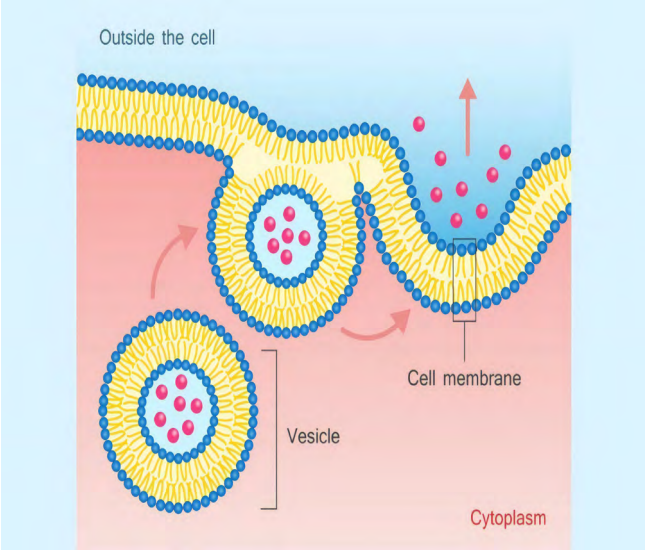


Figure 2.10: A cell carrying out exocytosis

Activity 2.3 Demonstration to illustrate endocytosis and exocytosis using balloons

Materials needed

- Balloons (various colours)
- Small objects to represent cellular cargo (substances), e.g. beads, small toffees,

- Tape or string
- Scissors
- Whiteboard or chart paper

Procedure

1. Blow up your balloon and tie it up to represent a cell membrane.

   Note: Do not blow up to be hard.

2. Place the small object (cargo) near the balloon.
3. Use a tape or string to create a small pocket in the balloon (simulating the cell membrane invaginating)
4. Engulf the cargo by wrapping the balloon around it.
5. Twist and tie the balloon to send the cargo inside, representing endocytosis.
6. Discuss with your friends how cells internalise substances through endocytosis.

   Demonstrating exocytosis with a balloon

   a. Blow up another balloon with the cargo (beads, small toy or toffee) already inside.

   (This represents a vesicle filled with waste or excess substances)

   b. Place the balloon with cargo near another balloon representing the cell membrane.

   c. Use tape or string to attach the two balloons, simulating vesicle fusion.

   d. Slowly release the air from the inner balloon, allowing the cargo to exit.

   e. Now, discuss with your friends the following points:

   - Similarities and differences between endocytosis and exocytosis.
   - Explain the importance of these processes in maintaining an internal balance of cells.

THE DNA, WATSON-CRICK MODEL, AND THE SIGNIFICANCE OF DNA IN EUKARYOTIC CELLS.

DNA

In the nucleus of eukaryotic cells are thread-like structures called chromosomes. The chromosomes appear as two strands and each strand is called a chromatid. The two chromatids which are identical are joined at the centromere.

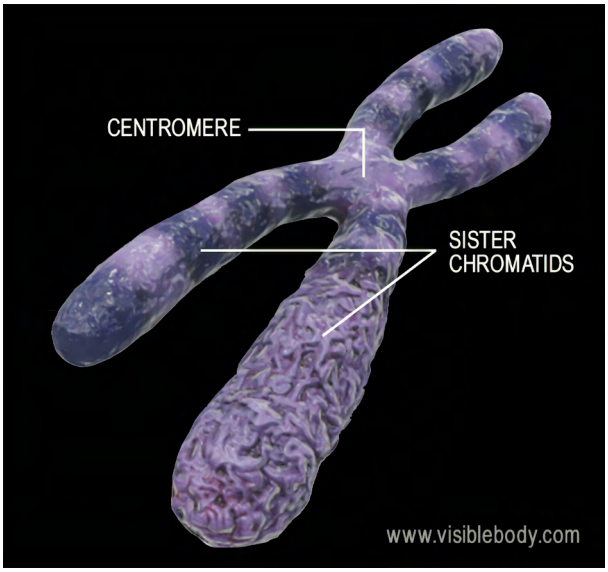


Figure 2.11: Three-dimensional structure of the Chromosome.

The chromosomes contain **Deoxyribonucleic Acid (DNA)** that carries the genetic information for organisms and is transferred to offspring. The **DNA** is an organic molecule that is made up of nucleic acids that carry genetic instructions used in growth, development, functioning and reproduction of all living things.

Nucleic acids are long-chain polymeric molecules (biopolymers), the monomer (the repeating unit) is known as a nucleotide, and hence sometimes nucleic acids are referred to as polynucleotides. Nucleic acids were discovered by a Swiss biologist and physician called Friedrich Miescher in 1869. The two main types of nucleic acids are DNA and RNA **(ribonucleic acid).**

Each nucleotide is made of three parts:

1. Pentose sugar: five-carbon sugar (this is deoxyribose in DNA and ribose in RNA)
2. Nitrogenous base: adenine (A), thymine (T), cytosine (C), guanine (G) and uracil(U)

3. Phosphate group/phosphoric acid (a molecule with one phosphorus atom bonded to four oxygen atoms)

The phosphate group of one nucleotide is linked to the pentose sugar of the next nucleotide by a phosphodiester bond. This bonding occurs between many nucleotides to form a long chain called a polynucleotide. Hydrogen bonding occurs between the nitrogenous bases to form a 'ladder' of two polynucleotides. The polynucleotide chains coil around each other to form a double helix, forming the DNA.

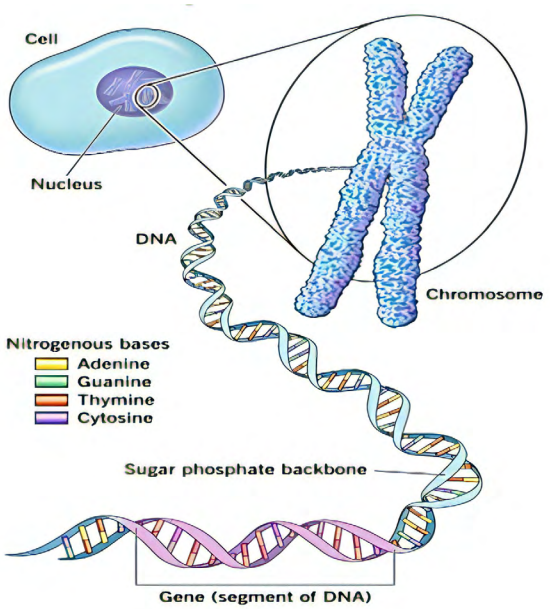


Figure 2.12: Structure of the DNA

DNA is found in the nucleus (of a eukaryotic cell as a complete set of genes), mitochondrion (mtDNA), with fewer genes for energy production, and chloroplasts (cpDNA) and in some algal cells.

Click on the link below for an interactive look at DNA

https://www.labxchange.org/library/items/lb:LabXchange:5e1fcef1:lx_simulation:1

Watson-Crick Model of DNA

A representation of the structure of DNA is proposed in models, and the most common model is the Watson-Crick model. This model was proposed by James Watson and Francis

Crick in 1953 by analysing X-ray crystallography data. The essential aspects in the model are as follows:

1. The DNA is composed of two antiparallel strands coiled around a central axis (forming a double helix structure).
2. There is a complementary base pairing of the nitrogenous bases, where adenine pairs with thymine, and guanine pairs with cytosine (that is, A-T and G-C) by hydrogen bonds.
3. The two DNA strands show antiparallel orientation (run in opposite directions, that is, 5' to 3' and 3' to 5', read as 5 to 3 direction, and 3 to 5 direction).
4. A sugar-phosphate backbone is formed by a phosphodiester bond between the pentose sugar and phosphate group.
5. Major and minor grooves are formed in the helical twist between the two DNA strands, and these grooves provide spaces (points of attachment) for enzymes and proteins and other molecules to bind to the DNA.

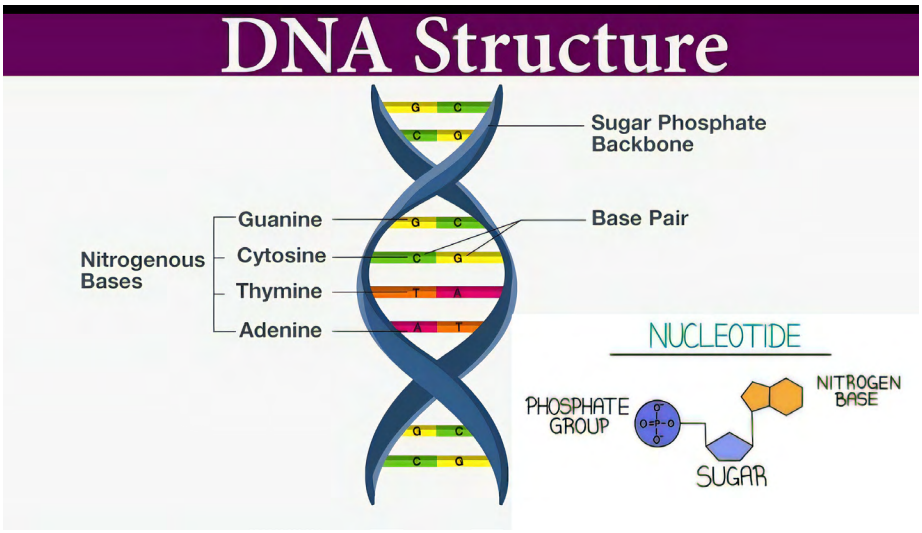


Figure 2.13: Watson-Crick model of the DNA

The significance of DNA in a eukaryotic cell

DNA is a life molecule; its presence in cells is very important because:

1. It stores genetic information with instructions for development, functioning and reproduction in living things.
2. It transmits genetic information from one cell to another by replicating or doubling itself before cell division.
3. It carries genetic codes called genes on the chromosomes that specify sequences of amino acids for protein synthesis.

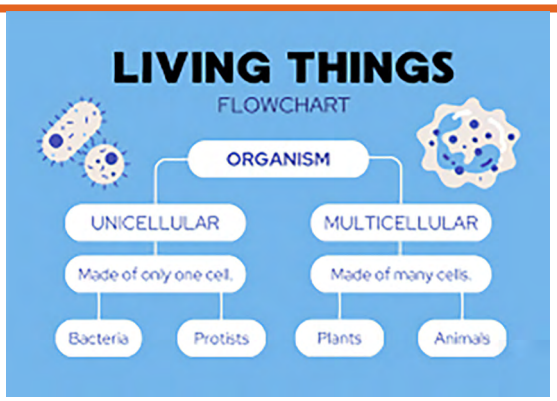
4. Changes in genetic sequences of DNA are called mutations, which serve as the basis for evolution and the adaptation of organisms to new environments.

Activity 2.4 DNA graphic organiser

1. Create a graphic organiser for DNA that best fits the structure of the DNA.
2. There should be boxes or shapes connected with labelled arrows.
3. Information in the boxes, shapes or on the arrows may be words or phrases linked to the structure of the DNA, e.g. DNA ladder, base pairs, double helix, backbone, pentose sugar, nitrogenous bases, phosphodiester bond, single strand, etc.
4. Use a computer (MS word, paint, etc) or by hand on a plain paper to draw the graphic organiser.

Note

Graphic organisers are visual thinking tools that make pictures of your thoughts. The pictures demonstrate relationships between facts, concepts, or ideas, and guide your thinking as you design the map or diagram. This is an example of a graphic organiser



Activity 2.5 Designing a DNA model

1. Gather materials like sheets of paper, manila cards, cardboard, coloured beads, different types and shapes of seeds, glue, pins, straws, etc.
2. Plan on how to use the gathered materials to design a model of the DNA structure

3. Design models of DNA using the materials gathered.
4. Outline the importance of DNA on a chart.
5. Display your model and the chart in class and explain to your peers the various components.

DNA REPLICATION AND ITS RELEVANCE IN LIVING THINGS

DNA Replication

Let us consider what DNA replication entails. DNA replication is the process through which a cell creates exact copies of its DNA molecules. This crucial activity occurs during the S phase or synthesis phase of the cell cycle, which is part of interphase before a cell divides.

The process of DNA replication involves three main steps. These are:

1. Unwinding or Opening the Double Helix: First, the DNA double helix unwinds, and the two strands separate, like unzipping a zipper.
2. Adding Primers: Once the strands are apart, short RNA sequences, known as primers, are attached to the template strands. These primers serve as starting points for building new DNA strands.
3. Building New DNA Strands: In the last step, the cell adds nucleotides (the basic units of DNA) to the primers, resulting in the formation of two new identical DNA molecules.

This entire process is essential for ensuring that each new cell receives genetic information from the original cell. This is demonstrated in the activity below

Activity 2.6 Demonstration of the Processes of DNA Replication

1. Use a zipper or string to show how the DNA double helix unwinds.

   Activity: In pairs, take two long strips of coloured paper to represent the DNA strands. Have one student hold each end and slowly "unzip" the strands while explaining this step.

   Discussion: Share what you think happens at this stage and why unwinding is important.

2. Use small pieces of paper or sticky notes to represent RNA primers.

Place the sticky notes on the template strands at various points, simulating where primers would attach.

Discuss the role of primers in starting the replication process.

3. Use coloured beads or small blocks as nucleotides.

   In turn, add nucleotides to the RNA primers, selecting colours to represent the different bases (A, T, C, G).

   Form groups to create two new strands of DNA by matching the nucleotides to the template strands and explain the base pairing rules as you go.

   Discuss how the new strands are formed and the importance of accuracy in this process.

Detailed activities or steps of DNA Replication

DNA replication is a highly coordinated process that ensures the accurate copying of genetic information, allowing cells to divide and pass on their DNA to the next generation.

1. **Initiation:** Replication begins at specific locations on the DNA molecule called origins of replication, where the DNA double helix is recognised by initiator proteins.
2. **Unwinding:** The enzyme DNA helicase unwinds the double-stranded DNA, separating the two strands to form the replication fork.
3. **Stabilisation:** Single-stranded binding proteins attach to the separated strands to prevent them from re-annealing or forming secondary structures.
4. **Priming:** The enzyme DNA primase synthesises short RNA primers on the template strands, providing a starting point for DNA synthesis.
5. **Elongation:** DNA polymerase adds nucleotides to the growing DNA strand, extending from the RNA primer and synthesising the new strand in the 5’ to 3’ direction.
6. **Synthesis of Okazaki Fragments:** On the lagging strand, DNA polymerase synthesises short segments of DNA called Okazaki fragments, which are created in the opposite direction of the replication fork.
7. **Removal of Primers and Fragment Joining:** RNA primers are removed by DNA polymerase, which fills in the gaps with DNA. DNA ligase then seals the Okazaki fragments together to create a continuous strand.

8. **Termination:** The replication process concludes when the replication forks meet termination sequences, signalling the end of DNA synthesis.

This sequence of activities ensures that each new cell receives an accurate and complete set of genetic instructions. These steps work together to ensure that each new cell gets a complete set of DNA.

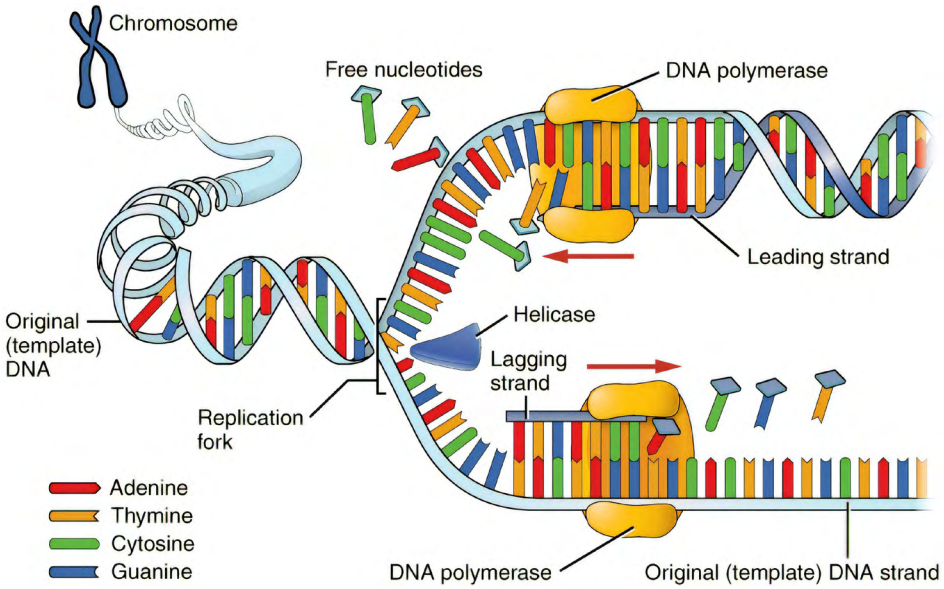


Figure 2.14: DNA Replication

Click on the link below to watch the short video on DNA Replication.

DNA Replication (Updated) (youtube.com)

Activity 2.7 Exploring DNA Replication

Materials Needed

- Access to videos, PowerPoint presentations, and simulations about DNA replication.
- Notebooks or digital devices for notetaking.

Instructions

1. Watch selected videos or PowerPoint presentations on DNA replication.
2. Discuss after viewing the content, focusing on:
   a. Key concepts of DNA replication.
   b. The roles of different enzymes.
   c. Any questions or points of clarification?
3. Share your thoughts, ensuring that all voices are heard and respected.

4. Summarise your discussion points and share with the class.

Title: Timeline of DNA Replication

Materials Needed

- Large paper or poster boards.
- Markers, coloured pencils, and other art supplies.
- Access to information resources (books, articles, or online sources).

Instructions

a. Research on the stages of DNA replication: Initiation, Elongation, and Termination.

b. Create a timeline chart that includes:

- Clear labels for each stage.
- Descriptions of what happens in each stage.
- Illustrations or icons representing key processes or enzymes involved.

c. Include a section on how DNA replication relates to real-world scenarios, such as genetic inheritance or cloning.

d. Present your timelines to the class, explaining the stages and their significance.

Relevance of DNA replication to living organisms

DNA replication plays a crucial role in the life of all organisms.

1. First and foremost, it enables the transfer of genetic information from one generation to the next. This transmission is essential for the continuity of species.
2. Additionally, DNA replication is vital for maintaining the stability of genetic information. If errors occur during replication, they can lead to harmful changes that may affect the organism's health and development, leading to mutations.
3. Furthermore, DNA replication is a source of evolution through mutations. While many mutations can be detrimental, some can lead to advantageous traits that may help species adapt to their environments over time.
4. In the process of cell division, particularly mitosis, DNA replication ensures that the daughter cells produced are identical and have the same genetic material. This is important for growth, development, and the repair of tissues.

5. Finally, DNA replication is essential for producing gametes, which contain half the set of chromosomes needed for sexual reproduction.

In summary, DNA replication is fundamental to the survival and evolution of living organisms, affecting everything from heredity to cellular function.

RNA TRANSCRIPTION AND ITS RELEVANCE IN LIVING THINGS

The RNA Molecule

RNA (Ribonucleic acid) is an important molecule found in all living cells. It is a single-stranded molecule, unlike DNA, which is double-stranded. The building blocks of RNA are nucleotides. Each nucleotide is composed of a five-carbon (pentose) sugar called ribose, a phosphate group and nitrogenous or organic bases: Adenine (A), Cytosine (C), Guanine (G) and Uracil (U); here, U replaces T found in DNA. It can be found in either the nucleus or the cytoplasm of the cell. The main types of RNA are messenger RNA (mRNA), which carries genetic information from the DNA to ribosomes for protein synthesis. In this process, it serves as a template. Ribosomal RNA (rRNA) makes up a large part of ribosomes. Transfer RNA (tRNA) brings amino acids to ribosomes during protein synthesis.

RNA plays key roles in biological processes such as protein synthesis, genetic information transmission, regulation of gene expression (the processes by which cells control the conversion of genetic information from DNA to RNA and then to proteins) and in the immune system (e.g. RNA interference)

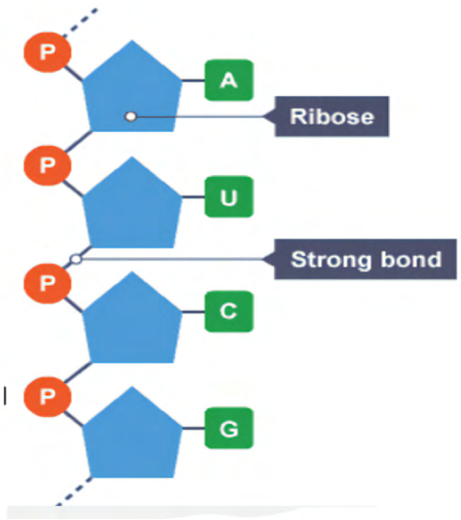


Figure 2.15: Structure of the RNA molecule

Activity 2.8 "RNA uncovered"

Materials needed

- Whiteboard or any presentation software
- Markers or a digital drawing tool
- Printed or digital diagrams of RNA structure
- Plain paper and coloured pencils (optional)

Procedure

1. Form a small group with your friends and assign a leader to facilitate discussions.
2. Gather information from textbooks, articles and online resources on RNA, focussing on what RNA is, its composition and its functions (note down your findings from your search).
3. Now with your friends, create a visual representation in the form of a diagram, poster or infographic, illustrating RNA's composition (the composition should include the sugar molecule, phosphate groups and nitrogenous bases. Employ your creative skills to make a near-perfect diagram of the RNA molecule.
4. Present your visual representation to the rest of the class for feedback and questions (this process will help increase your understanding of the RNA molecule).
5. Finally, reflect on what you have learnt from the activity and summarise your key points in your notebook (you may paste your diagram on the wall of your classroom for quick reference).

Activity 2.9 RNA Structure Simulation

(***NB:*** *Going through this activity will help you develop problem-solving and critical thinking skills through model creation. Have fun building your RNA model!*)

Materials needed

- Wire (copper or aluminium)
- Beads (different colours)
- Styrofoam balls (or small balls of clay)

- Straw
- Cardboard
- Scissors
- Glue
- Tape
- Markers or paint

Procedure

1. Cut the wire into desired lengths for the phosphate backbone,
2. Assign each bead to represent a particular organic base e.g. Adenine(A) red, Guanine(G) blue, Cytosine(C) yellow, Uracil(U) green.
3. Use the Styrofoam balls or clay to represent sugar molecules.
4. Bend the wire to form the phosphate backbone.
5. Use glue or tape to secure the wire shape.
6. Attach Styrofoam balls or clay representing sugar molecules to the backbone.
7. Use the straw to attach the bases to the sugar molecule.
8. Thread beads onto the straw and attach to the sugar molecule on the wire backbone, following the correct order of base pairing.
9. Use markers or paint to label the nucleotides on the cardboard.
10. Create a key or legend to explain the colours used.
11. Mount your model on the cardboard, display it to the rest of the class, and receive feedback from your teacher and colleagues.

RNA and Its Transcription

Transcription is the process by which an RNA strand is created from a template of DNA. The steps involved in the process are as follows:

1. *Initiation:* In this step, RNA polymerase binds to DNA at a promoter region, causing the double helix of the DNA to unwind, exposing a template strand.
2. *Elongation:* In this step, RNA polymerase reads the template strand and matches or aligns with complementary nucleotides. Synthesis of RNA occurs in the 5’ to 3’ direction.

3. *Termination*: Here, RNA polymerase reaches a termination sequence. Transcription ends, and RNA is released.
4. *RNA processing:* This is where the primary RNA (pre-mRNA) transcript undergoes several modifications to become mature mRNA. This is usually the case with RNA production in eukaryotes.

   After pre-mRNA has been formed, it undergoes modifications to form the mature RNA. These modifications (post-transcriptional processes) include:

   a. *Splicing:* removing introns (non-coding regions or sequences) and joining exons (coding regions or sequences).

   b. *Capping:* adding a 5' cap to mRNA protects it and enhances ribosome binding.

   c. *Polyadenylation:* adding a poly-A tail to mRNA at the 3' end to protect it and aid its transport from the nucleus.

NB: *In RNA (and DNA as well), the 5' and 3' notation refers to the orientation and direction of the nucleic acid chain. The 5' end is the beginning of the RNA chain, where the phosphate group is attached to the fifth carbon of ribose, while the 3' end is the opposite end of the RNA chain, where the hydroxyl group is attached to the third carbon atom of the ribose sugar.*

The importance of these modifications ensures that RNA is correctly synthesised and ready for protein synthesis as well as other cellular functions.

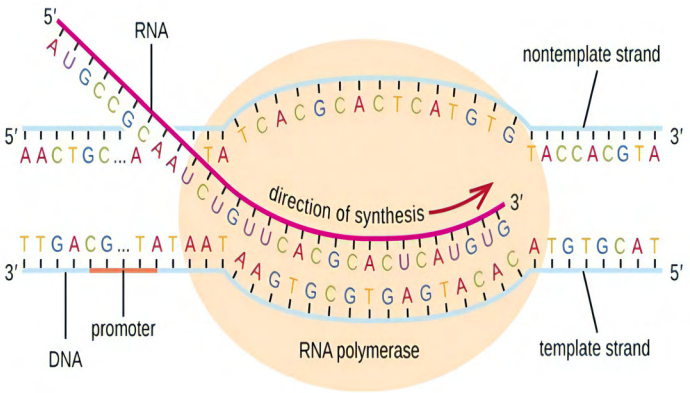


Figure 2.16: RNA Transcription

Relevance of RNA (transcription) to Living Things

Here is a summary of some of the relevance of RNA in living things:

1. Protein synthesis and genetic expression: RNA plays a crucial role in translating genetic information from DNA into proteins. mRNA also carries genetic information from the DNA to the ribosomes.
2. Cellular defence and immune response: RNA molecules help protect cells against pathogens and viral infections such as influenza.
3. Regulation of cellular processes: Apart from regulating gene expression, RNA molecules also influence cell growth, differentiation and survival.
4. Development, growth and adaptation: RNA directs embryonic development, tissue formation and organ development in the early stages of life. RNA molecules also drive evolutionary changes through mutations.
5. Therapeutic and biotechnological applications: RNA-based therapies such as mRNA vaccines could be used in future, with further research, to treat genetic disorders, cancer and infectious diseases such as Hepatitis C, COVID-19, Ebola and HIV.

Activity 2.10 RNA Transcription from DNA to RNA

Materials needed

- Large sheet of paper
- Markers of coloured pencils
- Printed diagrams of DNA and RNA structures (optional)
- Sticky notes or paper tape.

Procedure

1. Team up with some of your friends to create a visual representation (e.g. diagram or illustration) of any of the stages of transcription, e.g. initiation. Note that other groups will be working on the other stages of transcription.
2. Present your visual representation to the class and explain your creative design. Accept feedback from peers and your teacher.
3. Listen to the explanation of other peers with visual representations of other stages of transcription. Provide feedback questions for clarity where necessary.

4. Now work together with members of other groups to arrange all the visual representations in the correct order, i.e. initiation→ elongation, etc.
5. In groups, take turns to discuss and explain how each stage connects to the next.

You may put your visual representation on display in your classroom or laboratory or keep it in a safe cupboard for display on a science exhibition day!

Activity 2.11 Significance of RNA Transcription

1. Search the internet, textbooks, articles and other resource materials, relevance of RNA transcription in living things.
2. Note down your findings in your notebook.
3. Compare your findings with those of your friends and discuss the relevance written by each of you.

NB: *You may confer with your teacher for further clarification*

PROTEIN SYNTHESIS AND ITS RELEVANCE IN LIVING THINGS

The Genetic Code

Now let us look at what is called the Genetic code. The nucleotides in the DNA (adenine (A), cytosine (C), guanine (G) and thymine (T)) are arranged in a variety of sequences that is copied by the mRNA's nucleotides (A, U, C, and G). This encoded sequence of genetic message carried by the four bases A, U, C and G in the mRNA is decoded (translated or converted into meaningful language) by tRNA.

The Genetic code refers to the set of rules by which the sequence of nucleotides in DNA or RNA is translated into an amino acid sequence of proteins in living cells. A group of three bases (triplet base) called a codon specifies which amino acid is needed at each position within a protein. There are **64** different forms of codons. This is because each codon is three nucleotides long, and there are four possible nucleotides for each position; the total number of possible combinations

is **4 x 4 x 4 = 64**. 61 of these codons can each code for one amino acid. There are 20 different kinds of amino acids that these codons specify. Let's see a table of these codons and their corresponding amino acids

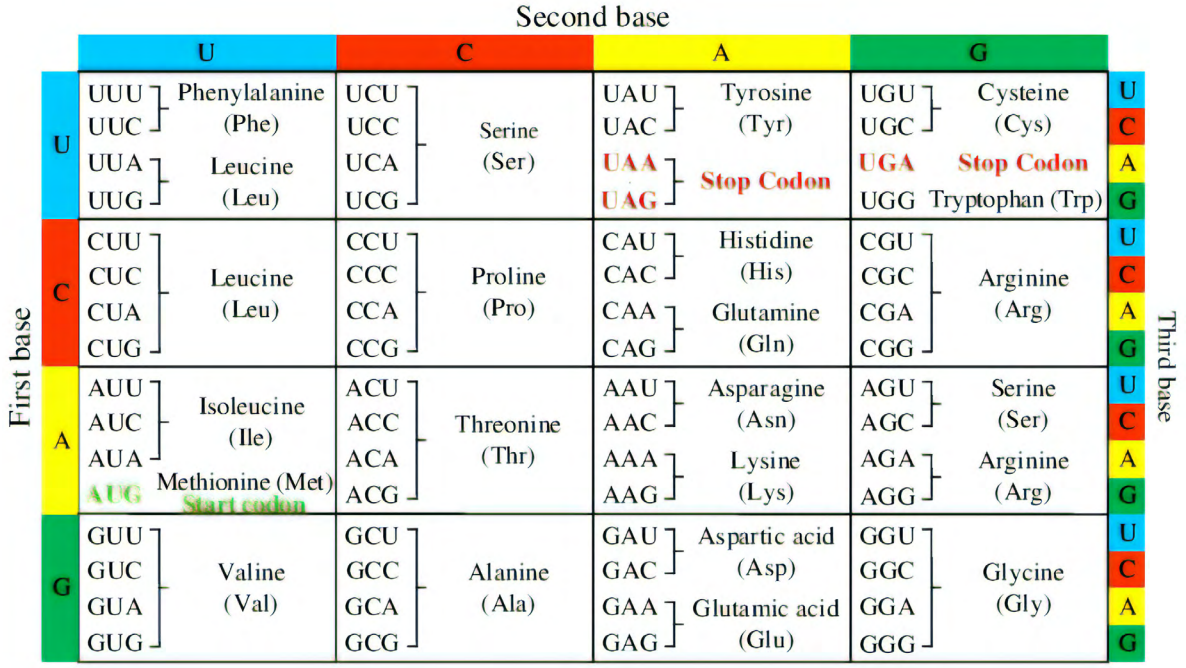


Figure 2.17: mRNA codons for all amino acids found in human proteins.

A start codon is the codon that initiates or directs the first amino acid to start the formation of a chain of amino acids (protein). Three of the codons, UGA, UAA and UAG, do not code for any amino acids and are therefore called nonsense codons. Nonsense codons are also referred to as stop codons because they mark the end (termination) of protein (the polypeptide chains) whenever they occur. The genetic code is described as universal because a triplet of bases codes for the same amino acid in almost all organisms. It is also said to be degenerate because each amino acid has more than one codon. The triplet of bases on tRNA which is complementary to a codon on the mRNA is called the anticodon.

Protein Synthesis and Its Mechanism

Now let us form some proteins: the process by which cells build proteins to be used in the body of an organism for growth and development is called Protein synthesis.

Protein synthesis in living things occurs in two major stages: transcription and translation.

Transcription

In this process a segment of DNA is copied by free nucleotides in the nucleus to form mRNA and is catalysed by the enzyme RNA polymerase. mRNA serves as a temporary copy of the genetic information from the DNA. This takes place in the nucleus of the cell. The mRNA formed leaves the nucleus into the cytoplasm through the nuclear pores, it attaches itself to a ribosome. This ends the process of transcription. The next stage is Translation.

