MINISTRY OF EDUCATION

GHANA ASSOCIATION OF SCIENCE TEACHERS

BIOLOGY

for Senior High Schools

Year 3



Writers

Jo-Ann Naa Deedei Neequaye

Gloria Naa Deedei Nartey

Reviewer

Rev. Joseph Kweku Delanyo

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Ghana Education Service (GES)

(GAST)



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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 Pre-Tertiary Teachers Association of Ghana-PRETAG) 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 A SCIENCE OF LIFE



BIOLOGY AND ENTREPRENEURSHIP

INTRODUCTION

In Year 3, learners dive into biotechnology and its link with entrepreneurship, especially within Ghana's unique setting. This lesson opens their eyes to how biological principles can help create local solutions—from nutritious food to clean energy—that improve lives and protect the environment. With agriculture as the backbone of Ghana's economy, crops like maize and cassava are more than just food; they're powerful resources for innovation. Beyond farming, biotechnology is being used in areas like biofuel production, offering cleaner energy options. These locally driven initiatives spark jobs for both young and old, encourage research, and even open doors to bigger industrial opportunities. Altogether, they help strengthen the economy, broaden market access, and uplift the quality of life across communities.

KEY IDEAS

- Biotechnology can create jobs and boost economic growth in Ghana.
- Biotechnology offers solutions for making biofuels, treating water and extracting minerals in an eco-friendly way.
- Ghana's rich resources, like maize and cassava, provide a solid foundation for using biotechnology.
- Local biotechnological products improve lives and protect the environment.
- The process of fermentation is applied in the production of traditional foods like kenkey and Pito.

BIOLOGICAL PRINCIPLES APPLIED IN THE PREPARATION OF SOME LOCAL FOODS AND BEVERAGES

What Is Food Biotechnology?

Food biotechnology involves using living organisms (microorganisms) or biological processes to create or improve the foods we eat. In Ghana, many traditional foods and drinks—such as kenkey, Banku, Pito, and Palm wine have been made using these natural methods for many years, even before people knew the science behind them.

Microorganisms are very important in food processing. They help by:

a. changing carbohydrates (starches and sugars) into other useful substances
b. producing flavour in food
c. preserving food by making acids or alcohol
d. improving the texture (feel and look) of food
e. adding more nutrients to food

Traditional Ghanaian food preparation methods are part of our indigenous knowledge. They were developed through observing and experimenting over time. This knowledge was passed down through generations and often matches modern scientific ideas. These practices are examples of biotechnological innovations specific to our culture.

Principles and Types of Fermentation

Fermentation is a natural process where sugars (carbohydrates) are broken down by microorganisms to form acids, alcohol, or gas. This mostly happens in places without oxygen (anaerobic conditions). Different kinds of fermentation are used to make various foods.

Table 1.1: Types of fermentation

Type of Fermentation	What It Does	Examples
Lactic Acid Fermentation	Turns sugars into lactic acid	Kenkey, Banku
Alcoholic Fermentation	Turns sugars into alcohol and carbon dioxide (CO_2)	Pito, Palm wine
Acetic Acid Fermentation	Turns alcohol into acetic acid (vinegar)	Vinegar production
Alkaline Fermentation	Creates alkaline conditions	Dawadawa

Here are the chemical paths for each type

a. ***Lactic Acid:*** Glucose → 2 Pyruvate → 2 Lactic Acid + Energy (2 ATP)

b. ***Alcoholic:*** Glucose → 2 Pyruvate → 2 Ethanol + 2 CO_2 + Energy (2 ATP)

c. ***Acetic Acid:*** Ethanol + Oxygen (O_2) → Acetic Acid + Water (H_2O)

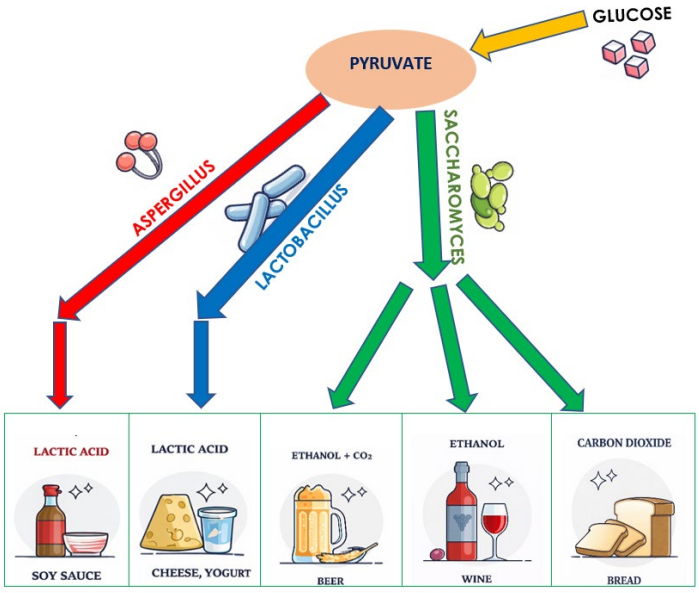


Figure 1.1: Types of microbial fermentation from pyruvate and their associated food products

Microorganisms Used in Ghanaian Fermented Foods

Various microorganisms are used to make our local fermented foods.

Bacteria

1. Lactic Acid Bacteria, e.g., Lactobacillus plantarum, Lactobacillus fermentum, Pediococcus sp.
2. Acetic Acid Bacteria, e.g. Acetobacter, Gluconobacter
3. Bacillus, e.g. Bacillus subtilis (used in Dawadawa)

Yeasts, e.g. Saccharomyces cerevisiae (used in Pito and palm wine), Candida species, Pichia species

Moulds e.g. Aspergillus species, Penicillium species

Factors That Affect Fermentation

Fermentation is controlled by several important factors.

Temperature

1. Temperature affects how quickly microbes grow and how active enzymes are.
2. Each microbe works best within a specific temperature range—usually between 25°C and 40°C.
3. Traditional fermentation methods rely on the natural temperature of the environment.

pH Level (Acidity or Alkalinity)

1. pH affects which microbes can survive and grow.
2. Most fermentation processes begin near neutral pH (around pH 7).
3. Lactic acid fermentation becomes quite acidic (around pH 3.5–4.5).
4. Alcoholic fermentation often ends up around pH 4.0–5.0.

Oxygen Availability

Whether oxygen is present or not decides the type of fermentation.

1. Lactic acid and alcoholic fermentation need anaerobic conditions (no oxygen).
2. Acetic acid fermentation happens in the presence of oxygen.

Substrate Composition

1. The type and amount of nutrients in the food material (substrate) affect microbial activity.
2. The kind of carbohydrate present influences the final product.
3. Proteins and minerals in the substrate help develop flavour and texture.

Nutrient Availability

1. Nutrients help microbes grow well.
2. Controlling nutrients can be used to manage the fermentation process.

Microbial Succession in Fermentation

Natural fermentation happens in stages, where different microbes appear at different times.

1. *Initial Phase:* Fast-growing microbes that can survive the early conditions (e.g., neutral pH and low alcohol).
2. *Middle Phase:* Microbes that grow as the environment changes—like when acidity or alcohol levels increase.
3. *Final Phase:* Microbes that complete the fermentation, improving the taste, texture, and quality of the food.

Common examples of fermented indigenous/local foods

Kenkey

Kenkey is a popular Ghanaian dish made from fermented corn dough, which is cooked in either corn husk or plantain leaves and often served with a variety of accompaniments, the most common of all being hot pepper and fried fish. The origin of kenkey is traced to the Ga people of Ghana.

The main ingredients used in preparing kenkey are corn dough, salt and water. Sometimes additional ingredients such as sugar and spices may be added depending on one's taste preferences.



Figure 1.2: Ga Kenkey being moulded

Preparation steps

a. Corn preparation: Corn is soaked in water for about 2-3 days, then milled and mixed with water to form a dough.

b. Fermentation: The dough is allowed to ferment for a few days, which gives kenkey its unique flavour and texture.

c. Dough preparation: A portion of the fermented dough is cooked and later mixed with a portion of the uncooked fermented dough; this is kneaded and divided into portions.

d. Wrapping: The portions are wrapped in corn husks (Ga kenkey) or plantain leaves (Fante kenkey)

e. Cooking: The wrapped kenkey is boiled or steamed until thoroughly cooked.

Biological principles in kenkey production

The production of kenkey involves several biological principles, as listed below.

a. Fermentation: microorganisms such as lactic acid bacteria (LAB) and yeast ferment the corn dough, producing lactic acid and other compounds in the process. This gives kenkey its characteristic flavour and texture. Some common LAB species involved in kenkey fermentation include Lactobacillus sp and Enterobacteriaceae. Yeast species involved in fermentation include Saccharomyces sp and Candida sp.

b. Microbial activity: LAB and other microbes break down complex carbohydrates, proteins and other compounds in the corn, which creates new flavour and texture.

c. pH reduction: the production of lactic acid during fermentation lowers the pH from around 6.0-6.5 to 3.5-4.5. This creates an acidic environment which inhibits the growth of pathogens and microorganisms that cause food spoilage.

d. Biochemical reactions: enzymes and microorganisms catalyse biochemical reactions. For example, enzymes such as amylase break down starch, and proteases break down proteins. Other compounds are also produced, which contribute to the flavour and texture of kenkey, as mentioned earlier

Nutritional value of kenkey

Kenkey is a good source of several nutrients, including carbohydrates, protein, vitamins (particularly vitamin B) and fibre. It also contains potassium, magnesium and phosphorus; these nutrients are required for growth and metabolic processes in the body.

Yoghurt production

Yoghurt is a dairy product made by adding bacterial cultures to milk, which ferment the lactose (milk sugar) and produce lactic acid. This process thickens the milk and gives yoghurt its characteristic texture and tangy flavour. Yoghurt can be made from various types of milk such as cow's, goat's or sheep's milk, and can be flavoured, sweetened or fortified with additional ingredients. The raw materials or ingredients used in yoghurt production are milk (whole, low-fat or non-fat), starter culture (a blend of bacteria,

typically *lactobacillus* and *streptococcus,* which initiate fermentation. Optional ingredients may include sugar or sweeteners, flavours (e.g. fruits and vanilla), thickeners (e.g. gelatin and pectin) and probiotic cultures (beneficial bacteria). Originally not Ghanaian, but they have become popular over the years.

Preparation steps

a. Milk preparation: the milk is first heated and sometimes fortified with milk solids or other ingredients.

b. Pasteurisation (Heat Treatment): Before homogenisation, the milk is pasteurised, which means it is heated to a high temperature (typically around 85–95°C for 15–30 minutes in yoghurt production — a higher heat treatment than standard drinking milk).

c. Homogenisation: The process of forcing milk through a very small nozzle or valve under high pressure. This breaks down the fat globules in the milk into much smaller, uniformly sized droplets.

d. Culture addition: a yoghurt starter culture containing live bacteria (Lactobacillus bulgaricus and Streptococcus thermophilus) is added to the milk.

e. Incubation: the milk mixture is incubated at a warm temperature, allowing the bacteria to ferment the lactose and produce lactic acid.

f. Fermentation: the bacteria convert the milk sugar (lactose) into lactic acid, causing the milk to curdle and thicken.

g. Cooling and packaging: after fermentation, the yoghurt is cooled and packaged for distribution.

Biological processes in Yoghurt production

The production of yoghurt involves several biological processes, which are mentioned below.

a. **Fermentation:** the process by which microorganisms (*Lactobacillus bulgaricus* and Streptococcus thermophilus) convert lactose to lactic acid.

b. Microbial metabolism: the bacteria in the starter culture metabolise lactose, producing lactic acid and other compounds that contribute to yoghurt's texture and flavour.

c. Enzymatic activity: enzymes produced by the bacteria break down milk proteins and fats, which contribute to yoghurt's texture and flavour.

d. Symbiotic relationship: the two bacterial species in the starter culture work together, with Streptococcus thermophilus creating an environment that favours the growth of Lactobacillus bulgaricus.

These biological processes work together to transform milk into yoghurt, thereby creating its characteristic texture, flavour and potential health benefits.

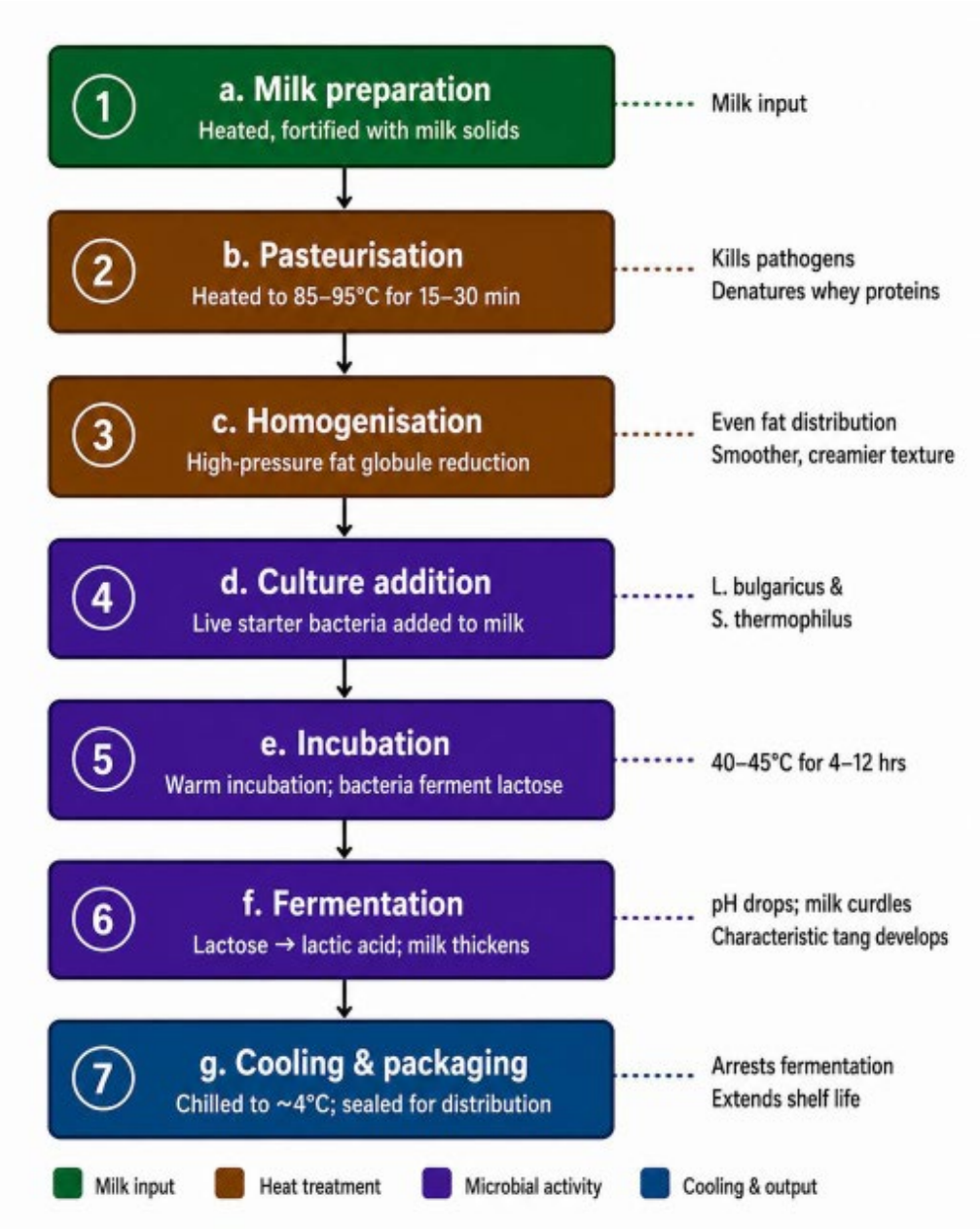


Figure 1.3: Steps involved in Yoghurt production

Nutritional value and benefits of yoghurt

Yoghurt is a nutrient-rich food that provides;

a. high-quality proteins which support muscle growth and repair.
b. calcium, vitamins, and minerals which are essential for bone health and overall development.
c. probiotics which support gut health, immune system function and digestive health.