Translation

This is the stage where the genetic information is copied (transcribed) into mRNA paired or matched to the tRNA and transformed into a sequence of amino acids to form proteins. This activity occurs on the ribosomes within the cytoplasm in three steps:

1. ***Initiation:*** This is the first stage,
   - A ribosome surrounds a mRNA and an initiator tRNA carrying the amino acid (methionine). It is on this ribosome that the amino acid chain will be formed.
   - The tRNA attached to the small ribosome binds to the 5' end of the mRNA.
   - They then move along the mRNA in the 3' direction, stopping when they reach the start codon (AUG).
   - This start codon AUG binds with anticodon UAC on the tRNA, which is carrying the amino acid, methionine.
2. ***Elongation:*** This is where the ribosome adds more amino acid molecules brought by tRNA to the growing polypeptide chain.
   - tRNA picks the amino acids from the cytoplasm to be assembled on the ribosomes.
   - A fresh codon is exposed for the next tRNA, whose anticodon is a perfect (complementary) match for the exposed codon
   - Once the matching tRNA pairs on the mRNA, the formation of the peptide bond that connects one amino acid to another begins.
   - This next step transfers the methionine from the first tRNA onto the amino acid of the second tRNA. We now have two amino acids, a (very tiny) polypeptide.

- Once the peptide bond is formed, the mRNA is pulled onward through the ribosome by exactly one codon. This shift allows the first, empty tRNA to drift out.
- A new codon is exposed, so the whole cycle can repeat, till the tRNA encounters a stop codon on the mRNA.

3. ***Termination:*** at this stage the synthesis of a polypeptide chain ends. This happens when
   - The ribosome on which the protein is being formed encounters a stop codon on the mRNA.
   - The newly formed polypeptide chain is released into the cytoplasm.
   - The new polypeptide joins other chains of polypeptides to form the protein.
   - The ribosomal subunits then disassemble.

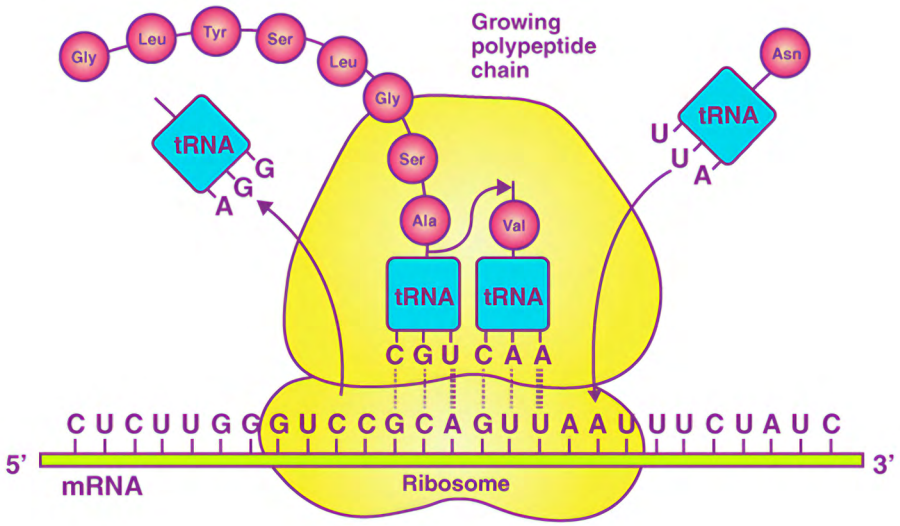


Figure 2.18: Formation of polypeptide chain (protein)

The pink balls in the diagram above represent the amino acids

Relevance of Proteins to Living Things

The process of protein synthesis in cells is crucial because the proteins formed are:

1. Essential for growth, development and repair of tissues in living things.
2. Used in the production of enzymes to catalyse biochemical activities.
3. used in communication between cells (e.g. hormones) and the regulation of cellular activities.

4. are required in the immune system to defend the body, e.g. antibodies and cytokines
5. required in the transport and storage of materials in cells (e.g. haemoglobin).
6. required to maintain cell shape, cell structure and cell motility, e.g. actin and tubulin.

Activity 2.12 Transcription Simulation

Materials needed

- Paper/notebook
- Pens.

Instructions:

1. Use the DNA template strand as provided and decode its corresponding mRNA.

   DNA strand 3'TGATACGTTGCCCCTACTAAT 5'
2. Write out the transcribed DNA sequence into mRNA by noting down the complementary RNA bases.
3. Show your final mRNA strand sequence to a friend or teacher to check it out.

Activity 2.13 Protein Synthesis Animation or Storyboard

Materials needed

- Computer
- Animation software or online tools, or a manila card
- Different coloured markers
- Tapes.

Instruction: Create a simple animation or storyboard that illustrates the steps of transcription and translation.

How to create a storyboard

1. Determine the key concepts you want to cover: DNA transcription, mRNA processing, translation, etc.

2. Break down each process of protein synthesis (key concepts) into clear, manageable parts.
3. Create scenes for each part of the process. Each scene should represent a specific step or key event in protein synthesis.
4. For each scene, draw a frame that represents the main action. Use simple sketches or diagrams to illustrate key elements (e.g., DNA, RNA polymerase, ribosomes, tRNA, amino acids).
5. Write a brief description under each frame explaining what is happening. Include key terms and concepts.
6. Arrange the frames in sequential order, ensuring the flow makes sense and each step logically follows the previous one.
7. Check for accuracy and clarity.

Note: *You may use any software or tools of your choice. You may work as a team with class members.*

Activity 2.14 Build a Protein Chain

Materials needed

- Beads of different colours
- String.

Instructions

1. Assign each bead colour to a different amino acid.
2. Use a codon chart (in in text above) to translate an mRNA sequence (you can use the mRNA developed in **Activity 2.11**) into a chain of beads, forming a protein.

EXTENDED READING

The links below provide resources for further studies

• https://www.khanacademy.org/science/biology/dna-as-the-genetic-material/dna-discovery-and-structure/v/the-discovery-of-the-double-helix-structure-of-dna	

Also, search YouTube for videos on DNA and the Watson-Crick model.

• https://youtu.be/qlREPsuYQrl?si=nq76Z1K14853Tz5K	
• https://youtu.be/qnNpGr6SDaw?si=kvZSbmakkFSrp0gw	
• https://youtu.be/qnNpGr6SDaw?si=vj5cbcKBcfDNJ10x	

ADDITIONAL READING MATERIALS

- Biology GAST Textbook
- Cambridge Biology
- College Biology
- McFadden, C.H. & Keeton, W.T. (1995). Biology: An exploration of life. (5th edition). W.W. Norton & Company, Inc., New York.
- Online Biology Resources
- Roberts, M.B.V. (1982). Biology: A Functional Approach. (3rd edition). Butler &Tanner Ltd.

REVIEW QUESTIONS

1. What are the fundamental principles that define the cell theory?
2. Explain how the unique structure of these cells helps it perform its specific function: nerve cell, red blood cell. Muscle cell, palisade mesophyll cell, root hair cell and xylem cell.
3. How do the structures of plant and animal cells differ, and how do these differences reflect their unique functions?
4. List two examples of active transport.
5. Describe how exocytosis occurs.
6. Describe the process of endocytosis.
7. Describe how endocytosis is of benefit to cells.
8. Compare active transport with osmosis.
9. Compare facilitated diffusion and active transport. How do they differ in terms of
   - **a.** energy needed
   - **b.** direction of movement across cell membranes?
10. What does the structure of DNA resemble?
    - **A.** Blueprints
    - **B.** Triple chain
    - **C.** Twisted ball
    - **D.** Twisted ladder
11. Describe the basic structure of DNA.
    - **A.** Nucleotides attached together in a mass.
    - **B.** Nucleotides on the outside attached to phosphates in the inside.
    - **C.** Phosphate strands on the outside with nucleotides bonded together on the inside.
    - **D** Phosphate strands on the outside with nucleotides attached at every other junction.
12. Which component of a nucleotide carries the genetic information?
    - **A.** Deoxyribose sugar

B. Hydrogen bond

C. Nitrogenous base

D. Phosphate group

13. Define the term "nucleotide" and describe its structural components.

14. Analyse how the structure of DNA in eukaryotic cells facilitates its role in genetic inheritance.

15. What is DNA replication, and why is it important for living organisms?

16. What are the major enzymes involved in DNA replication, and what functions do they perform?

17. What are the various stages of DNA replication, and how do they contribute to the overall process?

18. How can a designed model of the double helix structure of DNA be used to explain the process of DNA replication, including the roles of the leading and lagging strands?

19. What is RNA and what are its components?

20. Outline the stages involved in RNA transcription, and how they contribute to the process?

21. Why is RNA transcription crucial in living organisms?

22. How does RNA transcription influence protein synthesis?

23. How do the three types of RNA function, and what are their roles?

24. What is the basic structure of a nucleotide and its role in the genetic code?

25. Describe the process of transcription and its significance in protein synthesis.

26. Compare and contrast the processes of replication and transcription.

27. Describe the role of tRNA in translation.

28. How do ribosomes contribute to protein synthesis.

29. Discuss how the regulation of protein synthesis can affect cellular function.

30. Discuss the significance of RNA in ensuring the accuracy of protein synthesis.

SECTION

3 DIVERSITY OF LIVING THINGS

DIVERSITY OF LIVING THINGS AND THEIR ENVIRONMENT

Living Organism

Ecology

Diseases and Infections

INTRODUCTION

In this section, we delve into the life of the grain weevil, butterfly, housefly and honeybee by looking at their features, life cycles, economic importance and their impact on plants, animals and human life. For example, grain weevils destroy food grains, houseflies spread diseases, and butterflies and honeybees pollinate flowers. We also look at the key features of tropical ecosystems, the homes of organisms. How these organisms adapt to survive in them is examined, while an introduction to diseases and the basic terminology of infections is covered. By completing this section, learners can understand the life and importance of these insects, tropical habitats and organisms that are adapted to survive in them, and basic terms associated with diseases and infections. This will spike the interest of learners in various fields of biology and improve their perception of living in harmony with other organisms in the environment.

KEY IDEAS

- **Grain weevils**, *Sitophilus granarius*, are small pests characterised by elongated bodies and distinctive snouts that infest stored grains, causing significant damage and economic losses through reduced grain quality and increased management costs.
- The **butterfly** has distinctive features (hairy body, large colourful wings, club-shaped antenna and proboscis). It grows through four stages (the egg, the larvae, the pupa and the adult) and is important in terms of pollination, tourism and beautification purposes.
- The **Honeybee** has distinctive features (compound eyes, a pair of antennae, a proboscis and a pollen basket on its hind legs). It undergoes

complete metamorphosis (egg, larvae, pupa and adult) and is important as a pollinator of crops, the production of honey and beeswax.

- The **housefly** has distinctive features (red compound eye and greyish black body). It grows through four stages (the egg, larvae or maggot, pupa and adult), and is important in terms of disease causing, poisoning of food, biotechnology application and scientific research.
- The main terrestrial habitats are the **tropical rainforest**, **savannah** and **desert**. They differ from each other based on their vegetation types and their environmental conditions.
- The main aquatic habitats include **freshwater**, **marine** and **brackish** (a mix of fresh and saltwater) or estuary. These habitats vary in their species compositions based on the different abiotic conditions.
- The act of **vaccination**, **immunisation** and **inoculation** are the processes of stimulating a person's immune system to protect against a specific disease or infection through the administration of a vaccine, toxoid or other immunising agent.

DISTINCTIVE FEATURES, LIFE CYCLE, CHARACTERISTICS AND ECONOMIC IMPORTANCE OF THE GRAIN WEEVIL

Distinctive Features of the Grain Weevil

The grain weevil is a small insect commonly found in stored grains like wheat, rice, and corn. The grain weevil is known as ***Sitophilus granarius*.** Common examples are found in maize and rice grains. The weevil in maize is called ***Sitophilus zeamais,*** and the rice weevil is also known as ***Sitophilus oryzae*.** They belong to the order Coleoptera, characterised by elongated snouts called rostrum.

Here are their key features:

1. **Size:** Grain weevils are tiny, measuring approximately 2.5 to 5 millimetres long—about half the length of a grain of rice.
2. **Shape:** They have a long, oval, streamlined body that is typically dark brown or black. This streamlined shape allows them to fit easily into the grains they infest.

3. **Snout or Rostrum:** A notable characteristic of the grain weevil is its elongated snout, resembling a small nose. This snout helps the weevil to drill into grains to lay eggs and feed.
4. **Wings:** While they possess two pairs of wings, grain weevils are not strong fliers and prefer to move around by crawling. The first pair of wings is hardened to form the wing-cases called elytra.
5. **Legs:** They have six legs (three pairs) to navigate their surroundings, a pair each of front legs, middle legs and hind legs.
6. **Antennae:** They have two long, segmented antennae, which they use to detect chemicals such as the scent of food.

These features enable the grain weevil to thrive in stored grains, where it can cause significant damage.

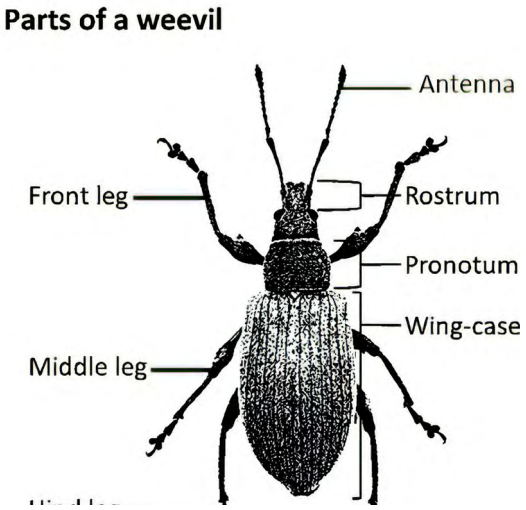


Figure 3.1: Structure of the grain weevil

Life Cycle and Adaptations of the Grain Weevil

The grain weevil undergoes complete metamorphosis: that is, the grain weevil goes through four stages in its life cycle from egg to larva to pupa and finally to the adult stage. The weevil completes these stages within **4 to 5 weeks** under ideal environmental conditions such as a temperature of about 30 degrees Celsius and a relative humidity of about 70% to 86%.

The stages are:

Egg: The female grain weevil lays eggs inside grains. The egg is whitish, oval, and measures about 0.5mm long and 0.2mm wide. Each female can lay up to 200 eggs in clusters.

Figure 3.2: Eggs of the grain weevil

Larva: Once the eggs hatch, the larvae start feeding on the grain. They remain inside the grain as they grow, which helps protect them from predators. A full-grown larva is 5 mm in length and a plumpy, fleshy, legless creature. The larvae, also called grubs, undergo a series of moulting (ecdysis) to become the pupa.

Figure 3.3: Larvae of grain weevils in a human palm

Pupa: After several weeks of feeding, the larvae pupate. This stage lasts for about a week, during which they transform into adult weevils.

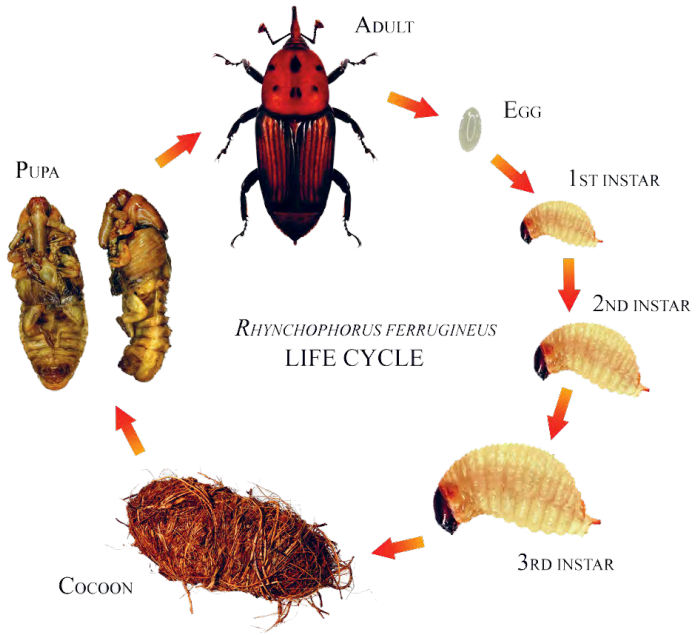


Figure 3.4: Pupa of a grain weevil

Adult: After emerging from the pupal stage, the adult grain weevil is ready to mate and start the cycle again. Adults can live for several months, continuing to infest stored grains.

Figure 3.5: Adult grain weevil on a maize grain

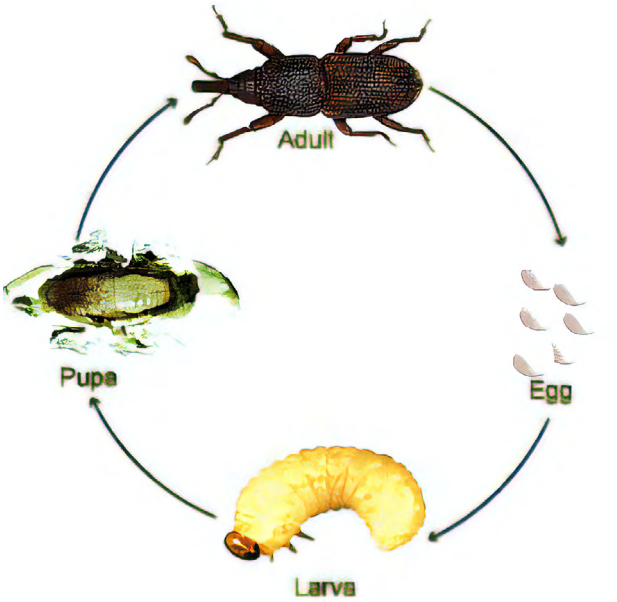


Figure 3.6: Life cycle of a grain weevil

Adaptations of the Grain Weevil

Adaptations refer to the characteristics or traits that enhance an organism's ability to survive in its environment.

The grain weevil has developed several adaptations that help it to survive in its environment, such as:

1. **Feeding mechanism:** Its long snout allows it to bore into grains easily, making it simple to access the food it needs to survive.
2. **Protected habitat:** By living inside the grains, the larva is shielded from many threats and can feed safely until it is ready to pupate.

3. **High reproductive rate:** With the ability to lay many eggs, grain weevils can quickly increase their population, ensuring their survival.
4. **Nocturnal behaviour:** Being more active at night helps the weevil avoid predators and human disturbances, allowing it to feed and reproduce more effectively.

These adaptations make the grain weevil a successful pest in stored grains, making it difficult to eradicate.

Activity 3.1 Exploring the grain weevil's life cycle and adaptations.

Materials needed:

- Pictures or diagrams of grain weevils at different life stages.
- Hand lenses or magnifying glasses
- Grain samples infested with weevils (optional)
- Large plain paper or cardboard.
- Markers or coloured pencils

Procedure:

1. Observe pictures or diagrams of the grain weevil's life stages: egg, larva, pupa and adult.
2. Explain each stage in detail, highlighting the physical changes and behaviours on the large plain white paper.
3. Now use the hand lenses or magnifying glasses to observe the grain weevil's physical features, if possible.
4. Discuss with your group members the grain weevil's adaptations that enable it to survive and reproduce.
5. Reflect and share your thoughts on how these adaptations help the grain weevil thrive in different environments.
6. Together with your group members, summarise the grain weevil's life cycle and adaptations on a large plain paper or cardboard.
7. Reflect on what you have learned and how you can apply this knowledge in your daily lives.

Economic Importance of Grain Weevil

The activity of grain weevils has significant economic effects in agriculture and food storage. These include:

Crop damage: The grain weevil infests stored grains, leading to extensive damage. Its feeding habits reduce the quality and quantity of grains, making them less suitable for consumption and sale.

Figure 3.7: Maize infested with weevils

Financial losses: The presence of grain weevils reduces the quality and quantity of stored grains, resulting in reduced proceeds from sales (locally and internationally), and high costs of pest control methods like fumigation and regular inspection.

Impact on food supply: Significant infestations can disrupt the supply chain of grains, affecting availability and market prices. This can lead to higher costs for consumers and reduced access to quality and essential food products.

Research: They are used in research into pest management and biological control methods.

They also contribute to ecological balance by serving as food for some species of birds, rodents and other insects.

Control of the Grain Weevil

To effectively manage grain weevils and protect stored grains, here are some strategies:

1. Using airtight containers to store grains prevents weevils from getting inside. This simple step can keep your grains safe.
2. Applying pesticides by fumigation involves treating the entire storage area with chemicals to eliminate weevils. It is highly effective and requires

professional help. Pesticides can effectively reduce weevil populations, but must be used responsibly. To ensure safety, make sure to read the instructions carefully, wear protective gear and apply them in well-ventilated areas.

3. Introducing natural predators like ground beetles or parasitic wasps on the farm can naturally control weevil populations. This method is eco-friendly.
4. Harvesting crops before they are fully mature can help reduce the risk of infestation. Younger grains are less attractive to weevils. Monitor your crops closely and plan your harvest to catch them at the right time, ensuring they are less likely to be infested.
5. Drying grains under direct sunlight or using smoking techniques removes moisture effectively before storing them. This is important because moisture attracts the weevils.

Activity 3.2 Farm visit

1. Visit a maize farm and observe the plants.
2. Take note of any unusual appearances in the maize grains on the cobs.
3. Speak to the farmer on the control measures he or she employs to reduce or stop weevil infestation. Be sure to note these down in your notebooks.
4. From your observations from the farm, outline the economic importance of the grain weevil and how its negative effects on crops can be controlled or checked.
5. Share your findings with your classmates and teacher.

DISTINCTIVE FEATURES, LIFE CYCLE, CHARACTERISTICS AND ECONOMIC IMPORTANCE OF THE BUTTERFLY

Structure and Distinctive Features of the Butterfly

Butterflies belong to the order Lepidoptera, characterised by the vibrant colours, large wings and club-shaped antennae. They are diurnal, meaning that they are active during the day. Their body comprises a head, thorax and abdomen.

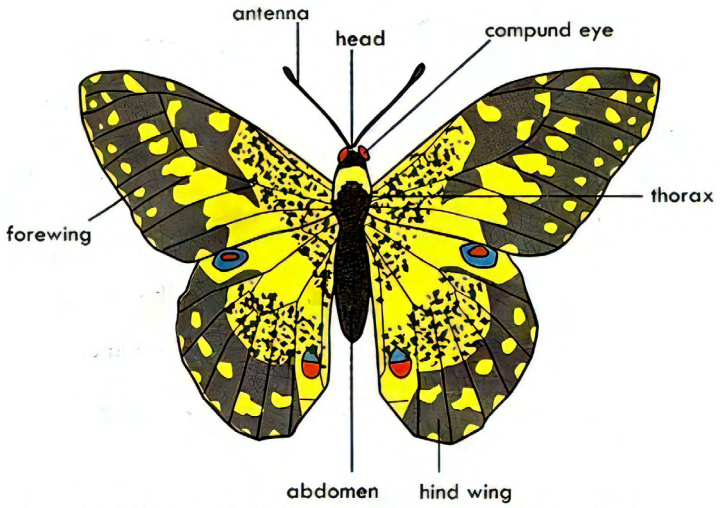
The head bears compound eyes, antennae and a proboscis. The compound eyes provide a wide field of vision, colour perception and motion detection. Their

distinctive club-shaped antennae detect airborne chemicals such as flower scents. The mouth is modified into a coiled tube called a proboscis, for sucking nectar from flowers.

The thorax consists of prothorax, mesothorax and metathorax, each bearing a pair of jointed legs. It bears the two pairs of scale-covered wings, the first (forewings) being attached to the mesothorax and the second (hindwings) being attached to the metathorax.

The abdomen has ten segments.

Examples of butterflies are the lime swallowtail, *Papilio demoleus,* the tiger swallowtail, *Papilio glaucus* and the citrus swallowtail, *Papilio demodocus*.



Dorsal view of citrus swallowtail butterfly

Figure 3.8: Structure of a citrus swallowtail butterfly, *Papilio demodocus*

Activity 3.3 Exploring Butterfly Anatomy

Materials needed

- Pictures or diagrams of butterflies
- Butterfly specimens (if available)
- Whiteboard or chart paper
- Markers or coloured pencils

Procedure

1. Observe different parts of the butterfly's body from the specimen or pictures.
2. Describe the parts identified.
3. Summarise the key points learned about the different parts of a butterfly's body.

Life Cycle and Adaptations of the Butterfly

The butterfly undergoes complete metamorphosis (the egg stage, larva or caterpillar stage, pupa or chrysalis stage and adult or imago stage). It lays its eggs in clusters under leaves. The eggs hatch into larvae or caterpillars that feed on the leaves and grow bigger. The caterpillar spins a special case called a cocoon around itself and becomes a pupa or chrysalis. Inside the cocoon, it changes (metamorphosis) into a butterfly and finally emerges as a beautiful butterfly.

Butterflies use their long antennae and big compound eyes to find their way and locate flower nectar. They suck the nectar with their long, sucking tube called a proboscis.

Most butterflies only live for a few weeks, so they spend their time flying from flower to flower, sucking nectar, and looking for a mate to start the butterfly life cycle all over again.

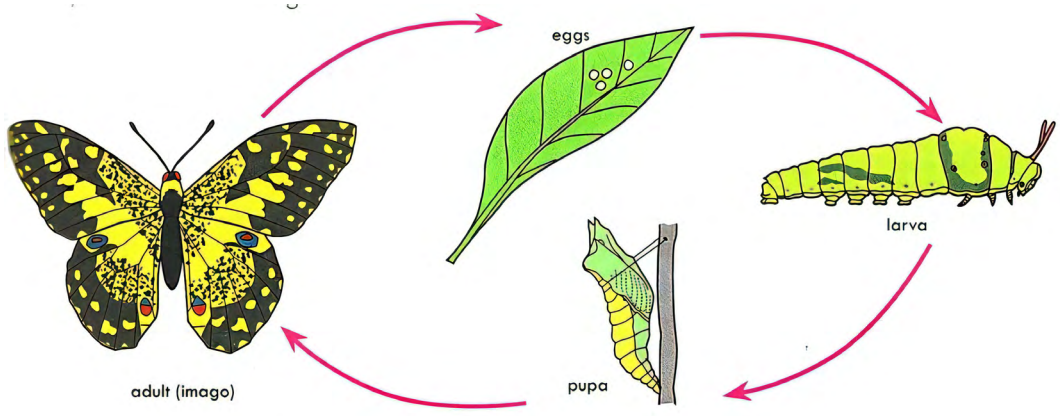


Figure 3.9: Life cycle of a swallowtail butterfly.

Activity 3.4 The life of a butterfly

Materials needed: Butterfly net, tweezers or spatula, transparent container with a perforated lid.

Procedure:

1. Visit the nearby vegetation in your assigned groups.
2. Use the butterfly nets to capture butterflies.
3. Transfer the captured butterflies into the transparent container with a lid and cover it immediately. (Be extra careful when transferring them into the container to avoid damage to the body parts.)
4. Use the tweezers or spatula to collect caterpillars and eggs, and with the leaves, put them into separate containers and keep them in the laboratory.
5. Critically observe the structure of the adult butterfly and make a labelled drawing.
6. Observe the caterpillar and eggs for at least four weeks to see the changes in development that will occur and note them down.
7. Present the individual report after four weeks.

Economic Importance of Butterflies

1. They are important agents of pollination in plants. When they visit flowers to suck up nectar pollen sticks to their bodies, and they then carry the pollen from flower to flower.
2. People love to see butterflies. Butterfly gardens and parks attract visitors, which can bring money to an area or country.
3. Butterflies have a short lifespan, and this makes them sensitive to environmental changes. For example, butterflies are sensitive to temperature, and any increase in temperature in their environment makes them uncomfortable and they die. This makes them indicators for climate change.

DISTINCTIVE FEATURES, LIFE CYCLE, CHARACTERISTICS AND ECONOMIC IMPORTANCE OF THE HOUSEFLY

Structure and Distinctive Features of the Housefly

The **housefly (*Musca domestica*)** is a common insect found almost everywhere. They belong to the order Diptera, characterised by short antennae, the use of only a single pair of wings to fly, with the hindwings having evolved into halteres. They love dirty places. It has a greyish-black body with stripes on its thorax.

Here are some of its key features:

1. **Big Red Compound Eyes**: Houseflies have large, red compound eyes on the head that allow them to see in many directions at once.
2. **Proboscis:** This is specialised for sponge feeding on liquids or semi-liquid substances. Houseflies have no teeth, instead, they have special mouthpart that acts like a sponge, perfect for soaking up liquids and soft foods.
3. **Thorax:** It bears two pairs of wings. The first pair, called the fore wings, are for flying, and the last pair (hindwings) are modified into halters for balancing its body.

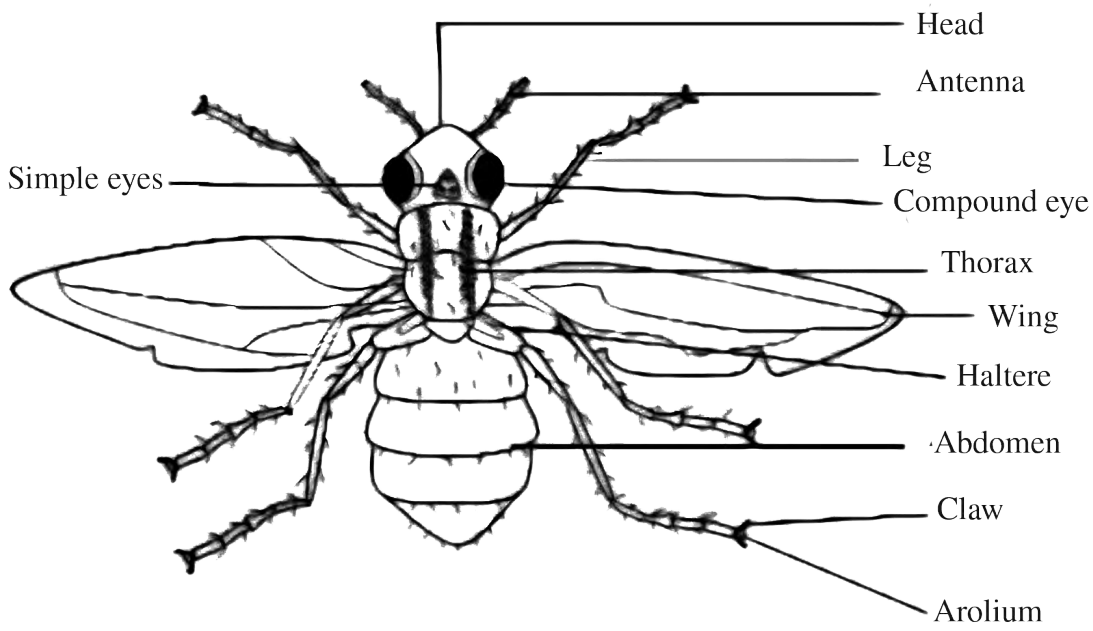


Figure 3.10: Structure of a housefly

Activity 3.5 Structure of a housefly

Materials needed

- Modelling clay of different colours
- Toothpicks
- Magnifying glass
- Images of houseflies
- Wet or dry preserved specimen of a housefly

Procedure

1. **Introduction**
   - **a.** Discuss what you already know about houseflies in groups.
   - **b.** Also discuss the importance of the housefly in ecosystems (decomposition)
   - **c.** Explain how the anatomy of a housefly will help you to understand how it functions.
2. **Observation**
   - **a.** Observe images of houseflies, pointing out key body parts: head, thorax, abdomen, legs, wings, antennae, eyes.
     OR Observe a housefly specimen with a magnifying glass.
   - **b.** Discuss the function of each body part.
3. **Model Building**
   - **a.** Be in groups.
   - **b.** Each group is to create a model of a housefly using modelling clay and toothpicks.
   - **c.** Ensure accuracy and attention to detail in your models.
4. **Presentation and Discussion**
   - **a.** Each group present their model to the class, indicating the different body parts and their functions.
   - **b.** Discuss any adaptations houseflies have that make them successful in their environment.

Life Cycle and Adaptations of the Housefly

Houseflies go through complete metamorphosis, as some other insects do. The stages are as follows:

1. **Egg:** A female housefly lays about five hundred eggs in her lifetime. It looks for moist decaying organic matter and lays its eggs on it. Within twenty-four hours after laying, the eggs hatch into larvae, also known as maggots.
2. **Larvae [maggot]:** The larvae develop through several instar stages for a period of five to fifteen days to form the pupa in a hardened case.
3. **Pupa:** After a couple of days, the larva forms a hard case around itself called a pupa. Metamorphosis of the larvae occurs inside the hardened case.
4. **Adult:** This stage emerges after the pupal stage. The adult housefly can live for several weeks.

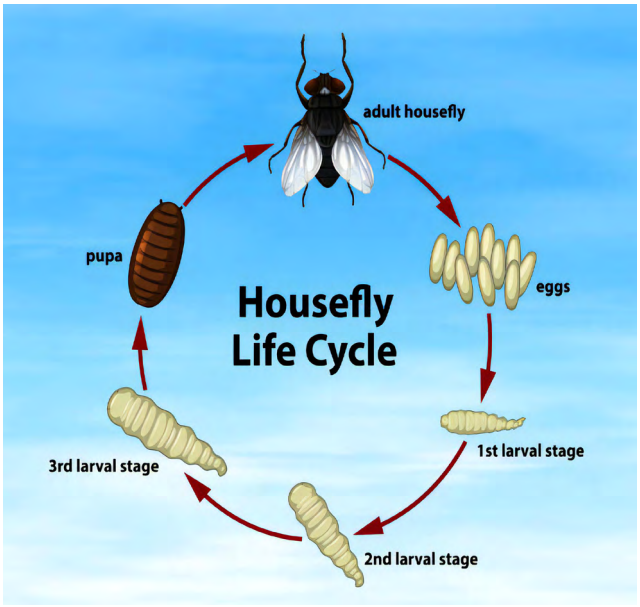


Figure 3.11: Life cycle of a housefly.

Activity 3.6 Worksheet on Life Cycle of a Housefly

Read the manual on the housefly and answer the following questions.

1. Where do houseflies lay their eggs?
2. What is a maggot?
3. The life cycle of a housefly is completed in how many days?
4. Is the housefly a harmful or harmless insect?
5. Give a reason for your answer above.

Economic Importance of the Housefly

1. Houseflies land on unpleasant stuff like garbage and even faeces. Then, they carry germs on their bodies and spread them to our food or anything else they land on. These germs can cause serious illnesses such as cholera, typhoid fever and dysentery.
2. They can contaminate food and spread toxins, leading to food poisoning. It is important to keep our surroundings clean, cover our food and wash our hands to avoid contamination.
3. Houseflies can bother animals, making them stressed and less productive.
4. Housefly larvae (maggots) help break down organic matter, which is important for nutrient cycling.
5. Researchers are exploring the potential of housefly larvae in biotechnology applications, particularly in the production of enzymes and biomolecules.
6. Houseflies are used in scientific research to study genetics, physiology and disease transmission.

Activity 3.7 The Economic Impact of Houseflies

Materials needed

- Whiteboard
- Markers
- Blank paper
- Pencils
- Printed copies of the following scenarios (one per group

Picture scenario 1: Food contamination

Picture scenario 2: Livestock production

Picture scenario 3: Biotechnology

Picture scenario 4: Waste Management

Procedure

In a group of 5 members, select a scenario.

1. Discuss the economic impact of houseflies in each scenario:
   - **a.** Housefly infestation in a food processing plant.
   - **b.** Housefly infestation in a hospital or healthcare facility.
   - **c.** Housefly infestation in a residential area.
2. Share your write-up with members of other groups and accept questions.

Control Measures for Houseflies

1. Houseflies need organic matter, like food waste or vegetable scraps, to lay their eggs. So, proper waste disposal can prevent them from laying their eggs on a suitable surface and prevent them from multiplying. This process is called the cultural control method.
2. Some insects, like parasitic wasps and fire ants, are natural predators of houseflies. They are used to control the housefly population without harming the environment. This is called biological control.
3. Chemically, insecticides can be used to control overwhelming populations of houseflies. However, this should be done carefully and only when necessary, as insecticides can also harm other living things.

DISTINCTIVE FEATURES, LIFE CYCLE, CHARACTERISTICS AND ECONOMIC IMPORTANCE OF THE HONEYBEE

Structure and Distinctive Features of the Honeybee

Honeybees (*Apis species*) are social insects of the order Hymenoptera that live together in groups. They make honey and beeswax, and propolis are very important to our environment. A honeybee colony has three castes of bees: a queen bee (a single, reproductive female that lays eggs), worker bees (non-reproductive females that perform various tasks, including foraging and cleaning of the hive) and drones (reproductive males).

Honeybees live in places with lots of flowers such as forests, gardens and grasslands. Some honeybees live in the wild, building their hives in trees or rocks, while others live in beehives kept by people.

Honeybees have three body parts: head, thorax, and abdomen. They have compound eyes, antennae, and a long proboscis to suck nectar from flowers. They also have two pairs of wings, and three pairs of legs attached to the thorax with special baskets known as pollen baskets on their hind legs to carry pollen grains. Worker bees and the queen also have a stinger to protect themselves.

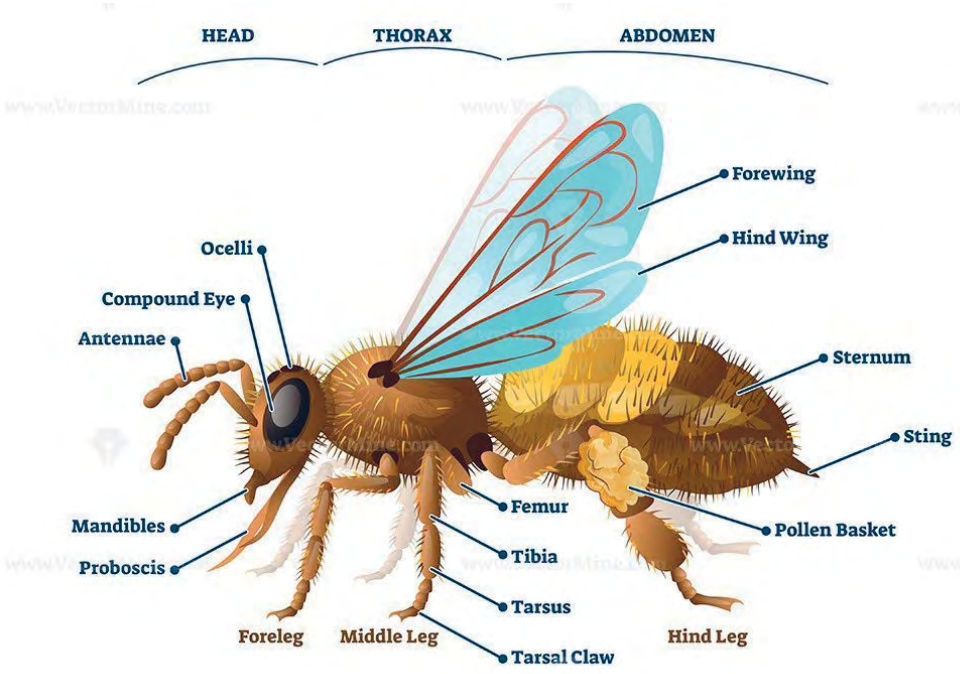


Figure 3.12: Structure of a honeybee

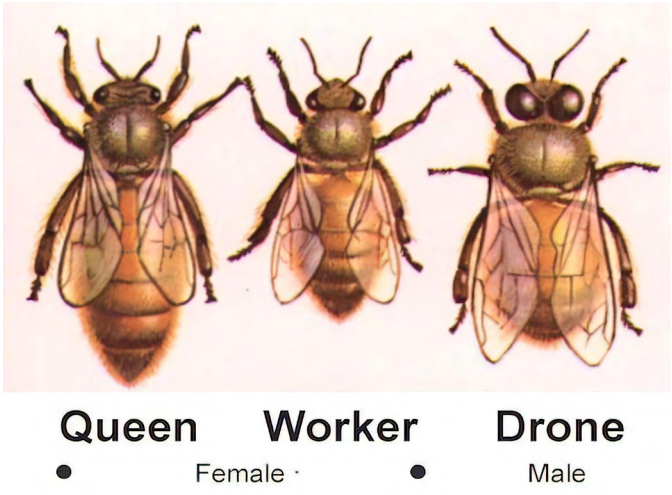


Figure 3.13: Caste of honeybees

Activity 3.8 The sweet economy of honeybees

Embark on a field trip to the following place to learn about the economic importance of honeybees:

1. Local bee farm or apiary
2. Botanical garden or pollinator-friendly park
3. Farmers' market

Local bee farm or apiary

1. Visit a local bee farm or apiary to observe honeybee colonies. Be sure to take along a writing pad to note down some key points.
2. At the farm, interact with the farmer and learn about beekeeping practices.

Caution: A bee sting can be very painful. Be careful to follow the instructions of the farmer to avoid any harm.

3. Discuss with a friend or friends the economic importance of honeybees in pollination, honey production and wax production.
4. Carefully note down the information you have gathered in your notebook for reference.

Botanical garden tour

1. Visit a botanical garden or pollinator-friendly park to observe the diversity of plants that rely on honeybees for pollination.

2. Discuss with your friend or friends the importance of pollinator-friendly plants and how you can support pollinator health in your community.

Farmers' market

1. Visit a local farmers' market and speak with farmers who rely on honeybees for pollination.
2. With the information you have gathered from the farmers, reflect on the economic impact of honeybee pollination on local food systems and economies.
3. Finally, share your findings and experiences of the economic importance of honeybees you were exposed to with your classmates.

Life Cycle of the Honeybee

Bees go through an amazing transformation as they grow, called complete metamorphosis. The queen bee lays eggs in the honeycomb cells, which are like tiny rooms. The eggs that are fertilised will become worker bees or a new queen bee, while the unfertilised eggs will become drones.

When the eggs hatch into larvae, the worker bees feed and take care of the larvae. The worker bees cover the cells with a special lid, so the larva can spin a cocoon around itself and transform into a pupa. Inside the cell, the pupa grows into a fully formed adult bee. When the adult bee comes out of the cell, it will be either a queen, a worker, or a drone. The worker bees give the queen bee special food called royal jelly when it is still a larva.

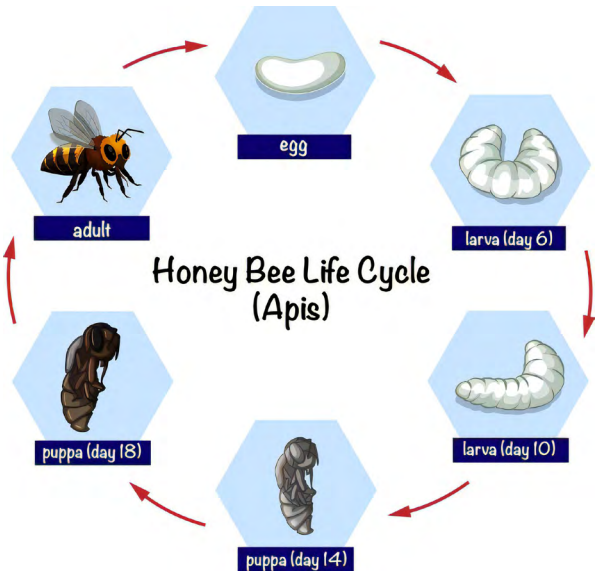


Figure 3.14: Life cycle of a honeybee

Activity 3.9 The life cycle of honeybees- 'A Stage-by-Stage Exploration'.

With the stages of development of the honeybee in mind:

1. Compare the egg stage to the larval stage
2. Compare the pupal stage to the adult stage.
3. Discuss the outcomes of the comparison among yourselves.

Economic Importance of Honeybees

1. Bees pollinate flowers, which means they assist plants in reproducing. Without bees, we would not have many of the foods we eat.
2. Bees manufacture honey. Honey has many uses, such as sweetening food, assisting in the healing of wounds, and soothing coughs.
3. Bees make other products such as beeswax, propolis and royal jelly. These products are used in making candles, cosmetics, polish and for medicinal purposes.
4. Some people use bee products to help with health problems. For example, royal jelly is used to reduce aging of the skin, propolis is used to reduce swelling.
5. A bee sting is very painful and can cause allergic reactions, which can be serious.

Figure 3.15: Products from honeybees

CHARACTERISTIC FEATURES OF A TROPICAL RAINFOREST AND ADAPTATIONS OF ORGANISMS IN TROPICAL RAINFOREST

Tropical Rainforest

The tropical rainforest is a forest that is consistently warm and has a high rainfall of more than 2000mm annually. It has a unique dense vegetation with different plant layers and unique characteristics. These include the emergent layer, characterised by very tall trees, the canopy layer, characterised by the primary layers of rainforest that form a dense roof of leaves and branches, the understory layer located below the canopies and receiving limited sunlight, and finally, the bottom layer of the rainforest called the forest floor.

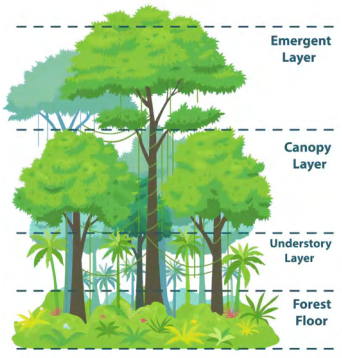


Figure 3.16: Rainforest canopy layers

The tropical rainforest is home to a huge variety of plants and animals because the weather is consistently warm and rainy, and there is plenty of food and resources available. This creates a stable and comfortable environment that allows many different species to thrive and coexist.

Figure 3.17: Tropical rainforest

This habitat is home to tiny microorganisms such as bacteria and fungi that help break down dead plants and animals in the soil. Some bacteria help plants grow by fixing nitrogen. when they grow in the roots of the plants. Nitrogen fixation is a biological process where nitrogen in the atmosphere is converted into ammonia (another form of nitrogen) by certain bacterial species like Rhizobium, Azotobacter, etc. Protoctista like *Amoebae* and Flagellates can also be found in the forest soil.

The rainforest is home to tall trees like ceiba or kapok, African mahogany, wawa, Odum and rubber. Other plants found include epiphytes such as orchids, ferns and bromeliads that grow on other plants, and vines that climb up the trees.

The rainforest is also home to a vast array of animals like monkeys, forest elephants and birds like parrots, sparrows and eagles. Reptiles such as snakes and lizards are also present along with amphibians like frogs and salamanders, Insects like butterflies and ants and arachnids such as spiders and scorpions.

National Geographic documentary on rainforests:
https://www.youtube.com/watch?v=3vijLre760w

Characteristics of tropical rainforests

1. Has heavy rain, over 2000mm every year.
2. Temperatures that stay between 20-30°C.
3. The air is always humid.
4. The rainforest is home to a huge variety of plants and animals.
5. The plants grow in layers with different levels of trees, shrubs, and vines.

Adaptations of plants in the tropical rainforest

1. Plants such as African mahogany have huge leaves with pointed tips that allow water to slide off, preventing fungi from growing on them.
2. Epiphytes such as orchids and bromeliads grow on other plants to reach the sunlight filtering through the dense canopy.
3. Vines and lianas such as pothos (candle vine) climb up trees to reach the sunlight in the upper canopy.
4. Trees such as kapok develop big, flat roots (buttress roots) that help them stand tall in thin soil and absorb nutrients

Figure 3.18: A large tropical rainforest tree with supporting buttress roots.

Adaptations of animals in the tropical rainforest

1. Animals like chameleons have colours and patterns (camouflage) that help them to blend with the environment and hide from predators.
2. Bush babies and other animals live in trees to avoid predators that roam the forest floor.
3. Monkeys and pangolins have prehensile tails that act like an extra hand, helping them grip tree branches and move through the forest canopy.
4. Pangolins and other animals are nocturnal, meaning they are active at night, to avoid predators that hunt during the day.

Activity 3.10 Exploring Tropical Rainforests

Materials needed

- Whiteboard
- Markers
- Diagrams of tropical rainforest layers (emergent, canopy, understory, forest floor)

Procedure

1. In groups, share what you know about tropical rainforests.
2. Discuss each layer's unique features and how plants and animals adapt to that layer, using the printed copies of the tropical rainforest layers and zones as a guide.
3. Choose a plant or animal as a group and create a poster or drawing that illustrates its adaptations.
4. Share your drawing or poster with other groups.

CHARACTERISTIC FEATURES OF SAVANNAH AND DESERT HABITATS, AND ADAPTATIONS OF ORGANISMS IN SAVANNAH AND DESERT HABITATS

Savannah and Desert Habitats

The savannah is a mixed grassland characterised by a variety of grasses, scattered trees and seasonal wet and dry cycles supporting a rich range of plant and animal species. In contrast, deserts are dry regions defined by extremely low rainfall, extreme temperature fluctuations and bare vegetation where life has adapted to survive in challenging conditions. The savannahs near the equator are called tropical savannahs.

Figure 3.19: Tropical Savannah

Types of Tropical Savannahs

In Africa, there are three main types of tropical savannahs:

Table 3.1: Types of Savannahs in Africa and their grass vegetation.

Types of savannahs in Africa	Grass vegetation
Guinea	Guinea grass, Bermuda grass, Gamba grass, and elephant grass.
Sudan	Tussock grasses and thatching grasses
Sahel	Drin grass, tussock grass and Bushman grass

Figure 3.20: Types of grasses

Organisms in the Savannah

1. **Microorganisms:** These are usually bacteria and the fruiting body of fungi, such as mushrooms (for example, the termitomyces).

Figure 3.21: Fruiting body of Termitomyces

2. **Trees:** These comprise acacia trees, shea trees, palm trees and baobabs.

Figure 3.22: The baobab tree

Figure 3.23: Acacia tree

3. **Animals:** The savannah is home to many animals, e.g. giraffes, elephants, antelopes, snakes, termites, ostriches and lions roaming freely among the grasses and trees.

Figure 3.24: Ostriches

NOTE: Click on the link below to watch a short documentary on Savannah

Bing Videos

Desert

Deserts are dry areas where rainfall is extremely low. They can be very hot during the day and freezing at night, and because of these tough conditions, you will not find many plants or animals there.

Figure 3.25: Desert

Organisms in the Desert

1. **Bacteria:** They are mostly algae and thermophiles (bacteria that love hot temperatures).
2. **Fungi:** These desert fungi help recycle nutrients in the soil.
3. **Plants:** The saguaro and prickly pear cacti are tough and can store water.

Figure 3.26: Saguaro and cacti

You will also find shrubs like sagebrush and creosote bush. They have adapted to survive in the heat.

Figure 3.27: Sage bush

4. **Animals** like camels, kangaroos, fennec foxes, rattlesnakes, burrowing owls, roadrunner Birds, Ants and scarab beetles are found.

Figure 3.28: Camel

Figure 3.29: Fennec Fox

Figure 3.30: Dessert Lark

NOTE: Click on the link below to watch a short documentary on Deserts

Bing Videos

Characteristics of Savannahs and Desert Habitats

The Savannah

1. Seasonal rainfall: Savannahs experience distinct wet and dry seasons.
2. Vegetation: The flora mainly consists of grasses with scattered drought-resistant trees.
3. Animal life: Fauna includes animals adapted to grazing, browsing and seasonal migration.
4. Soil quality: Soils are often nutrient-poor but well-drained.

The Desert

1. Low rainfall: Deserts receive extremely low rainfall, often less than ten inches per year, with high evaporation.
2. Vegetation: Flora is scarce, primarily made up of succulent and drought-resistant shrubs.
3. Animal adaptations**:** Fauna is adapted to survive extreme temperatures and water scarcity.
4. Soil composition**:** Desert soils are mainly sandy with minimal organic content or consist of rocky terrain.

Adaptations of organisms in the Savannah

1. *Camouflage:* Some animals, such as lions and zebras, use camouflage for hunting and protection.
2. *Migration:* Large mammals like wildebeests migrate to find water and fresh grazing.
3. Water conservation**:** Some savannah animals, such as giraffes, can go long periods without water.
4. *Deep roots:* Savannah plants, like acacia trees, develop deep roots (tap roots) to access groundwater.
5. *Fire resistance:* Many grasses and trees can withstand periodic fires, such as elephant grass.

Adaptations of organisms in the Desert

1. *Nocturnal behaviour:* Many desert animals, including kangaroo rats and foxes, are nocturnal to avoid daytime heat.
2. *Burrowing:* Some animals, like ground squirrels and meerkats, burrow into the soil to escape heat and predators.
3. *Fat storage:* Certain animals, such as gerbils and camels.
4. *Water storage:* Many desert plants, like cacti and aloe vera, store significant amounts of water in their tissues.
5. *Reduced leaves:* Some desert plants, such as the Joshua tree, have reduced leaves to minimise water loss.
6. *Extensive roots:* Plants like Welwitschia have deep and extensive root systems to increase water absorption. Welwitschia is found only in the Namib desert of south-western Africa, near the coast of Angola and Namibia

Figure 3.31: Welwitschia

Activity 3.12 Selection of favourites in the habitat

1. Draw your favourite desert animal or plant and outline its unique adaptations that help it survive in such a harsh environment.
2. Why do you think deserts have fewer plants and animals compared to other habitats like forests or savannahs? Discuss your answer in groups.

Activity 3.13 Debate on the feasibility and implications of converting desert areas into forested regions

Materials needed

- Paper
- Pens
- Research materials (Textbooks, articles, or internet access if available)

Instructions

1. With your debate team, research and discuss your stance, such as:
   a. Proponents (for reclaiming deserts into forests): Potential benefits (e.g., increased biodiversity, carbon sequestration, improved climate), methods for reclamation (e.g., irrigation, soil improvement), and successful case studies.
   b. Opponents (NOT possible to reclaim deserts into forests): Challenges (e.g., water scarcity, cost, ecological impact), potential negative consequences (e.g., displacing native species), and the practicality of large-scale projects.

2. Present your arguments and, alternatively, respond to each other's arguments.
3. The class discusses the arguments presented.

CHARACTERISTIC FEATURES AND ADAPTATIONS OF ORGANISMS IN LAGOON AND ESTUARY HABITATS

Lagoon Habitats

A lagoon is a shallow body of water that is separated from larger bodies of water, like seas and oceans. This separation is often caused by barriers such as sandbars, barrier islands or coral reefs. Lagoons are formed through several natural processes:

1. **Sediment deposition** occurs when soil and sand are carried by water and settle in one place.
2. **Wave action:** Waves shape the shoreline and help create barriers.
3. **Growth of coral reefs or barrier islands:** These structures can form over time, creating a lagoon behind them.
4. Lagoons often contain a mix of freshwater and saltwater from the sea, called brackish water. The salinity (saltiness) can change. During low tide**,** freshwater mixes easily with lagoon water, lowering the salinity. At high tide**,** more ocean water flows in, increasing the salinity.

Biodiversity in Lagoons

Lagoons are rich in biodiversity, meaning they are habitats for many different species, including fish, birds, insects and plants. They also serve as important breeding grounds for many species.

Types of Lagoons

There are two main types of lagoons:

1. Coastal lagoons: Found along coastlines, separated from the sea.
2. Atoll lagoons: Located within coral atolls, surrounded by coral reefs.

Lagoons in Ghana

In Ghana, you can find several lagoons, including Benya Lagoon in Elmina.

Figure 3.32: Benya Lagoon in Elmina in the Central region of Ghana

Figure 3.33: Korle Lagoon in Accra

Figure 3.34: Keta Lagoon in the Volta region of Ghana

Threats to Lagoons

Unfortunately, lagoons face many threats, such as:

1. **Pollution:** Harmful substances that can damage ecosystems, such as seen in the Korle Lagoon below.

Figure 3.35: A polluted lagoon

2. **Eutrophication:** When excessive nutrients lead to algae overgrowth. During the day, algae photosynthesise in the light and produce vast quantities of oxygen, more than enough to oxygenate any body of water, even where there is much decay and decomposition. At night, every organism in an ecosystem (in this case, the lagoon), including the algae, respires. Aerobic respiration results in the removal of oxygen from the surroundings by many organisms, respiring at night, when there is no photosynthesis to supply them with oxygen, leading to the death of the organisms.
3. **Habitat destruction:** Human activities that destroy these important environments.

To wrap up on the threats to lagoons, lagoons are vital ecosystems that support a wide range of life. By learning about them, we can appreciate their importance and find ways to help protect them. Happy exploring.

Self-Reflection

What do you think we can do to help protect lagoons and their ecosystems?

Characteristics of Lagoons

1. **Fluctuating salinity and temperature:** Lagoons experience changes in saltiness(creating brackish water) and temperature due to tides and freshwater inflows.
2. **Shallow depth:** Most lagoons are relatively shallow, typically just a few metres deep.
3. **High biodiversity:** Lagoons support a wide variety of life, including fish, birds, and plants.
4. **Slow water flow:** The water in lagoons flows slowly and sluggishly, creating a unique habitat.

Adaptations of organisms in lagoon habitats

Now, let's explore how different organisms have adapted to thrive in lagoons.

1. **Osmoregulation:** Some organisms, like crabs and oysters, have special features to tolerate changing salt levels.
2. **Respiratory features:** Organisms may have efficient ways to breathe in low-oxygen conditions. For example, some move to the surface to breathe.
3. **Burrowing behaviour:** Oysters and other organisms burrow into sediments to cope with extreme temperatures.
4. **Feeding strategies:** Many lagoon organisms, like snails, are detritivores or filter feeders, feeding on organic matter that collects in sediments.
5. **Reproductive strategies:** Some species produce many eggs that hatch into larvae, which can disperse widely.
6. **Camouflage and toxins:** To avoid predators, some organisms use camouflage or produce toxins.
7. **Mobility:** Many lagoon animals are highly mobile and can quickly move to better conditions.
8. **Mangroves:** Some of these coastal plants have special roots called pneumatophores that help them exchange gases with the atmosphere.

Lagoons are incredible ecosystems rich in life and diversity. By understanding their characteristics and the adaptations of the organisms that inhabit them, we can appreciate the delicate balance of these environments.

Activity 3.14 Surviving in the Lagoon - exploring adaptations through fieldtrips

1. Visit a lagoon and take note of all the organisms found in and around it.
2. How are they able to survive respectively?
3. Look out for special features or structures, if any.
4. Write down all observations and findings for discussion.

Activity 3.15 Exploring mangroves

1. Look up pictures of mangrove trees from textbooks, journals or the internet.

Figure 3.36: A mangrove tree

2. How do you think their unique roots help them survive in lagoon environments?

Estuaries

In estuaries, freshwater meets the sea. Let's discover what makes these ecosystems so special and how the organisms living there adapt to their unique environment.

Estuaries are coastal water bodies where freshwater from rivers and streams converges or meets with saltwater from the ocean. These ecosystems are dynamic, influenced by tides that bring in seawater and freshwater inflows that dilute it. Acting as transitional zones between land and sea, estuaries feature varying salinity levels (brackish) and nutrient concentrations, shaped by tidal movements, river flow, and wind patterns.

These habitats are crucial for many species, offering nurseries for juvenile fish and feeding grounds for migratory birds. However, estuaries face significant

threats from pollution, including runoff from agriculture, industrial waste, and urban development. Examples of estuaries include the Volta River Estuary near Ada and the Rivers Pra and Densu estuaries located in Ghana.

Characteristics of Estuaries

1. **Deeper than lagoons:** Estuaries tend to be deeper than lagoons, creating different habitats for organisms.
2. **Consistent freshwater inflow:** Estuaries always receive freshwater from rivers and streams.
3. **Fast and strong water flow:** The flow of water into an estuary can be quick and powerful, especially during heavy rains or floods.
4. **Fluctuating salinity:** Salinity levels in estuaries can change rapidly, influenced by tides and freshwater input.

Activity 3.16 Exploring Estuaries - a delicate balance

Materials needed: Pictures of different estuaries (as shown below).

Figure 3.37: Ankobra estuary in Ghana

Figure 3.38: Ada estuary in Ghana

Figure 3.39: Pamlico Sound estuary in the USA

Procedure:

1. Observe pictures of different estuaries and discuss the types of plants and animals likely to be found there.
2. How well are these organisms going to survive?
3. Write down all findings and discuss with other classmates.

Adaptations of Organisms in Estuaries

1. **Salt regulation in fish:** Many fish, like salmon and eels, can regulate their internal salt concentrations, allowing them to thrive in both freshwater and saltwater.

   For example, salmon hatch in freshwater, migrate to the ocean, and return to rivers to spawn.
2. **Burrowing for safety:** Species like mussels and clams burrow in sediment to avoid predators and harsh conditions.
3. **Streamlined bodies:** Some organisms have flattened or streamlined bodies to navigate strong currents and hide in sediments.
4. **Anadromous fish migration:** Anadromous fish, such as pink salmon, use estuaries as a pathway from the ocean to freshwater for spawning.
5. **Filter feeders:** Oysters and barnacles have specialised feeding structures to filter plankton and detritus from the water.
6. **Mangrove roots:** The roots of mangrove plants provide habitat and protection for young fish and other aquatic organisms.
7. **Salt-tolerant seagrasses:** Seagrasses can tolerate high salt concentrations, providing food and shelter for marine life.

Activity 3.17 Creating an Interactive Map

1. Draw a migration route of a pink salmon from the ocean to a river.
2. Research different types of seagrasses and other organisms that may be found along the migration route, and include these organisms on your map
3. Mount your work in class to compare and discuss with your friends.

CHARACTERISTIC FEATURES AND ADAPTATIONS OF ORGANISMS AT THE SEASHORE

Exploring Seashore Habitats

Learners, today, we are diving into the fascinating world of seashore habitats, where land meets the ocean. This vibrant ecosystem is rich in nutrients and filled with diverse life forms. Let's explore the different zones of the seashore and discover the amazing organisms that inhabit them.

The Zones of the Seashore

The seashore is made up of zones. These are:

1. **Supralittoral Zone (Splash Zone)**

   Description: This is the uppermost zone; it's often exposed to salt spray and strong waves.

   Organisms: Lichens, algae, barnacles, and periwinkles thrive here.

   Adaptations: Organisms in this zone must withstand drying out (desiccation) and fluctuating temperature changes because of sea water splashing.

2. **Littoral Zone (Intertidal Zone)**

   Description: This area lies between the high and low tide marks, experiencing regular submersion and exposure due to tidal movements.

   Organisms: Seaweeds (algae), mussels, barnacles, crabs, starfish, and sea anemones call this zone home.

   Adaptations: These organisms deal with frequent changes in temperature, salinity, and moisture.

3. **Sublittoral Zone (Subtidal Zone)**

   Description: This zone extends from the low tide mark to the edge of the continental shelf and is always submerged.

   Organisms: Sea grasses, kelp, various fish species, sea urchins, and coral reefs thrive here.

   Adaptations: Organisms in this zone adapt to stable aquatic conditions while needing to tolerate varying light levels.

Figure 3.40: A rocky seashore

Figure 3.41: A sandy beach at Krokobite in Ghana

Activity 3.18 Our seashore world

1. Draw and describe how a barnacle would anchor itself to survive in the intertidal zone. What adaptations does it need to survive?
2. Imagine you're a crab. Create a short story about a day in your life in the intertidal zone. How do you find food and avoid predators?
3. Research one organism from the sublittoral zone. Create a poster that includes its habitat, adaptations, and any interesting facts.
4. Share your drawing, story and posters with the class.

Adaptations of Organisms in the Seashore Habitat

Let's dive into the fascinating adaptations that help organisms survive in the challenging seashore environment and discover how these amazing animals and plants, and algae thrive in their unique habitat.

Adaptations of seashore animals

1. *Protective Shells and Exoskeletons:* Many seashore animals, like snails and crabs, have shells or exoskeletons that protect them from predators and desiccation (drying out).
2. *Anchoring Mechanisms:* Some animals, such as mussels and starfish, use byssal threads and tube feet, respectively, to cling tightly to rocks, preventing them from being swept away by waves.
3. *Flattened Bodies:* Animals like limpets and chitons have flattened bodies to reduce resistance against strong waves.