Consuming yoghurt may also support weight management due to protein and fibre content.

Pito production

Pito is a traditional Ghanaian alcoholic beverage made from fermented millet or sorghum. It is locally brewed and slightly sour or sweet depending on the length of fermentation. It is an integral part of Ghanaian culture and originates from the northern part of Ghana, where it is widely consumed at social gatherings, ceremonies and celebrations.



Figure 1.4: Brewed Pito in a calabash

The raw materials and ingredients used in Pito production are millet or sorghum, water, yeast or a fermentation starter, and optional ingredients such as herbs or spices to flavour the Pito.

Steps involved in the production of Pito

a. *Malting:* the millet or sorghum grains are soaked in water to initiate germination and then dried to stop the process.

b. *Milling:* the malted grains are ground into flour.

c. Mashing: the flour is mixed with water to create a mash, thereby extracting the sugars.

d. *Fermentation:* allowing the mash to ferment for 12 - 24 hours. This converts the sugars into alcohol and develops the flavour.

e. *Filtering:* the fermented liquid is strained to remove solids.

f. *Secondary fermentation (optional):* this process helps to develop the flavour further.

Biological processes in Pito production

The production of Pito involves several biological principles, which are mentioned below.

a. **Germination:** Germination is a key part of the malting process, where soaked grains germinate, causing enzymes to be activated to break down starches.
b. **Enzymatic activity:** enzymes break down starches into sugars (maltose) that can be fermented during mashing.
c. **Fermentation:** Microorganisms (yeast and bacteria) convert sugars (glucose) into alcohol (ethanol), carbon dioxide and other compounds, which helps to develop the flavour of Pito.

These biological processes work together to transform the raw materials into the final product, Pito.

Nutritional value and benefits of Pito

a. The probiotics in Pito support the health of the digestive system
b. Pito is a good source of carbohydrates, which provide energy.
c. It contains trace minerals like potassium, iron and zinc.

Note: Caution should be exercised when consuming pito, as it is an alcoholic beverage. It should be consumed in moderation, and you must be 18 years or older to drink it.

Asana (Asaana) Production

Asana is a traditional Ghanaian non-alcoholic beverage originating from the Volta Region of Ghana. It is made from fermented corn and caramelised sugar, which gives it a unique caramel flavour and sweetness. It is also known as “ale-wonyo” or “Liha” in some parts of Ghana. Asana is a popular drink enjoyed for its refreshing qualities and cultural significance.

The raw materials or ingredients used in producing Asana are corn, sugar and water. Optional ingredients may include spices such as cinnamon, nutmeg or ginger for added flavour.

Steps involved in the production of Asana

a. *Soaking and fermentation:* the corn is soaked in water to initiate fermentation.
b. *Milling or grinding:* the fermented corn is milled or ground into a flour or paste.
c. *Boiling:* the corn paste or flour is boiled with water to create a liquid mixture.
d. *Caramelisation:* sugar is caramelised (heated till it turns brown or golden brown) to create a rich, sweet flavour.
e. *Mixing:* the boiled corn mixture and caramelised sugar are combined.
f. *Filtering:* the mixture may be filtered to achieve the desired consistency.
g. Asana is cooled and served chilled with or without milk.



Figure 1.5: Asana, chilled with ice blocks

Biological principles involved in the production of Asana

a. **Fermentation:** microorganisms break down corn starches into simpler compounds, contributing to flavour and texture.

b. **Enzymatic action:** enzymes which are naturally present in the corn or produced during fermentation help break down complex molecules.

These biological processes enhance the nutritional value, flavour and overall quality of Asana.

Nutritional value and benefits of consuming Asana

These include:

a. A carbohydrate which is a source of energy.

b. probiotics which support gut health.

c. minerals such as iron, zinc or potassium which support proper functioning of the body.

Pasteurisation

Principle and its Applications

Pasteurisation is a preservation process that kills harmful microorganisms in liquids, such as beverages, through heat treatment. The principles involve heat application (heating the liquid to a specific temperature for a period) and microbial inactivation (cell membranes of microbes are disrupted and their proteins denatured due to the heat treatment). The process of pasteurisation is widely used in various industries, including food and beverages, pharmaceuticals and in the sterilisation of medical equipment.

Biological Principles of Pasteurisation

The biological principles of pasteurisation involve:

1. **Denaturing of proteins:** heat disrupts protein structures and inactivates enzymes.
2. **Disruption of cell membranes:** heat damages microbial cell membranes, leading to loss of microbial cell function and viability.
3. **Inactivation of microorganisms:** heat kills or inactivates microorganisms, including bacteria (e.g. *Salmonella, E. coli and Listeria)*, viruses and other pathogens.

Factors Affecting Pasteurisation

1. Temperature: high temperatures generally increase the rate of microbial inactivation but may also affect the quality of the product.
2. Time: longer exposure to heat can increase the effectiveness of pasteurisation.
3. Type of microorganism: Different microorganisms have varying levels of heat resistance.
4. pH level: The acidity or alkalinity can influence microbial heat resistance.
5. Product composition: the presence of solids, fats or other components can affect heat transfer and microbial inactivation.
6. Microbial Density/Load: the higher the microbial load, the more intense the process of pasteurisation.

Pasteurisation Methods

1. High Temperature Short Time (**HTST**): heating to about 72oC for about 15 seconds.
2. Low-Temperature Long-Time (**LTLT**): heating to about 65oC for about 30 minutes. It may also involve the traditional batch method.
3. Ultra-High Temperature (**UHT**): This heats between 135 °C and 150 °C for 1-5 seconds and produces a commercially sterile product.

Steps Involved in Pasteurisation

The steps involved in pasteurisation are summarised as follows

1. Pre-heating: the product to be pasteurised is heated to the desired temperature.
2. Holding: the product is maintained at the pasteurisation temperature for a specified time
3. Cooling: The product is cooled to a temperature suitable for packaging or further processing.

Additional steps may include pre-treatment (such as filtration and standardisation) and packaging.

Activity 1.1 Science in Our Homes

Objective: Learn how biological processes like fermentation and enzyme activity are used to make traditional Ghanaian foods such as Kenkey, Pito, yoghurt, dawadawa, bread, etc.

Materials: Notebook, Pen, pencils, cardboard, coloured pencils (optional)

Instructions: Choose a Local Food, e.g. Kenkey, Pito, yoghurt, Dawadawa.

1. Find out how the food is prepared at home or by a vendor.
2. Identify the main biological process involved in the production of the food.
3. Identify and note down any other biological processes.
4. Write down the:
   a. ingredients used?
   b. what steps are followed in making the food?
   c. the changes that occur during the production of the food and how it affects the quality of the food?
   d. role microorganisms or enzymes play in the production of the food.
   e. science underlying each part of the process.
5. Write a report on the step-by-step production of the food for a poster or oral presentation. Include pictures or drawings where possible.
6. Present your report to the class.

Hint: Be ready to answer questions and explain your findings.

Activity 1.2 Improving Ghanaian Food Production with Science

Objective: Design a modified method for producing a traditional drink (Pito) that improves the biological process of enzyme activity.

Instructions

1. Team up with two or three members of your class.
2. Research on the traditional method of producing Pito.
3. Identify the biological processes involved
4. Note down any steps indicating enzyme activity.
5. List the changes you would make to boost enzyme activities.
6. Use the changes listed to modify the traditional production method of Pito.
7. Create a Visual Poster or Report to include:
   a. the original method.
   b. your new design and what it improves.
   c. diagrams or drawings.
   d. scientific reasoning behind your idea.
8. Present to the Class, explaining your innovation and the biology underlying it.

TISSUE CULTURE AND ITS APPLICATION

Tissue culture

Tissue culture is a method used to grow cells, tissues or organs from plants or animals in a controlled artificial environment such as a laboratory. It is done in laboratories using sterile conditions to avoid contamination. This technique allows scientists to study cells closely, produce disease-free organisms and multiply plants or animal cells quickly. In tissue culture, a small part of a plant or animal called an explant is taken and placed in a growth medium containing nutrients and hormones, such as agar or broth medium. The explant grows and multiplies into new cells, tissues or even whole plants in a nutrient-rich agar or broth. Tissue culture is also known as micropropagation. The technique is used by scientists and farmers to produce plants that are free from diseases, to increase the number of plants quickly and to improve the quality and yield of crops.

To carry out tissue culture, the following are needed.

a. A sterile laboratory where the plant parts can grow safely.
b. A greenhouse to care for young plants.
c. Trained workers who understand the process.
d. A nursery to grow the plants until they are ready to be planted outside.

Plants commonly grown through tissue culture include oil palm, banana, eggplant, pineapple, tomato, sweet potato and rubber tree.



Figure 1.6: Plantlets, product of tissue culture

Key Principles of Tissue Culture

1. **Aseptic conditions or sterility:** The success of tissue culture relies on maintaining a sterile environment to prevent contamination by microorganisms such as bacteria.
2. **Nutrient-rich medium:** cells, tissues, and organs require a suitable nutrient-rich medium that supports growth and development. This medium typically contains

macronutrients (carbohydrates, proteins and lipids), micronutrients (vitamins and minerals essential for cellular function) and hormones (auxins and cytokinins) that control cell division and differentiation.

3. **Controlled environment:** It is important to maintain a controlled environment, which includes temperature, humidity and light to support the growth and development of cells, tissues or organs. For plant cells, light is crucial for photosynthesis.
4. **Cell totipotency:** plant cells are totipotent, meaning they can develop into entire plants under the right conditions
5. **Plant growth regulators:** Plant growth regulators such as auxins, cytokinins, and gibberellins regulate cell growth, differentiation and development.

Types of Cultures

Primary culture: This is the initial culture of cells or tissues taken directly from the organism. These cells require specific growth factors or conditions to thrive. Primary cultures are often used for research, diagnostics or vaccine production. When plant tissues are initially cultured in primary culture, they can undergo callus formation as a response to the culture conditions, such as the presence of specific plant growth regulators. Callus formation in primary culture can be an intermediate step towards plant regeneration, allowing the production of large numbers of plants and the introduction of new traits through genetic engineering.

Secondary culture: this is the culture derived from a primary culture, often used for further experimentation or subculturing. They can be used for long-term studies, large-scale production or cell banking. Advantages of this type of culture are that the cell can be frozen and stored for future use. They can also be expanded and used for various types of applications.

Embryo culture: this involves growing embryos in a controlled environment to "rescue embryos" from wild crosses or to produce disease-free plants. "To rescue an embryo" refers to a technique where plant embryos are carefully removed from seeds or ovules and grown in a controlled environment. In embryo culture, embryos are carefully isolated from seeds or ovules under sterile conditions and grown in a controlled environment such as a greenhouse with specific control over temperature, light and humidity. This type of tissue culture is used to improve seed germination, especially seeds that are difficult to germinate or have low viability and is applied in plant breeding, seed production and biotechnology.

Cell suspension culture: This is a type of culture where cells are grown in a liquid medium (broth). It is often used for large-scale production of cells. With this type of culture, cells are dispersed throughout the medium and can be easily manipulated. Cell suspension cultures can be used for bioprocessing, vaccine production or research.

Organ culture: this involves growing entire organs or parts of organs like root tissues, shoot tips or leaf tissues in a controlled environment. This type of culture gives the opportunity for the preservation of organ structure and the study of organ development. Organ culture is applied in plant propagation and the production of medicinal compounds.

Somatic cell culture: This is a type of culture that involves growing somatic cells (non-reproductive cells) in a controlled environment. Somatic cells are derived from various tissues, including the skin. Somatic cell cultures can be used for research, diagnostics or cell therapy. Culture of somatic cells can be used for genetic studies, somatic cell biology, disease modelling or in pharmaceutical production.

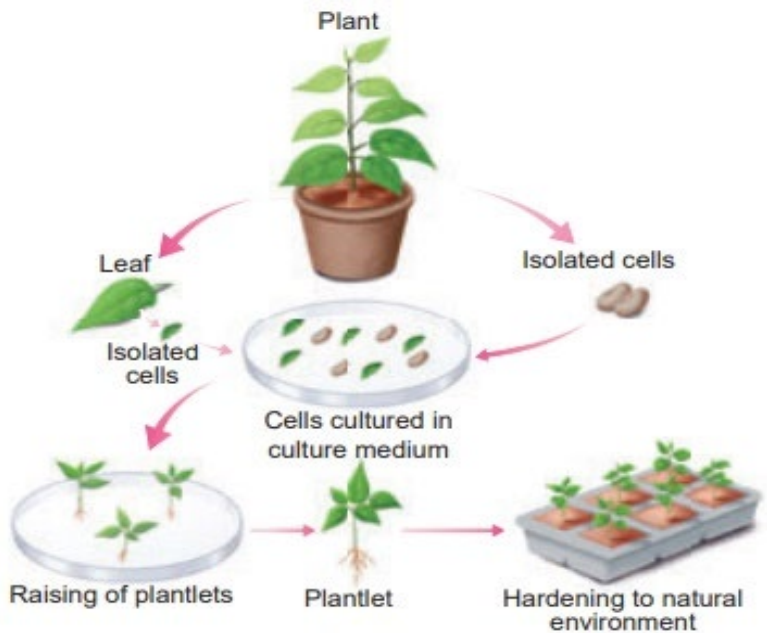


Figure 1.7: Plant tissue culture process, a type of tissue culture

Specific Techniques/Steps in Tissue Culture

Explant preparation involves

a. Selecting and preparing the plant material (explant) for culture
b. Sterilising the explant to prevent contamination using chemical agents such as bleach or alcohol.

Media composition involves;

a. preparing a nutrient-rich medium that supports cell growth and multiplication. Basic components in a medium are nutrient agar, sugars (usually sucrose), and plant growth regulators.
b. plant growth regulators (PGRs) which promote cell growth and differentiation.
c. growth regulators called auxins, which are plant hormones that promote root formation) and cytokinin, plant hormones that promote shoot formation.

Cultivation Conditions

a. Light: period of light exposure (Photoperiod) is controlled to optimise growth. Some cultures may require specific light wavelengths and intensities.

b. Temperature and humidity: Maintaining optimal conditions for specific plants is crucial for successful growth.

Subculturing

This technique involves the transfer of cultured tissue to fresh media at regular intervals to provide nutrients and encourage further growth of the roots and shoots.

Acclimatisation

When the plant starts developing (called a plantlet), it is transferred to the greenhouse to develop under controlled environmental conditions. It is then finally transferred to the nurseries to grow under natural environmental conditions.