Figure 3.42: Limpets on a rocky seashore

4. *Burrowing Behaviour:* Clams and worms burrow into the mud to escape predators and prevent drying out.
5. *Movement Strategies:* Some seashore animals move to tidal pools or migrate to deeper waters during low tides to find shelter and food.

Activity 3.19 Deep dive at the seashore

1. Draw an imaginative shell that would best protect a seashore animal. List the features it has for keeping the animal safe.
2. Think like a mussel. Write a short diary entry about your day clinging to a rock during a storm. What challenges do you face?
3. Imagine you're a crab, create a map of your journey from the shoreline to a tidal pool during low tide. What obstacles would you encounter?
4. Share these results with your friends in class.

Adaptations of seashore plants

1. *Physical Adaptations:* Seashore vascular plants develop deep roots, thick cuticles, and waxy coatings to withstand high tides, waves, and to conserve water.

Figure 3.43: A plant at the seashore

2. *Physiological Adaptations:* Some plants have developed salt tolerance and drought resistance to survive during periods of high salinity and water scarcity.

Activity 3.20 Plants on the shore discussions

1. Imagine a "super plant" that can survive in harsh seashore conditions. What special features would it have? Draw it and share with the class.
2. Why do you think being able to tolerate salt and drought is important for plants in the seashore habitat? Share your thoughts in small groups.

CHARACTERISTIC FEATURES AND ADAPTATIONS OF ORGANISMS IN THE RIVER, POND AND LAKE

River

A river is a natural flowing freshwater body which is connected to other water bodies such as oceans, lakes, other rivers and wetlands. It typically has a narrow and winding course with constant movement, and may take its source from springs, lakes, rocks and glaciers. Depth varies along its length and may have rapids, waterfalls, dams or tributaries. Rivers support aquatic life forms such as algae, plants (e.g. water lily, water lettuce and water hyacinth), fish (e.g. salmon, Tilapia and catfish), and insects (e.g. water beetles, dragonflies, mayflies and stoneflies), amphibians (e.g. frogs, toads and newts) and other invertebrates such as snails.

Adaptations of organisms in rivers and streams

1. Plants that are adapted to life in rivers often have flexible stems that allow them to bend without breaking when swept over by the water current, e.g. cattails
2. Amphibians such as frogs and toads obtain oxygen through their moist skin when in water.
3. Aquatic organisms such as fish have streamlined bodies and fins for movement, and gills for the exchange of gases in water.

4. Also, some aquatic organisms have hooks, suckers or muscular feet that enable them attach to rock surfaces. E.g. mussels and leeches.
5. Aquatic organisms like crocodiles and turtles have webbed feet and strong swimming muscles for swimming.
6. Plants adapted to rivers and streams also have aerenchyma (air-filled tissues) for the supply of air and buoyancy, to keep the leaves closer to the surface where there is sunlight and carbon dioxide.

Figure 3.44: Black Volta River in Ghana

Activity 3.21 Exploring aquatic ecosystems.

1. Embark on a field trip to a nearby river, lake or pond (if possible) or search for videos of rivers, lakes and ponds on the internet.
2. Discuss in groups the definition and nature you observed of rivers, lakes and ponds as you observed from the video or your field trip.
3. Select a specific freshwater body (river, lake or pond) and create a poster or presentation defining your selected water body.
4. Present your work before the class for discussion.
5. Compare your work with presentations on other water bodies from other groups.

Lakes

Lakes are typically a large body of standing water surrounded by land. They are larger than ponds with generally no significant water flow. The water level is

relatively stable however, the depth varies. It has three distinct zones based on temperature differences: the littoral (shallow), limnetic (open water zone) and profundal (deep water zone). The chemical composition of lakes is influenced by the surrounding geology and climate, i.e. the type of rocks, soil and minerals, as well as weather patterns and temperature. Lakes support a variety of living organisms, including phytoplankton, plants such as water lilies and cattails, various kinds of fish such as catfish and mudfish, perch and trout, birds such as swans, herons, geese, egrets and ducks. Examples of lakes found in Ghana are Lakes Bosomtwe and Volta.

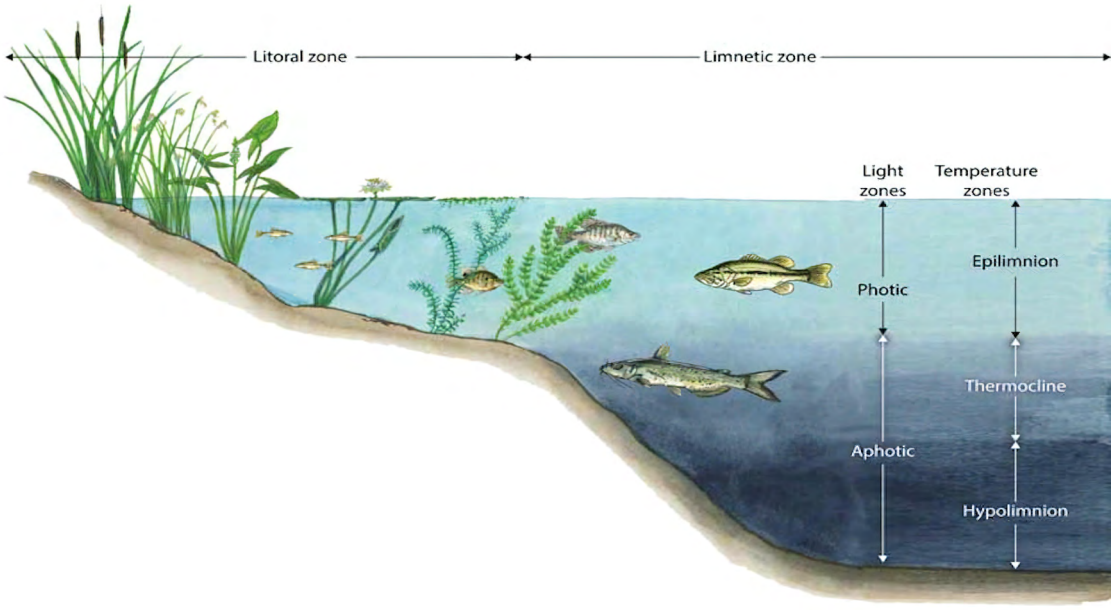


Figure 3.45: Structure of a lake showing different zones.

Adaptations of organisms in lakes

1. Lake plants such as cattails have tall stalks to enable them to reach sunlight and fibrous roots for stability.
2. Fish possess swim bladders, which enable them to maintain buoyancy.
3. Lake plants such as water lettuce have air-filled tissues in the stem, which enable them to float, and large, flat, floating leaves to increase the surface area for absorption of sunlight and for gas exchange.
4. Many lake insects have (hydrophobic) water-repellent surfaces that help them stay dry and float, using the surface tension of the water
5. Some insects, like diving beetles, can be underwater for long periods.
6. Insects like water boatman and backswimmers have air-filled structures for buoyancy.

7. Insects like mayflies and caddisflies have slender bodies for efficient swimming.

Pond

Ponds are small, shallow standing bodies of water, typically smaller than lakes. Ponds have limited water volume and surface area. Water levels fluctuate with precipitation and evaporation. Ponds are often connected to groundwater or nearby water bodies such as the ocean, which could form tidal pools and rock pools. Due to the shallowness of ponds, light easily penetrates to the bottom to support aquatic life. Ponds serve as important habitats for various living organisms. These include algae, plants (duckweed, water ferns and water lilies), fish (minnows, catfish, goldfish, trout and golden shiners), insects (water beetles, mosquitoes, as well as their larvae), amphibians and birds.

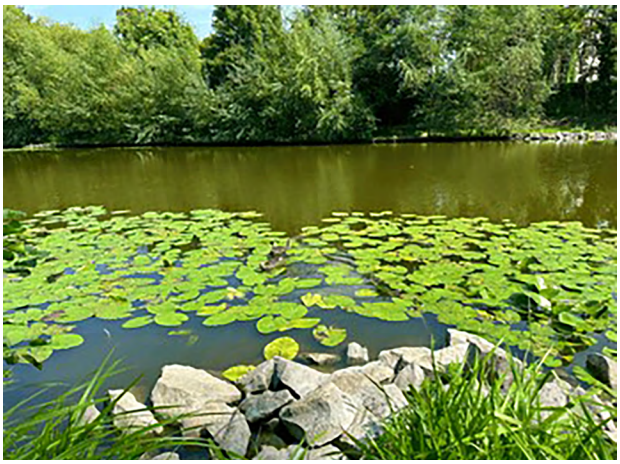


Figure 3.46: A pond, partly covered on the surface by leaves of a water lily.

Adaptations to Pond Habitats

1. Pond dwellers, such as fish, survive in varying oxygen levels, and some can also hide under rocks or mud when the pond water dries out.
2. Pond plants exhibit rapid growth to capitalise on seasonal opportunities like rainfall periods with high nutrient levels to ensure their survival.
3. Amphibians such as toads lay eggs in shallow water, which offers ideal breeding conditions including warmth, oxygen, food availability and protection from predators, thereby increasing reproductive success.
4. Certain insect larvae, like mosquito larvae, possess breathing tubes that allow them to obtain air from the surface of the water.

Activity 3.22 Freshwater Habitat Exploration

1. Embark on a field trip to a nearby river, lake or pond.
2. Observe and record in your notebooks the different organisms you come across (your teacher will provide you with equipment to collect and identify aquatic organisms).
3. Discuss in groups the sampled organisms and their different adaptations to the aquatic habitat where you collected them.
4. Do a presentation of your write-up in class.

DIFFERENCES AND IMPORTANCE OF IMMUNISATION, VACCINATION AND INOCULATION

Immunisation

Immunisation is a process that helps the body's immune system fight against infectious diseases. It involves introducing a small piece of a pathogen, which could be a virus or a bacterium, in its weakened or killed form into the body. These weakened or killed pathogens are called immunogens. They provide immunity by triggering the immune system to produce antibodies and immune cells. These antibodies and immune cells recognise and attack the pathogen if the body is exposed to it in future. Immunisation is usually carried out artificially but can also be achieved naturally when a person encounters a pathogen.

Immunisations are of two types. These are active immunisation (*which involves the introduction of vaccines into the body to stimulate the immune system to produce antibodies*) and passive immunisation (*which involves acquiring pre-formed antibodies, e.g. a mother passing on antibodies to her newborn*).

Although both forms of immunisation provide immunity, it is important to note that active immunisation is more permanent while passive immunisation is temporary.

Figure 3.47: A male adult being immunised through injection.

Steps Involved in Immunisation

The steps involved in immunisation are as follows:

1. Introduction of an antigen (a harmless piece of a pathogen) into the body.
2. Recognition of antigen by immune cells (T-cells and B-cells) of the immune system.
3. Activation of immune response (process by which the body's immune system recognises and responds to the presence of foreign substances such as pathogens).
4. Production of antibodies and immune cells.
5. Memory cell formation for future protection (whenever the same kind of antigen enters the body again, the immune system uses the memory cells to recognise it and produce antibodies against it).

Antigens may or may not stimulate an immune response. However, when introduced intentionally as immunogens, their purpose is to produce an immune response. This explanation points to the fact that all immunogens are antigens, but not all antigens are immunogens, as immunogens induce an immune response, whereas antigens may not.

Vaccination

Vaccination is the act of administering a vaccine into the body of an individual to stimulate the body's immune system to produce antibodies against a specific pathogen. The vaccines usually contain weakened or killed pathogens or components of pathogens (e.g. proteins or sugars). Vaccines work by stimulating the body's immune system to recognise and fight the pathogen, in so doing providing active immunity, meaning the body produces antibodies to fight the disease. Apart from the commonly known forms of vaccines (live but weakened

or killed pathogens), vaccines could also be in the form of toxoid (mRNA-based vaccines).

An infant receiving a vaccine orally

A child receiving a vaccine through injection

Figure 3.48: Images of children receiving a vaccination

Steps involved in vaccination

1. Production of a vaccine by processes such as attenuation and inactivation.
2. The vaccine is introduced into the body orally, through the nasal route or by injection.
3. The body's immune system responds to the vaccine by producing antibodies and memory cells.
4. The specific antibodies produced now fight the pathogen.

Differences between Vaccination and Immunisation

1. Vaccination is a specific intervention involving administering a vaccine, while immunisation is acquiring immunity.
2. Vaccination induces active immunity, while immunisation can result from active or passive immunity.
3. Vaccination is a medical intervention (involves the use of vaccines) while immunisation can occur naturally or through medical means.

Inoculation

This is the introduction of a substance or an agent to a material. The term is applicable in various fields. For example, in agriculture, inoculation is used to introduce beneficial microorganisms into soil, plants or seeds to improve nutrient uptake or induce disease resistance. In medicine, however, inoculation is a medical

procedure where a pathogen or antigen is intentionally introduced into the body to induce immunity. In earlier years, it was done by collecting antigens from sores developed from smallpox and introducing them into healthy individuals to induce immunity. In modern times, this can be done through various methods, including exposure to a mild form of the disease, injection of a small dose of inactivated or weakened pathogens or administration of antibodies or immune cells. The goal of inoculation is to stimulate the immune system to produce antibodies and immune cells that can recognise and fight the pathogen.

Steps involved in inoculation

1. A mild form of the pathogen is obtained from a sick person's wound or lesion.
2. The pathogen is weakened through processes such as heating or chemical treatment.
3. The skin of a healthy person was scratched or pricked to create a small wound.
4. The healthy person was observed for signs of infection and disease progression.
5. The body of the individual reacts by producing antibodies which fight the pathogen and therefore bring about recovery.

Note

While this method was principally the means of acquiring immunity in historic times, it was a risky method and sometimes resulted in full-blown disease or transmission to others.

Figure 3.49: A child being inoculated against smallpox by Edward Jenner.

Differences between Inoculation and Vaccination

1. Scope: Inoculation is a broader term that includes various methods of introducing pathogens or antigens to induce immunity, while vaccination specifically refers to the use of vaccines.
2. Method: inoculation may involve exposure to pathogens through various routes, such as the skin and mucous membranes, while vaccination typically involves injection or oral administration of vaccines.
3. Safety: inoculation has a higher risk due to the use of weakened pathogens, while vaccination is generally considered safer than inoculation because vaccines are carefully tested and regulated to ensure safety and efficacy.
4. Effectiveness: Vaccination is a modern practice often more effective in providing long-term immunity because it uses refined and regulated vaccines, while inoculation is a less popular health practice and was used in the control of smallpox.
5. Purpose: inoculation may be used for research or therapeutic purposes, while vaccination is basically for preventive purposes.

Activity 3.23 Understanding Immunisation, Vaccination and Inoculation

1. Get together with three or four of your friends and research one of the following terms: immunisation, vaccination and inoculation for the definition of your assigned term.
2. Discuss with your friends and write your definition on sticky notes or a sheet of paper.
3. Read out your group's definition to the hearing of the rest of the class.
4. With your friends, get a large sheet of paper or cardboard and use diagrams, flowcharts or illustrations to create a mental picture to describe the steps involved in carrying out your assigned term, i.e. immunisation, vaccination or inoculation.
5. Compare your work with members of the other groups in your class.
6. Identify similarities and differences between your work and those of other groups.
7. Engage in a class discussion facilitated by your teacher with members from other groups to clarify any misconceptions.

Importance of Immunisation, Vaccination and Inoculation

The importance of immunisation, vaccination and inoculation can be grouped under the following broad headings:

1. Individual benefits: the prevent serious illnesses and diseases polio, measles, hepatitis B and yellow fever, by boosting the immune system, also reducing the chances of hospitalisation and the risk of serious complications.
2. Community benefits: vulnerable individuals (newborns, the elderly and those with compromised immune systems) are protected through herd immunity. It also reduces disease transmission and outbreaks and protects future generations through lasting immunity. It decreases disease-related mortality rates and supports economic growth by reducing healthcare costs.
3. Global benefits: diseases such as smallpox and poliomyelitis have been controlled, and others such as measles and malaria. Also, international travellers can travel to disease-endemic areas without the fear of catching infections such as the dreaded COVID-19 disease.
4. Social benefits: people can freely associate with family and friends and have equal access to services without the fear of being infected. Furthermore, vulnerable populations like children and the elderly are protected. Finally, it supports education and social development.

Activity 3.24 Immunisation forum

Your teacher will invite the community health nurse or public health nurse to deliver a talk on immunisation, vaccination and inoculation. Listen attentively and ask questions where necessary.

1. Write out your presentation to be delivered before your classmates in class under the following headings:
   - **a.** Introduction
   - **b.** Immunisation, vaccination and inoculation
   - **c.** Differences between immunisation, vaccination and inoculation.
   - **d.** Reasons why immunisation, vaccination and inoculation are important among humans.
2. Try and answer questions from your friends as best as you can. Consult with your teacher if you are not sure.

EXTENDED READING

• https://blogger.googleusercontent.com/img/b/R29vZ2xl/AVvXsEjbBghT139wrS5NhauD3hU-h9yS9WS1DPGX1xInp4NCqtHIvTMAuQY-WAdv3ExG9UuViXOdMf3TlYn9S2JnTaCAX-vp3qMorNNXDWkpW8JEz_aQzwBNAECRlmrx-1Gh4BvEpMfImaETj0Ej8QkCe8lyqcLEgX7W8F-dZrqzf65FB4YtmFR5YnRk8k7L_-YXuqQ/s428rw/Dorsal%20view%20of%20citrus%20swallowtail%20butterfly.webp	
• https://www.notesforshs.com/2022/11/butterfly.html	
• https://www.who.int/health-topics/vaccines-and-immunisation	
• https://www.who.int/news-room/questions-and-answers/item/vaccines-and-immunisation-what-is-vaccination	

REVIEW QUESTIONS

1. What are the distinctive features of the grain weevil?
2. How do the distinctive and adaptive features of grain weevils contribute to their survival?
3. What are the phases of development in the life cycle of grain weevils?
4. What effects do grain weevils have on grain production and ecological stability?
5. Describe the main features of a butterfly: wings, proboscis and antennae.
6. Describe the life cycle of butterflies.
7. Outline three economic importance of butterflies.
8. What is the characteristic shape of a housefly's body?
   - **A.** Elongated and cylindrical
   - **B.** Flattened and oval
   - **C.** Triangular and pointed
   - **D.** Spherical and rounded
9. Which of the following is a distinctive feature of a housefly's wings?
   - **A.** Long and narrow
   - **B.** Short and broad
   - **C.** Transparent and veined
   - **D.** Colourful and patterned
10. What is unique about a housefly's mouthparts?
    - **A.** They have sharp teeth for biting
    - **B.** They have a long proboscis for sipping nectar
    - **C.** They have a spongy mouth pad for absorbing liquids
    - **D.** They have a tongue for lapping up food
11. Which of the following is a distinctive feature of a housefly's eyes?
    - **A.** Large and round
    - **B.** Small and bead-like

C. Compound and faceted

D. Simple and single-lensed

12. What is the name of the stage in a housefly's life cycle where it lays eggs?

A. Larva

B. Pupa

C. Adult

D. Ovum

13. Which stage of a housefly's life cycle is characterised by a legless, maggot appearance?

A. Egg

B. Larva

C. Pupa

D. Adult

14. What is an adaptation that allows houseflies to survive in a wide range of environments?

A. Hibernation

B. Migration

C. Reproduction

D. Camouflage

15. Which of the following is an adaptation that helps houseflies find food?

A. Strong sense of smell

B. Good eyesight

C. Taste buds on their feet

D. All of the above

16. Explain how houseflies contribute to the spread of diseases and the economic impact on human health.

17. Discuss the role of houseflies in decomposition and how the process affects agricultural productivity and waste management.

18. What are the three main parts of a honeybee's body?

A. Head, thorax, and abdomen

B. Head, wings, and legs

C. Body, wings, and stinger

D. Legs, wings, and antennae

19. What is the purpose of the pollen baskets (corbiculae) on a honeybee's legs?

A. To collect nectar from flowers

B. To store honey in the hive

C. To carry pollen back to the hive

D. To defend against predators

20. Which of the following is a unique feature of the honeybee queen?

A. She has wings

B. She has a stinger

C. She lays eggs

D. She has pheromone

21. What is the name of the special food produced by worker bees to feed the larvae?

A. Royal jelly

B. Honey

C. Pollen

D. Beeswax

22. Describe the different stages of a honeybee's life cycle, from egg to adult. How do the roles of the honeybee change as it develops? (50-80 words)

23. Explain the process of metamorphosis in honeybees. How do the larvae transform into pupae, and what changes occur during this stage? (50-80 words)

24. Discuss the importance of the queen bee in the life cycle of honeybees. How does her role differ from that of worker bees and drones? What happens to the colony when the queen bee is no longer present? (50-80 words)

25. How do honeybees contribute to the production of food crops in Ghana, and what would happen to our food supply if they were to disappear? (100-150 words).

26. What is the primary characteristic of a tropical rainforest?

A. High temperature and low rainfall

B. High temperature and high rainfall

C. Low temperature and high rainfall

D. Low temperature and low rainfall

27. Which of the following is a feature of a tropical rainforest?

A. Limited biodiversity

B. High altitude

C. Dense canopy

D. Cold climate

28. What is the name of the largest tropical rainforest in the world?

A. Amazon rainforest

B. Congo basin

C. Valdivian rainforest

D. Daintree rainforest

29. Which of the following is a threat to tropical rainforests?

A. Deforestation

B. Climate change

C. Overgrazing

D. All of the above

30. What is the importance of tropical rainforests in the global ecosystem?

A. They store carbon in their biomass and support biodiversity

B. They regulate the water cycle and support agriculture

C. They provide timber and support urbanization

D. They offer tourist attractions and support mining

31. What is the average annual rainfall in a tropical rainforest?

A. 1000 mm

B. 2000 mm

C. 300 mm

D. 500 mm

32. What is the typical temperature range in a tropical rainforest?

A. 10-20°C

B. 20-30°C

C. 30-40°C

D. 40-50°C

33. What is the main feature of a tropical rainforest that supports a vast array of plant and animal life?

A. High altitude

B. Low constant humidity

C. High constant temperature

D. Low winds

34. What is the name of the highest layer of the tropical rainforest?

A. Emergent layer

B. Canopy layer

C. Understory layer

D. Forest floor

35. What is the primary source of food for most organisms in a tropical rainforest?

A. Sunlight

B. Nitrogen

C. Soil nutrients

D. CO_2 and water

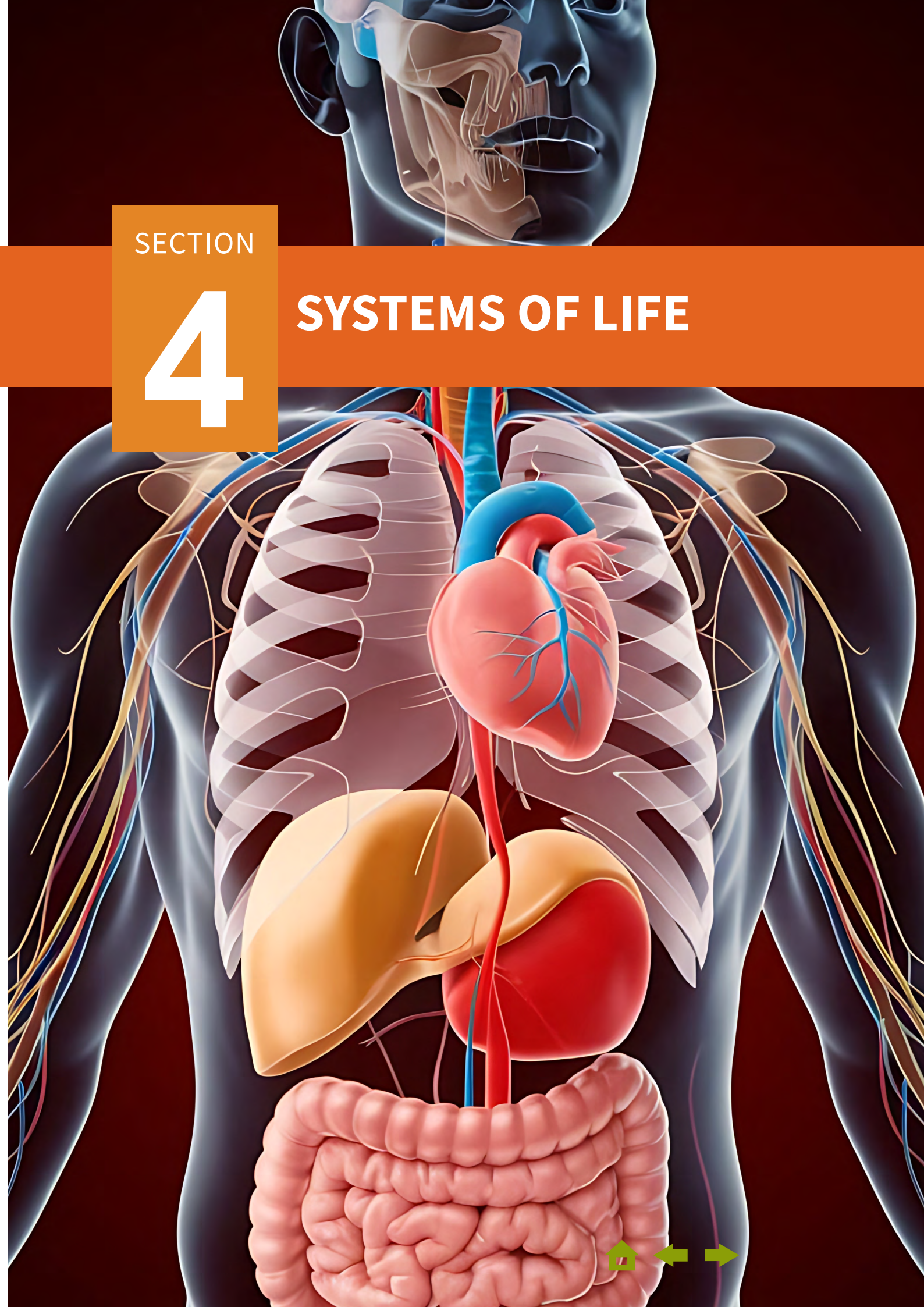
36. In 80- 120 words, discuss how plants adapt to the tropical rain forest.

37. In 80- 120 words, discuss how animals adapt to the tropical rain forest.

38. How do tropical savannahs differ from deserts?

39. What are the major characteristics of tropical savannahs and deserts?

40. How do plants and animals adapt to life in tropical savannahs and deserts?
41. What are the advantages and disadvantages of living in tropical savannahs and deserts, and how can living conditions be improved to enhance biodiversity in these habitats?
42. What are the possibilities and challenges of reclaiming a desert and transforming it into a forest?
43. What are the key differences between a lagoon and an estuary?
44. What are the main features of lagoons and estuaries in terms of water content, salinity, and the types of living organisms that inhabit them?
45. How do the adaptive features of organisms enable them to survive in the unique environments of lagoons and estuaries?
46. What specific examples illustrate how human activities interfere with lagoons and estuaries, and what are the resulting ecological implications of these actions?
47. What is a seashore habitat, and what are the various zones within it?
48. What are the main features of each zone in a seashore habitat, and what common organisms can be found in these zones?
49. How do living organisms in a seashore habitat adapt to their environment?
50. What human activities occur in seashore habitats, and how do these activities impact the living organisms that inhabit these areas?
51. How do rivers, lakes and ponds differ from one another?
52. What are the main characteristics of rivers, lakes and ponds?
53. How do living organisms adapt to rivers, lakes and ponds?
54. What are the consequences of small-scale mining on water bodies, and how can they be mitigated?
55. What is immunisation, vaccination and inoculation?
56. What are the main steps involved in immunisation, vaccination and inoculation?
57. What are the differences between immunisation and vaccination, and inoculation and vaccination?
58. Which is more acceptable in contemporary times, inoculation or vaccination, considering benefits and risks?



SECTION

4

SYSTEMS OF LIFE

MAMMALIAN SYSTEMS

Plant Systems

INTRODUCTION

This section is a continuation of the study of "systems of life", which was started in year one. Two of the mammalian systems, the circulatory and excretory systems, will be discussed in this section. These two systems play very vital roles in the proper functioning of the human body through their functions, which can be said to be closely related. The cardiovascular system is composed of the heart, blood vessels and blood tissue. The circulatory function of the cardiovascular system is necessary for maintaining a stable internal balance within the internal environment of the organism. The excretory system, which works in harmony with the cardiovascular system, is composed of the kidneys, skin, lungs and liver. The main function of these organs is primarily to remove waste from the body of the organism. For instance, the kidneys excrete urine while the skin excretes sweat. As mentioned earlier, maintaining a stable internal environment (homeostasis) is vital to healthy living, and therefore, the need for these processes to take place. Failure of these processes to occur will lead to the accumulation of toxins within the body of the animals, which, without treatment, may lead to eventual death. The interactions of these two systems in their functions are key to ensuring the optimum functioning of the organism and, ultimately, its survival. This section ends with discussions on the transport system in plants and photosynthesis, which is the basic biological process used by plants, algae and some bacteria, e.g. *Chlorobium,* to turn light energy into chemical energy. This is an important process as it is the source of all the energy supply in all ecosystems, as well as maintaining a balance of the oxygen and carbon dioxide levels in the atmosphere.

KEY IDEAS

- **Photosynthesis** occurs in the chloroplasts of organisms in two stages, that is, the light stage and the dark stage.
- Plants use vascular tissues (xylem and phloem) to transport water, dissolved minerals and produced food substances.
- The photosynthetic process is performed by organisms that have the chlorophyll pigment in their systems and use light energy.

- The **cardiovascular system**, also known as the circulatory system, is responsible for transporting oxygen, nutrients, hormones and waste products throughout the body. It consists of the heart, arteries, veins, capillaries and blood tissue.
- The **excretory system** is made up of organs and structures responsible for removing waste materials from the body to ensure homeostasis.

STRUCTURE OF THE CARDIOVASCULAR SYSTEM OF HUMANS AND HOW THE PARTS RELATE TO THEIR FUNCTIONS

The cardiovascular system is a complex network of organs and tissues that transports oxygen, nutrients, hormones, and other materials, such as carbon dioxide and urea, throughout the body to specific organs to be excreted. The structure of the various components relates to their function in attaining a functional system.

The Heart

This is a muscular organ that pumps blood throughout the body. it is divided into four chambers: the right atrium or auricle (RA), the left atrium or auricle (LA), the right ventricle (RV) and the left ventricle (LV). The RA and RV are separated from the LA and LV by a thick muscular wall called the septum. This prevents blood in the left side of the heart from mixing with that of the right side. The right side receives deoxygenated blood from the cells of the body and pumps it to the lungs for oxygen uptake and carbon dioxide release, while the left side receives oxygenated blood from the lungs and pumps it to all parts of the body. The atrioventricular septum separates the atria from the ventricles. The thick muscular wall, the ellipsoidal shape and large chamber volume of the left ventricle adapt it to its function of pumping blood to all parts of the body. Between the RA and the RV is the tricuspid valve, and between the LA and the LV is the bicuspid valve or mitral valve. Both valves ensure blood flows in one direction, preventing backflow and ensuring efficient circulation of blood.

A healthy blood pressure reading for most adults is less than 120/80 millimetres of mercury (mmHg), with the top number (systolic) representing the pressure when the heart beats or pumps, while the bottom number (diastolic), when the heart rests or relaxes. When the pressure at which the heart pumps rises to 140/90

mmHg or higher, it results in a condition called hypertension. This can occur because of ageing, family history, being overweight, being physically inactive, high salt intake or drinking too much alcohol.

Other common conditions that affect the heart include; coronary artery disease (CAD), which is a narrowing or blockage of the coronary arteries; heart failure (inability of the heart to pump enough blood), arrhythmia (abnormal heart rhythms), myocardial infarction (heart attack), cardiac arrest (sudden loss of heart function), endocarditis (infection of the heart valves and inner lining) and dilated cardiomyopathy (enlarged heart muscle).

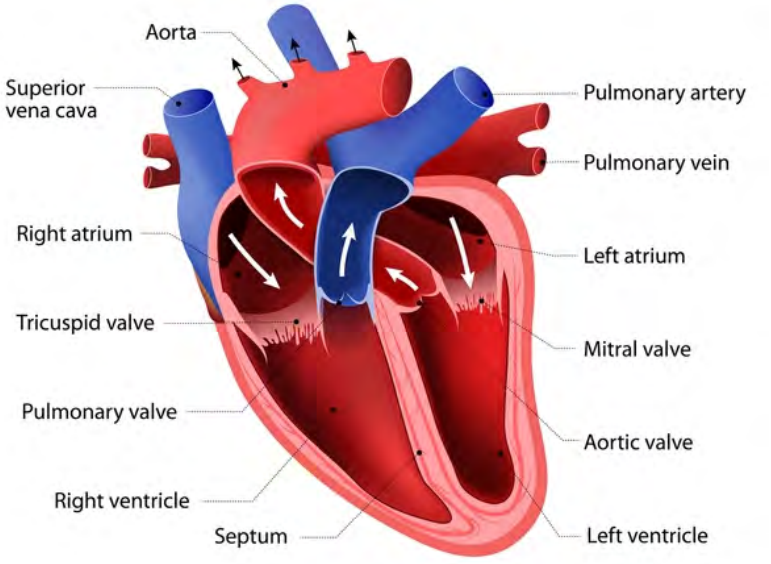


Figure 4.1: Anatomy of the human heart

Blood vessels

Blood vessels are a crucial part of the circulatory system, responsible for transporting blood (oxygenated and deoxygenated) throughout the body. The three main types of blood vessels in humans and other mammals are arteries, veins and capillaries. The arteries (except for the pulmonary artery and umbilical artery) transport oxygenated blood from the heart to the body tissues. The thick walls enable them to withstand the high blood pressure flowing through them. Veins, on the other hand (except for the pulmonary veins), transport deoxygenated blood to the heart and have thinner walls with valves to prevent backflow of blood. Veins can be divided into large veins (e.g. vena cava, pulmonary veins), medium veins (e.g. femoral vein and jugular vein) and small veins (e.g. venules). jugular veins are a pair of veins which are located on either side of the neck. Femoral veins are in the thigh, starting from the knee through the groin to the abdomen. Capillaries

are tiny blood vessels with very thin walls, usually one cell thick. This unique structure allows for efficient exchange of oxygen, nutrients, hormones and waste products between the blood and surrounding tissues.

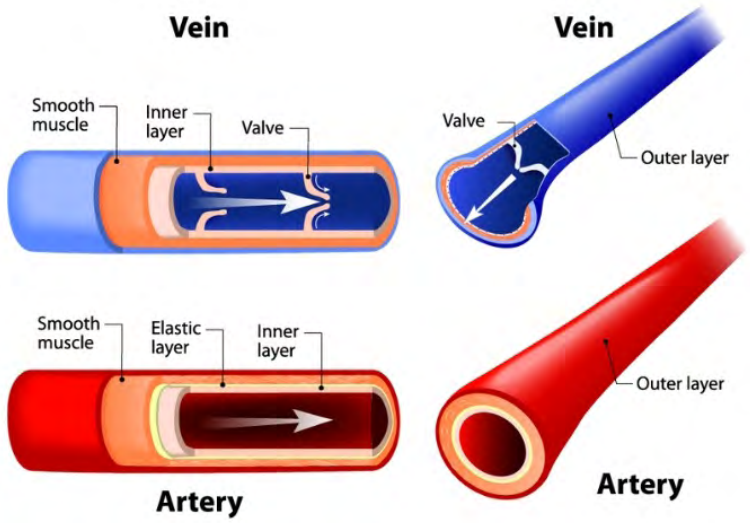


Figure 4.2: Image showing the interior of a vein and an artery.

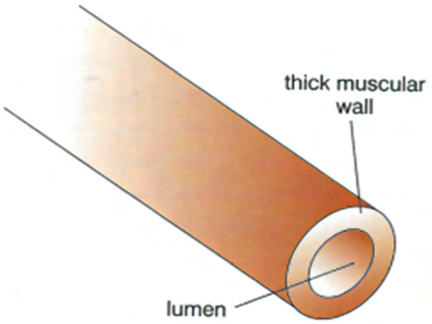


Figure 4.3: Cross section of an artery

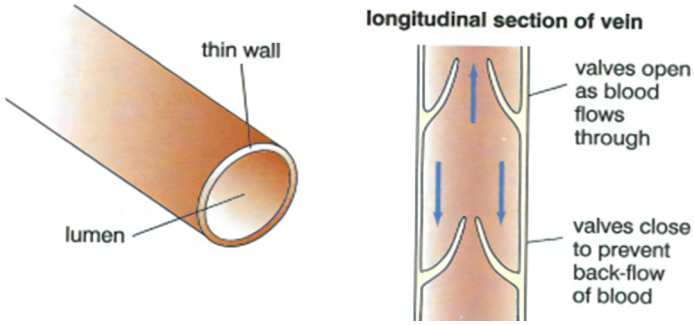


Figure 4.4: Cross section of a vein

Table 4.1: Summary of differences between arteries, veins and capillaries.

	Arteries	Veins	Capillaries
Function	Carry oxygenated blood from the heart to various parts of the body except the pulmonary artery.	Carry oxygenated blood from various parts of the body to the heart.	Facilitates the exchange of materials between blood and tissues.
Location	Deeply seated in the body to protect them from damage.	Superficially located in the body because they play a crucial role in temperature regulation.	Form a network inside the body organs
Pressure	Blood flows at high pressure	Blood flows at low pressure because of the presence of one-way valves, relaxed vessel walls and gravity's effect.	Blood flows at very minimal pressure compared to that of arteries, but higher than in veins.
Lumen Diameter	Marrow	Wide because of their thinner walls, the low pressure of blood flowing through them and the need to accommodate a larger volume of blood returning to the heart.	Extremely narrow (one cell wide)
Wall Thickness	Have thick elastic walls to withstand the high pressure of blood pumped by the heart	Thin	Extremely thin (single cell thick) to facilitate efficient exchange of substances between the bloodstream and surrounding tissues.
Wall Layers	Three layers	Three layers	One layer

	Arteries	Veins	Capillaries
Muscle and Elastic Fibres	Large amounts to allow them to expand and recoil with each heartbeat to withstand the high pressure of blood coming from the heart.	Small amounts	None
Valves	Absent because the high pressure at which the heart pumps ensures one-way (unidirectional) flow of blood, giving less chance for a backflow.	Present to ensure that blood flows in one direction towards the heart, preventing backflow due to the low pressure of the blood.	Absent because of their extremely narrow diametre and the pressure at which blood flows prevents a backflow.

Blood

Blood is a vital fluid in the human circulatory system, delivering oxygen and nutrients to cells and transporting waste products to specific organs for excretion. The components of blood are the plasma (liquid portion) and corpuscles or cells (solid portion). The solid part is made up of:

1. **The red blood cells (RBCs) or erythrocytes:** These are biconcave, disk-shaped cells produced in the bone marrow. Mature RBCs, called corpuscles, do not have a nucleus and many organelles. Dissolved within the cytoplasm is haemoglobin, which is a globular protein, meaning it has a roughly rounded shape. Haemoglobin contains four heme groups, with each containing an iron atom (in the form of Fe^{2+}). This iron atom in haemoglobin allows it to bind to oxygen in the lungs, transport oxygen to the body's tissues and release oxygen where it is needed.

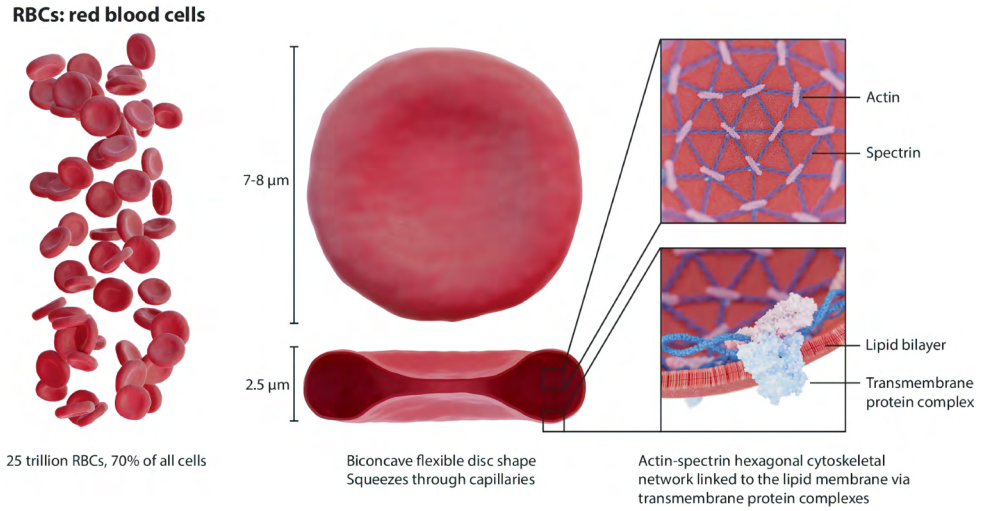


Figure 4.5: Red blood cells

2. **The white blood cells (WBCs) or leucocytes:** the function of WBCs is to fight infections or foreign materials in the body through an immune response. They form a key part of the immune system and are produced in the bone marrow with a variable lifespan of hours to days. Also, there is a nucleus within the cytoplasm. The types of WBCs are neutrophils, lymphocytes, monocytes, eosinophils and basophils. The structure of each type differs from the other due to variations in the shape of the nucleus and other materials found in the cell.

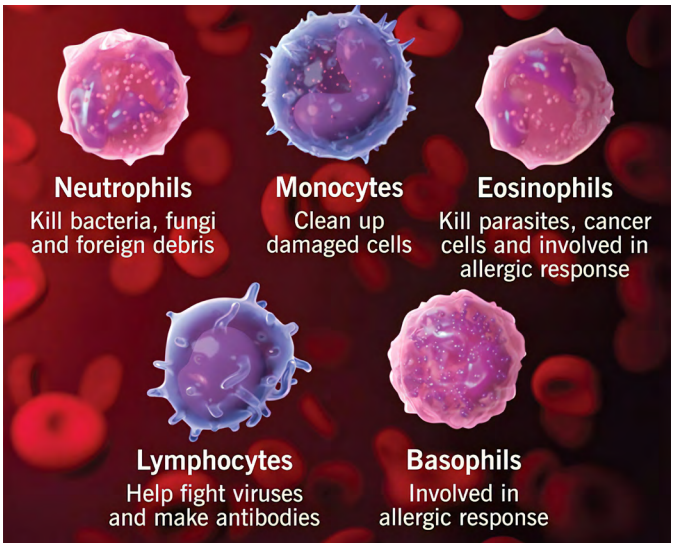


Figure 4.6: Types of white blood cells

3. **Platelets (thrombocytes):** Platelets are small, irregular non non-nucleated (without nucleus) fragments of cells produced in the bone marrow with a life span of about 8-12 days. Their primary function includes blood clotting, wound healing and homeostasis.

The liquid portion of blood, called plasma, is largely composed of water. Other materials present are proteins, dissolved food nutrients, dissolved gases, mineral salts, hormones, electrolytes and waste products. The functions include:

a. Transport of nutrients, hormones and waste products.

b. Regulation of blood pH, temperature and osmotic balance.

c. Blood clotting.

d. Blood pressure regulation.

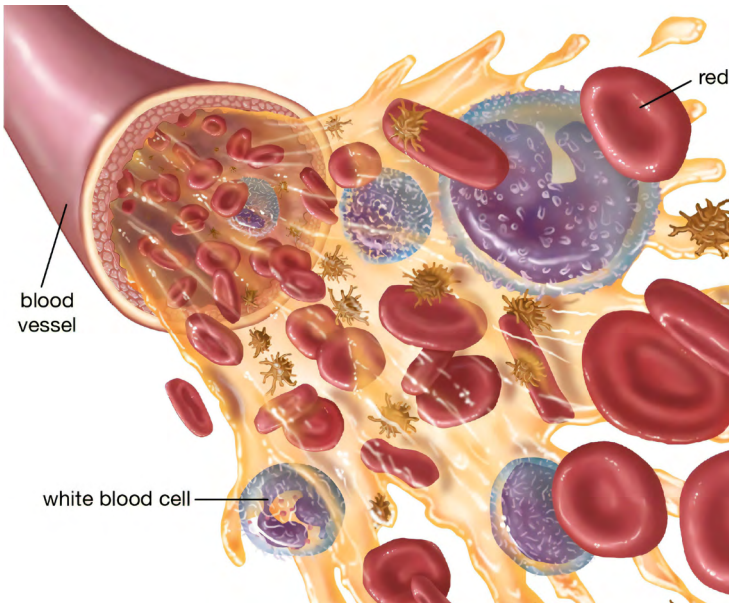


Figure 4.6: Image of the cellular and fluid components of human blood

Activity 4.1 Anatomy of the human heart

1. Visit the following website (https://www.youtube.com/watch?v=CWFyxn0qDEU on YouTube and watch videos of the anatomy or structure of the human heart. Do this together with your friends. (If unable to get access to the internet, use charts on the human heart.)

2. From the video you watched or the charts you studied, identify the organs and tissues that form the cardiovascular system in humans and relate the structures of the heart to their functions.

3. Work with two or three of your friends to design a mind map on the cardiovascular system, its structures and how the structures relate to their functions.

4. Display your design on your classroom wall as reference material.

Activity 4.2 Cardiovascular health

1. Search the internet or read medical journals for information on some common defects of the organs and tissues of the cardiovascular system in humans. (You may also speak with a medical professional for information on some common defects of the organs and tissues of the cardiovascular system in humans.)
2. Carefully note down the information you gathered from your source in your notebook.
3. Discuss with your friends the effects of a diseased or defective cardiovascular system and how it can affect the normal functioning of the body.

STRUCTURE OF THE EXCRETORY SYSTEM OF HUMANS AND HOW THE PARTS RELATE TO THEIR FUNCTIONS IN HOMEOSTASIS

Excretory System of Humans

The excretory system in multicellular organisms is responsible for the removal of waste materials from the body and for regulating water and ion balance. It is made up of organs and structures that perform various functions to ensure that the body is balanced and healthy, to achieve **homeostasis**. Homeostasis is the ability to maintain internal stability in an organism despite any environmental changes. The focus of this session is on the main excretory organs in humans, which are the kidneys, skin, lungs and the liver. Here we will study the structures of the excretory organs and their functioning to maintain a healthy balance in the human body. We will briefly mention some common diseases or infections that occur when these organs are not functioning properly.

Parts and structure of the excretory system in humans and their functions

The **Kidneys** are a part of the urinary system. This system consists of other parts such as the ureter, the urinary bladder and the urethra, which all work together to produce and remove urine from the human body. The kidneys are a pair of bean-shaped organs in the upper abdominal region of the human body.

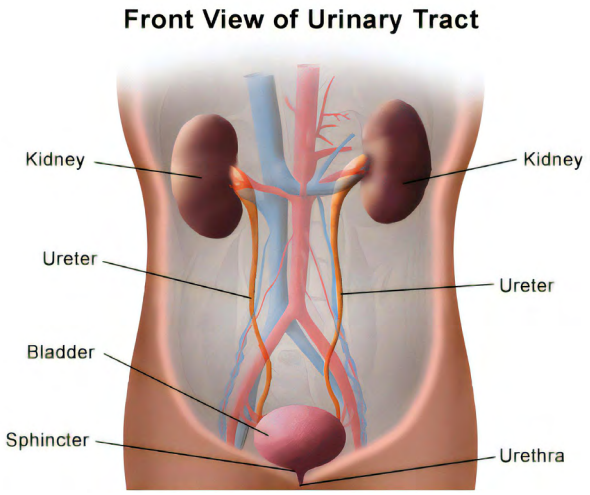


Figure 4.7: Front view of the Urinary tract.

Table 4.2: Parts and functions of the urinary system

Parts of the Urinary System	Function
Kidney	• Regulates blood volume and composition. • Regulates blood pH. • Regulates ions in the blood. • Produces hormones, e.g. Erythropoietin (which stimulates bone marrow to produce red blood cells). • Removes waste materials from the blood to form urine.
Ureter	Transports urine from the kidney to the bladder.
Bladder	Stores and expels urine through the urethra.
Urethra	Discharges urine from the body.

Each pair contains millions of basic structural and functional microscopic units, called nephrons or kidney tubules. Each kidney tubule or nephron has several parts that perform various function. Some of these parts include the afferent arterioles and efferent arterioles that form a knot in the Bowman's capsule, proximal/first convoluted tubules, loop of Henlé, distal/proximal convoluted tubule, and collecting ducts.

The kidneys filter blood flowing from the renal artery into the afferent arteriole to the glomerulus to remove unwanted materials like urea and salts to form urine.

The glomerulus allows water, ions, small molecules and wastes to pass into the Bowman's capsule and retains large molecules like blood cells and proteins. This process is called ultrafiltration. The kidneys reabsorb from the filtrate, essential nutrients, ions and water back into the bloodstream in the proximal convoluted tubule. Further reabsorption of water, nutrients and salts to concentrate the filtrate occurs in the loop of Henle. The distal convoluted tubule adjusts the composition of the filtrate by reabsorbing water and ions. The collecting duct further reabsorbs water to concentrate the urine and transports it to the bladder through the ureter. These two main processes in urine formation, ultrafiltration and reabsorption, are regulated by **anti-diuretic hormone** (ADH), thus reducing urine output. Anti-diuretic hormone (ADH) is a hormone produced in the hypothalamus and released by the pituitary gland that regulates water balance in the body by controlling how much water the kidneys excrete.

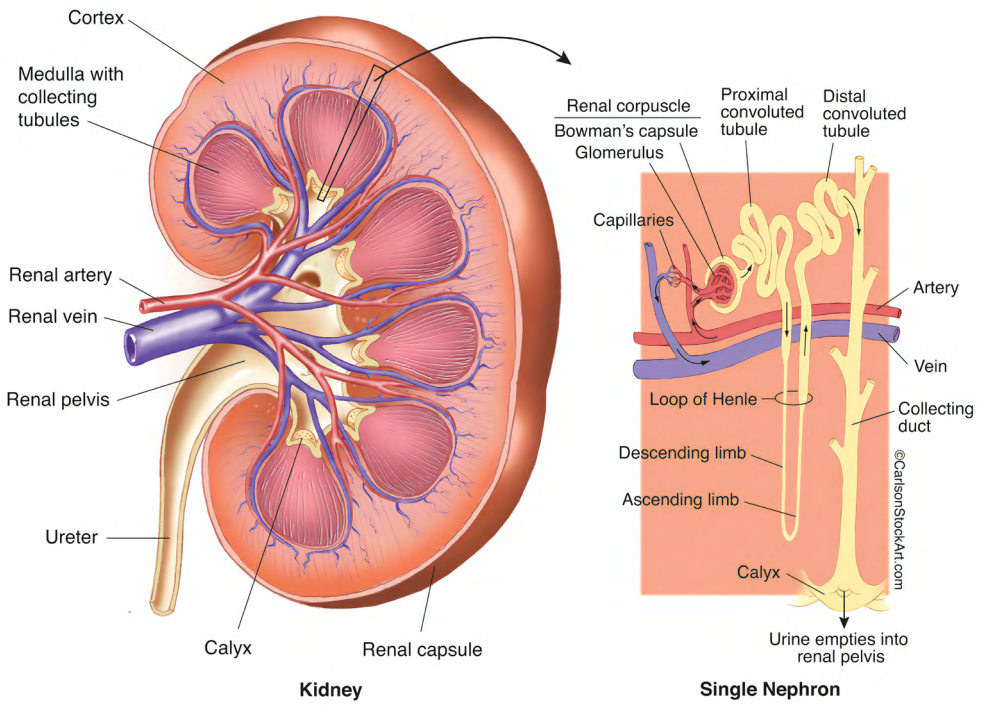


Figure 4.8: Components of the urinary system.

The main components of urine are water (about 95%), nitrogenous compounds (urea, uric acids and ammonia), creatinine (waste produced from creatine by the natural and normal breakdown of muscle tissues), organic and inorganic salts and ions. Blood cells and proteins are not removed due to their large molecular size. Besides processing and removing metabolic waste, the kidney also produces hormones, regulate blood volume and ensure pH and ion balance by osmoregulation. Filtered blood leaves the kidney through the renal vein.

Some common diseases and infections of the kidney are kidney stones, kidney cancer and urinary tract infections (UTI's). Kidney stones are formed when waste substances like extra salt, water, potassium, acid and nitrogen are sometimes in excess in the blood, and the kidneys cannot filter it all out. When these substances build up, they can form crystals in the kidneys, and these crystals can attract one another to form a solid object called a kidney stone. Kidney stones vary in size and shape. They can be as small as a grain of sand or as large as a golf ball. Kidney stones can be either smooth or jagged on the edges. If a kidney stone is not passed or removed from the body, it can continue to grow, and surgery would be needed to remove it. Kidney failure occurs when the kidneys have stopped working well enough for survival without dialysis or a kidney transplant. Kidney failure can be caused by severe infections and cancer. Urinary tract infection (UTI) is a common infection that affects any part of the urinary tract, including the bladder, urethra, or kidneys, and is often caused by bacteria entering through the urethra.

Activity 4.3 Understand the parts of the kidney and the nephron.

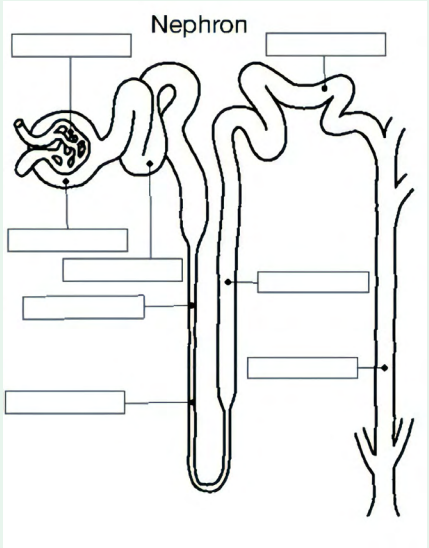
1. Build a chart of the kidney

- **a.** Use papers, colours to draw the structure of the kidney.
- **b.** Label the drawn structure.
- **c.** Write a one-sentence note describing each labelled part.
- **d.** Paste your diagram on the walls in your classroom.

2. Labelling the Nephron

Activity:

- **a.** Print out or draw the diagram of the nephron



b. Use these key words or phrases to label the diagram of the nephron above: Bowman's capsule, Glomerulus, Proximal convoluted tubule, Loop of Henle, Distal convoluted tubule, Collecting duct, ascending limb of the loop of Henle, descending limb of the loop of Henle.

Skin

The skin is a continuous, flat layer that covers the entire body. It is composed of three main layers: the epidermis, the dermis and the hypodermis. The epidermis is the outermost layer formed from stratified epithelial cells, and contains some blood vessels, nerves, hair follicles and glands; the epidermis is interlocked with the dermis, which is an inner layer and has the same composition as the epidermis. The hypodermis is a subcutaneous structure, which is the deepest layer of the skin, primarily composed of adipose and connective tissues.

Through the sweat glands, the skin produces sweat, which evaporates, drawing heat away from the body and cooling it down to regulate body temperature. This is evidenced by the cooling effect experienced by the body after sweat evaporates from the skin. The skin also detects stimuli through the numerous nerves scattered within it. It also protects the body and internal organs and tissues from pathogens and mechanical injuries

The main components of sweat are water, salts, traces of urea, uric acids and ammonia. The exact composition of sweat may vary due to factors such as diet, level of hydration and the specific physiology of the individual.

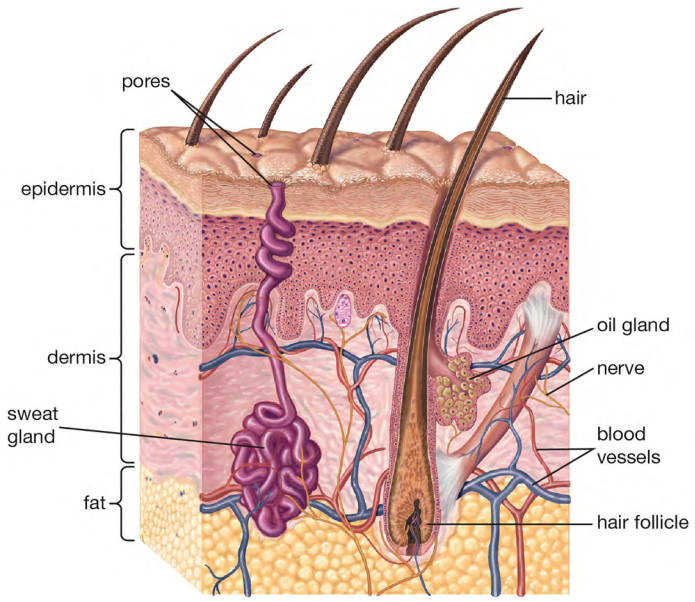


Figure 4.9: The human skin

Some common diseases of the skin are acne, eczema and vitiligo. Acne is a common skin condition that happens when hair follicles under the skin become clogged with sebum (an oil that helps keep skin from drying out) and dead skin cells, which leads to outbreaks of lesions, commonly called pimples or zits. Eczema (dermatitis) is an inflammation that causes the skin to become dry and itchy with bumpy patches, weakening the skin as a barrier of protection. This condition happens when the skin comes into contact with substances that trigger eczema, e.g. dry weather, fabrics, skin care products, smoke and pollutants and other substances one may be allergic to. Vitiligo (resulting in white patches on the skin or hair) occurs because of a lack of the skin pigment, melanin. This can cover parts of the skin or sometimes the entire body. What causes vitiligo is unknown, but it is not contagious.

Activity 4.4 Action of Sweating

Objective: Understand the role of sweat glands in maintaining homeostasis.

Materials needed

- Exercise equipment (e.g., jump rope)
- Paper towels
- Stopwatch.

Procedure

1. Work with your team to observe and record the dryness of the skin before exercise, using paper towels or tissue.
2. Perform a physical activity with your team members, like jumping rope or skipping rope, for 5-10 minutes.
3. Observe and record the presence of sweat on the skin, using another paper towel.
4. Discuss with your team how sweating helps cool the body and maintain temperature homeostasis.
5. Share your discussions and observations with other teams in the class.

Note

Be careful not to share paper towels, as this may lead to the spread of infectious skin diseases.

The Lungs

The Lungs are paired organs located within the thoracic cavity, at the chest region, extending from the clavicle (collar bones) at the upper side and the diaphragm at the lower part above the abdomen. They are a part of the respiratory system. These cone-shaped organs have a broad base and a pointed apex containing tiny air sacs called alveoli, surrounded by capillaries.

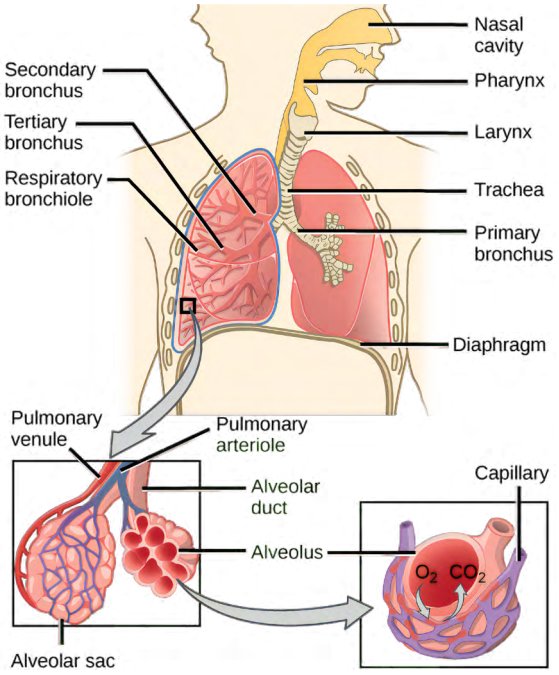


Figure 4.10: Air enters the lungs through the nasal cavity and then passes through the pharynx and the trachea into the alveoli.

The lungs are primarily responsible for the exchange of gases. Carbon dioxide from body tissues diffuses into the blood and is transported in the capillaries and veins to the alveoli. Carbon dioxide diffuses into the alveoli and is excreted through the bronchioles and bronchi to be exhaled through the nasal passage. Water in the form of vapour is also excreted.

Some common diseases associated with the lungs are pneumonia, bronchitis, lung cancer and asthma.

The Liver

This is a wedge-shaped organ with broad, rounded edges, responsible for producing bile, deamination and detoxification. The organ performs these functions mainly by specialised cells called hepatocytes (liver cells). Bile is produced from red blood cells and contains bilirubin (a yellowish-orange pigment) and Biliverdin (a green, water-soluble bile pigment), which are the waste products from the

breakdown of haemoglobin in red blood cells. Bile itself is not a waste product but a digestive juice which is stored in the gall bladder. Bile is released into the intestine to break down fats into fatty acids, to absorb fat-soluble vitamins and is excreted from the body through egestion with faeces. The liver helps detoxify the body by breaking down harmful substances, e.g. drugs and alcohol and excreting them. Deamination is the conversion of ammonia (a toxic by-product from the breakdown of proteins) into urea and released into the blood to be excreted in the urine. These functions play a major role in maintaining homeostasis.

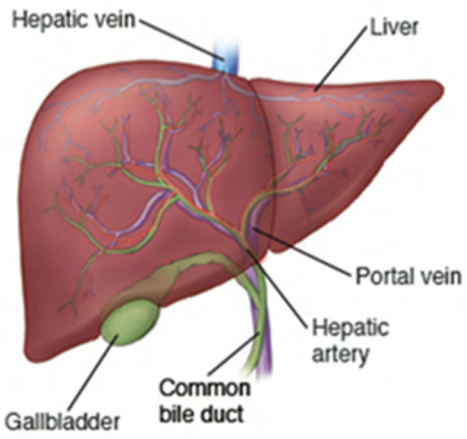


Figure 4.11: The front view of the human liver.

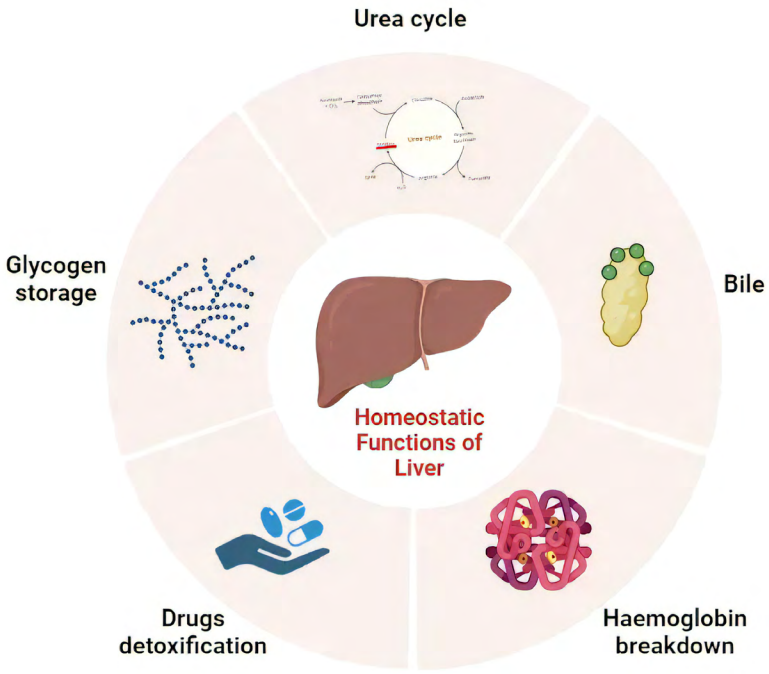


Figure 4.12: Homeostatic functions of the liver.

Some common diseases of the liver are cirrhosis (where the liver tissue is replaced by scar tissue) and hepatitis.

Activity 4.5 Homeostatic Functions of the Liver and Lungs

Objective: Summarise and compare the homeostatic functions of the liver and lungs.

Materials needed

- Sheets of paper
- Pens or digital devices for notetaking

Instructions

1. Find your team members and create a summary table with organ, homeostatic function and description as the columns. Decide with your team on information that fits as a homeostatic function.
2. Use textbooks, online resources, or class notes to research homeostatic functions and the description of the liver and lungs.
3. Fill in the summary table created with the information gathered.
4. Discuss with your team the findings and ensure that the information gathered is accurate and comprehensive.
5. Review the completed tables as a class and discuss the key points.
6. Reflect on the importance of the liver and lungs in maintaining homeostasis and how these organs work together to keep the body functioning properly.