Applications of Tissue Culture

1. *Plant propagation:* It is used in the large-scale production of plants such as orchids.
2. *Crop improvement:* the technique is used to produce disease-free crops, hybrid seeds and genetically modified crops (GMOs).
3. *Genetic engineering:* The technique is also used to introduce new traits such as pest resistance or drought tolerance into plants.
4. *Research and development:* It is also applied in the study of plant growth, development and responses to different conditions. Tissue culture again plays a significant role in cancer research, vaccine production and the development of gene therapies, which involve introducing genes into cells to treat genetic diseases.
5. *Pharmaceutical production:* in pharmacy, tissue culture is used in the production of medicinal compounds, toxicity testing of new drugs and pharmaceutical compounds, screening of new drugs for efficacy and potency and standardisation of herbal products.

Advantages of Tissue Culture

1. *Rapid propagation:* tissue culture allows for fast production of plants, thereby enabling large-scale production.
2. *Disease-free plants:* Tissue culture can produce disease-free plants. This reduces the risk of disease transmission.
3. *Uniformity:* tissue culture can produce uniform plants. This reduces variability.
4. Year-round production: tissue culture can be done year-round, regardless of the season or climate.
5. *Conservation of rare species:* Tissue culture can be used to conserve rare or endangered species.
6. *Improved crop yield:* Tissue culture can be used to produce high-quality crops with improved yield.
7. *Reduced space requirement:* tissue culture can be done in small spaces, making it ideal for areas with limited space.

8. *Genetic engineering*: tissue culture is a key tool in genetic engineering, enabling the introduction of new traits into plants.
9. *Research and development:* tissue culture is a valuable tool for research and development, enabling scientists to study plant growth, development and responses to different conditions.

Limitations of Tissue Culture

1. *Contamination risk:* there is the risk of contamination by microorganisms, which can lead to loss of cultures.
2. *Limited shelf life:* tissue cultures have a limited shelf life and often require subculturing.
3. *Genotype changes or variations:* cells or tissues may undergo genotype changes during culture. This can affect their behaviour or characteristics.
4. *High costs:* tissue culture techniques can be expensive, especially for large-scale applications
5. *Technical expertise:* tissue culture requires specialised technical expertise and equipment
6. *Dependence on growth regulators:* many tissue culture systems require specific growth regulators, which can be expensive and may have unintended effects.

Not all plant species or tissues can be successfully cultured using tissue culture techniques.

Activity 1.3 "Roots and Clones" – Comparing Plant Propagation Methods

Objective: Explore, design, and compare traditional propagation and tissue culture techniques for plant propagation, analysing their advantages, limitations, and practical applications.

Instructions

1. Select a plant species commonly propagated, e.g. cassava.
2. Research on the traditional method used in propagating it.
3. Research on cassava propagation using tissue culture
4. Design a Comparison Plan
    a. Write down steps involved in each method
    b. Identify biological principles (cell division and meristem activity)
    c. Consider requirements of both methods: equipment, time, cost, success rate
5. Create a Comparison Chart or Poster to include the following:
    a. Preparation steps
    b. Conditions needed
    c. Growth results

d. Advantages and disadvantages of each method
e. Which method is better for different purposes (e.g. farming, conservation)

6. Share your comparative analysis results in a presentation with visuals, explaining which method is better and why.

Sample Comparison Table Format

Aspect	Traditional Propagation	Tissue Culture Propagation
Method Used		
Time to Produce Plant		
Environment Needed		
Uniformity of Plants		
Disease Resistance		
Cost & Equipment		

Activity 1.4 "Growing Success: Tissue Culture in Ghanaian Agriculture"

Objective: Explore how tissue culture has been successfully applied in Ghanaian agriculture and analyse its entrepreneurial potential through a self-guided research project.

Instructions

Work individually to investigate a real case of tissue culture use in Ghana. Your goal is to understand the science behind it and its impact as a business opportunity.

Steps to Follow

1. Choose a Case Study on one of these.
   a. Pineapple production in Ghana
   b. Bean production on a commercial farm in Ghana.
2. Research from textbooks, internet articles, agricultural reports, or interviews with experts on your selected case study. Focus your notes on:
   a. How tissue culture was applied.
   b. The benefits compared to traditional methods.
   c. Challenges faced and how they were solved.
   d. How this approach led to entrepreneurial success (e.g. farm scale-up, exports).
3. Create an Analysis Report and present your findings in one of the following formats:
   a. A 2–3-page written report
   b. A digital slide presentation (6–8 slides)
   c. A poster

Note: Your report should include the following:

i. Title of the Case Study.
ii. Tissue Culture Method Used.
iii. Scientific Explanation of tissue culture.
iv. Entrepreneurial Prospects
v. Results and Impact
vi. Your Reflections – What can Ghana learn from this case?

As an alternative to a case study, you may also choose to:

a. Interview a local farmer or an agro scientist
b. Explore tissue culture labs through videos

GENETIC RECOMBINANT TECHNOLOGY AND ITS APPLICATION

Genetic Recombinant Technology

Genetic recombinant technology, also known as recombinant DNA (rDNA) technology, refers to a set of molecular techniques that involve combining DNA molecules from different sources to create a new set of genes. This technology allows scientists to cut and join DNA molecules from different organisms and insert them into host organisms to produce new genetic combinations in organisms. In this way, scientists mix DNA from different organisms to create new genes. This produces new useful traits and characteristics in the host organism. The technique is applied in medical, agricultural, and industrial research.

Key Processes in Genetic Recombinant Technology

rDNA technology involves a series of steps which lead to the formation of several copies of the recombinant DNA in which the gene of interest is found to produce the required product. These steps are complex, but have been simplified in the outline below

Steps

1. Identify and isolate the portion of the DNA with the specific gene that is to be copied.
2. Extract DNA from the donor organism containing the gene of interest by cutting the DNA at specific places using restriction enzyme digestion. Special enzymes called restriction endonucleases cut the DNA at specific recognition sites, creating fragments with sticky ends.
3. Vector Preparation is a process where a vector (such as a plasmid or bacteriophage) is cut with the same restriction enzyme to create compatible sticky ends.
4. DNA ligation occurs when a DNA fragment of interest is joined with the prepared vector using the DNA ligase enzyme to create a recombinant DNA molecule.

5. The recombinant DNA molecule is introduced into a host cell or organism (e.g. bacteria) through processes such as transformation or transfection.
6. Host cells that have successfully taken up the recombinant DNA are identified through selection markers (e.g. antibiotic resistance genes).
7. *Amplification and Expression*: The host cells replicate, producing many copies of the recombinant DNA with the gene(s) of interest. The donor DNA is carried through a special laboratory technique to amplify specific DNA sequences to produce more copies of the gene or DNA fragment of interest. This technique is called polymerase chain reaction (PCR).

Here's how PCR works.

a. *Heating (Denaturation):* The DNA is heated to separate the two strands.
b. *Cooling (Annealing):* The temperature is lowered so that short DNA pieces (primers) can attach to the target DNA.
c. *Synthesis (Extension):* The temperature rises again, and an enzyme helps build new DNA strands.

After PCR, scientists can separate and analyse the DNA fragments by size using a method called gel electrophoresis. This helps them see how long each DNA piece is.

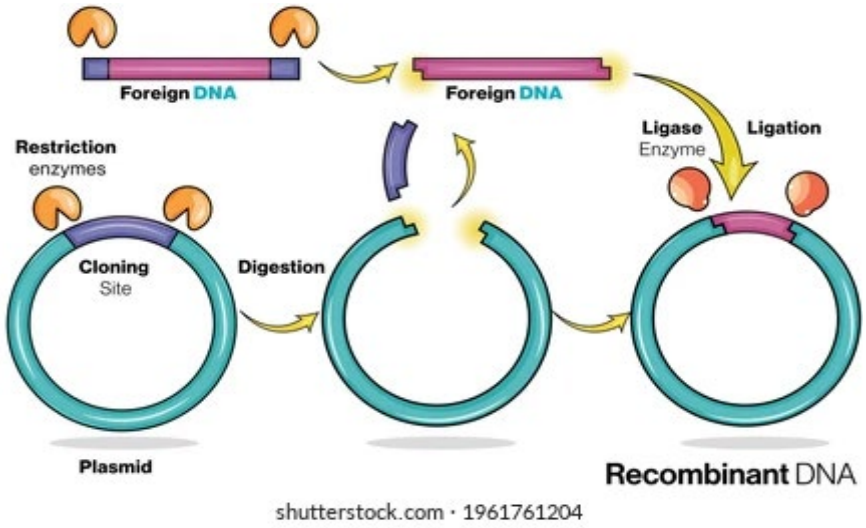


Figure 1.8: Genetic recombinant DNA

Some common examples of Genetically Modified Organisms

Genetically Modified Organisms (GMOs) are living organisms whose genetic material has been artificially manipulated through genetic engineering techniques to introduce novel/ desired traits.

Some common examples

1. Genetically Modified Crops (GMCs)
    a. *Bt* crops are crops modified to express the *Bacillus thuringiensis* (*Bt*) toxin gene, making them resistant to certain insects. Examples are *Bt* cotton and *Bt* maize.
    b. Herbicide-resistant DNA is produced for crops such as soybeans, cotton, and maize.
    c. Nutritionally enhanced crops, e.g. the golden rice, which is enriched with beta-carotene.
    d. Drought and salinity-tolerant crops e.g. drought-resistant maize, salt-tolerant rice)
2. Genetically Modified Animals
    a. Fast-Growing Fish, e.g., AquAdvantage salmon with a growth hormone gene from Chinook salmon
    b. Disease-resistant animals, e.g. pigs modified to resist diseases like Porcine Reproductive and Respiratory Syndrome (PRRS).
3. Genetically modified microorganisms
    a. Bacteria (*E.coli*) which have been modified to produce human insulin.
    b. Microorganisms used for breaking down pollutants in bioremediation, e.g. *Bacillus* and mycorrhizal fungi.

Socio-cultural and Emotional Concerns about GMOs in Africa

Cultural concerns

1. Effect on traditional farming practices and seed-saving traditions: Many African communities have long histories of farming where saving seeds from the best crops is common. This practice helps preserve local varieties and connects people to their culture. Introducing GMOs, especially those that are patented, can disturb these traditions. Farmers may need to buy new seeds each season, reducing their independence and changing age-old practices.
2. Cultural significance of certain crops and farming methods: Some crops, like millet and yams, have deep cultural meanings. These crops are often tied to local identities and rituals, e.g. the Odwira festival of the Akwapims in Ghana is linked to the end of the harvesting season of yams, which features the presentation of new yams to the chief, and public feasting. Also, indigenous seed varieties like millet, sorghum, Bambara beans, and local groundnuts are vital to the cultural identity and food security of communities in the Upper East Region of Ghana. These are often kept safe in community seed banks. Introducing GMOs could threaten the cultural importance of these traditional crops, leading to a loss of heritage. Many communities may resist GMOs to protect their cultural practices.

Economic Concerns

1. *Dependence on multinational seed companies:* genetically modified (GM) seeds are often produced by large companies that control their distribution and pricing. This can make local farmers reliant on these corporations, leaving them vulnerable to price changes. Such dependence can undermine local economies and reduce farmers' control over their crops.
2. *Cost of GM seeds and export market acceptance:* GM seeds tend to be more expensive than traditional seeds, which can strain the small-scale farmers' budgets. Additionally, some international markets have restrictions on GM products. If African countries invest heavily in GMOs, they may struggle to access markets that prefer non-GM items.

Health and Safety Concerns

1. *Perceptions about the safety of GM foods for consumption:* Many people worry about the safety of GM foods. There are fears that GMOs could pose health risks, especially if long-term studies are lacking. This suspicion can lead to resistance, as consumers may prefer traditional foods.
2. *Concerns about potential allergen reactions or toxicity:* there are worries that GM foods could introduce new allergens or toxins. For instance, modifying a crop to enhance nutrition might accidentally create new health risks. These concerns are especially serious in communities with limited healthcare access.

Environmental Concerns

1. *Possibility for cross-pollination with wild relatives:* a major environmental concern is the risk of GM crops cross-pollinating with wild plants to cause modified genes to spread into natural ecosystems. This could disrupt local plant populations.
2. *Effect on non-target organisms and biodiversity:* The use of GMOs can also affect beneficial insects and soil microorganisms. For example, insect-resistant crops might harm pollinators like bees. Loss of biodiversity can weaken ecosystems, making them less resilient to changes.

Activity 1.5 GMO Quest: Tomorrow's Super Crops

Objective: Design and evaluate a genetically modified organism (GMO) that tackles a global issue while exploring the science, ethics, and societal impacts.

Instructions

1. Choose a Global issue that you think could be solved with genetic modification. Examples of Issues to consider:
    a. Food security (making sure everyone has enough to eat)
    b. Climate change and its effects on farming
    c. Reducing pest problems with fewer pesticides

   d. Improving nutrition (like adding vitamins to crops)
   e. Dealing with water shortages in agriculture
2. Team Up for Research: work with a partner(s) to learn about existing GMOs related to your chosen issue. Look into:
   a. scientific advancements and examples of GMOs
   b. ethical questions about modifying genes
   c. how people view GMOs and any rules around them
3. Design your GMO by creating a detailed plan for your GMO that addresses the challenge you picked. Make sure to include:
   a. specific genes you will modify or add? What will be the benefits?
   b. how will you modify the genes? (e.g., using CRISPR or other techniques)
   c. the potential benefits and risks? Think about the environment, health, and economy.
4. Prepare an engaging presentation that includes:
   a. overview of the challenge and your GMO plan
   b. the scientific reasons behind your genetic changes
   c. ethical considerations and social impacts
   d. any regulatory hurdles and how you plan to overcome them
   e. visuals or interactive elements (e.g. concept maps, flow charts, etc) to make it exciting.
5. Share your proposal with the class in a conference-style presentation. Be ready to answer questions and defend your design when classmates provide feedback.
6. After the presentations, give constructive feedback on your classmates' projects, focusing on the science, ethics, and societal impacts.
7. Write a brief reflection on what you learned during this project. Share any new insights about the relationship between science, ethics, and society, and how your view on GMOs may have changed.

Activity 1.6 From DNA to Everyday Food

Objective: Explore the science behind the fascinating world of recombinant DNA technology and genetically modified organisms (GMOs) to create visual representations(flowchart) and evaluate real-world implications, specifically focusing on drought-resistant maize in Ghana.

Instructions

1. Design a flowchart illustrating the key processes involved in recombinant DNA technology. Use visuals and colours to make it easy to understand.
2. List examples of GMOs in:

a. crops
b. animals
c. microorganisms

3. Focusing on the introduction of drought-resistant maize in Ghana, evaluate the:
   a. potential ecological impacts (e.g., effects on local biodiversity, soil health).
   b. socioeconomic impacts (e.g., effects on farmers' livelihoods, food security).
   c. possible benefits and challenges of implementing this technology in Ghana.

APPLICATION OF BIOLOGICAL CONCEPTS IN THE TREATMENT OF WATER, EXTRACTION OF MINERALS (E.G., GOLD) AND PRODUCTION OF BIO-OILS

Biological Water Treatment

Biological water treatment refers to the use of natural systems, such as microorganisms (e.g. bacteria, protozoa, algae), to clean water by removing contaminants and pollutants from water. Biological water treatment methods include bioremediation, activated sludge and biofiltration.

These methods break down organic matter, nutrients and other substances to improve water quality and are considered cost-effective and relatively less harmful than chemical treatments.

Bioremediation

This is the use of living organisms such as microbes, plants or enzymes to detoxify or degrade pollutants and remove them from the environment. The contaminated medium that is being cleaned can be soil, water or air. The method improves the quality of the environment. An example of bioremediation is the use of *Pseudomonas sp*. to break down petroleum hydrocarbons in contaminated water.

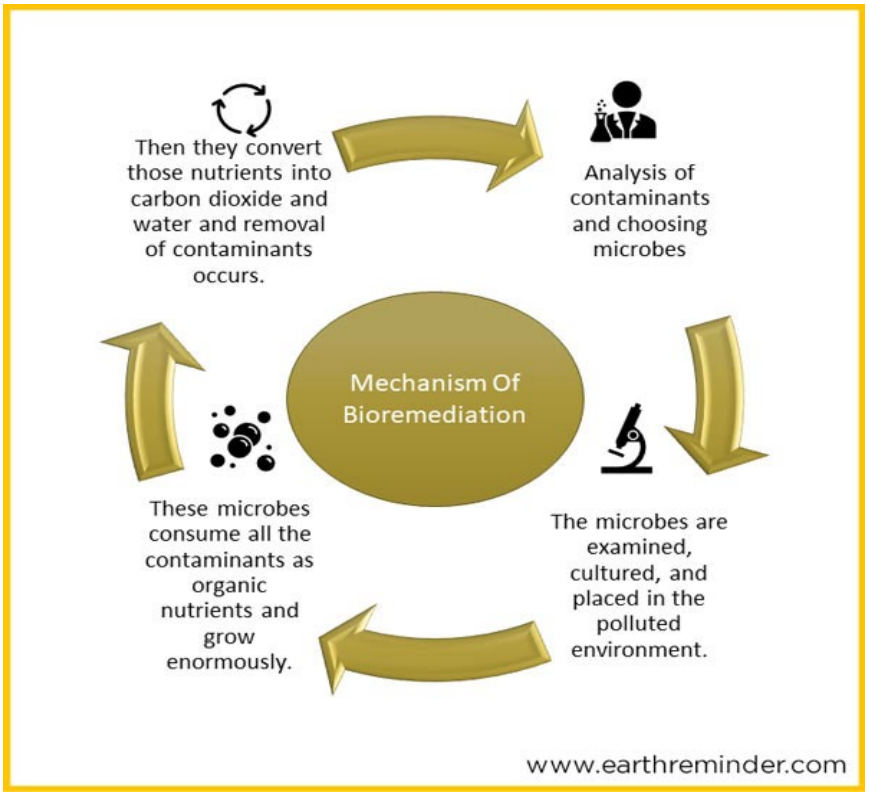


Figure 1.9: Bioremediation process

Click on the link below to watch a video on the process of bioremediation.

https://youtu.be/uHhM0U73zpk?t=1

Steps in the process of bioremediation

a. Identify Pollutants and Contamination Sites: This could involve analysing soil, water, or air samples to pinpoint the harmful substances, such as heavy metals, oil spills, or chemical waste.

b. Select a Microorganism or Biodegrading Agent: choosing the right microorganism or biodegrading agent that can break down those specific contaminants is important because different microorganisms have varying abilities to degrade different substances.

c. Acquire a Bioremediation System: depending on the level and type of contamination, a bioremediation system must be set up. This could involve using bioreactors. Examples of bioreactors are:

   i. controlled environments where microorganisms can thrive and degrade pollutants.

ii. landfarming, where contaminated soil is spread out and treated with microorganisms to enhance degradation.

d. Apply the Microorganism or Biodegrading Agent: This could be done by adding the microorganisms directly to the soil or water, or by applying them through the bioremediation system.

e. Monitor Contaminant Levels and Microbial Activities: it is crucial to regularly monitor the levels of contaminants and the activity of the microorganisms. This involves taking samples and analysing them to see how effectively the pollutants are being broken down. This is to ensure that conditions or contamination decrease to safe levels for the environment and public health.

Biological concepts or principles involved in bioremediation

a. **Biodegradation**: This is where microorganisms break down pollutants into simpler, degradable compounds.

b. **Enzymatic reactions**: This is where microbial enzymes catalyse and initiate degradation reactions.

c. **Microbial metabolism**: This refers to the conversion of pollutants into energy sources.

d. **Bioaugmentation**: It is the addition of microorganisms to a pollutant to enhance degradation or digestion.

e. **Bio stimulation**: This is the provision of nutrients and suitable conditions to facilitate the growth of microbes, used in bioremediation processes.

Activated Sludge Process

This is a biological water treatment method that uses aerobic microbes to break down organic matter in wastewater. The activities of the microbes form a sludge, which is separated from the treated water. The microorganisms involved include various species of bacteria, protozoa, rotifers and fungi that form a complex ecosystem.



Figure 1.10: Brown sludge on the surface of water

The steps involved in the treatment process

a. Air is incorporated into wastewater to provide oxygen for the microbes.

b. The microbes break down organic matter in the wastewater.

c. The treated water is separated from the sludge (or collection of microbes).

d. Some sludge is recycled back into the aeration tank to maintain microbial population.

The biological concepts or principles involved in this treatment method

a. **Aerobic degradation**: This is where oxygen is supplied to the microbes to break down organic matter.

b. **Microbial metabolism** is the biochemical process by which microorganisms convert nutrients into usable energy and cellular components. This includes various pathways that enable microbes to grow, reproduce, and respond to their environment.

c. **Bio flocculation**: This refers to the formation of flocs by microorganisms to speed up sludge separation.

Advantages of biological water treatment

1. *Less Harm to the Environment:* Biological water treatment is more eco-friendly than chemical methods. It uses natural processes to break down pollutants, which reduces the risk of harmful chemicals entering the ecosystem. This helps protect biodiversity and keeps water sources clean.
2. *Cost-Effective:* These methods often have lower costs for operation and maintenance. Since they rely on natural organisms, there is less need for expensive chemicals and infrastructure. This makes biological treatment a more effective and affordable choice for communities and industries wanting to improve water quality.
3. *Permanent Solution to Pollution*: Biological methods can destroy pollutants instead of just moving them somewhere else. By breaking down harmful substances into harmless byproducts, these processes offer a lasting solution for cleaning contaminated water that benefits the environment in the long run.

Disadvantages of biological water treatment

1. *Slow Process:* One downside of biological water treatment is that it can be slow. The natural processes take time, which can be a problem when quick action is needed to address pollution. This delay may hinder prompt responses to contamination issues.
2. *Dependence on Site Conditions:* The success of biological treatment depends on specific site conditions, like temperature, moisture and nutrients. If these conditions are not ideal, microorganisms may not work effectively, leading to slower pollutant breakdown.
3. *Limitations on Pollutant Types:* Biological methods may not work for all pollutants.

Some chemicals, especially heavy metals and certain synthetic substances, might not break down easily with microorganisms. In these cases, other treatment options may be needed to handle the contamination effectively.

Biomining and Bioleaching for Mineral Extraction

Biomining uses microorganisms to extract valuable metals from low-grade ores that would otherwise be uneconomical to extract using conventional methods.

Key Processes in Biomining

1. *Leaching:* The process of extracting metals from ores by dissolving them in a solution.
2. *Microbial Activity:* Specific bacteria or *archaea* oxidise metal sulphides, facilitating the release of metals into solution.

Bioleaching is a process under biomining that focuses on the use of microorganisms to extract metals from low-grade ores or mine tailings. Microorganisms involved include *Acidithiobacillus ferrooxidans, Acidithiobacillus thiooxidans, and Leptospirillum ferrooxidans.*

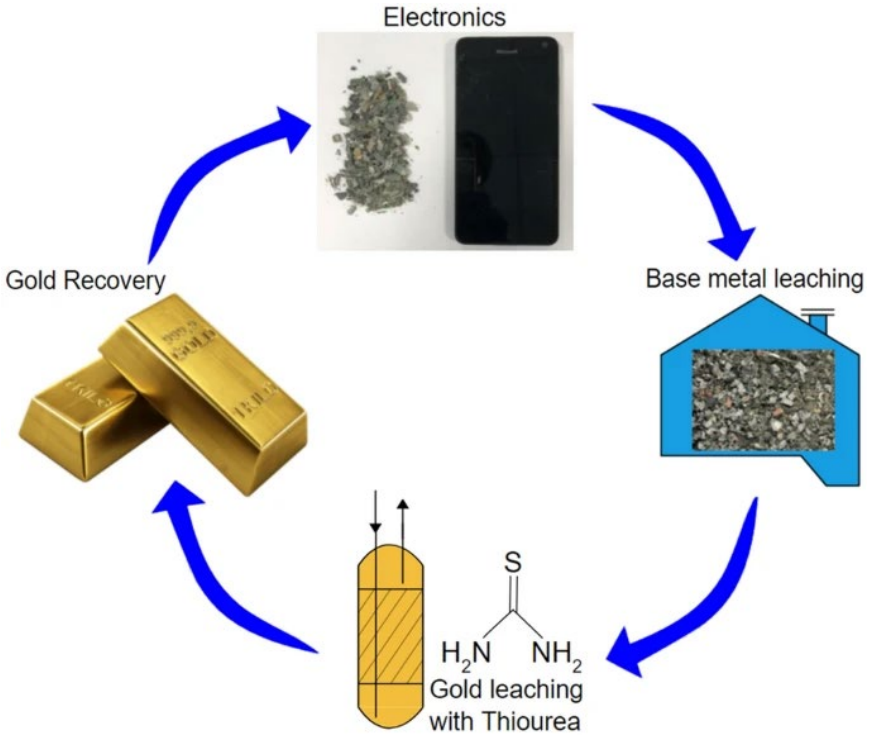


Figure 1.11: A chart showing gold extraction from electronic waste by bioleaching

The processes involved

1. Microbes Oxidise Sulphides Containing Gold: Specific microorganisms that can oxidise sulphide minerals containing gold break down the sulphide compounds to release the gold trapped within them.
2. Gold Becomes Exposed and Accessible: As the microbes work, the oxidation process makes the gold more accessible, allowing it to be extracted more easily.

3. Cyanide Solution Dissolves the Gold: Once the gold is exposed, a cyanide solution is introduced to dissolve the gold. This step is crucial because it effectively separates the gold from other materials.
4. Gold is recovered from the Solution through Precipitation: the dissolved gold in the cyanide solution is recovered through precipitation and purification.

Biochemical Mechanisms involved

a. Direct leaching: Microbes attach directly to mineral surfaces and extract metals through enzymatic reactions.
b. Indirect leaching: Microbes produce chemical oxidants (Fe^{3+}) that dissolve the minerals.

Environmental and Economic Benefits

1. Requires less energy than conventional mining.
2. Reduces greenhouse gas emissions.
3. Can extract metals from low-grade ores (increasing resource availability).
4. Produces less toxic waste.
5. Can be used to remediate mine sites.

Current Applications

1. Commercial bioleaching operations for gold in South Africa, Brazil, and Australia.
2. Copper extraction in Chile and the United States.
3. Uranium extraction in Canada.

Bio-oils Production

Bio-oils are liquid fuels made from biological materials through various processes that use natural principles. They provide a sustainable alternative to fossil fuels and can be produced from different sources using innovative methods.

Sources and Production Methods

Microalgae-Based Bio-oil Production

Process

1. Cultivation of Oil-Rich Microalgae: Certain types of microalgae, like *Chlorella* and *Botryococcus*, are grown because they contain a lot of oil and grow quickly.
2. Harvesting of Algal Biomass: The algae are collected once they reach the right amount.
3. Extraction of Lipids: Oils are extracted from the harvested algae.
4. Conversion to Biofuels: The extracted oils are turned into biodiesel through a process called transesterification.

Advantages

a. Microalgae are efficient at using sunlight and can grow fast.

b. Microalgae can have up to 60% oil.

Environmental Benefits

a. This process is carbon-neutral, meaning it does not add extra carbon dioxide to the atmosphere.

b. It can also use wastewater and absorb CO_2 from emissions.

Enzymatic Conversion of Biomass

Process

This method uses enzymes, which are natural catalysts, to break down complex plant materials into simpler compounds for bio-oil production. Key Enzymes are:

1. Cellulases: Break down cellulose into glucose.
2. Lipases: Help convert fats into biodiesel.
3. Amylases: Turn starch into fermentable sugar.

Advantage: This process works at lower temperatures than traditional methods, saving energy.

Fermentation for Bio-oil Production

Process: Microorganisms like yeast convert sugar into alcohol that can be used as fuel. E.g. Yeast fermentation of sugars produces bioethanol, a common biofuel.

Advanced Applications: Scientists are developing bacteria that can directly produce fuel-like hydrocarbons from sugars.

Pyrolysis with Biological Pre-treatments

Process: Pyrolysis involves heating organic material without oxygen, breaking it down into bio-oil, char and gas. Biological Pre-treatment uses enzymes or microorganisms that can partially break down biomass before pyrolysis, making it more effective and increasing both the yield and quality of the bio-oil.

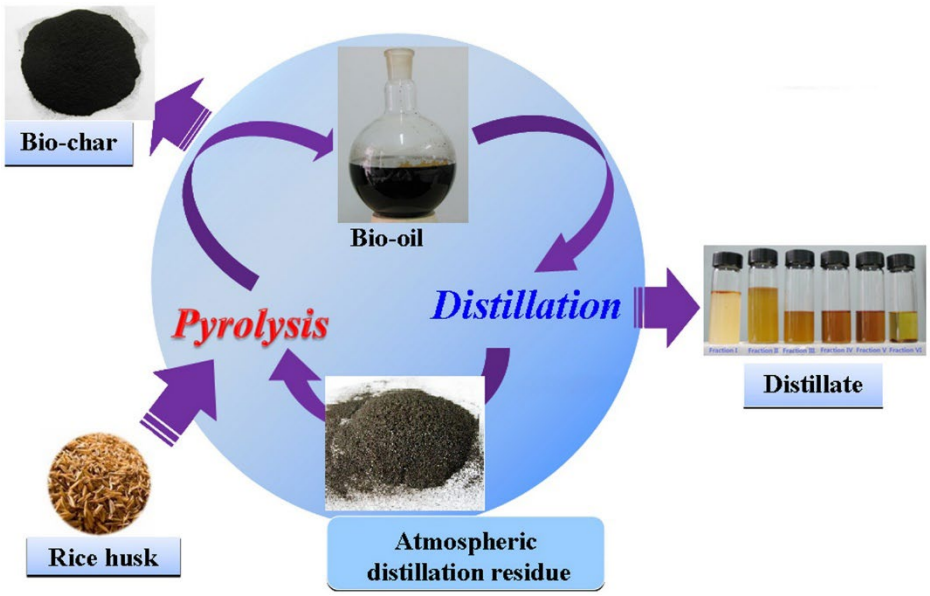


Figure 1.12: Pyrolysis

Applications for Bio-oils

Bio-oils can be used in many ways, including:

1. Transportation Fuels: Used as biodiesel or bioethanol to power vehicles, reducing reliance on fossil fuels.
2. Heating and Electricity Generation: Bio-oils can be burned in boilers and engines for heating or generating electricity.
3. Production of Biochemicals and Bioplastics: They can be used to create biochemicals and biodegradable plastics.
4. Carbon Sequestration: When combined with carbon capture technologies, bio-oils can help reduce carbon dioxide in the atmosphere.