Activity 4.6 Health Awareness

Objective: Raise awareness about kidney, skin, lung, and liver diseases and prevention.

Materials needed

- Posters
- Brochures
- Digital tools

Instructions

1. Research common kidney, skin, lung, and liver diseases.
2. Create informational materials like flyers, brochures and charts to educate others about causes and prevention of the various diseases.
3. Share the informational materials with the school community.

TRANSPORT OF SUBSTANCES IN FLOWERING PLANTS AND FACTORS AFFECTING THE TRANSPORT SYSTEMS IN FLOWERING PLANTS

Transport of Substances in Flowering Plants

Transport in flowering plants involves the movement of water, mineral salts and organic compounds through the vascular tissues (phloem and xylem).

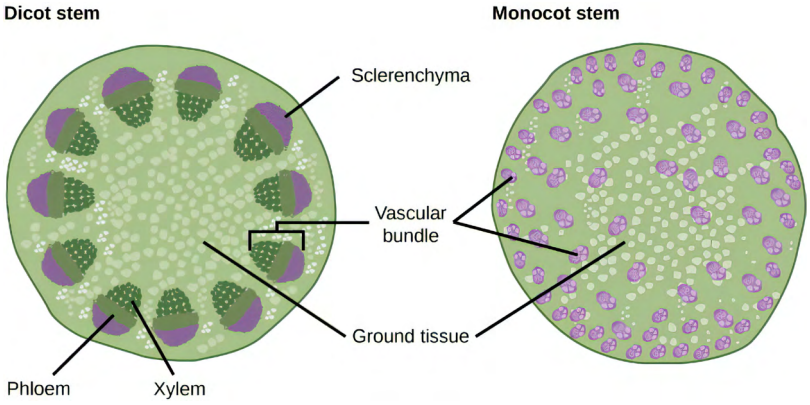


Figure. 4.13: Vascular tissue of a monocot and dicot stem

The movement of water from the soil to the leaves is termed the transpiration stream, while the movement of food and other organic materials from the leaves to all parts of the plant is called translocation.

Water and mineral transport occur in the xylem tissue. The main cells of the xylem are the xylem vessels, tracheids, xylem parenchyma and xylem fibres. These cells have various adaptations and function together to facilitate the efficient transport of water and minerals.

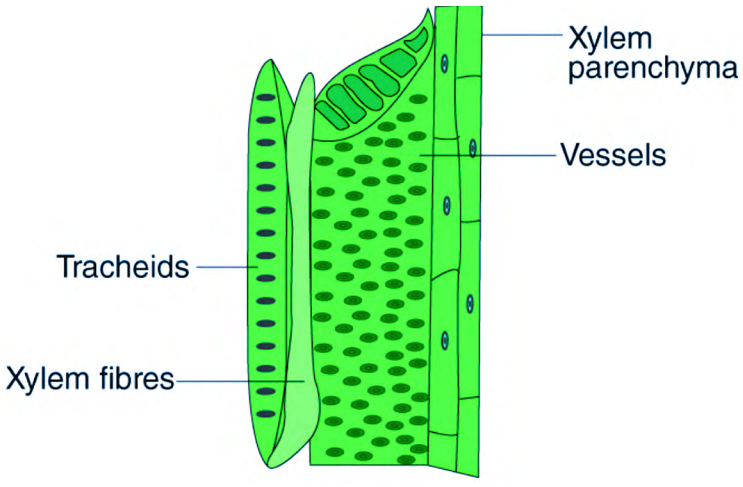


Figure. 4.14: Cells of the xylem

Table 4.3: Parts of a xylem cell

Xylem cell type	Description or adaptation	Functions
Tracheids	Elongated shape, thick lignified walls with pits	Water and mineral transport, structural support
Vessels	Short and wide with perforation plates, lignified walls	Efficient water transport, structural support
Xylem Parenchyma	Living cells with thin cell walls	Storage of nutrients, lateral transport
Xylem Fibers	Thick lignified walls, elongated shape	Structural support

The process by which plants lose water through their leaves is called transpiration. This occurs through a mechanism called transpiration pull, which refers to the continuous movement of water through the xylem that is drawn upwards from roots to the leaves. The processes of water and mineral transport are aided by:

a. evaporation of water from the leaves
b. Cohesion: the attraction among water molecules helps the molecules to be pulled along in the xylem.
c. Adhesion: the attraction between water molecules and the xylem cell walls
d. Tension: negative pressure in the xylem

Dissolved minerals (minerals dissolved in water) from the soil are generally transported by diffusion through the root hairs. However, the movement of dissolved minerals from the xylem to the leaves is by mass flow. Mass flow is the bulk movement of substances through a medium by factors such as pressure gradient and concentration gradient.

Use this link to watch a video on transpiration:

https://youtube.com/@fuseschool?si=ttVZLL02C2RKLT87

The phloem tissue is responsible for transporting food and other organic compounds in plants. Organic food materials (usually sucrose, a carbohydrate) are translocated from the leaves to all growing areas such as shoot tips, roots, flowers and fruits. Other substances transported are amino acids in dissolved form, small quantities of plant hormones (e.g. auxins, gibberellins and cytokinins) and organic acids, including malic and citric acids. These substances are transported in the phloem

mainly by mass flow (which ensures long-distance transport of materials in the phloem), diffusion and active transport. The cells that form the phloem tissue are sieve tubes, companion cells, phloem parenchyma and phloem fibres.

Table 4.4: Parts of a phloem cell

Phloem cell type	Description or adaptations	Functions
Sieve Tube Elements	Elongated shape, sieve plates, lack of organelles	Transport of organic nutrients, e.g. glucose
Companion Cells	Close association with sieve tube elements, abundant organelles	Support and metabolic assistance to sieve tube elements
Phloem Parenchyma	Living cells, thin cell walls	Storage of nutrients, lateral transport
Phloem Fibers	Thick lignified walls, elongated shape	Structural support

Use this link to watch a video on translocation in phloem:

https://youtube.com/@fuseschool?si=ttVZLL02C2RKLT87

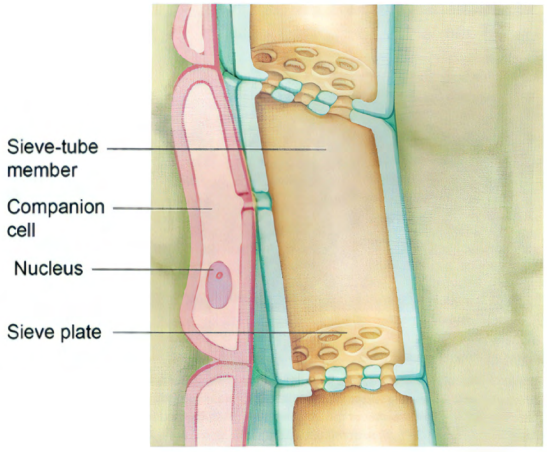


Figure 4.15: Phloem.

The main difference between the transport of materials in phloem and xylem is that the phloem transports food in bidirectional paths to all parts of the plant, mostly by pressure flow, while the xylem transports water and dissolved minerals upward from the roots to the leaves, generally by transpiration pull.

Table 4.5: Table of differences in xylem and phloem tissue

Xylem	Phloem
It consists of vessels, tracheids, xylem fibres and xylem parenchyma	It consists of sieve tubes, companion cells, phloem fibres and phloem parenchyma
Absence of any cross wall	Presence of sieve plates at the end of sieve tube cells.
Xylem fibres are smaller when compared with phloem	Phloem fibres are larger when compared with xylem
No companion cells	Companion cells control the activities of the sieve tubes,
Transports water and dissolved minerals in an upward direction from the soil, through the roots to the leaves.	Transports food substances in all directions to all parts of the plant
All cells in the xylem are dead except the xylem parenchyma	All cells are living except phloem fibres

Factors Affecting the Transport System in Flowering Plants

Several factors affect the transport system in flowering plants. These can broadly be considered as physiological, morphological and environmental factors.

Physiological factors

These refer to the internal processes of the plant which affect the movement of water and nutrients. These include

a. Rate of transpiration: As transpiration increases, more water and minerals are absorbed from the soil to be transported in the xylem. Higher rate of occurrence of transpiration also means that movement of water with dissolved organic nutrients, such as sucrose, is enhanced in the phloem.

b. Root pressure: As the root pressure increases, more water is pushed up through the xylem, hence more water uptake. The action by the root pressure can be seen, where fluid emerges (exudation) from a cut stem from which the leaves have been removed. The action is also seen during **guttation**. This is the exudation of water droplets, containing dissolved minerals and

sugars, from the tips or edges of leaves, usually at night, through specialised pores called hydathodes, when stomata are closed, and root pressure is high.

c. Photosynthesis: A high rate of photosynthesis increases sugar concentration in photosynthetic cells, creating a concentration gradient, thereby causing the movement of these organic compounds through the phloem to other parts of the plant, such as the roots and fruits.

Morphological factors

These are the factors that relate to plant structures which influence the absorption and transport of substances in plants. They include

a. Surface area and nature of the leaf: Leaves with a large surface area show an increased rate of transpiration, hence higher uptake of water and minerals in the xylem. The opening and closure of the stomata on the leaves control the movement of water through the leaves by transpiration. The stomata open to allow water vapour from the plant into the atmosphere and close to prevent water loss. Generally, the stomata are located on the lower side of the leaf or are concentrated at the lower surface more than on the upper surface. Again, hairs on the leaves reduce water loss. Some plants also roll their leaves to prevent excessive water loss in dry environments.

b. Structure of cells of xylem: Wider vessels have less resistance to the flow of water within the xylem tissue.

c. Density of root hair: The higher the density of root hair (the greater the number of root hairs), the higher the surface area of the roots and hence better contact with the soil to absorb water and dissolved minerals and transport them through the xylem.

Environmental factors

These are the external conditions which affect the rate of transpiration. Environmental factors affecting water movement in plants are

a. Temperature: The higher the temperature, the higher the rate of transpiration in the xylem. Movement of food materials within the phloem is increased as higher temperatures increase metabolic activity.

b. Light intensity: The higher the light intensity, the better the rate of photosynthesis to produce sugars, with increased transport of food from the leaves. Light also causes the stomata to open, as more sugar is produced in the guard cells to make them turgid. This increases the rate of transpiration from the leaves.

c. Humidity: Low humidity in the environment increases the rate of transpiration, which enhances water movement in the xylem.

d. Availability of water in the soil: Adequate water levels in the soil facilitate the movement of water through the xylem and movement of nutrients through the phloem.

Activity 4.7 Observation of xylem action in plant flowers

Materials needed

- Plastic cup or beaker
- Food colour (red or blue)
- White flowers with their stalks, e.g. carnation, water lily, hibiscus, rose or periwinkle flowers
- Water

Instructions

1. With your partner, gather the materials needed.
2. Half fill the beaker or cup with water
3. Add three to four drops of the food colour to the water
4. Put the flower in the coloured water
5. Observe for one to two hours the changes in the flower.
6. Record and discuss your observations with other teams in your class.
7. Predict the possible observations to be made if a transverse section of the stalk of the flower is placed under the microscope.
8. Predict the possible conditions that will affect the xylem action in the flowers used.

Activity 4.8 Ringing experiment or Girdling experiment

Aim: Demonstrate the role of phloem in the transport of nutrients in plants.

Materials needed

- A healthy potted plant or a young tree
- Sharp knife or scalpel
- Ruler

- Marker
- Plastic wrap or aluminium foil
- Watering can

Procedure

1. Select a healthy plant with a stem that is thick enough to handle the ringing process without breaking the stem.
2. Use the marker to draw two parallel lines around the stem, about 2-3 cm apart. This will be the area where the bark with the phloem will be removed.
3. Carefully use a sharp knife or scalpel to cut along the marked lines. Remove the bark and the underlying phloem layer between the two lines, exposing the xylem. Be careful not to damage the xylem.
4. Wrap the exposed area with plastic wrap or aluminium foil to prevent it from drying out and to protect it from pests and diseases.
5. Water the plant regularly and ensure it receives adequate sunlight, if it is a potted plant.
6. Observe the plant within the first few days
7. Observe the plants after a few weeks.
8. Suggest reasons for the observations you have made.

PHOTOSYNTHESIS AND FACTORS AFFECTING PHOTOSYNTHESIS

Photosynthesis

Photosynthesis is the biochemical process where green plants and other chlorophyll-containing organisms (e.g. algae and some bacteria) make their food using light energy. The conditions that are needed for photosynthesis to occur are;

1. Carbon dioxide from the atmosphere
2. Water from the soil
3. chlorophyll (mainly in the chloroplasts in the leaf)
4. Light energy (generally from the sun) absorbed by chlorophyll.

These conditions and factors can be verified with experiments in the laboratory. In plants, photosynthesis occurs in the chloroplasts because chloroplasts contain the green pigment chlorophyll, which absorbs light.

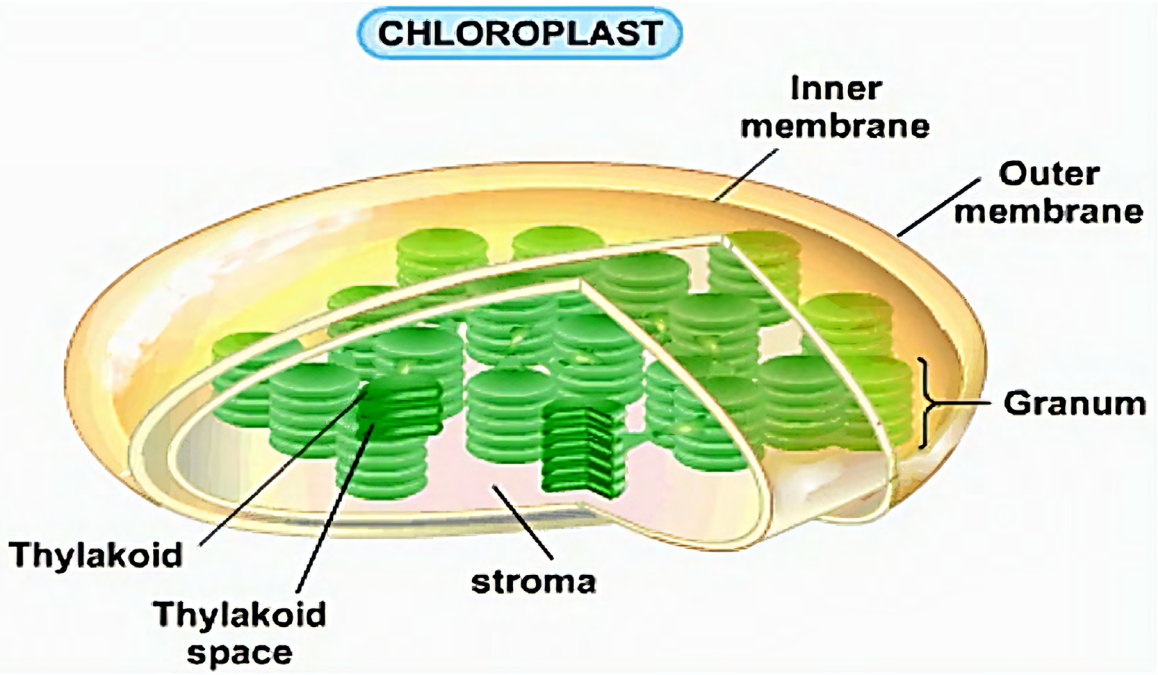


Figure 4.16: Structure of a chloroplast.

Photosynthesis results in the conversion of light energy into chemical energy stored in glucose, a food molecule.

The chemical equation for photosynthesis is:

$$6CO_2 + 6H_2O \xrightarrow[\text{light energy}]{\text{chlorophyll}} C_6H_{12}O_6 + 6H_2O + 6O_2$$

Where,

- **$6CO_2$** means that there are six molecules of carbon dioxide needed.
- **$6H_2O$** means that there are six molecules of water needed.
- Carbon dioxide and water are reactants.
- Light energy is required.
- Chlorophyll is required.
- **$C_6H_{12}O_6$** means that one molecule of glucose is manufactured, and it is the primary product of photosynthesis.
- **$6O_2$** means that there are six oxygen molecules formed in the reaction. Oxygen is released as a by-product of photosynthesis.

Photosynthesis produces glucose and oxygen as by-products.

This is the simplest representation of photosynthesis, as it is a complex reaction that involves multiple numbers of intermediate steps and various enzymes, which are outlined below.

The **two main stages in photosynthesis** are ;

1. The light-dependent stage, or light reactions, or photochemical stage:
   a. Occurs in the thylakoid membranes of the chloroplast.
   b. Uses light energy to split water molecules to produce oxygen, protons (hydrogen ions) and electrons.
   c. Produces ATP (adenosine triphosphate) and NADPH (nicotinamide adenine dinucleotide phosphate): energy-rich molecules needed for the dark reactions.
2. The light-independent stage, or Dark Reactions, or Calvin Cycle:
   a. Occurs in the stroma of the chloroplast.
   b. Uses NADPH (energy molecule) from the light-dependent stage to combine hydrogen with carbon dioxide to make glucose through a series of enzyme-catalysed reactions. The chemical energy needed for these processes to occur is from ATP (an energy molecule)
   c. NADP+, ADP + P, and glucose are the end products of the reaction.

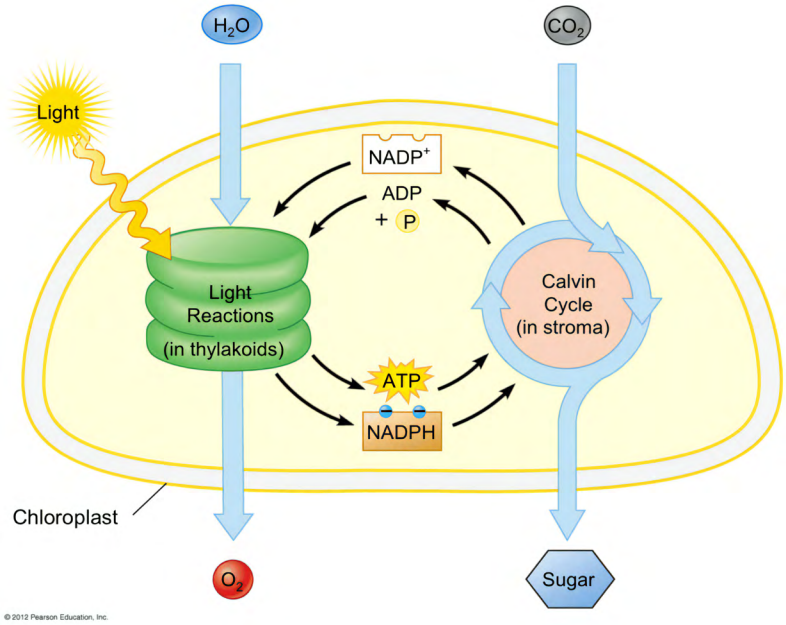


Figure. 4.17: The processes of photosynthesis.

Factors affecting photosynthesis

Light intensity

The range of light absorbed by plants for photosynthesis is between 400 nm and 700 nm. This range is called photosynthetically active radiation. The most important light wavelengths for photosynthesis are 430nm (blue light) and 660 nm (red light), absorbed by chlorophyll a, and 450nm (blue light) and 635nm (red light) absorbed by chlorophyll b. The rate of photosynthesis generally increases with increasing light intensity as light is required in the light-dependent stage. However, after an optimum light intensity is reached, additional light does not affect the process.

Carbon dioxide concentration

Generally, an increase in carbon dioxide concentration increases the rate of photosynthesis, as CO_2 is required for fixing carbon at the light-independent stage. This happens when CO_2 concentration is the limiting factor.

Temperature

An increase in temperature generally increases the rate of photosynthesis, since this speeds up enzymatic reactions. However, beyond an optimum temperature, the rate of photosynthesis decreases because such high temperatures can denature/ destroy enzymes, thereby hindering the rate at which photosynthesis occurs.

Availability of water

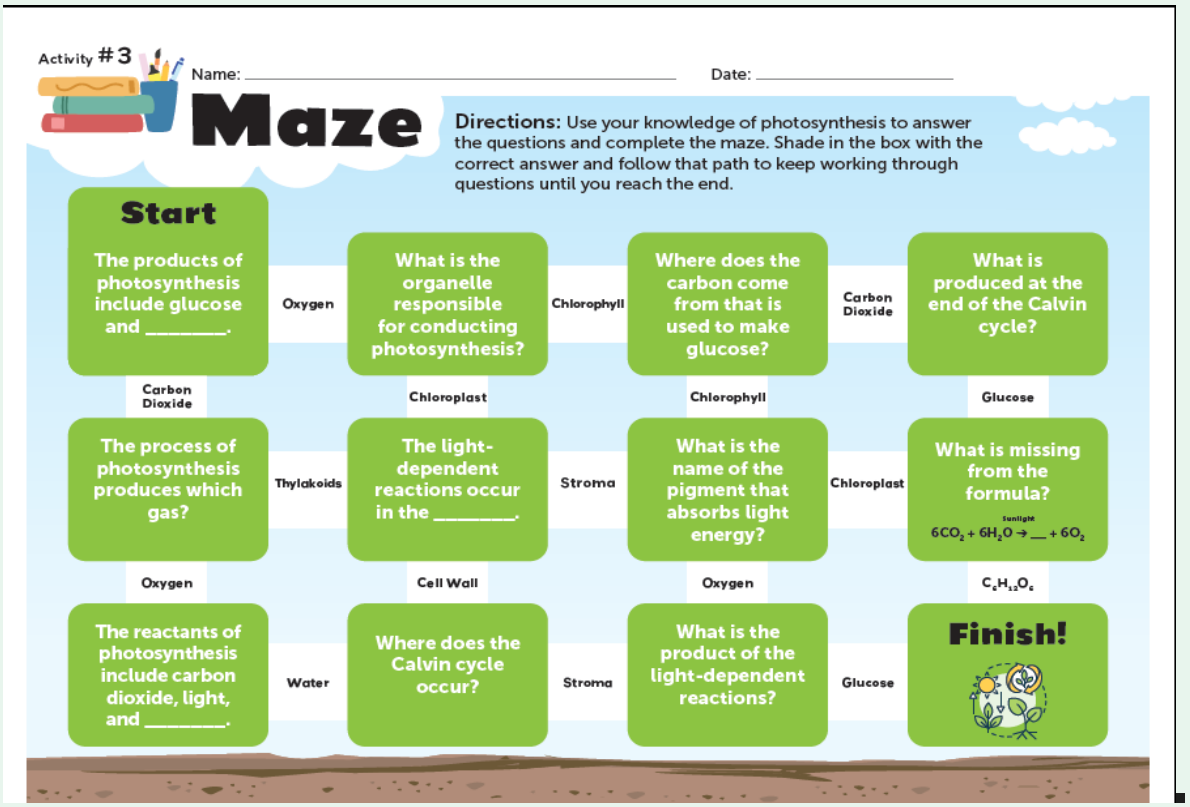
Insufficient water supply indirectly reduces the rate of photosynthesis. This is because when water is in short supply, the stomata close to prevent water loss. Thus, the amount of carbon dioxide entering the leaves also reduces, thereby reducing the rate of photosynthesis.

Chlorophyll concentration

Higher concentrations of chlorophyll increase the rate of photosynthesis due to efficient absorption of sunlight.

Watch this video on photosynthesis:
https://www.youtube.com/watch?v=qkRe_OMfwv4),

Activity 4.9 The photosynthesis maze.



Activity 4.10 Data analysis of light intensity and photosynthesis.

Given the following data collected after an experiment on the effect of light intensity on the rate of photosynthesis, analyse and interpret the results:

Light Intensity/nm	100	200	400	800	1600
Rate of Photosynthesis (O_2 produced in ml/min)	2	5	8	12	12

Use the information in the table to plot a graph of the rate of photosynthesis at different light intensities.

1. What trend do you observe in the data?
2. Explain why the rate of photosynthesis levels off at higher light intensities.

EXTENDED READING

• https://www.biologydiscussion.com/photosynthesis/blackmans-law-of-limiting-factors-and-his-criticism-photosynthesis/23006	
• https://www.careerpower.in/school/biology/photosynthesis	
• https://www.nhs.uk/conditions/cardiovascular-disease/	
• https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds)	
• https://youtu.be/CWFyxn0qDEU?si=GFeJY87_0K_Q-SRD	

REVIEW QUESTIONS

1. What is the role of the heart in the cardiovascular system, and how do its structural components contribute to its function?
2. What are the solid components of blood, and what function does each serve in maintaining overall health?
3. How do the structures of arteries, veins and capillaries support their distinct functions within the cardiovascular system?
4. What are the symptoms and prevention strategies for a major cardiovascular disease, such as hypertension?
5. Describe the function of alveoli.
6. List the main parts of a nephron.
7. Describe how the kidneys maintain homeostasis in the body.
8. Name the three main layers of the skin.
9. Explain the role of sweat glands in the skin.
10. Evaluate the importance of the skin's barrier function.
11. Describe the role of the liver in detoxification.
12. Analyse how the liver contributes to homeostasis.
13. What is the primary cause of kidney stones?
    - **A.** Bacterial infection
    - **B.** Excessive calcium in the urine
    - **C.** Low blood sugar
    - **D.** Viral infection
14. Which of the following is a common symptom of eczema?
    - **A.** Itchy, inflamed skin
    - **B.** Increased appetite
    - **C.** Improved vision
    - **D.** Weight gain

15. What is the primary cause of acne?

A. Bacterial infection

B. Excessive sweating

C. High glucose levels

D. Low cholesterol levels

16. Identify the main components of the xylem.

17. Describe the function of phloem in plants.

18. Explain how the structure of vessels in the xylem contributes to their function.

19. List three environmental factors that can affect the rate of transpiration in plants.

20. Explain how high humidity affects the rate of transpiration.

21. Analyse the impact of wind on the rate of transpiration in plants.

22. What is translocation in plants?

23. Explain the role of companion cells in translocation.

24. List three factors that can affect the rate of translocation in plants.

25. What is the primary function of photosynthesis?

26. Identify the main pigment involved in photosynthesis.

27. Describe the role of light in the light-dependent reactions of photosynthesis.

28. What is the main purpose of the Calvin cycle?

29. List three factors that can affect the rate of photosynthesis.

30. Analyse how increasing carbon dioxide concentration affects the rate of photosynthesis.

31. How important is photosynthesis to the survival of plants and other organisms?

32. Professor Nebo has an array of indoor plants in her classroom and forgot to keep the windows in her class open during a two-week break from school. How would this room condition affect the indoor plants after the school break?

33. An experiment was conducted on the effect of temperature on the rate of photosynthesis, and the following data were obtained

a. Use the data to plot a graph.

b. Explain why the rate begins to drop off after twenty-five degrees Celsius.

Temperature (°C)	Rate of Photosynthesis (O2 produced in ml/min)
10	2
15	4
20	8
25	12
30	10
35	6
40	2

ANSWERS TO REVIEW QUESTIONS

SECTION 1

1. Rhizopus has several key structural characteristics:
    - It consists of filamentous structures called hyphae, which are long, thread-like cells that form a network known as mycelium.
    - Rhizopus produces sporangia, which are spherical structures that contain spores for reproduction. These sporangia are typically found at the tips of upright hyphae.
    - Rhizoids: These are specialised hyphae that anchor the organism to the substrate and help absorb nutrients.
    - Coenocytic Structure: Rhizopus hyphae are coenocytic, meaning they lack septa (cross-walls) and contain multiple nuclei within a single cell.
2. The hyphae of Rhizopus play crucial roles depending on their position relative to the substrate:
    - Substrate Attachment: Rhizoids anchor the Rhizopus to its food source, such as decaying organic matter, allowing for stability and nutrient absorption.
    - Nutrient Absorption: Hyphae spread out across the substrate, increasing the surface area for absorption. They secrete enzymes that break down complex organic materials, allowing the organism to absorb the resulting simpler compounds.
    - Reproductive Structures: Upright hyphae develop into sporangia, which release spores into the environment. This positioning allows for effective dispersal, increasing the chances of colonising new substrates.
3. Rhizopus carries out several important life processes:

- Nutrition: Rhizopus is a saprophyte, obtaining nutrients by decomposing organic matter. It secretes enzymes that break down complex substances, which are then absorbed through the hyphae.

- Reproduction: Rhizopus reproduces both sexually and asexually. Asexual reproduction occurs through the formation of spores within sporangia, while sexual reproduction involves the fusion of specialised hyphae from different mating types.
- Growth: Rhizopus grows rapidly under suitable conditions, extending its hyphae to explore and colonise new organic matter for sustenance.

4. Rhizopus impacts everyday life in several ways:

- Food Production: It is used in the fermentation of foods, such as tempeh, a traditional soy product, and certain types of alcohol. This highlights its role in culinary practices.
- Decomposition: Rhizopus is essential in natural ecosystems for breaking down organic material, recycling nutrients, and maintaining soil health.
- Medical and Industrial Applications: Some species of Rhizopus are studied for their potential to produce enzymes used in biotechnology and pharmaceuticals, contributing to various industries.
- Food Spoilage: On the downside, Rhizopus can cause spoilage in food products, leading to economic losses and health concerns related to mould exposure.

5.

- gametophyte (leaf-like, stem-like and root-like structures)
- sporophyte (capsule, seta and operculum)
- protonema

6. The Moss plant will undergo adaptations such as:

- development of thicker cuticles.
- growing more leaves to provide shade and reduce transpiration.
- producing more rhizoids to anchor themselves securely in the dry soil.

7. Ferns are characterised by several distinct features:

- Fronds: Ferns have large, divided leaves known as fronds. These fronds can be highly complex and often have smaller leaflets called pinnae.

- Rhizomes: Ferns grow from underground stems called rhizomes, which help store nutrients and produce new fronds and roots.
- Sori: On the underside of the fronds, ferns have clusters called sori, which contain sporangia that produce spores for reproduction.
- No Seeds: Ferns reproduce through spores instead of seeds, which distinguishes them from many other plants.

8. The presence of many ferns in an ecosystem can have several ecological impacts:

- Soil Improvement: Ferns can help improve soil quality by breaking down organic matter and adding nutrients as they decay.
- Habitat Creation: They provide shelter and habitat for various organisms, including insects and small animals, contributing to biodiversity.
- Water Regulation: Ferns help retain moisture in the soil, which can benefit other plants and organisms in the area.
- Toxic Metal Removal: Some fern species can absorb and remove harmful heavy metals from the soil, contributing to environmental cleanup.
- Competition: A high abundance of ferns can compete with other plants for sunlight, water, and nutrients, potentially affecting the overall plant diversity in the area.

9. Weeding, manuring, watering, tillage, pruning.

10. Biological concepts related to cultural practices include:

- Soil Fertility, which is related to crop rotation because it enhances nutrient availability and reduces soil depletion by varying the nutrient demands of different crops.
- Pest Management is employed during Intercropping, which can disrupt pest life cycles when beneficial plants are introduced to attract natural predators.
- Water Cycle: Irrigation practices affect water distribution and availability, influencing plant growth and ecosystem health.
- Microbial activity in the soil can be affected when tillage is practised because soil microorganisms play a crucial role in nutrient cycling and soil health.

11. Ways in which cultural and farming practices can enhance crop production.

- Improving Soil Health: Practices like crop rotation and cover cropping maintain nutrient levels and reduce erosion.
- Maximising Resource Efficiency: Efficient irrigation and mulching conserve water and improve moisture retention, promoting healthier crops.
- Promoting Biodiversity: Diverse planting strategies, such as intercropping, increase resilience against pests and environmental changes.

12.

- Increased Yields: Effective cultural practices can lead to higher crop yields due to improved soil health and reduced pest pressure.
- b Sustainability: Practices like crop rotation and organic farming promote long-term agricultural sustainability by preserving the environment.
- Enhanced Soil Quality: Regularly applying mulch and practising no-till farming improves soil structure, fertility, and moisture retention.
- Economic Benefits: Improved crop production can lead to higher profits for farmers and contribute to food security in communities.