Activity 1.7 Bioremediation of Oil Spills using Microbial Techniques

Objective: To understand the principles of bioremediation and the role of specific microbes in degrading oil spills, using the study on *Acinetobacter junii* and *Alcanivorax xenomutans* as a case study.

Materials Needed

- Presentation tools (PowerPoint, poster boards), graph paper or digital tools for data representation, markers, stationery and internet access.
- Access to the article: "In vitro assessment of crude oil degradation by *Acinetobacter junii* and *Alcanivorax xenomutans* isolated from the coast of Ghana"

Link to the full article on: https://pmc.ncbi.nlm.nih.gov/articles/PMC10838785/

Summaries from the article.

Authors: Victor Nana Amaah, Elijah Kobla Akrong, David Dankwa, Michael Kwaku, Christian Agyare.

Published In: PLOS ONE, January 22, 2024

Abstract

This study investigates the effectiveness of two bacterial species, *Acinetobacter junii* and *Alcanivorax xenomutans*, in degrading crude oil in seawater. These bacteria were isolated from marine environments along the coast of Ghana, specifically from the shores of Takoradi and Tema. The researchers simulated oil spills in controlled laboratory conditions and monitored the degradation process over a period of 45 days.

Introduction

Oil spills are a significant environmental challenge, particularly in coastal regions where they can severely impact marine ecosystems and local economies. Traditional cleanup methods often fall short, leading to a growing interest in bioremediation as a sustainable solution. This study focuses on two bacterial species known for their oil-degrading capabilities, highlighting their potential role in environmental restoration efforts.

Methodology

Microbial Isolation: Researchers collected seawater samples from the coasts of Takoradi and Tema. The samples were analysed to isolate the bacterial strains capable of degrading hydrocarbons.

Experimental Setup: To simulate an oil spill, researchers added crude oil to seawater samples in laboratory conditions. The isolated bacteria were then introduced to these samples.

Monitoring and Data Collection: The degradation of crude oil was monitored over 45 days, with samples taken at 15-day intervals. Key measurements included the concentration of hydrocarbons and the growth of bacterial populations.

Data Summary

Time (Days)	Acinetobacter junii Degradation (%)	Alcanivorax xenomutans Degradation (%)
0	0	0
15	25	15
30	45	30
45	57	40

Results

Degradation Efficiency: Both *Acinetobacter junii* and *Alcanivorax xenomutans* demonstrated significant oil degradation capabilities. The highest degradation efficiency recorded was 57% after 45 days.

Bacterial Growth: *Acinetobacter junii* showed a higher growth rate and degradation efficiency compared to *Alcanivorax xenomutans,* indicating its potential as a more effective bioremediator.

Discussion

The results indicate that these native bacterial species possess the necessary adaptations to thrive in oil-contaminated environments. Their application in bioremediation efforts could provide an effective and environmentally friendly method for cleaning up oil spills in Ghana.

Conclusion

This study underscores the importance of utilising indigenous microbial strains for bioremediation. The findings suggest a viable path forward for managing oil pollution in coastal Ghana, emphasising the need for further research and application of these techniques on a larger scale.

References

Nana Amaah, V., Akrong, E. K., Dankwa, D., Kwaku, M., & Agyare, C. (2024). In vitro assessment of crude oil degradation by *Acinetobacter junii* and *Alcanivorax xenomutans* isolated from the coast of Ghana. PLOS ONE.

Instructions

1. Article Review
    a. Read the article individually or in groups:
    b. Access to the article is provided in the material list above. Article titled "In Vitro Assessment of Crude Oil Degradation by *Acinetobacter junii* and *Alcanivorax xenomutans* isolated from the coast of Ghana."
    c. As you read, take notes on the microbial species studied, the process of isolation, key experimental results, etc.
2. In groups, discuss the following questions:
    a. What are the main findings of the study?
    b. How do the identified microbes contribute to bioremediation?
    c. What are the potential applications of these findings in Ghana?
3. Design a visual representation (graph, chart, or infographic) summarising the oil degradation results from the article. Focus on illustrating the change in degradation efficiency over time for both microbial species.
4. Present the visual aids and discuss the significance of bioremediation as a sustainable solution for oil spills.
5. Individually, write a short reflection answering:

a. What did you learn about bioremediation and the specific microbes studied?
b. What are the broader implications for environmental conservation in Ghana?

Activity 1.8 Green Galamsey: Innovating Sustainable Biomining Solutions

Objective: To devise innovative optimisation strategies for biomining at a specific site with low-grade ore in a water-sensitive region, focusing on sustainability and environmental protection.

Instructions

1. In a group, discuss the concept of biomining, its benefits, and its relevance in extracting metals from low-grade ores.
2. Propose a hypothetical site with low-grade ore located in a water-sensitive region. Consider factors such as local biodiversity, water sources, and community impact.
3. Research the various biomining techniques and microorganisms used in the process. Focus on those that are effective for gold extraction.
4. Collaborate within your group to propose innovative strategies that could enhance biomining at your chosen site with these consideration factors:
    a. microorganism selection,
    b. water management,
    c. technological innovations
    d. community involvement.
5. Prepare a concise presentation of your proposed strategies. Ensure your presentation:
    a. clearly outlines the strategies and their expected benefits.
    b. addresses potential challenges and solutions for implementation.
    c. engages the audience with visual aids or demonstrative materials if possible.

Activity 1.9 "Bio-Entrepreneurship in Action: – Exploring Fish Farming, Crop Production and Local Food Production"

Objective: To apply biological principles to entrepreneurial ventures in fish farming, crop production and local food production, while developing critical thinking and problem-solving skills.

Instructions

Part 1: Fish Farming

1. Research and discuss the biological principles underlying fish farming, such as:
    a. water quality management
    b. fish nutrition and feeding
    c. disease prevention and control
2. Design a simple fish farm business plan, considering:
    a. market demand and competition
    b. production costs and revenue projections
    c. sustainability and environmental impact.

Part 2: Crop Production

1. Investigate the biological principles underlying crop production, such as:
    a. photosynthesis and plant nutrition
    b. soil science and irrigation management
    c. pest and disease management
2. Develop a crop production plan for a specific crop (e.g. maize or cassava) taking into consideration:
    a. climate and soil suitability
    b. market demand and competition
    c. sustainable practices and environmental impact.

Part 3: Local Food Production (e.g. kenkey)

1. Explore the biological principles underlying kenkey, such as:
    a. fermentation and microbial activity
    b. food safety and preservation
2. Design a simple business plan for kenkey production, taking into consideration:
    a. market demand and competition
    b. production costs and revenue projections
    c. quality control and food safety measures

Share in a presentation, your research findings and business plans with your teacher and classmates.

EXTENDED READING

- www.biologynotesonline.com/recombinant-dna-technology

- www.scientiaeducare.com/recombinant-dna-technology-tools-techniques-and- applications

- www.microbenotes.com/recombinant-dna-technology-steps-applications-and-limitations

REVIEW QUESTIONS 1

1. Discuss how food biotechnology has changed traditional Ghanaian foods and their preparation methods.
2. Compare the different types of fermentation processes (lactic acid, alcoholic, acetic acid, alkaline) and explain their uses and products.
3. Explain the roles of specific microorganisms (like *Lactobacillus* and *Saccharomyces*) in improving the quality and safety of fermented foods.
4. Discuss how controlling factors such as temperature, pH, and oxygen can improve fermentation in food production.
5. Describe the different stages of microbial succession in a fermentation process, such as when making kenkey or yoghurt, and how each stage helps develop the final product.
6. Examine how fermentation affects the nutritional value of kenkey, yoghurt, and pito, and compare their health benefits.
7. Mention the nutritional benefits of asana compared to other fermented drinks and how fermentation improves these benefits.
8. Evaluate the different pasteurisation methods (LTLT, HTST, UHT) in terms of their effectiveness for ensuring food safety and quality.
9. Explain the steps involved in pasteurisation and suggest ways to make the process more efficient in food production.
10. Discuss the cultural importance of traditional fermentation methods in Ghana and how modern food biotechnology can help preserve these practices while ensuring safety.
11. Compare and contrast the different types of fermentation processes (lactic acid, alcoholic, acetic acid, alkaline) in terms of their applications and end products.
12. Evaluate the significance of specific microorganisms (e.g., *Lactobacillus, Saccharomyces*) in enhancing the quality and safety of fermented foods.
13. Discuss how controlling environmental factors (temperature, pH, oxygen) can optimise fermentation outcomes in food production.
14. Illustrate microbial succession in a specific fermentation process (e.g., kenkey or yoghurt) and explain how each phase contributes to the final product.
15. Investigate the impact of fermentation on the nutritional profile of kenkey, yoghurt, and pito, and compare their health benefits.
16. Briefly describe the nutritional values of asana in relation to other fermented beverages and discuss how fermentation enhances these values.
17. Critique the steps involved in pasteurisation and propose improvements to increase efficiency and effectiveness in a food processing context.
18. Evaluate the cultural significance of traditional fermentation methods in Ghana

and discuss how modern food biotechnology can preserve these practices while improving food safety.

19. Explain why understanding specific nutrient requirements is essential when developing a tissue culture protocol for a crop.
20. Describe how contamination can affect each stage of tissue culture (lab-based method for growing plants) and suggest strategies for managing it in a flowchart.
21. Justify the use of a circular flowchart with feedback loops in illustrating the tissue culture process.
22. Why is it important to assess physiological and genetic stability in tissue-cultured plants? Explain how this affects their sustainability.
23. Explain how environmental factors like temperature and humidity influence tissue culture success and how these should be represented in planning tools.
24. Analyse the advantages tissue culture offers over traditional methods in terms of meeting market demand quickly.
25. Discuss how genetic uniformity in tissue culture affects crop yield and disease resistance, pointing out both benefits and risks.
26. Evaluate how tissue culture's high initial costs might still lead to long-term profitability for farmers.
27. Compare the environmental impacts of tissue culture and traditional propagation, identifying features that contribute to sustainability.
28. Assess how consumer attitudes toward tissue-cultured plants influence farming decisions and market strategies.
29. Explain how initial investment challenges affect the adoption of tissue culture by farmers, and what long-term factors justify the cost.
30. Identify economic features of tissue culture that enhance cash crop profitability and explain why they matter.
31. Analyse how the demand for disease-resistant plants boosts economic success in tissue culture farming.
32. Evaluate how government subsidies and policies can influence farmers' decisions to adopt tissue culture methods.
33. Propose sustainable strategies farmers can adopt to reduce financial risks in tissue culture ventures.

SECTION

2

CYTOLOGY



CELL STRUCTURE AND FUNCTIONS

INTRODUCTION

In the previous year, we studied DNA synthesis and its role in protein creation, highlighting its importance in living organisms. DNA, the genetic material in eukaryotic cells, is housed in the nucleus within chromosomes, which carry genes that determine traits passed from parents to offspring.

This year, we will delve deeper into the fascinating world of genetics to uncover the principles governing inheritance, the significance of blood groups and RH factor, and the intricate processes of cell division that enable growth and reproduction. During the cell cycle, DNA duplicates and separates through mitosis for growth and repair, or meiosis for sexual reproduction, introducing genetic variation. This foundation explains Mendelian inheritance patterns, such as blood groups, which follow rules of dominance, segregation, and independent assortment.

Understanding cell structure and function reveals how genetic information is organised and passed on, linking microscopic processes to visible traits and evolution. This knowledge is vital for fields like medicine, agriculture, and biotechnology, making genetics central to modern biological sciences.

KEY IDEAS

- Genetics is the study of heredity and variation in living organisms and focuses on how traits are passed from one generation to the next.
- Genetic variation arises from processes like mutation, genetic recombination, and environmental influences, impacting evolution and adaptation.
- Mendel's first, second and third laws of inheritance explain the inheritance patterns observed in human blood groups.
- Mitosis produces two identical daughter cells, while meiosis results in four genetically diverse gametes, crucial for sexual reproduction.
- The cell cycle begins with interphase, followed by the mitotic phases, essential for growth, repair and reproduction in eukaryotic cells.
- Understanding the reaction between the different blood groups and Rhesus factor is vital in medical science, especially in the areas of blood transfusion and genetic counselling.

GENETIC TERMS AND THEIR MEANINGS

Genetics

Genetics is the branch of biology that studies **heredity** and **variation** in living organisms. It involves understanding how traits and characteristics are passed from one generation to another through **genes**.

Heredity is the process by which genetic traits and characteristics are passed from parents to their offspring. This fundamental principle of biology explains how traits are inherited through generations.

Genes are segments of DNA that carry the information for specific traits necessary for the development and functioning of living organisms. How these genes are inherited determines similarities and differences between individuals and their parents.

Variation refers to the differences in inherited traits or characteristics among individuals within a population. It underlies the mechanisms of how traits and characteristics are naturally selected and how cells adapt to changes both internally and externally.



Figure 2.1: Variation in kittens from the same litter

Other Key concepts or terms discussed in this section are outlined below.

Alleles: Different forms of a gene found at a specific locus (location on a chromosome) and can lead to variations in traits.

Dominant allele: The allele that expresses its trait in the phenotype even when it occurs in the heterozygous state. This means the trait will be expressed in the organism even when only one copy is present in the genotype; if an individual carries at least one dominant allele for a specific trait, that trait will be expressed.

Recessive allele: It is the allele that only expresses its trait in the phenotype when it occurs in the homozygous state. This means two identical copies of the recessive alleles must be present in the genotype for a specific trait to be expressed in the phenotype.

Genotype: The genetic makeup of an organism. This is represented by the alleles inherited by the organism. e.g., AA, Aa or aa.

Phenotype: The observable characteristics or traits of an organism determined by its genotype and environmental influences. e.g., purple or white flowers.

Purebred: A purebred organism comes from a lineage of ancestors that are genetically uniform for a specific trait or traits. This means that the organism has consistently inherited the same alleles from its parents.

P Generation: The original parent generation.

First filial (F1) Generation: Offspring from the P generation; physically shows the dominant trait. They may show a recessive trait too, depending on the genotype of the parents.

Second filial (F2) Generation: Offspring from crossing F1 individuals; may exhibit a mix of both dominant and recessive traits.

Homozygous: An organism with two identical alleles for a particular gene.

Heterozygous: An organism with two different alleles for a particular gene.

Monohybrid Cross: A genetic cross that examines the inheritance of a single pair of contrasting traits. For example, crossing two heterozygous pea plants (Aa x Aa) to study flower colour.

Dihybrid Cross: A genetic cross that examines the inheritance of two pairs of contrasting traits simultaneously (e.g., seed shape and colour).

Test cross: it is a genetic cross performed to determine the genotype of an individual expressing a dominant phenotype. It involves crossing the individual in question with a homozygous recessive individual for the trait being examined.

Punnett Square: A grid used to predict the genotypes and phenotypes of offspring from a cross between two parents.

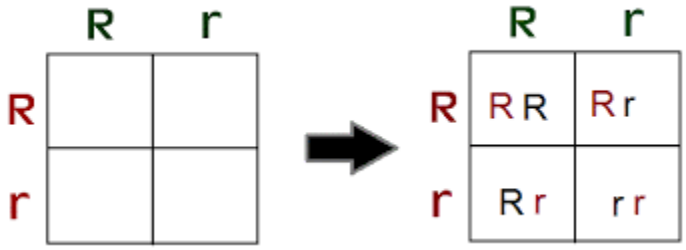


Figure 2.2: An example of a Punnett square

Activity 2.1 Understanding Genetic Terminology

Objective: Enhance understanding of key genetic concepts by identifying, defining and illustrating relationships among genetic terminology.

Instructions

1. Use online and other scientific reading resources to find definitions of at least ten key genetic terms, e.g. gene, allele, genotype, phenotype, etc.
2. Write the definition of each term and give an example of each in a notebook.
3. Create a concept map connecting the terms to show relationships (e.g. how genotypes affect phenotypes).
4. Describe your glossary and concept map to a peer, focusing on how each term relates to the study of genetics.

Activity 2.2 Exploring Genetic Terminology Flashcards

Objective: Create and review flashcards of genetic terms and engage in peer quizzing

Materials: Cardboard or paper, scissors,

Instructions

1. Use old cardboard or paper to cut out cards.
2. Write one genetic term on one side of the card and its definition on the other.
3. Create a minimum of ten of these cards with terms and definitions written on it.
4. Spend 15 minutes reviewing the flashcards on your own, trying to recall each definition before flipping the card.
5. Pair up with a classmate and quiz each other using the flashcards created.
6. Share three terms you learned and explain their significance in genetics.

Mendelian Inheritance

Gregor Mendel (1822- 1884) was a monk born in Austria. He was a botanist and a teacher who performed breeding experiments with pea plants *(Pisum sativum*) in the monastery's garden to understand patterns of inheritance. Mendel's work on pea plants (1856-1863) led to the discovery of the fundamental laws of inheritance, including the *law of segregation* and the *law of independent assortment*. Although his findings were largely unnoticed during his lifetime, Mendel's laws were rediscovered in the early 20th century and remain the foundation of modern genetics. Today, he is celebrated as the "father of genetics" for his pioneering work in the field.



Figure 2.3: Gregor Mendel, the "father of genetics"



Figure 2.4: Garden pea plant with pods

When Mendel crossed a true-breeding tall pea plant (TT) and a true-breeding dwarf plant (tt), he discovered that all the offspring in the first generation (F1) showed only the dominant trait of tallness (Tt).

Parental generation (P)	TT	x	tt
		↓	
First filial (F1) generation		Tt (all phenotypically tall)	

Later, when Mendel crossed the F1, the products, which were the F2, showed a mix of traits. In the F2 generation, three-quarters of the total number of seedlings showed the

same dominant trait of tallness as the original parent, while one-quarter showed the trait of the dwarf parent. The result thus was in the ratio of 3:1.

F1 selfed

Second filial (F2) generation
Phenotypic ratio

T	TT	Tt
t	Tt	tt

From these experiments, Mendel established important concepts about how traits are inherited, which are now known as Mendel's Laws of Segregation and Independent Assortment, discussed in the next topic.

MENDEL'S FIRST LAW OF INHERITANCE

Mendelian Inheritance

Mendel proposed that factors come in three combinations of hereditary units for a trait to be determined. For example, TT, tt, and Tt. The uppercase 'T' represents the dominant factor, while the lowercase 't' represents the recessive factor. In other words, a particular trait or character can be determined by two dominant alleles (TT), two recessive alleles (tt) or a combination of the two (Tt).

The original parent plants were homozygous, meaning they had two of the same genes (either TT or tt). He described them as true-bred. The first generation of offspring (F1) had a mix of these genes, shown as Tt. In the second generation (F2), the offspring had a combination of TT, tt and Tt. These combinations determine the visible traits in the plants. Mendel's experiments with pea plants established key principles of heredity, known as Mendel's laws.

Mendel's first law: The Law of Segregation

Mendel's first law of inheritance, also known as the Law of Segregation, states that *the characteristics of an organism are controlled by heritable factors that occur in pairs. Of a pair of factors, only one can be passed on to the offspring through reproduction.* The law can also be stated in modern biology terms as thus: *"The characteristics of a diploid organism are controlled by alleles occurring in pairs. Of a pair of alleles, only one can be carried by a single gamete.* During fertilisation, the offspring receive one factor from each parent, and which factor they receive is a matter of chance.

When Mendel crossed contrasting, true-breeding white- and purple-flowered pea plants, all the F1 hybrids were purple. When Mendel crossed the F1 hybrids, many of the F2 plants had purple flowers, but some had white. Mendel discovered a ratio of three purple flowers to one white flower in the F2 generation. Mendel reasoned that only the purple flower factor was affecting flower colour in the F1 hybrids. He called the purple flower colour a **dominant** trait and the white flower colour a **recessive** trait. The factor for white flowers was not blended or destroyed because it reappeared in the F2 generation.

Mendel observed the same pattern of inheritance in six other pea plant characteristics, each represented by two contrasting traits. What Mendel called a "heritable factor" is what scientists today call a **gene**, and the different forms of a gene are called **alleles**. Mendel was also remarkably fortunate that the seven characteristics he studied were each controlled by factors located on different chromosomes — had any of them been linked on the same chromosome, the patterns of inheritance he observed would have been far more complex, and his laws may never have been formulated.

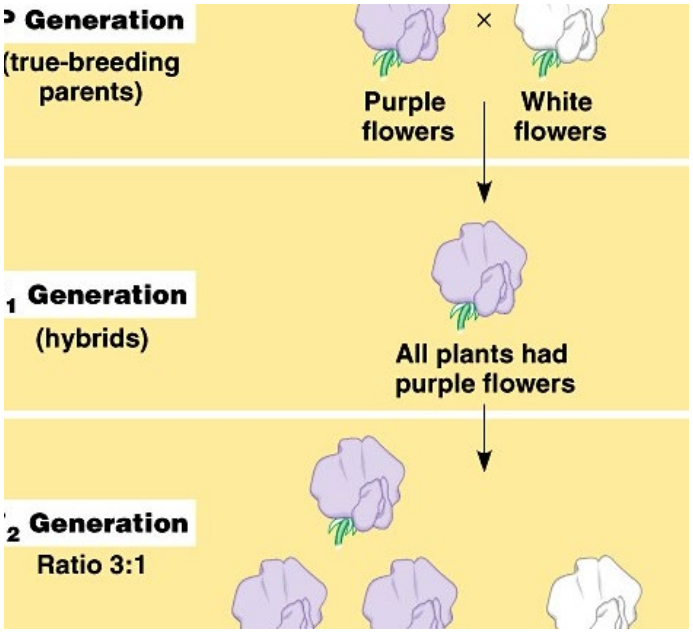


Figure 2.5: Illustration of the law of segregation.

The law of segregation is based on four basic concepts.

a. A gene exists in more than one form, called an allele.

b. When gametes are produced by meiosis, the paired alleles separate, leaving each gamete with a single allele.

c. Every organism inherits two alleles for each trait.

d. The two alleles of a pair are different.

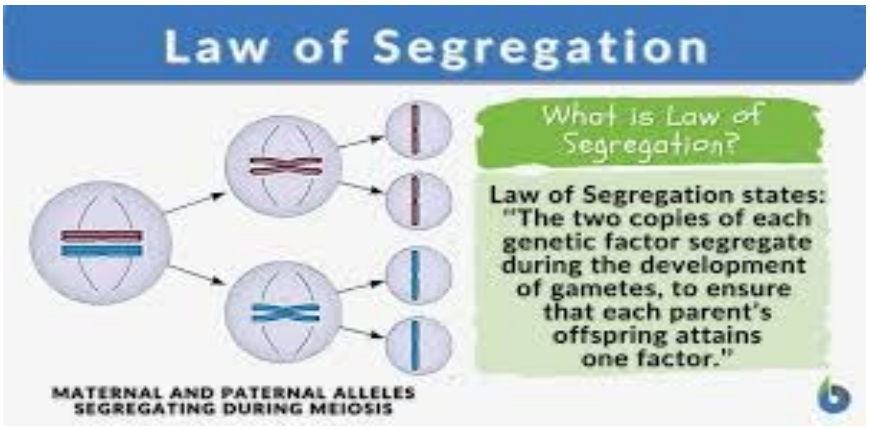


Figure 2.6: Segregation of chromosomes

Monohybrid cross

In the early part of Mendel's work, he studied the inheritance of a pair of contrasting traits or characteristics through a monohybrid cross. This is a genetic cross between two individuals that differ in only one trait or allele set. It is used to study the inheritance pattern of a single characteristic, such as plant height or flower colour. The pea plant is one with a unique number of contrasting characteristics or traits; hence, it is the choice plant for Mendel's study of how traits are passed from parents to offspring.

Mendel began with a pair of purebred pea plants with two contrasting traits, i.e., one tall (TT) and the other dwarf (tt). The cross-pollination of tall and dwarf plants resulted in tall plants, and the offspring were called F1 progeny. The trait which is expressed in the phenotype is called the dominant trait, while the one that is not is called the recessive trait.

The Parent Generation (P Generation): Involved two true-breeding individuals with contrasting traits, i.e. one homozygous tall plant (TT) and a homozygous dwarf plant (tt).

F1 Generation (First Filial Generation): Offspring resulting from the P generation cross. All F1 offspring have the genotype Tt (heterozygous) and display the dominant trait (tall).

F2 Generation (Second Filial Generation): Produced by crossing two F1 individuals (Tt x Tt).

The genotypic outcome was in the ratio of 1:2:1 (1 TT: 2 Tt: 1 tt). This can be expressed in a genetic mapping in ***Figure 2.7*** or in a Punnett square as in ***Table 2.2***.

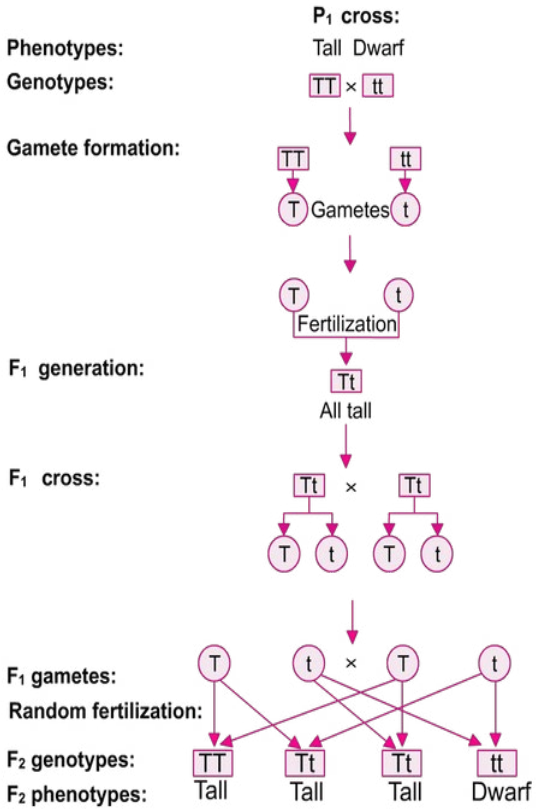


Figure 2.7: Monohybrid genetic mapping

Table 2.1: Punnett square showing the cross of the P generation resulting in the F1 generation

Gametes	t	t
T	Tt	Tt
T	Tt	Tt

Genotype------- all Tt

Phenotype----- all tall plants

Table 2.2: Punnett square showing the cross between two F1s, resulting in the F2 generation.

Gametes	T	t
T	TT	Tt
t	Tt	tt

Genotypic ratio----- 1TT: 2Tt: 1tt

Phenotypic ratio----3 tall plants: 1 short plant

Typical examples of monohybrid inheritance in humans are the ability to roll the tongue (R) versus inability (r), where the gene for tongue rolling is dominant, cleft chin (C) versus smooth chin (c), where the gene for cleft chin is dominant, Free earlobes (F) versus. attached earlobes (f), where the free earlobe gene is dominant, and albinism: normal pigmentation (A) is dominant over the gene for albinism (a).

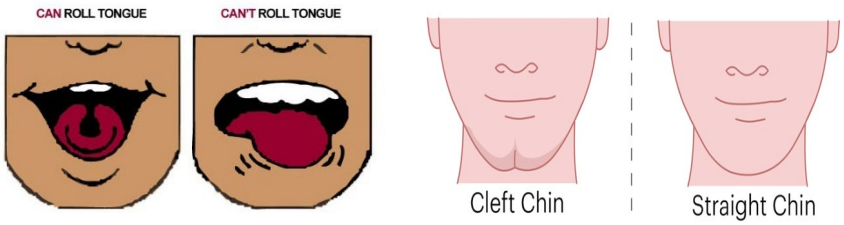


Figure 2.8: Left: Tongue rolling, Right: cleft chin

Activity 2.3 The Mendelian Garden Experiment Simulation

Objective: Simulate Mendel's pea plant experiments to understand genetic inheritance

Materials

- Coloured beads (representing alleles: e.g. blue for dominant, white for recessive)
- Punnett square sheet
- Notebook
- Pen or pencils

Instructions

1. Select coloured beads, e.g. blue for the dominant (round) allele and white for the recessive (wrinkled) allele, to represent a specific trait (seed shape).
2. Put two beads together to represent the genotype of parent organisms, e.g. one blue and another blue bead together form a genotype for a round seed.
3. Form new genotypes with other possible bead combinations and record your results.
4. Predict and record the phenotypes of the parent organisms formed. Identify the true breed from your results
5. Simulate Offspring Creation
   a. Select two parent genotypes that are true-bred
   b. Using a Punnett square, place the beads of the true-bred parent (each bead represents an allele in a gamete) on the square to predict the possible genotypes of the offspring.

Parent 1 **Parent 2**	**Place one bead here (gamete)**	**Place the other bead here (gamete)**
Place one bead here (gamete)		
Place the other bead here (gamete)		

   c. Record the genotypes and phenotypes of the offspring (F1 generation)
6. Repeat instruction number 5, using the F1 generation as the parents
7. Record the results of the offspring as the F2 generation.
8. Analyse the results obtained from the F1 and F2 generations.
9. Reflect and write about what you have learned regarding genetic inheritance.
10. Share your results and reflections with another learner in your class.

Activity 2.4 Exploring Variations in Characteristics

Objective: To identify variations in characteristics of organisms in the environment and relate them to Mendelian principles.

Instructions

1. Observe and record variations in characteristics of organisms in a specific environment (e.g. plants in a garden or animals in a park)
2. Identify the traits that vary, such as:
    a. plant height
    b. flower colour
    c. leaf shape
    d. animal coat colour
    e. beak shape
3. Analyse the variations and relate them to Mendelian principles, such as
    a. dominant and recessive traits
    b. genotype and phenotype
    c. segregation and independent assortment
4. Explore the following questions:
    a. How do the variations in characteristics relate to genetic traits?
    b. Can you identify potential genotypes and phenotypes for the observed traits?
    c. How do environmental factors influence the expression of these traits?

Guiding example: observe the variation in flower colour in a garden, e.g. red, pink, white and analyse the possible genotypes and phenotypes for the flower colour traits.