13. Animal Husbandry refers to the day-to-day care, management, production, feeding, and raising of farm animals.

14. The basic principles of animal husbandry include:

- Breeding: Selecting animals with desirable traits to improve genetic quality.
- Nutrition: Providing balanced diets to meet the specific needs of different animal species.
- Health Care: Implementing vaccination and disease prevention measures to maintain animal health.

15. Cattle, Pigs, Sheep, Goats, Poultry

SECTION 2

1. The cell theory is a foundational concept in biology. It states that:

- All living organisms are composed of one or more cells. This means that cells are the basic building blocks of life, whether we're talking about a tiny bacterium or a giant redwood tree.
- The cell is the basic unit of structure and organization in organisms. This means the cell is the smallest units that carry out the processes of life.
- All cells arise from pre-existing cells. Cells don't just spontaneously appear; they come from the division of other cells.

2. **Animal Cells:**

- Nerve Cell: This is also known as neuron has long, thin extensions called axons that transmit electrical impulses over long distances. They also have branching dendrites that receive signals from other neurons. This structure allows for rapid communication throughout the body.
- Red Blood Cell: Red blood cells have a biconcave disc shape, which increases their surface area for oxygen absorption. They lack a nucleus, which allows them to carry more haemoglobin, the protein that binds to oxygen.
- Muscle Cell: Muscle cells are elongated and contain specialized proteins (actin and myosin) that slide past each other, enabling muscle contraction. They also have numerous mitochondria to provide the energy needed for movement.

Plant Cells:

- Palisade Mesophyll Cell: These cells are found in leaves and are packed with chloroplasts, the organelles responsible for photosynthesis. Their elongated shape maximizes their exposure to sunlight.
- Root Hair Cell: Root hair cells have a long, thin extension that increases their surface area for absorbing water and nutrients from the soil.
- Xylem Vessel Element: Xylem cells are dead at maturity and form long, hollow tubes that transport water from the roots to the rest of

the plant. Their walls are thickened with lignin, providing structural support.

3.

Structure	Plant Cell	Animal Cell	Functional Significance
Cell Wall	Present (made of cellulose)	Absent	Provides structural support and protection to plant cells.
Chloroplasts	Present (contain chlorophyll)	Absent	Enables photosynthesis in plant cells.
Vacuole	Large, central	Small temporary	Contains and stores inorganic materials.

4. Hint: refer to text **on active transport** on **page 31**.

5. Exocytosis is the process by which cells release substances (e.g. hormones) to the outside environment. It occurs through the following steps:

   - vesicles containing the substance to be released from inside the cell.
   - vesicles move to the cell membrane.
   - vesicles fuse with the cell membrane.
   - contents are released outside the cell.

6. **Hint**: refer to text on **endocytosis** on **page 31 and 32** for explanation. The following steps are involved in the process:

   - cell membrane invaginates (folds in)
   - substances enter the cell through invagination.
   - vesicles form, enclosing the substances.
   - vesicles separate from the cell membrane.

7. Hint: refer to text on **endocytosis** on **page 31 and 32.**

8.

Active transport	Osmosis
Moves molecules against concentration gradients.	Moves water molecules down concentration gradients.
Requires energy (ATP).	Does not require energy from the cell.
Equalises or balances solvent concentrations	Maintains concentration gradients.
Transports or moves various molecules.	Specifically moves only water molecules.

9. Facilitated diffusion and active transport are two ways substances move across cell membranes. They differ in the following ways:

	Energy needed	Direction of movement across cell membranes
Facilitated diffusion	No energy required	Energy required (from ATP)
Active transport	moves from high to low concentration (down the concentration gradient)	Moves from high to low (against the concentration gradient)

10. **D. Twisted ladder.**

11. **C. Phosphate strands on the outside with nucleotides bonded together on the inside.**

12. **C. Nitrogenous base.**

13. A nucleotide is the basic building block of DNA and consists of three components: a phosphate group, a deoxyribose sugar, and a nitrogenous base. The nitrogenous base is attached to the deoxyribose sugar, which is, in turn connected to the phosphate group.

14. DNA's double-helix structure allows for precise replication of genes during cell division, this ensures that genetic information is accurately passed from parent to offspring.

15. DNA replication is the process by which a cell makes identical copies of its DNA molecules. It is essential for living organisms because it allows for the transmission of genetic information from one generation to the next, ensures the stability and maintenance of genetic material, enables

growth and tissue repair, and facilitates genetic diversity through sexual reproduction.

16.

- DNA Helicase: This enzyme unwinds the double helix and separates the two DNA strands, creating the replication fork.
- DNA Primase: It synthesizes short RNA primers on the DNA template strands, providing starting points for DNA synthesis.
- DNA Polymerase: This enzyme adds nucleotides to the growing DNA strand, extending the new DNA from the primers. It also has proofreading abilities to ensure accuracy.
- DNA Ligase: It joins Okazaki fragments on the lagging strand, sealing gaps and creating a continuous DNA strand.

17.

- *Initiation:* Replication begins at specific locations called origins.
- *Unwinding:* DNA helicase unwinds the double strands.
- *Stabilisation:* Single-stranded binding proteins stabilize the separated strands.
- *Priming:* DNA primase synthesizes RNA primers on the template strands.
- *Elongation:* DNA polymerase adds nucleotides to the primers, extending the new DNA strands.
- *Synthesis of Okazaki Fragments:* On the lagging strand, DNA polymerase creates short DNA segments known as Okazaki fragments.
- *Removal of Primers and Fragment Joining:* RNA primers are replaced with DNA, and DNA ligase seals the fragments together.
- *Termination:* The replication process ends when replication forks meet termination sequences.

18. To create a model of DNA, you can use coloured sheets of paper to represent the different bases (adenine, thymine, cytosine, and guanine) and cut them into shapes. Use two long strips of paper twisted together to represent the sugar-phosphate backbone and connect the base pairs with lines to show how they pair (A with T and C with G).

Using the model, you can demonstrate how the double helix unwinds and separates. The leading strand runs continuously toward the replication fork, while the lagging strand is synthesised in short segments (Okazaki fragments) away from the fork. This visual representation helps clarify how both strands are replicated simultaneously but in different ways.

The unwinding of the double helix allows the enzyme access to the single strands. Priming provides starting points for the new DNA strands, and the assembly occurs as DNA polymerase adds nucleotides to the primers. This coordinated effort results in two new, identical DNA molecules, each containing one original strand and one newly synthesised strand.

19. RNA is a single-stranded nucleic acid composed of nitrogenous bases, sugar molecule and phosphate groups.

20. Hint: refer to text on **transcription** on **page 50**.

21. RNA transcription is vital for:

- Gene expression and regulation
- Protein synthesis
- Cellular differentiation and development
- Maintenance of genetic information.

22. RNA transcription produces mRNA which carries genetic information for protein synthesis.

23.

- mRNA carries genetic information from DNA to ribosomes for protein synthesis.
- tRNA transfers amino acids to ribosomes during protein synthesis.
- rRNA forms ribosomes, thus providing structural support for protein synthesis.

24. A nucleotide consists of a phosphate group, a deoxyribose sugar, and a nitrogenous base. The sequence of nucleotides in DNA forms the genetic code that determines the sequence of amino acids in proteins.

25. Transcription is the process where a segment of DNA is copied into mRNA by the enzyme RNA polymerase. This mRNA carries the genetic information from the DNA in the nucleus to the ribosomes in the cytoplasm, where protein synthesis occurs.

26. Both replication and transcription involve the synthesis of nucleic acids using DNA as a template. Replication produces a double-stranded DNA molecule (not a helix) to ensure each new cell receives an exact copy of the genome, while transcription produces a single-stranded mRNA molecule that carries the code for a protein. Replication uses DNA polymerase, while transcription uses RNA polymerase.

27. tRNA molecules carry amino acids to the ribosome, where they match their anticodons with the codons on the mRNA strand, facilitating the addition of the correct amino acids to the growing polypeptide chain.

28. Ribosomes are the cellular structures where translation occurs. They read the sequence of codons in mRNA and, with the help of tRNA, assemble the corresponding amino acids into a polypeptide chain.

29. The regulation of protein synthesis ensures that proteins are produced at the right time and in the right amounts, which is crucial for maintaining cellular function and responding to environmental changes. Disruptions in this regulation can lead to disorders such as cancer, where abnormal protein synthesis can cause uncontrolled cell growth.

30. tRNA (transfer RNA) molecules match their anticodons with the corresponding codons on the mRNA sequence, ensuring that the correct amino acids are added to the growing polypeptide chain. This accuracy is important for producing functional proteins.

SECTION 3

1. Grain weevils are small insects, typically measuring 2.5 to 5 mm in length. They have an elongated, oval-shaped body that is usually dark brown or black. A key characteristic is their long snout, which allows them to bore into grains. They possess wings but are not strong fliers, and their six legs and segmented antennae help them navigate their environment.

2. The grain weevil's elongated snout enables it to access the interior of grains for feeding and laying eggs, providing protection for larvae as they develop. Their dark colouration helps them blend into their environment, reducing the risk of predation. Additionally, being small allows them to fit into tight spaces in stored grains. Their ability to reproduce quickly and thrive in various temperatures also enhances their survival in different environments.

3. The life cycle of grain weevils consists of four main phases:
   - Egg: The female lays eggs inside grains, with a single female capable of laying up to 200 eggs.
   - Larva: Once the eggs hatch, the larvae feed on the grain, remaining sheltered within until they mature.
   - Pupa: After sufficient feeding, the larvae pupate, transforming into adults.
   - Adult: The mature grain weevils emerge and are ready to mate, continuing the cycle. This entire process takes about 4 to 5 weeks under optimal conditions.

4. Grain weevils can cause significant damage to stored grains, leading to reduced quality and quantity of food supplies. This results in economic losses for farmers and grain storage facilities. Their infestations can lead to increased management costs for pest control and reduced marketability of affected grains. Ecologically, grain weevils can disrupt the balance of ecosystems by affecting food availability for other species, influencing the dynamics of both predator and prey relationships.

5. Butterfly Features:
   a. Wings: Butterflies are famous for their colourful, patterned wings. These wings are covered in tiny scales.
   b. Proboscis: A long, tubular structure used for sucking nectar and coiled under the head when not in use.
   c. Antennae**:** They are long slender sensitive structures which are clubbed at the tip and located on the head. They are sensitive to chemicals like the scent of flowers.

6. The Butterfly Life Cycle

   Egg (3- 14 days): Eggs are laid at the underside of the leaves of a plant.

   Larva (Caterpillar) 14 -28 days:
   - A caterpillar hatches from the egg, which eats the eggshells and surrounding plant materials.
   - Caterpillars moult several times as they outgrow their skin to become a pupa.

   Pupa (14-28 days): The caterpillar forms a protective case called a chrysalis or pupa and rests inside.

Adult (14-52days):

- The adult butterfly emerges from the chrysalis with its wings still soft and folded.
- The butterfly will pump blood into its wings, expanding them and drying them out.
- Once its wings are fully expanded and dry, the butterfly is ready to fly, feed, and reproduce.

7. Butterflies are important for more than just their beauty:

- *Pollination:* They are essential for the fertilisation of many plants, by carrying pollen from one flower to another.
- *Tourism:* People love to see butterflies, so butterfly gardens and parks can bring in money.
- *Environmental Indicators:* Butterflies are sensitive to changes in the environment. By watching them, we can learn if our planet is healthy or not. In a healthy environment, butterflies move about freely and go through their life processes with no hindrance but in an unhealthy environment, the reverse happens.

8. **B.** Flattened and oval

9. **C.** Transparent and veined

10. **C.** They have a spongy mouth pad for absorbing liquids

11. **C.** Compound and faceted

12. **C.** Adult

13. **B.** Larvae

14. **C.** Reproduction

15. **D.** All the above

16. Houseflies play a significant role in spreading diseases, acting as vectors for various pathogens. Through their contaminated mouthparts and legs, they transmit harmful diseases such as typhoid fever, cholera, dysentery, and gastroenteritis. As they land on contaminated surfaces, they pick up pathogens and transport them to food, water, and human contact, leading to outbreaks of waterborne and foodborne illnesses. This, in turn, results in increased healthcare costs, lost productivity due to absenteeism, and economic burdens on individuals, communities, and healthcare systems. The economic impact is substantial, with

estimates suggesting billions of cedis in medical expenses, millions of workdays lost, and significant morbidity and mortality rates. However, effective fly control measures such as sanitation, waste management, and insecticides can help mitigate the spread of diseases and reduce the economic burden on human health.

17. Despite their notorious reputation, houseflies play a vital role in maintaining ecological balance and supporting sustainable agricultural practices. Houseflies' decomposition activities, through their larvae, breakdown organic matter, recycle nutrients, reduce waste, and create a nutrient-rich environment for plants. This process contributes significantly to increased crop yields and quality, improved soil fertility, and reduced waste and nutrient loss. Additionally, houseflies' decomposition activities help break down organic waste, reduce waste volume and odour, and recycle nutrients, minimizing the need for synthetic fertilizers. By recognizing the importance of houseflies in decomposition, we can appreciate their contribution to maintaining ecological balance and supporting sustainable agricultural practices.

18. **A.** Head, thorax and abdomen

19. **C.** To carry pollen back to the hive

20. **D.** She has pheromone

21. **A.** Royal jelly

22. A honeybee's life cycle starts as an egg, laid by the queen. The egg hatches into a larva, fed by workers. The larva spins a cocoon, transforms into a pupa, and emerges as an adult. As a honeybee develops, its role changes: from a dependent larva to a worker bee caring for young and foraging, or a drone responsible for mating, or a queen bee laying eggs and leading the colony.

23. In honeybees, metamorphosis occurs when larvae transform into pupae. The larva spins a cocoon, releases enzymes to break down its body, and reorganizes its tissues. During this stage, the pupa develops adult features like wings, eyes, and legs. The pupa is non-feeding, immobile, and undergoes a dramatic transformation, eventually emerging as a fully formed adult bee with distinct physical and behavioural characteristics. This process takes about 10-14 days.

24. The queen bee is crucial to the life cycle of honeybees, laying eggs and ensuring colony survival. Unlike worker bees, which care for young

and forage, and drones, which mate with the queen, the queen's sole role is reproduction. Without a queen, the colony cannot reproduce and eventually dies. Workers can replace a lost queen by creating a new one from a larva, but if this fails, the colony collapses, highlighting the queen's vital importance.

25. Honeybees play a vital role in Ghana's food production by pollinating many crops, including mangoes, papayas, and cocoa. As they move from flower to flower in search of nectar, they transfer pollen, allowing plants to reproduce and set seed. Without honeybees, many of these crops would either disappear or significantly decline in yield. For example, cocoa, a major cash crop in Ghana, relies heavily on honeybees for pollination. If honeybees were to disappear, cocoa production would severely decline, leading to economic losses and food insecurity. Additionally, the lack of pollination would affect the diversity and availability of fruits and vegetables, leading to a reduced food supply and potential nutritional deficiencies. It is essential to conserve and protect honeybee populations to ensure the continued production of food crops in Ghana.

26. **B.** High temperature and high rainfall

27. **C.** Dense canopy

28. **A.** Amazon rainforest

29. **D.** All the above

30. **A.** They store carbon in their biomass and support biodiversity

31. **B.** 2000mm

32. **B.** 20-30°C

33. **C.** High constant temperature

34. **A.** Emergent layer

35. **D.** CO_2 and water

36. In the tropical rainforest, plants adapt to the environment in various ways. Some plants have large leaves with drip tips to shed excess water, while others have buttress roots to support their growth in shallow soil. Epiphytes, such as orchids and bromeliads, grow on other plants to access sunlight. Vines and lianas use their long stems to climb up trees, while others have adapted to live in low-light conditions. Some plants even have specialised roots to absorb nutrients from the air! These incredible adaptations enable plants to thrive in this lush, competitive

ecosystem. By evolving unique strategies, plants have secured their place in the tropical rainforest, exploiting every opportunity to survive and flourish.

37. In the tropical rainforest, animals adapt to the environment in remarkable ways. Some animals, like monkeys and sloths, have developed strong arms and claws to navigate through the dense canopy. Others, like forest genet and pythons have evolved camouflage and stealth to hunt in the understory. Birds like toucans and macaws have brightly coloured beaks and feathers to attract mates and warn off predators. Even insects like butterflies and leafcutter ants have adapted to the rainforest, with specialized wings and social colonies. These adaptations enable animals to thrive in this lush, competitive ecosystem, where every trait is a vital survival tool.

38. Tropical savannahs and deserts differ primarily in their climate, vegetation and biodiversity. Savannahs have seasonal rainfall with distinct wet and dry seasons, supporting a mix of grasses and scattered trees. In contrast, deserts receive extremely low rainfall and have scarce vegetation, primarily consisting of drought-resistant plants. This leads to a greater diversity of wildlife in savannahs compared to the more limited species found in deserts.

39. **Tropical savannahs:**

- Seasonal rainfall with distinct wet and dry seasons.
- Predominantly grasses with scattered drought-resistant trees.
- Rich biodiversity, including large herbivores and predators.
- Nutrient-poor but well-drained soils.

Deserts:

- Extremely low rainfall, often less than ten inches per year.
- Scarce vegetation, mainly consisting of succulents and drought-resistant shrubs.
- Adaptations in fauna and flora for extreme temperatures and water scarcity.
- Sandy or rocky soils with minimal organic content.

40. Savannah adaptations:

- Animals like zebras and lions use camouflage for protection and hunting.
- Large mammals migrate to find water and fresh grazing, e.g., wildebeests.
- Some species, such as giraffes, can survive long periods without water.
- Plants such as acacia develop deep roots to access groundwater.
- Many grasses are fire-resistant, able to survive periodic fires.

Desert adaptations:

- Nocturnal animals, such as kangaroo rats, avoid daytime heat.
- Creatures like meerkats and ground squirrels burrow into the soil for protection.
- Animals like camels store fat to conserve water; they metabolise fat for energy and water as a by-product.
- Desert plants, such as cacti, store water in their tissues.
- Some plants have reduced leaves to minimise water loss, and extensive root systems for water absorption.

41. Advantages of savannahs:

- Rich biodiversity supports various species.
- Seasonal rains allow for agricultural practices.

Disadvantages of savannahs: Vulnerability to droughts and fires can threaten ecosystems.

Advantages of deserts:

- Unique adaptations of flora and fauna provide interesting research opportunities.
- Low population density can mean less human impact on ecosystems.

Disadvantages of deserts:

- Harsh living conditions limit human habitation and agriculture.
- Biodiversity is often lower, and it makes ecosystems more fragile.

Improvements for biodiversity:

- In savannahs, sustainable land management and conservation efforts can protect habitats.
- In deserts, water conservation techniques and the introduction of native plant species can enhance biodiversity.

42. *Possibilities:*

- Increasing biodiversity and restoring habitats can occur if successful.
- The potential for carbon sequestration can help fight climate change.
- Improved agricultural opportunities could support local communities.

Challenges:

- High costs and resource requirements for irrigation and soil enhancement.
- The risk of disrupting existing ecosystems and native species.
- Long-term sustainability concerns include water availability and climate compatibility.

43.

- **Lagoon:** A lagoon is a body of water separated from the ocean by a barrier such as sandbars, barrier islands, or coral reefs. It typically has more stable salinity levels and is often more protected from oceanic waves.
- **Estuary:** An estuary is a partially enclosed coastal water body where freshwater from rivers and streams mixes with saltwater from the ocean. It experiences significant fluctuations in salinity due to tidal influences and freshwater inflow.

44.

- Water Content**:** Lagoons generally contain a mixture of freshwater and saltwater, while estuaries have a more dynamic mix of freshwater and saltwater, influenced by tides.
- Salinity: Lagoons tend to have more stable salinity levels, whereas estuaries experience fluctuating salinity due to the mixing of freshwater and saltwater.

- Living organisms**:** Lagoons are home to various fish species, crustaceans, molluscs, and aquatic plants. Estuaries support many fish and bird species, including migratory birds and juvenile fish, which rely on these areas for breeding and feeding.

45. Organisms in lagoons may have specialised osmoregulatory mechanisms to tolerate varying salt concentrations, allowing them to thrive in brackish waters. For instance, crabs and oysters can manage their internal salt levels effectively. In estuaries, fishlike salmon can regulate their salt concentrations to move between freshwater and saltwater. Many species also burrow into sediments to escape predators and harsh conditions, while filter feeders like oysters use specialized structures to extract nutrients from the water.

46.

- *Pollution:* Agricultural runoff containing fertilisers and pesticides can lead to eutrophication in estuaries, causing harmful algal blooms, where the alga is food for more organisms. These organisms feed and respire more leading to depletion in oxygen levels causing harm aquatic life.
- *Urbanisation:* Coastal development can lead to habitat destruction, altering the natural flow of water and sediment, which affects the health of both lagoons and estuaries.
- *Industrial discharges:* Release of toxins from factories can contaminate water sources, impacting the organisms that rely on these habitats for survival.

  Example: In Ghana, the Volta River Estuary has been affected by pollution and urbanisation, leading to declining fish populations and loss of biodiversity, which undermines the ecological balance and the livelihoods of communities that depend on these resources.

47. A seashore habitat, also known as a coastal or intertidal habitat, is the area where land meets the ocean. It is characterised by varying environmental conditions due to tidal movements. The main zones within a seashore habitat include:

- Supratidal Zone: Above high tide, often dry and subject to occasional splashes from waves.
- Intertidal Zone: Between high and low tide, exposed to air at low tide and submerged at high tide.

- Subtidal Zone: Always submerged underwater, typically rich in marine life.

48.

Supratidal Zone:

- Features: Dry most of the time, receives minimal saltwater exposure, often has sand dunes or rocky outcrops.
- Common Organisms: lichens and vascular plants, and various birds that feed on invertebrates.

Intertidal Zone:

- Features: Alternates between being submerged and exposed, experiences significant wave action, and has varying salinity and temperature.
- Common Organisms: Barnacles, sea stars, and various molluscs.

Subtidal Zone:

- Features: Remains underwater, generally stable temperatures and salinity, supports diverse ecosystems.
- Common Organisms**:** Fish, sea turtles, kelp forests, and coral reefs.

49. Organisms in seashore habitats exhibit various adaptive features:

- Supratidal Zone: Many organisms have developed protective shells or burrowing behaviours to avoid desiccation.
- Intertidal Zone: Species like barnacles and mussels have strong attachments to substrates to withstand wave action. Some can close their shells to retain moisture during low tide.
- Subtidal Zone: Fish and marine mammals have streamlined bodies for efficient swimming, while many organisms have developed camouflage or bright colours for communication and mating.

50. Human activities that affect seashore habitats include:

- Coastal Development: Construction of homes and businesses can lead to habitat loss and fragmentation, disrupting local ecosystems.
- Pollution: Runoff from land can introduce toxins and excess nutrients into the water, leading to algal blooms that deplete oxygen and harm marine life.

- Fishing and Harvesting**:** Overfishing and destructive fishing practices can deplete fish populations and damage coral reefs and other habitats.
- Tourism: Increased foot traffic can lead to erosion, disturbance of wildlife, and littering, which negatively affects the habitat.

  These activities can result in loss of biodiversity, altered species interactions, and diminished ecosystems.

51.

- Rivers are natural flowing water bodies of water connecting lakes, wetlands and oceans.
- Lakes are bodies of fresh or saltwater surrounded by land.
- Ponds are small bodies of still or slow-moving water.

52.

Characteristics Freshwater	Formation / source	Water current	Water depth	Size of water body	Salinity
Rivers	From higher elevation, rock or other water body	Constant flow	Varies	Generally long and narrow	(insignificant) freshwater
Lakes	Tectonic activity, glaciation	Minimal current	Varies	Large and enclosed	Freshwater or saline
Ponds	Rainfall or groundwater	None	Shallow	Small and contained	freshwater

53.

- In rivers, fish for example have streamlined bodies for swift movement against water currents. Plants also have roots buried in the bottom of the river which provide anchorage against water current.

- The different thermal zones in lakes allow aquatic organisms to adjust to different depths and temperatures.
- The calm and stable wave action of ponds makes the banks of ponds a convenient habitat for certain organisms e.g. mosquito larvae.

54.

The consequences include:

- Water pollution
- Habitat destruction
- Sedimentation
- Chemical contamination
- Genetic mutations

Recommendations are as follows:

- Regular monitoring and enforcement of laws protecting water bodies.
- Creating alternative livelihoods for miners.
- Rehabilitation of affected water bodies.
- Adoption of sustainable mining practices.
- Provision of portable water.

55.

- Immunisation is the process of stimulating a person's immune system to provide protection against a specific disease or infection through administration of a vaccine, toxoid or other immunising agent
- Vaccination is the act of administering a vaccine to stimulate the body's immune system against a specific disease or infection.
- Inoculation is the process of introducing a pathogen or vaccine into the body to induce immunity.

56.

The steps involved in immunisation are as follows:

- Introduction of antigen (harmless piece of pathogen) into the body.
- Recognition of antigen by immune cells (T-cells and B-cells) of the immune system.

- Activation of immune response (process by which the body's immune system recognises and responds to the presence of foreign substances such as pathogens).
- Production of antibodies and immune cells.

Steps involved in vaccination:

- Production of a vaccine by processes such as attenuation and inactivation.
- The vaccine is introduced into the body orally, through the nasal route or by injection.
- The body's immune system responds to the vaccine by producing antibodies and memory cells.
- The specific antibodies produced now fight the pathogen.

Steps involved in inoculation:

- A mild form of the pathogen is obtained from a sick person's wound or lesion.
- The pathogen is weakened through processes such as heating or chemical treatment.
- The skin of a healthy person is scratched or pricked to create a small wound.
- The healthy person was observed for signs of infection and disease progression.
- The body of the individual reacts by producing antibodies, which fight the pathogen and therefore bring about recovery

57.

- Immunisation is a broader process, while vaccination is a method of achieving immunisation.
- Inoculation involves exposure to a live pathogen or a mild form of the disease, while vaccination involves administration of a vaccine.

58. Vaccination is more acceptable due to:

- proven efficacy and safety.
- targeted immune response.
- lower risk of complications.

- wide protection against various diseases.

SECTION 4

1. The heart is the primary organ in the cardiovascular system, which is responsible for pumping blood throughout the body. Its structural components include:
   - Atria or auricles (upper chamber): receive blood from the veins.
   - Ventricles (lower chamber): pump blood out of the heart.
   - The septum separates the atria and ventricles.
   - Valves: regulate blood flow between chambers by stopping the backflow of blood.
   - Coronary artery: supplies oxygenated blood to the heart.
2. The solid components of blood are:
   - Red blood cells (RBCs) or erythrocytes: carry oxygen from the lungs to body tissues.
   - White blood cells (WBCs): fight infections and diseases.
   - Platelets (thrombocytes): aid blood clotting to prevent excessive bleeding.
3. **Arteries**
   - Thick walls with smooth muscle and elastic fibres.
   - Carry oxygenated blood away from the heart to the body, except in the pulmonary artery.
   - Regulate blood pressure.

   Veins
   - Thinner walls with less smooth muscle.
   - Carry deoxygenated blood back to the heart except the pulmonary and umbilical veins.
   - Have valves to prevent backflow.

   Capillaries
   - Thin permeable walls.
   - Allow gaseous and nutrient exchange between blood and tissues.

- Enable waste removal.

4.

Causes	a. Genetics (heredity). b. Obesity. c. Physical inactivity. d. High sodium or salt intake. e. Stress.
Symptoms	a. Dizziness. b. Headache. c. Nosebleeds. d. Fatigue. e. Vision problems.
Prevention or control strategies	a. Regular exercise. b. Balanced diet (low sodium, high potassium). c. Stress management. d. Blood pressure monitoring. e. Medication (prescribed).

5. Alveoli are tiny air sacs where gas exchange occurs. Oxygen from inhaled air diffuses into the blood, and carbon dioxide from the blood diffuses into the alveoli to be exhaled.

6. The main parts are Bowman's capsule, glomerulus, proximal convoluted tubule, Loop of Henle, distal convoluted tubule, and collecting duct.

7. The kidneys regulate the body's fluid balance, electrolyte levels, and pH by filtering blood, reabsorbing necessary substances, and excreting waste products in urine.

8. The three main layers are the epidermis, dermis, and hypodermis (subcutaneous layer).

9. Sweat glands produce sweat, which helps regulate body temperature through evaporation and excretes waste products like salts and urea.

10. The skin's barrier function protects against pathogens, prevents water loss, and shields the body from harmful environmental factors like UV radiation. It also plays a role in sensory perception and thermoregulation.
11. The liver detoxifies harmful substances by converting them into less toxic forms that can be excreted. It metabolises drugs, alcohol, and other toxins, and produces bile to aid in the digestion and absorption of fats.
12. The liver maintains homeostasis by regulating blood glucose levels, breaking down excess amino acids, producing bile, and detoxifying harmful substances.
13. **B. Excessive calcium in the urine.**
14. **A. Itchy, inflamed skin.**
15. **A. Bacterial infection.**
16. Tracheids, xylem vessels, xylem parenchyma, and xylem fibres.
17. The phloem transports sugars and other organic nutrients from the leaves to other parts of the plant.
18. Xylem vessels are wide with perforation plates at their ends, allowing for efficient water transport. Their lignified walls provide structural support to prevent cavitation. That is enormous tension existing in the xylem columns, so great that the water columns in the tubes sometimes break.
19. Light intensity, temperature, humidity.
20. High humidity reduces the rate of transpiration because the air is already saturated with moisture, decreasing the water vapour gradient between the leaf and the air.
21. Wind increases the rate of transpiration by removing the boundary layer of humid air around the leaf, enhancing the water vapour gradient and promoting water loss.
22. Translocation is the process by which organic nutrients, particularly sugars, are transported from the leaves to other parts of the plant through the phloem.
23. Companion cells assist in maintaining the function of sieve tubes in the phloem.
24. Concentration gradient, temperature, and water availability.

25. The primary function of photosynthesis is to convert carbon dioxide and water into glucose, using light as a source of energy. Oxygen is released to the surrounding air or water as a by-product.

26. The main pigment involved in photosynthesis is chlorophyll.

27. Light energy is absorbed by chlorophyll and other pigments, which excite electrons and initiate the electron transport chain, leading to the production of ATP and NADPH.

28. The main purpose of the Calvin cycle is to convert carbon dioxide and the hydrogen from NADP(H) into glucose using energy from ATP.

29. Light intensity, carbon dioxide concentration, temperature, availability of water, and chlorophyll concentration.

30. Increasing carbon dioxide concentration generally increases the rate of photosynthesis up to a certain point, as more CO_2 is available for the Calvin cycle. However, other factors such as light intensity and temperature must also be optimal for maximum photosynthesis.

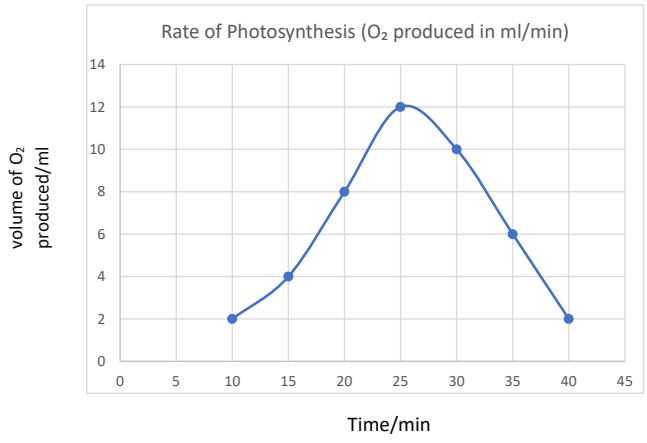
31. Photosynthesis provides the energy and organic compounds necessary for plant growth and development. It also produces oxygen, which is essential for the respiration of most living organisms.

32. When Professor Nebo opens the curtains and door to her classroom after the two-week break, she will possibly notice that her plants will;

- Be less green due to reduced chlorophyll production.
- It has grown long and weak in its attempts to search for light.
- Have shed older leaves to conserve energy due to a lack of production of food production.