MENDEL'S SECOND LAW OF INHERITANCE

Law of Independent Assortment

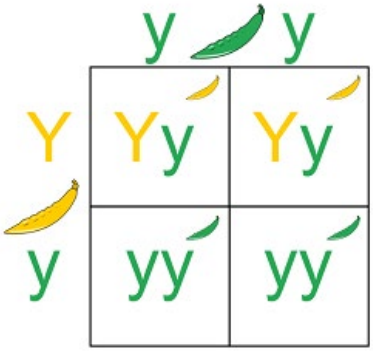


Figure 2.9: Example of independent assortment

Mendel's second law, also known as the Law of Independent Assortment, states that *each of a pair of heritable factors may combine randomly with either of another pair during the formation of reproductive cells*. In other words, the inheritance of one characteristic is independent of the inheritance of another.

Note: The inheritance of a gene on a particular chromosome does not affect the inheritance of a gene on another chromosome - the chromosomes act independently of one another. See **ANNEXES** on page pages 238-240 for further information.

This law is best explained through a **dihybrid cross**. This is a cross between two true-breeding parents that differ in two characteristics. For example, when Mendel crossed a true-breeding pea plant with round yellow seeds with one that had wrinkled green seeds, the F1 generation all showed round yellow seeds. When the F1 plants were crossed with each other, the F2 generation showed four combinations of traits in a 9:3:3:1 ratio (See ***Figure 2.10*** below). This result demonstrated that the factors controlling seed shape were sorted independently of the factors controlling seed colour during reproduction.

The inheritance of a factor on one chromosome does not affect the inheritance of a factor on a different chromosome; each chromosome is sorted independently of the others. This means that every possible combination of factors can occur with equal likelihood, producing the variety of traits observed in the offspring.

It is important to note, however, that independent assortment applies only to factors located on **different chromosomes**. Factors located close together on the **same chromosome** tend to be inherited together, a phenomenon known as **genetic linkage**. Mendel was fortunate that the seven characteristics he studied were each controlled by factors on different chromosomes, which is why his results showed clear independent assortment.

Dihybrid cross

Consider two characteristics in pea plants: seed texture and seed colour. Round is dominant over wrinkled, and yellow is dominant over green. The genes controlling seed texture and seed colour are located on **different chromosomes** and therefore assort independently.

Using R for round, r for wrinkled, Y for yellow and y for green

Parental generation **(P):** YYRR × yyrr

The yellow/round parent is written first by convention. Because each parent is homozygous, the Law of Segregation tells us that all gametes from the yellow/round parent carry YR, and all gametes from the green/wrinkled parent carry yr. Therefore, all F1 offspring are YyRr.

F1 to F2 generation

Each F1 plant (YyRr) produces gametes by independent assortment. Because the genes are on different chromosomes, the allele for seed texture that enters a gamete has no influence on which seed colour allele accompanies it. This produces four equally likely gamete types: YR, Yr, yR, and yr.

Arranging these four gamete types along the top and left of a 4 × 4 Punnett square gives 16 possible F2 combinations. From these 16 combinations, the following phenotypic ratio is obtained:

9 round/yellow : 3 round/green : 3 wrinkled/yellow: 1 wrinkled/green

This ratio, shown in ***Figure 2.10***, is the expected outcome when a large sample size is used. With smaller samples, the ratio may not be exact, but the pattern becomes clearer as the number of crosses increases.

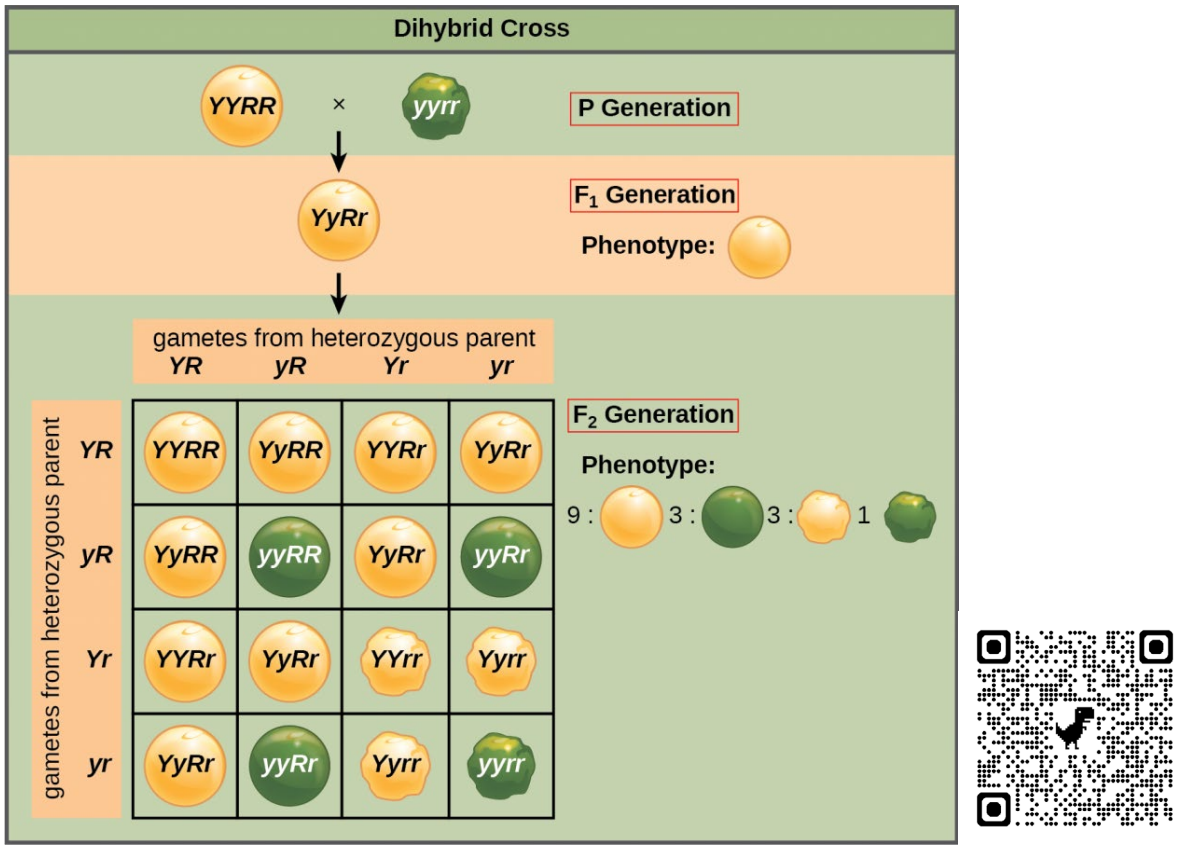


Figure 2.10: Dihybrid cross of pea plants involving the alleles for seed colour and texture.

The expected phenotypic ratio in a dihybrid cross is typically 9:3:3:1. This ratio reflects the independent assortment of the two traits. A dihybrid cross helps us understand how different traits are inherited independently and how genetic variation is generated.

The proportion of round and yellow F2 offspring is expected to be 9/16, and the proportion of wrinkled and green offspring is expected to be 1/16. Round, green and wrinkled, yellow offspring can be found in proportions of 3/16, as each of these genotypes includes one dominant and one recessive phenotype.

Note: All of this only applies if the gene loci are on different chromosomes.

The law of independent assortment also indicates that a cross between yellow, wrinkled (*YYrr*) and green, round (*yyRR*) parents would yield the same F1 and F2 offspring as in the *YYRR* x *yyrr* cross.

Typical examples of dihybrid inheritance in humans are tongue rolling and earlobe attachment, or tongue rolling and albinism, and Widow's Peak and Hitchhiker's Thumb

a. **Tongue Rolling and Earlobe Attachment:** The ability to roll the tongue (dominant) versus inability (recessive), combined with free earlobes (dominant) versus attached earlobes (recessive).

b. **Albinism and Tongue Rolling** Albinism (recessive) versus normal pigmentation (dominant) combined with tongue rolling (dominant) versus non-rolling (recessive).

c. **Widow's Peak and Hitchhiker's Thumb:** Widow's peak hairline (dominant) versus straight hairline (recessive), combined with straight thumb (dominant) versus hitchhiker's thumb, which bends backwards (recessive).

Activity 2.5 Demonstrating Independent Assortment

Objective: To simulate Mendel's dihybrid cross and demonstrate the Law of Independent Assortment

Materials

- 4 colours of beads or bottle caps (e.g. yellow and green for seed colour alleles; red and white for seed texture alleles)
- Two small bags or cups (one representing each parent)
- A recording sheet

Instructions

1. Label your four bead colours as follows: Yellow bead = Y (yellow seed allele), Green bead = y (green seed allele), Red bead = R (round seed allele), White bead = r (wrinkled seed allele)
2. Place 10 yellow and 10 green beads in one bag to represent the seed colour alleles of an F1 plant (Yy). Place 10 red and 10 white beads in a second bag to represent the seed texture alleles of the same F1 plant (Rr).
3. Without looking, pick one bead from each bag at the same time. Record the combination. This represents one gamete produced by independent assortment.
4. Return the beads, shake the bags, and repeat at least 20 times. Record every combination.
5. Repeat steps 3 and 4 to represent the second parent plant producing gametes.
6. Pair your gametes from both parents randomly to represent fertilisation. Record the genotype and phenotype of each offspring.
7. Count your results and calculate your phenotypic ratio. How close is it to 9:3:3:1?
8. Combine your results with the rest of the class. Does the ratio get closer to 9:3:3:1 as the sample size increases?

Discussion Questions

a. Why do we get four different gamete types from a YyRr plant?

b. What would happen to the ratio if the two genes were on the same chromosome?
c. Why does increasing the sample size give a more accurate ratio?

Activity 2.6 Trait Inheritance Chart

Objective: To explore and understand the inheritance of traits by creating a family tree that visually represents how specific traits are passed down through generations.

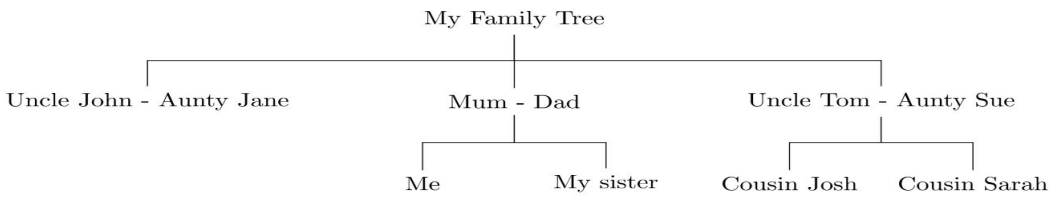
Materials

- Paper (for drawing the family tree)
- Pencils and colored markers
- Ruler (optional for neat lines)
- Reference materials on common traits (e.g., ability to roll tongue, attached vs. free earlobes)
- Symbols guide (circles for females, squares for males)

Instructions

1. Choose 2-3 common traits to track (e.g., ability to roll tongue, attached vs. free earlobes).
2. On a sheet of paper, draw a simple family tree structure. Include yourself, parents, siblings, and grandparents.
3. Use circles to represent females and squares for males. Mark the selected traits for each family member clearly (e.g. shading or symbols).
4. Write a short paragraph(reflection) about how traits were inherited in your family tree. Discuss any patterns observed and what they might suggest about genetic inheritance.
5. Present your family tree and reflections to the class, highlighting interesting patterns or traits.

An example of a simple family tree



Activity 2.7 Mendelian Scenarios Role-Play

Objective: You will understand the principles of genetic crosses by creating scenarios, role-playing the inheritance process, and calculating expected offspring ratios.

Materials

- Paper and pencils (for writing scenarios)
- Props (optional, for role-playing)
- Chart paper or whiteboard (for calculating ratios)
- Genetic cross-reference materials (e.g., Punnett squares, trait definitions)

Instructions

1. In pairs or small groups, write simple scenarios of genetic crosses (e.g., a tall plant crossed with a short plant). Include details about the traits involved.
2. Role-play the scenario, explaining what happens at each stage of the genetic cross.
    a. P Generation: Introduce the parent organisms and their traits.
    b. F1 Generation: Show the offspring produced from the P generation and describe their traits.
    c. F2 Generation: Discuss the next generation and how traits may vary, using the F1 generation as parents.
3. Calculate the expected ratios of offspring based on the scenario acted out. Use a Punnett square if necessary and share the results with the class.
4. Discuss any variations observed in the role-play compared to the theoretical ratios.

BLOOD GROUPING

Human blood is grouped under two main blood group systems. These are the ABO blood group system, discovered by Karl Landsteiner and the Rhesus blood group system.

The ABO Blood Group System

The ABO blood group system is a method of classifying human blood based on the presence or absence of specific antigens (A and B) on the surface of red blood cells (erythrocytes). An **antigen** refers to any substance that triggers an immune response, such as the production of **antibodies**, to protect the body from harm. These antigens are glycoproteins and glycolipids that protrude from the cell membrane. Antibodies are proteins produced by the immune system in response to the presence of a foreign substance (that fights them off) in the body, such as antigens. Antigens are represented with capital letters, while antibodies are represented with small letters.

There are four main types of blood groups in the ABO system. These are **blood group A**, **blood group B**, **blood group AB**, and **blood group O**. Blood Group A has antigen A on

its red blood cells and antibody **B** in plasma. Blood group B possesses antigen B on its red blood cells and antibody A in the plasma. Blood group AB has both antigens A and B on the red blood cells but has no antibodies in the plasma. Blood group O lacks both antigens A and B but possesses both antibodies a and b in the plasma.

The ABO blood group is determined by a single gene (the ABO gene) with three multiple alleles (alleles IA, IB and IO, or simply allele A, allele B and allele O). These alleles control the production of antigens A and B in the human blood. Alleles A and B are co-dominant. This means neither the A nor the B allele is dominant over the other. They are equally expressed. In other words, both alleles have an equal effect on the phenotype, resulting in the AB blood group. Blood group O is determined by a homozygous recessive allele.

ABO Blood Group System and Co-dominance

Human blood group is determined by a single gene with three possible alleles: IA, IB, and IO. The alleles IA and IB are both dominant over the recessive allele IO, which produces no surface antigens on red blood cells. However, IA and IB show neither dominance over each other; instead, when both are present together in an individual (IAIB), both alleles are fully expressed, producing both A and B antigens on the surface of the red blood cells. This results in blood type AB. This relationship, where two alleles are both fully expressed in the heterozygote rather than one masking the other, is called co-dominance. An individual who inherits two copies of the recessive allele (ii) has no surface antigens and therefore has blood type O.

See **ANNEXES** on page 238-240 for more information.

Shown below is a summary of the various attributes of the different blood types of the ABO blood system.

Table 2.3: ABO blood grouping system

Blood group	Antigen	Antibody	Phenotype	Possible Genotypes
A	A	b	A	IAIA (AA) or IAIO (AO)
B	B	a	B	IBIB (BB) or IBIO (BO)
AB	A and B	None	AB	IAIB (AB)
O	None	a and b	O	IOIO (OO)

Blood groups follow Mendelian inheritance patterns. Blood type O is determined by a recessive allele (IO), and an individual must inherit two copies of this recessive allele (IOIO) to have blood type O. Therefore, a couple who are both blood type O (both having the genotype IOIO) can only pass the recessive allele to their children, meaning all their offspring will also have blood type O. Blood type A parent who is heterozygous (AO) and a type O parent have a 50% chance of having children with blood type A and 50% chance of having children with blood type O. A parent, heterozygous for blood group A (AO) and a parent, heterozygous for blood group B (BO) can have children of all four blood types i.e. AB, AO, BO and OO.