33.

a.



b. The enzyme action leading to photosynthesis increases with increasing temperature; however, beyond an optimum temperature in this case, twenty-five degrees Celsius, the rate of photosynthesis decreases because such high temperatures can denature/destroy enzymes.

BIBLIOGRAPHY

Aber, J. D., & Melillo, J. M. (2001). *Terrestrial ecosystems*. Academic Press.

Alberts, B., Johnson, A., Lewis, J., Raff, M., Roberts, K., & Walter, P. (2002). *Molecular biology of the cell* (4th ed.). Garland Science.

Andrzejewski, C., & Kearney, J. (2021). The role of vaccines in preventing infectious diseases: An overview. *Journal of Infection and Public Health, 14*(5), 641–648. https://doi.org/10.1016/j.jiph.2020.09.013

Blackiston, H. (2018). *Beekeeping for dummies* (5th ed.).

Bold, H. C., Alexopoulos, C. J., & Delevoryas, T. (1987). *Morphology of plants and fungi*. Harper & Row.

Brown, R. D., & Arguelles, R. A. (2016). *Essentials of human physiology* (2nd ed.). McGraw-Hill Education.

Campbell, J. R., & Campbell, M. (2003). *Introduction to animal science: Global, biological, social, and industry perspectives* (3rd ed.). Pearson.

Centers for Disease Control and Prevention. (2023). *Vaccines and immunizations*. https://www.cdc.gov/vaccines/index.html

Chapin, F. S., Matson, P. A., & Vitousek, P. M. (2011). *Principles of terrestrial ecosystem ecology* (2nd ed.). Springer.

Cooper, G. M., & Hausman, R. E. (2019). *The cell: A molecular approach* (8th ed.). Oxford University Press.

Day, J. W., Hall, C. A. S., Kemp, W. M., & Yáñez-Arancibia, A. (1989). *Estuarine ecology*. Wiley.

Dearnaley, J. D. W., & Tsuneda, A. (2001). *Plant microbiology*. Garland Science.

Emery, R., & Cousins, D. (2023). *Insect pests of stored grain*. Department of Primary Industries and Regional Development's Agriculture and Food Division. https://www.agric.wa.gov.au/insect-pests-stored-grain

Gill, R. A. (2006). *Grassland ecology: The effect of climate change*. Springer.

Graham, L. E., Graham, J. M., & Wilcox, L. W. (2003). *Plant biology*. Prentice Hall.

Griffiths, A. J. F., Wessler, S. R., Carroll, S. B., & Doebley, J. (2015). *Introduction to genetic analysis* (11th ed.). W.H. Freeman and Company.

Guyton, A. C., & Hall, J. E. (2006). *Textbook of medical physiology* (11th ed.).

Hargrove, M. S., & Smith, S. A. (2012). *Cardiovascular physiology* (2nd ed.). Elsevier Health Sciences.

Hartmann, H. T., Kofranek, A. M., Rubatzky, V. E., & Flocker, W. J. (1988). *Plant science*.

Hynes, H. B. N. (1970). *The ecology of running waters*. University of Toronto Press.

Keddy, P. A. (2010). *Wetland ecology: Principles and conservation* (2nd ed.). Cambridge University Press.

Kennish, M. J. (2001). *Estuaries*. CRC Press.

Lehninger, A. L., Nelson, D. L., & Cox, M. M. (2008). *Principles of biochemistry* (5th ed.). W.H. Freeman and Company.

Lewin, B. (2007). *Genes IX*. Jones and Bartlett Publishers.

Mann, K. H., & Lazier, J. R. N. (2013). *Dynamics of marine ecosystems: Biological-physical interactions in the oceans* (3rd ed.). Wiley-Blackwell.

McFadden, C. H., & Keeton, W. T. (1995). *Biology: An exploration of life* (5th ed.). W.W. Norton & Company.

McLachlan, A., & Brown, A. C. (2006). *The ecology of sandy shores*. Academic Press.

Meyer, J. L., & Wallace, J. B. (2001). Lost linkages and lotic ecology: Rediscovering the role of streams in the landscape. In S. E. G. Findlay & R. L. Sinsabaugh (Eds.), *Aquatic ecosystems: Interactivity and management* (pp. 223–238). CRC Press.

Mishler, B. D. (2001). *Bryophyte biology*. Cambridge University Press.

Monto, A. S. (2020). The importance of vaccination in preventing disease: A comprehensive review. *Clinical Infectious Diseases, 71*(12), 3671–3682. https://doi.org/10.1093/cid/ciaa854

Prescott, L. M., Harley, J. P., & Klein, D. A. (2004). *Microbiology*. McGraw-Hill Education.

Pyle, R. M. (2018). *Butterflies of the Pacific Northwest*. Timber Press.

Raven, P. H., Evert, R. F., & Eichhorn, S. E. (2005). *Biology of plants*. W.H. Freeman and Company.

Raven, P. H., Evert, R. F., & Eichhorn, S. E. (2013). *Biology of plants* (8th ed.). W.H. Freeman and Company.

Ricketts, E. F., Calvin, J., & Hedgpeth, J. W. (1985). *Between Pacific tides* (5th ed.). Stanford University Press.

Rozendaal, J. A. (1997). *Vector control: Methods for use by individuals and communities*. World Health Organisation.

Schlesinger, W. H., & Bernhardt, E. S. (2013). *Biogeochemistry: An analysis of global change* (3rd ed.). Academic Press.

Smith, G. M. (1955). *Cryptogamic botany, Volume II: Bryophytes and pteridophytes*. McGraw Hill Book Company.

Sundberg, M. D. (2014). *Introduction to plant biology*. McGraw-Hill Education.

Taiz, L., & Zeiger, E. (2010). *Plant physiology* (5th ed.). Sinauer Associates.

Taylor, R. E., & Field, T. G. (2004). *Scientific farm animal production: An introduction to animal science* (8th ed.).

Vashishta, B. R., Sinha, A. K., & Kumar, A. (2006). *Botany for degree students: Bryophyta*. S Chand & Company.

Watson, J. D., Baker, T. A., Bell, S. P., Gann, A., Levine, M., & Losick, R. (2013). *Molecular biology of the gene* (7th ed.). Pearson Education.

Webster, J., & Weber, R. (2007). *Introduction to fungi*. Cambridge University Press.

Wetzel, R. G. (2001). *Limnology: Lake and river ecosystems* (3rd ed.). Academic Press.

W. J., & Lindner, H. (2014). *Physiology of the human kidney* (1st ed.). Springer.

World Health Organisation. (2023). *Immunisation, vaccines and biologicals*.

Zimmermann, M. H., & Jeje, N. S. (1981). *Xylem structure and the ascent of sap*. Springer.

GLOSSARY

A

Abdomen: the rear segment of an insect's body containing the digestive organs.

Abiotic: the non-living components of an ecosystem, such as water, temperature, light and minerals.

Actin: a protein that polymerises to form microfilaments, which form part of the cell structure involved in shape, movement and muscle contraction.

Active Immunisation: process of inducing immunity by introducing an antigen or vaccine, which stimulates the body's immune response.

Active transport: movement of molecules across a cell membrane from an area of lower concentration to an area of higher concentration, requiring energy.

Adipose tissue: a type of connective tissue that stores energy in the form of fat. Commonly called body fat.

Aerenchyma: a type of plant tissue that contains large air spaces, allowing for gas exchange and helping plants to survive in low-oxygen environments.

Algae: simple, non-flowering, eukaryotic organisms found in aquatic environments that are capable of photosynthesis.

Algal blooms: rapid growth and accumulation of algae in aquatic ecosystems, often caused by excess nutrients.

Allergy: an immune system response to a foreign substance that's not typically harmful to your body.

Amino acid: the building block of proteins, composed of a central carbon atom, an amino group, a carboxylic group and a side chain.

Anadromous: fish that migrate from saltwater to freshwater to spawn.

Annealing: the process by which two complementary DNA or RNA strands come together and form a double-stranded molecule.

Antennae: sensory organs on an insect's head used for detecting smells, sounds and other stimuli.

Antibodies: proteins produced by B-cells that recognise and bind to specific antigens to neutralise or remove them.

Antibodies: proteins produced by the immune system in response to the presence of foreign substances such as pathogens.

Anticodon: a sequence of three nucleotides on a tRNA molecule that is complimentary to a codon on an mRNA molecule.

Antiparallel strands: the two strands of DNA that run in opposite directions, with one strand oriented 5' to 3' and the other 3' to 5'.

Arachnids: a group of eight-legged animals including spiders, scorpions and ticks.

Asthma: a chronic respiratory disease characterised by recurring episodes of wheezing, airway obstruction, shortness of breath and coughing.

Atoll: a ring-shaped coral reef surrounding a lagoon often formed around a submerged volcanic island.

ATP (adenosine triphosphate): a molecule that serves as the primary source of energy for various cellular activities of cells.

ATP (adenosine triphosphate): a molecule that serves as the primary source of energy for various cellular activities of cells.

Attenuation: process of weakening a pathogen to reduce its virulence while maintaining its immunogenicity (its ability to trigger an immune response in an individual).

Auxin: a plant hormone that regulates cell elongation, cell division and differentiation.

B

B-cells: a type of white blood cell responsible for producing antibodies.

Bile: yellowish, green digestive fluid produced by the liver and stored in the gall bladder.

Bilirubin: a yellowish, orange compound that is produced during the breakdown of haem in the liver.

Biliverdin: greenish fluid that is produced during the breakdown of haem in the liver.

Biodiversity: the variety of different species of plants, animals and microorganisms that live in an ecosystem or on Earth.

Biopolymer: large molecules composed of many smaller subunits such as proteins, carbohydrates or nucleic acids.

Biotechnology: the use of biological systems, living organisms or material derived from them to develop new products and technologies.

Brackish: a mixture of fresh water from rivers or streams and saltwater from the ocean, typically found in estuaries, mangroves or river mouths.

Bromeliads: a family of tropical plants that grow on other plants or rocks.

Bronchioles: small branching airways in the lungs that lead to air sacs where gas exchange occurs.

Bronchitis: an inflammation of the larger airways (bronchi) in the lungs.

Bryophytes are small, non-flowering plants, such as mosses and liverworts. They usually grow in damp places and do not have true roots, stems, or leaves. They reproduce using spores instead of seeds.

Byssal: refers to the threads or filaments used by some animals, such as mussels and oysters, to anchor themselves to the surface.

C

Camouflage: a defence mechanism where animals blend into their surroundings, making it difficult for predators to spot them.

Canopy: the upper layer of a forest formed by the leaves and branches of trees.

Capping: a process of adding a modified guanine nucleotide to the 5' end of a messenger RNA (mRNA) molecule to protect it from degradation.

Carbon sequestration is a natural or artificial process by which carbon dioxide is removed from the atmosphere and held in solid or liquid form. Mosses are used to absorb high amounts of carbon in the atmosphere.

Cardiac: relating to the heart.

Castes: social classes within a colony of insects, such as worker bees and drones.

Catalyse: to speed up a chemical reaction without being consumed or altered in the process.

Cell motility: the ability of cells to move. Crucial for processes like wound healing, immune responses and development.

Cell wall: a rigid layer outside a cell membrane that provides support and protection.

Cellulose: a polysaccharide found in plant cell walls which provides structural support and protection.

Central vacuole: a large storage organelle found in plant cells.

Chitin: is a tough, flexible substance that makes up the cell walls of fungi and the exoskeletons of some animals, like insects and crustaceans. It helps provide structure and protection.

Chlorophyll: the green pigment found in chloroplasts that absorbs light energy for photosynthesis.

Chloroplast: an organelle found in plant cells responsible for photosynthesis.

Chrysalis: the pupal stage of a butterfly's life cycle.

Cob: the central part of an ear of corn(maize).

Cocoon: a protective covering around a pupa, often made of silk.

Codon: a sequence of three nucleotides in mRNA that specifies a particular amino acid during protein synthesis.

Colony: a group of organisms living together, often cooperating for mutual benefit.

Companion cells: specialised cells in plant leaves that assist sieve tube elements in transporting sugars, amino acids and other nutrients throughout the plant.

Complete metamorphosis: a biological process where an animal transforms a juvenile to an adult form through distinct stages of egg, larva, pupa and adult.

Compound eyes: large, complex eyes made up of many smaller lenses, which give insects a wide-angle vision.

Concentration gradient: the gradual change in the concentration of a substance across a given area or space.

Connective tissue: one of the four main types of tissue in the body that plays a crucial role in supporting, binding, and protecting other tissues and organs.

Contagious: a disease or condition that can be spread from person to person through physical contact, air or other means.

Corbiculae: a type of freshwater clam.

Cultural control method: a technique used to manage pests or diseases, which involves modifications to agricultural practices or the environment.

Cytokines: are signalling molecules that help in cell-to-cell communication, influencing cell behaviour, growth and differentiation in immune responses.

Cytokinin: a class of plant hormones that promote cell division, growth and differentiation.

Cytology: the study of cell structure, function and behaviour.

Cytosine: a nitrogenous base found in DNA and RNA.

D

Deamination: a chemical reaction that involves the removal of an amino group from a molecule.

Degenerate: the redundancy of the genetic code, where more than one codon sequence can code for the same amino acid.

Deserts: dry and often hot ecosystems with limited vegetation and rainfall.

Desiccation: the process of drying out moisture to preserve organisms or tissues.

Detoxification: the process by which the body removes toxic substances such as poisons, pollutants and waste products.

Detritivores: organisms that feed on dead and decaying plant and animal matter.

Detritus: dead and decaying plant and animal matter.

Dialysis: a medical treatment that is used to remove waste products and excess fluid from the blood when the kidneys are no longer able to do so effectively.

Diaphragm: a dome- shaped muscular sheet that separates the chest cavity from the abdominal cavity.

Differentiation: process by which a cell becomes specialised in structure and function to perform a specific role.

Diffusion: movement of particles from an area of higher concentration to an area of lower concentration.

Diploid (2n) cell: one that has two sets of chromosomes, one from each parent. This means it has the full set of chromosomes.

DNA (deoxyribonucleic acid): a molecule containing genetic instructions for an organism.

DNA ligase: an enzyme that seals gaps between DNA fragments by forming phosphodiester bonds.

DNA polymerase: an enzyme responsible for adding nucleotides to a growing DNA chain during replication and repair.

DNA primase: an enzyme that synthesises RNA primers during DNA replication.

Double helix: the spiral shape of DNA, consisting of two complementary strands twisted together.

Drones: male bees, responsible for mating with the queen.

E

Ecdysis: another term used to describe the process of moulting.

Ecosystem: a community of living organisms, including plants, animals and microorganisms interacting with each other and their environment.

Efficacy: ability of treatment, intervention or product to produce the desired outcome or result.

Electrolytes: electrically charged minerals such as sodium and potassium.

Ellipsoidal: refers to a shape that resembles an ellipse or elongated sphere, often used to describe the shape of cells or organs.

Elongation: the stage during translation or transcription where the protein chain is lengthened by adding nucleotides or amino acids.

Emergent: trees or plants that rise above the canopy of a forest.

Emulsify: the process of breaking down fat into smaller droplets, making them more accessible to enzymes.

Endocrine: a system of glands that produce and secrete hormones directly into the bloodstream to regulate various bodily functions.

Endocytosis: process by which cells take in substances by engulfing them with their cell membrane.

Endosome: membrane–bound compartments that form when a vesicle fuses with a lysosome, containing digestive enzymes.

Enzyme: a biological molecule that speeds up chemical reactions in living organisms.

Epidermal: relating to the outermost layer of cells in a plant or animal.

Epiphytes: plants that grow on other plants such as plants such as trees, without harming them.

Estuary: a partially enclosed coastal body of water where freshwater from rivers and streams mixes with saltwater from the ocean.

Eukaryotic: relating to cells with a true nucleus and other membrane-bound organelles.

Eutrophication: excessive growth of algae and plants in a water body due to an overabundance of nutrients.

Exocytosis: process by which cells release substances to the outside by fusing vesicles with the cell membrane.

Exons: coding DNA sequences within a gene that are retained and expressed in the final RNA molecule.

Exoskeleton: a hard, outer covering that provides protection and support for an organism, such as the cuticle of an insect.

F

Faceted: having many different aspects, features or perspectives.

Facilitated diffusion: the process by which molecules move across cell membranes with the assistance of transport proteins without requiring energy.

Fauna: the animals of a particular region or period.

Fixing nitrogen: the process by which certain organisms convert atmospheric nitrogen into a usable form for other living organisms.

Flagellates: microorganisms with whip-like structures (flagella) used for movement.

Flagellum: a whip-like structure found on some cells, such as sperm or bacteria, that provides motility.

Flora: the plants of a particular region or period.

Follicles: a small secretory cavity, sac, or gland. Follicles are found in various parts of the body and serve different functions depending on their location.

Fumigation: the process of using smoke or gas to kill pests, often in agricultural or indoor settings.

G

Genome: refers to the complete set of genetic information encoded in an organism's DNA.

Gibberellins: a class of plant hormones that promote cell elongation, seed germination and stem growth.

Groundwater: water stored beneath the earth's surface in soil, rock and aquifers which can be accessed through wells, springs or other sources.

Guanine: a nitrogenous base found in DNA and RNA.

Guard cells: specialised cells that surround stomata on leaves and regulate gas exchange and water loss by opening or closing the stomata.

H

Haem: a molecule containing iron which is found in haemoglobin, myoglobin and other haemoproteins.

Haemoglobin: a protein in red blood cells that carries oxygen from the lungs to the body's tissues.

Halteres: small, club-shaped structures replacing hind wings in certain insects, like houseflies.

Haploid (n) cell: is a cell that has only one set of chromosomes, which is seen in the stage where spores are produced.

Helical: the spiral shape of the DNA double helix.

Helicase: an enzyme that unwinds double-stranded DNA into single strands by breaking the hydrogen bonds between the nucleotide bases.

Herd immunity: protection of a population from an infectious disease when a sufficient percentage of individuals are immunised, thereby preventing the spread of the disease.

Homeostasis: the ability of the body to maintain a stable internal environment despite changes in external conditions.

Hormones: chemical messengers produced by glands in the endocrine system that regulate various bodily functions such as growth and reproduction.

Hormones: chemical messengers produced by glands in the endocrine system that regulate various bodily functions such as growth and reproduction.

Hyphae are the thread-like structures that make up the body of fungi.

Hypertension refers to high blood pressure, a medical condition where the blood pressure in the arteries is persistently elevated.

Hydrophilic: a substance or surface that has an affinity for water.

Hydrophobic: a substance or surface that repels or resists water.

Hydroxyl: a functional group (-OH) consisting of an oxygen atom bonded to a hydrogen atom.

I

Imago: the adult stage of an insect's life cycle.

Immunisation: a process of making an individual resistant to a specific disease by introducing a vaccine into the body.

Immunogens: substances that trigger an immune response, often used interchangeably with antigens.

Inoculation: introduction of a pathogen or antigen into an individual's body to induce immunity.

Insecticides: chemical substances used to control or kill insects.

Instar: a stage in an insect's growth and development between moults.

Initiation: the first stage of transcription or translation where the process begins, and the RNA polymerase or ribosome binds to the DNA or mRNA.

Initiator proteins: proteins that bind to specific DNA sequences to initiate DNA replication.

Interphase: the longest stage of the cell cycle, during which the cell grows, replicates its DNA and prepares for cell division.

Introns: non-coding DNA sequences within a gene that are removed during RNA splicing.

Invagination: the process of folding inward of a cell membrane, which can lead to the formation of vesicles or organelles.

K

Kidney transplant: a surgical procedure where a healthy kidney from a living or recently deceased donor is placed in a person whose kidneys are no longer functioning properly.

L

Lagging strand: one of the two strands of DNA synthesised in short, discontinuous segments (Okazaki fragments) during DNA replication.

Lagoon: a shallow body of water separated from the ocean by a barrier such as a sandbar.

Larva: the juvenile stage of an animal, usually different from the adult form, such as the caterpillar (larva) of a butterfly.

Lesion: a region in an organ or tissue that has suffered damage due to injury or disease.

Liane's: long, woody vines grow in tropical forests.

Lichens: composite organisms consisting of fungi and algae living together in a symbiotic relationship.

Ligase: an enzyme that seals gaps in DNA strands by forming phosphodiester bonds between nucleotides.

Limnetic: open water area of a lake or pond, away from the shore and bottom.

Littoral: area near the shore where the water is shallow, and plants and animals are adapted to survive in a changing environment.

M

Macrophages: a type of immune cell that engulfs and digests foreign particles.

Mangroves: a type of coastal ecosystem characterised by dense stands of mangrove trees, which thrive in salty, low-oxygen conditions.

Manure is a decomposed organic matter typically from animal waste that is used as a natural fertiliser to enrich the soil.

Memory cells: specialised immune cells that remember specific pathogens and enable a quick response upon future infections.

Mesothorax: the mid-segment of the thorax which bears a pair of wings and a pair of walking legs.

Metamorphosis: a biological process where an animal transforms from a juvenile to an adult form.

Metathorax: the last segment of the thorax just before the abdomen, bearing a pair of wings and walking legs.

Migration: seasonal or permanent movement of animals from one region to another in search of food, shelter or breeding grounds.

Mitochondria: a membrane-bound organelle found in eukaryotic cells that generates energy for the cell through cellular respiration.

Monomer: a small molecule that can be linked to other monomers to form a polymer.

Moulting: the process of shedding and replacing an animal's skin, exoskeleton or other outer covering to allow growth.

mRNA (messenger RNA): a type of RNA that carries genetic information from DNA to the ribosome for protein synthesis.

Mycelium is a mass of interconnected hyphae that forms the main body of a fungus. It grows underground or within its food source, helping the fungus to absorb nutrients.

N

NADP: nicotinamide adenine dinucleotide phosphate, a coenzyme found in all living cells, which plays a crucial role in various metabolic processes, including energy production.

Nephron: the functional unit of the kidney, responsible for filtering waste and excess fluids from the blood and regulating electrolyte levels.

Neurons: specialised cells that transmit and process information through electrical and chemical signals.

Neurotransmitter: chemical messenger released by neurons to transmit signals to other neurons, muscles or glands.

Nitrogenous base: one of the four chemical bases that make up DNA and RNA.

Nocturnal: active at night, often refers to animals that sleep during the day and are awake during the night.

Nonsense codon: a codon that does not code for any amino acid.

Nucleic acids: a class of biomolecules that include DNA and RNA.

Nucleotide: the building block of nucleic acids, composed of a sugar, phosphate and nitrogenous base.

O

Okazaki fragments: short, discontinuous DNA segments synthesised on the lagging strand during DNA replication.

Organic: compounds containing carbon and hydrogen atoms.

Organic matter: materials derived from living organisms such as plants and animals.

Osmoregulation: the process by which an organism regulates the balance of water and salts within its body.

Osmoregulatory: the ability of an organism to regulate its internal osmotic pressure in response to changes in the external environment.

Osmosis: movement of water molecules through a selectively permeable membrane from an area of higher concentration to an area of lower concentration.

P

Palisade mesophyll: a layer of cells in a plant leaf responsible for photosynthesis.

Parasitic: organisms that live on or inside another organism(host) and feed on its tissues or fluids, causing harm to the host.

Passive immunisation: the transfer of pre-formed antibodies from one individual to another, providing temporary immunity.

Pathogen: a microorganism that causes disease in an individual.

Pathogens: microorganisms such as bacteria, viruses or fungi that cause disease in humans, animals or plants.

Pentose sugar: a type of simple sugar with five carbon atoms.

Pesticides: chemical substances used to control or kill pests, including insects, weeds and diseases.

Phagocytosis: a type of endocytosis where cells engulf and digest foreign particles.

Pheromone: a chemical signal released by an individual that elicits a response in other members of the same species.

Phloem fibres: type of cells found in the phloem tissues of plants which provide support, strength and rigidity to the plant stem.

Phloem parenchyma: a type of cell found in the phloem tissue of plants, which is responsible for storing and transporting nutrients such as sugars.

Phosphate group: a molecule composed of phosphorus and oxygen atoms, which forms part of the backbone of DNA and RNA.

Phosphodiester bond: a chemical bond between two nucleotides, formed by a phosphate group linking the sugar molecules.

Phospholipids: a class of lipids that contain a phosphate group, often found in membranes.

Phospholipid bilayer: a double layer of phospholipid molecules that makes up the structure of cell membranes.

Phytoplankton: microscopic plant-like organisms that drift in oceans and freshwater bodies.

Pigment: a coloured substance produced by cells or organisms.

Pinocytosis: type of endocytosis where cells take in liquids and dissolved substances.

Plankton: small, usually microscopic organisms that drift in oceans and freshwater bodies.

Pneumatophores: specialized roots that grow above the water surface to allow plants, particularly mangroves, to breathe in low-oxygen environments. It is commonly called breathing roots.

Pneumonia: an inflammatory infection of the air sacs in the lungs.

Polyadenylation: process of adding a long sequence of adenine nucleotides to the 3’ end of a messenger RNA (mRNA) molecule to protect it from degradation and aid in translation.

Polymerase: an enzyme responsible for adding nucleotides to a growing DNA and RNA chain during replication, repair or transcription.

Polymeric: large molecules composed of many smaller subunits.

Polynucleotides: long chains of nucleotides, such as DNA or RNA.

Polypeptide: chain of amino acids linked by peptide bonds, which can fold into a protein.

Pothos: a type of climbing plant with heart-shaped leaves.

Precipitation: the formation of water droplets in the atmosphere that fall to the earth's surface such as rain.

Predator: organisms that hunt and feed on other organisms.

Prehensile: a tail or other appendage that can grasp or hold unto objects.

Pressure gradient: the rate of change of pressure across a given area or space.

Primase: an enzyme responsible for adding RNA primers unto a template strand during DNA replication.

Primers: short DNA or RNA sequences that provide a starting point for DNA synthesis during replication.

Proboscis: a long, flexible tube used by some insects for feeding.

Processing: the modification of RNA transcripts after transcription, which includes splicing, capping and polyadenylation.

Profundal: the deepest part of a lake or pond, where the water is cold and dark, and few organisms can survive.

Prokaryotic: relating to cells without a true nucleus and other membrane-bound organelles.

Promoter region: a specific DNA sequence where RNA polymerase binds to initiate transcription.

Pronotum: the dorsal(upper) surface of an insect's thorax, often forming a shield-like structure.

Propolis: a mixture of wax and plant resin used by bees to seal and repair their hives.

Prothorax: the first and largest segment of the thorax which bears a pair of walking legs.

Proton pump: a transport protein that pumps protons across a cell membrane.

Protoctista: a group of eukaryotic microorganisms, including algae.

Pteridophytes: are a group of vascular plants that reproduce using spores, including ferns and horsetails. They have true roots, stems, and leaves, which help them grow larger and more complex.

Pupa: a non-feeding resting stage in the life cycle of some animals, such as the chrysalis stage of the butterfly.

R

Replication: the process by which DNA is copied during cell division.

Replication forks: a region where the DNA double helix is unwound and separated into two strands during DNA replication.

Ribosomes: complex cellular organelles responsible for translating mRNA into proteins.

RNA (ribonucleic acid): a molecule involved in protein synthesis, regulation and other cellular processes.

RNA primers: short RNA sequences that provide a starting point for DNA synthesis during replication.

Root hair: a specialised cell on a plant root that increases the surface area for water absorption.

Rostrum: a beak-like or snout-like structure often found in insects, fish or other animals.

rRNA (ribosomal RNA): a type of RNA that makes up a large part of the ribosome.

S

S phase: also known as the synthesis stage, the stage of the cell cycle during which DNA replication occurs.

Savannah: a grassland ecosystem with scattered trees.

Segmented: divided into repeating parts or sections, often found in animal bodies such as insect exoskeletons or the bodies of worms.

Sequestration: process of capturing, storing or isolating a substance, often to prevent its release into the environment.

Seta: a stalk produced by a gametophyte which bears a capsule with a cap called a calyptra.

Sieve tubes, also known as sieve elements, are specialised cells in plants that facilitate the transport of nutrients throughout the plant.

Skeletal: relating to the skeleton or bones.

Smooth muscle: a type of muscle that is involuntary, meaning it is not under conscious control.

Sodium–potassium pump: a transport protein that moves sodium ions out of a cell and potassium ions into a cell using energy from ATP.

Spongy mesophyll: a layer of cells in a plant leaf responsible for gas exchange and photosynthesis.

Sporangium: is a capsule or sac where spores are produced in plants and fungi. It releases spores into the environment for reproduction.

Stomata: small openings on a plant leaf that allow for gas exchange.

Stratified epithelial cells: a type of epithelial tissue composed of multiple layers of cells. This structure protects against physical and chemical wear and tear.

Sublittoral: area between the littoral zone, where the water is deeper, and plants and animals are adapted to survive in a more stable environment.

Succulent: a plant adapted to store water in its leaves, stem or roots.

Supralittoral: area above the high tide mark where plants and animals are adapted to survive in a harsh, salt-spray or marine environment.

Sweat glands: small tubular glands found in the skin of mammals.

Swim bladder: an internal gas-filled organ that helps fish maintain their buoyancy and balance in the water.

T

Taproot: a primary root that grows straight down into the soil, anchoring the plant and absorbing water and nutrients.

T-cells: a type of white blood cell that plays a central role in cell-mediated immunity.

Tectonic glaciation: the study of the Earth's crust and the formation and movement of large, slow-moving rivers of ice and snow formed on land over time.

Termination: the conclusion of transcription or translation, where the process is stopped, and the final product is released.

Termination sequences: specific DNA sequences that signal the end of transcription, leading to the termination of RNA synthesis.

Thermophiles: organisms that thrive in extremely hot environments.

Thermoregulation: the ability of an organism to regulate its body temperature despite changes in external temperature.

Thorax: the middle segment of an insect's body bearing the legs and wings.

Thylakoid membranes: structures found in chloroplasts in plant cells, which contain pigments like chlorophyll.

Thymine: a nitrogenous base found in DNA, where it is replaced by uracil in RNA.

Tissues: groups of similar cells that work together to perform specific functions in an organism.

Toxins: poisonous substances produced by living organisms such as bacteria, plants or animals.

Toxoid: a toxin that has been modified to be non-toxic but still induces an immune response, often used in vaccines.

Transcribed: process of creating a complementary RNA molecule from a DNA template.

Transcription: a process of creating a complementary RNA molecule from a DNA template.

Translocation: movement of material such as sugars and amino acids from one part of a plant to another through the phloem tissue.

Translation: a process of creating protein from an mRNA molecule.

Transpiration: the process by which water is transported through a plant from the roots to the leaves.

tRNA (transfer RNA): A type of RNA that brings amino acids to the ribosome during protein synthesis.

Tubulin: a protein that polymerises to form microtubules, which are part of the cytoplasm's components that provide structure, shape and play a role in cell division.

Turgid: the state of a plant cell that is swollen and rigid due to the uptake of water.

U

Ultrafiltration: the process that uses a semipermeable membrane to separate particles from a solution based on their size.

Understory: the layer of vegetation below the canopy of a forest.

Uracil: a nitrogenous base found in RNA where it replaces thymine.

Urbanisation: the process of people moving from rural areas to cities, resulting in the growth and development of urban areas.

Universal: the consistency of the genetic code across different organisms.

V

Vaccination: the act of administering a vaccine to an individual to provide immunity against a specific disease.

Vacuole: a storage organelle found in cells.

Vesicle: small, membrane-bound sac that transports substances within a cell.

Vines: plants that climb or twine around other plants or structures.

Voluntary: relating to muscles that can be controlled consciously.

W

Wing cases, also referred to as elytra, are the hardened protective covers of an insect's wings, often found in beetles.

Worker bee: a female bee that performs tasks such as foraging and caring for young members.

This book is intended to be used for the Year Two Biology Senior High School (SHS) Curriculum. It contains information and activities to support teachers to deliver the curriculum in the classroom as well as additional exercises to support learners' selfstudy and revision. Learners can use the review questions to assess their understanding and explore concepts and additional content in their own time using the extended reading list provided.

All materials can be accessed electronically from the Ministry of Education's Curriculum Microsite.

[Scan the QR Code to visit the website]

Ghana Education Service (GES)