Blood type distribution varies among different populations, with blood group O being the most common globally (45-60%). The approximate distributions among the Ghanaian population are blood group O: 50-55%, A: 20-25%, B: 20-22% and AB: 3-5%.

ABO Blood Type and the Rh Factor — Independent Assortment

The ABO blood group gene and the Rh factor gene are located on **different chromosomes**. The Rh factor is controlled by a separate gene, where the allele for Rh positive (Rh^+) is dominant over the allele for Rh negative (Rh^-). Because these two genes are on different chromosomes, they assort independently of each other during gamete formation, in accordance with Mendel's Law of Independent Assortment. This means that a person's ABO blood type has no influence on whether they are Rh positive or Rh negative, and vice versa. The combination of these two independently assorting genes produces eight possible blood type combinations: A^+, A^-, B^+, B^-, AB^+, AB^-, O^+, and O^-. This is a human example of dihybrid inheritance, where two traits controlled by genes on different chromosomes are inherited independently of one another.

Blood Transfusion

Blood transfusion is the process of transferring blood or blood components from one person (donor) to another (recipient). Successful transfusion requires compatibility between donor and recipient blood types. **Blood compatibility** refers to the ability of one's blood to be safely transfused into another person without any adverse reactions. Compatibility depends on the reaction between donor antigens and recipient antibodies. The adverse effect is agglutination. **Agglutination** refers to the clumping of red blood cells (RBCs) in a recipient when incompatible blood types are mixed. This reaction is caused by the presence of antibodies in the recipient's plasma recognising and binding to specific antigens on the surface of the donor's RBCs, resulting in the clumping of red blood cells. People with blood group O negative (O-) can donate red blood cells to all blood groups (recipients) and are therefore called **universal donors**. Individuals with blood type AB positive (AB+) can receive blood cells from all the other blood groups and are therefore called **universal recipients**. Signs of transfusion reactions (agglutination or incompatibility transfusion) include acute haemolytic reactions with symptoms such as fever, chills, lower back pain, chest pain and difficulty in breathing. This can potentially cause kidney damage, shock and even death in severe cases. The chart below is a detailed guide to a successful blood transfusion.

Rhesus Factor

The Rhesus factor (Rh factor) was discovered in 1940 by Karl Landsteiner and Alexander S. Wiener. They identified the Rh factor while studying the blood of Rhesus macaque monkeys, which led to the discovery of the Rh antigen in humans. It is an antigen found on the surface of red blood cells and named after the Rhesus monkey in which it was first discovered.

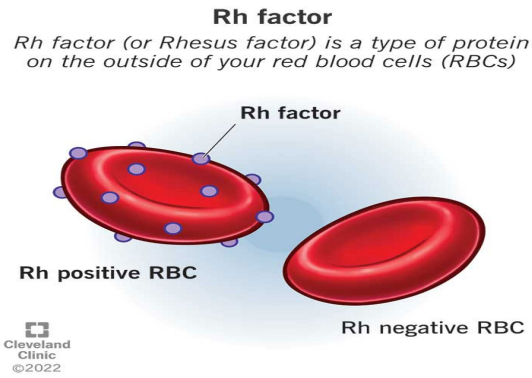


Figure 2.11: Rh factor on red blood cell

The most important Rhesus antigen is the D antigen (RhD). It is the primary antigen responsible for Rh type blood classification and a major consideration in transfusion medicine and pregnancy care.

People who have the D antigen on their red blood cells are described as **Rh-positive (Rh+)**. **Rh-negative (Rh-)** individuals are people who do not have antigen D on their red blood cells. Rhesus factor status of a person is determined by a gene with two alleles, a dominant allele R, which codes for antigen D, and a recessive allele r, coding for the absence of antigen D. Thus, the possible genotypes for an individual who is Rhesus positive (Rh+) are *RR* or *Rr*. For an individual lacking the Rhesus antigen (Rhesus negative or Rh-), the genotype is *rr*.

During a blood transfusion, both the ABO and Rhesus factor classifications are required to be compatible for a successful process. People with negative or positive superscripts on their blood groups (e.g. O-, O+**)** are Rhesus negative and positive individuals, respectively.

Table 2.4: Blood group compatibility among the different groups

RED BLOOD CELL COMPATIBILITY TABLE								
Recipient	Donor							
	O-	O+	A-	A+	B-	B+	AB-	AB+
O-	✓	✗	✗	✗	✗	✗	✗	✗
O+	✓	✓	✗	✗	✗	✗	✗	✗
A-	✓	✗	✓	✗	✗	✗	✗	✗
A+	✓	✓	✓	✓	✗	✗	✗	✗
B-	✓	✗	✗	✗	✓	✗	✗	✗
B+	✓	✓	✗	✗	✓	✓	✗	✗
AB-	✓	✗	✓	✗	✓	✗	✓	✗
AB+	✓	✓	✓	✓	✓	✓	✓	✓

Key: agglutination (x) no agglutination (✓)

It is important to know one's blood group for the following reasons:

a. It is a requirement for emergency blood transfusion.
b. It is required in determining compatibility for organ transplantation.
c. To understand complications in pregnancy.
d. For blood donation exercise for storage at blood banks.

Rhesus Incompatibility in Pregnancy

This occurs when a Rh-negative woman gets pregnant with a Rh-positive baby because the father of the baby is Rh-positive. The processes leading to Rhesus incompatibility are as follows.

1. A Rhesus negative woman and a Rhesus positive man marry and conceive an Rh+ baby inherited from the father.
2. During pregnancy, the mother may be exposed to the baby's Rh-positive blood, thereby causing the mother's immune system to produce anti-Rh antibodies.
3. At this first pregnancy, the response is too late and too weak to cause a problem
4. In subsequent pregnancies, if the mother carries Rh-positive babies, these maternal antibodies are produced quickly and in greater quantity, and can cross the placenta to attack the foetus' red blood cells, causing haemolytic disease of the newborn (**HDN**), also known as erythroblastosis fetalis.

HDN can lead to consequences such as anaemia in the foetus, jaundice in the newborn, brain damage and stillbirths in the most severe cases.

Mothers who experience Rhesus incompatibility consequences can receive anti-D immunoglobulin (**RhoGAM**) injection during pregnancy and after delivery to prevent the mother from developing antibodies against Rh-positive blood in future pregnancies.

The process of communication that guides individuals and families to understand and adapt to the medical, psychological and familial effects of genetic disease on an individual or family is known as **genetic counselling.**

Genetic counselling is important for the following reasons

a. Rhesus-negative women planning pregnancies need to be aware of possible complications after first pregnancies and available remedies.
b. For families with histories of blood disorders to understand their family background.
c. For people to understand unusual blood group inheritance patterns among families.
d. It may be required for planning potential medical interventions such as organ transplant or blood transfusion.

Some important ethical principles are providing information without seeking to influence decisions (non-directiveness), confidentiality (being confidential), informed consent

(seeking permission before taking information), respecting people's independent decisions (respect for autonomy).

Activity 2.8 Blood Group Sorting Game

Objectives: Simulate different blood types (A, B, AB, and O) and their compatibility while engaging in hands-on sorting to visualise blood type distribution and understand the importance of blood type knowledge in medical situations.

Materials

- Colored paper or beads representing blood types (e.g., red for A, blue for B, green for AB, yellow for O)
- A container for mixing materials
- Chart paper or a whiteboard for group discussions
- Reference materials on blood type compatibility

Instructions

1. Collect colored paper or beads to represent the different blood types: A, B, AB, and O.
2. Mix the colored materials in a container.
3. Sort the materials into groups based on blood types, discussing the characteristics of each type as you sort.
4. As a group, discuss which blood types can donate to and receive from each other.
5. Create a chart to illustrate compatibility (e.g., A can donate to A and AB, can receive from A and O).
6. Explain the importance of understanding blood types in medical situations, such as blood transfusions and organ donations.
7. Discuss how knowing blood type can impact patient care and safety.

Activity 2.9 Genetics and Pregnancy: The Rh Factor Showdown!

Objective: Explore the genetic basis of the Rhesus (Rh) factor and its implications for pregnancy, then create an informative and visually engaging poster to raise awareness.

Instructions

1. Use reliable sources like medical websites, textbooks, and scientific articles to investigate;
   a. What is the Rh factor, and how is it inherited?
   b. What happens when a Rh-negative mother carries a Rh-positive baby?

c. What Rh incompatibility is and how it affects the foetus.
d. What medical interventions exist (e.g., Rho(D) immune globulin)?

Note: Some links to articles and medical websites

https://www.mayoclinic.org/tests-procedures/rh-factor/about/pac-20394960

https://healthy.kaiserpermanente.org/health-wellness/health-encyclopedia/he.rh-sensitization-during-pregnancy.hw135942

https://scienceofbiogenetics.com/articles/the-role-of-genetics-in-rh-factor-and-its-implications-for-human-health

https://frontiersrj.com/journals/ijflsr/sites/default/files/IJFLSR-2023-0081.pdf

2. Design a poster titled **"Genetics vs. Pregnancy: The Rh Factor Showdown!"**

   The poster should have:

   a. a bold, eye-catching subtitle and layout
   b. diagrams (Punnett squares, blood compatibility charts)
   c. clear explanations of Rh inheritance and incompatibility
   d. medical solutions and preventive measures
   e. a call to action (e.g., "Know Your Blood Type!" or "Test Early, Protect Your Baby!")

3. Present your poster to your class.

Activity 2.9 Blood Group: Personal Data Project

Objective: To carry out an anonymous survey on blood groups, organise the data, and present it using simple graphs and charts.

Materials

- 10–20 small slips of paper or a notebook
- A box or envelope to collect responses
- Graph paper or a computer with Excel
- Pencil, ruler, coloured pens
- A4 paper or card for your final presentation

Instructions

1. Read about the four main blood groups (A, B, AB, and O), Rh factor and why blood groups are important in medicine and genetics.
2. Write these two questions on 10–20 small slips of paper:

   What is your ABO blood type? What is your Rh type?

Note: Make sure you do not collect names. Keep it anonymous.

3. Collect the data
   a. Ask classmates, teachers, or family members to fill in a slip
   b. Place the slips in an envelope or box
   c. After collecting, count how many people gave each blood group and Rh type
4. Organise Your Results

Blood Group	Rh+	Rh–	Total
A			
B			
AB			
O			

   a. Make a table like this in your notebook, and fill in the boxes with your data
5. Choose to draw one or both:
   a. **Bar chart** – shows how many people have each blood group
   b. **Pie chart** – shows the percentage of each group
6. Use colours to make your graphs clear and attractive.
7. Write a short paragraph explaining:
   a. Which blood group was most common
   b. How many people were Rh-positive vs Rh-negative
   c. Why this information is useful
8. Present your table, graph(s) and summary on an A4 paper or card as a mini poster.

VARIATION AND ITS CAUSES

Variation and Its Types

Variation refers to the differences that exist among individuals of the same species. These differences can be observed in physical characteristics, physiological functions, and genetic makeup of organisms. Variation is of two main types. These are **continuous variation** where traits show intermediate phenotypes between two extreme characters (e.g. height in humans (ranges from very short to very tall), weight in animals, intelligence in humans, skin colour in humans) and **discontinuous variation,** where traits show distinct and separate sets of phenotypes without any intermediates, i.e. there is no blending of traits or characteristics.

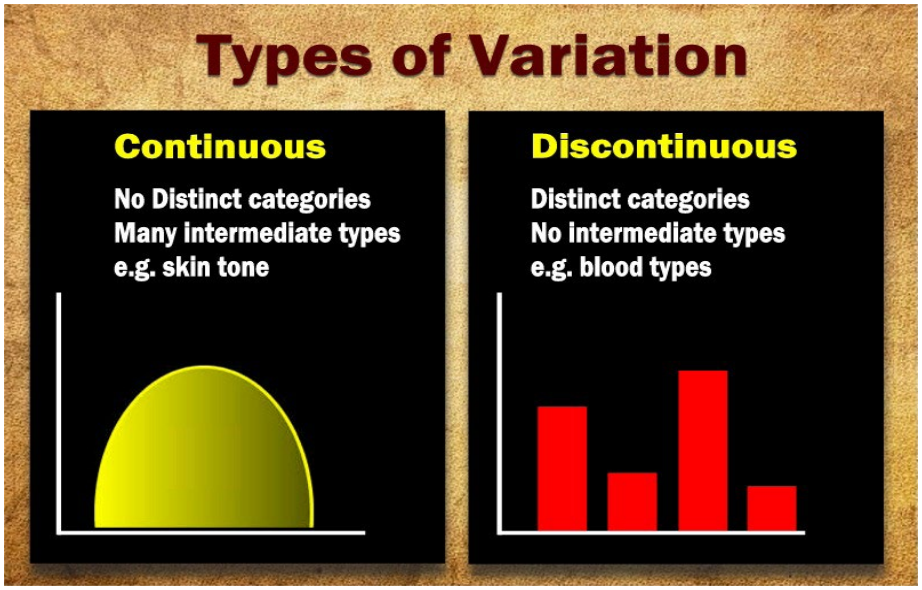


Figure 2.12: Variation types

Examples are blood groups (A, B, AB and O), tongue rolling ability (either can roll or cannot), attached or free earlobes, ability to taste PTC (phenylthiocarbamide) as bitter or neutral.

Basic Principles of Variation (Why Variation Occurs in Any Population)

Several factors account for the occurrence of variation in a population. These include

1. *Genetic Recombination:* During meiosis, crossing over and independent assortment of chromosomes create new gene combinations.
2. *Random Fertilisation:* The random union of gametes contributes to genetic diversity.
3. *Mutation:* Changes in DNA sequences, thereby creating new alleles.
4. *Genetic Drift:* Random changes in allele frequencies, especially in small populations.
5. *Gene Flow:* This refers to the movement of genes from one population to another through migration.
6. *Natural Selection:* Selection pressures favour certain traits, leading to changes in populations over time.

Mechanism of Natural Selection

Natural selection is the process by which populations of living organisms adapt and evolve in response to environmental pressures, resulting in the survival and reproduction of individuals with advantageous traits. The main mechanisms involved in the process are as follows.

1. Variation occurs in all populations, causing differences among individuals of the same species.
2. Environmental factors such as climate, predation and competition affect survival and reproduction in populations.

3. Individuals with favourable traits are more likely to survive and reproduce successfully, while those with less favourable traits are eliminated.
4. These favourable traits are passed on to the next generation, increasing their number in the population.
5. Over time, the population adapts to the habitat and evolves.

Use this link to watch a video on natural selection: https://youtu.be/UKETe78t5p8

Importance of Variation

1. Variation enables adaptation to changing environments.
2. It provides resistance against diseases.
3. It forms the basis for evolution.
4. Variation increases the chances of species survival.

Factors Affecting Variation and How They Affect the Process

Factors that result in variation are grouped into two main forms: genetic and environmental.

Genetic Factors

1. Mutation: Random changes in genetic material can create new alleles and phenotypes. Mutation may be a gene (point) mutation or chromosomal mutation. It may be spontaneous or induced by mutagens (e.g., radiation or chemicals).
2. Segregation and Recombination: This results from activities such as the rearrangement of genetic material during meiosis, crossing over, resulting in the exchange of segments between chromosomes (See illustration below in ***Figure 2.13***), and the independent assortment of chromosomes, which creates new combinations.

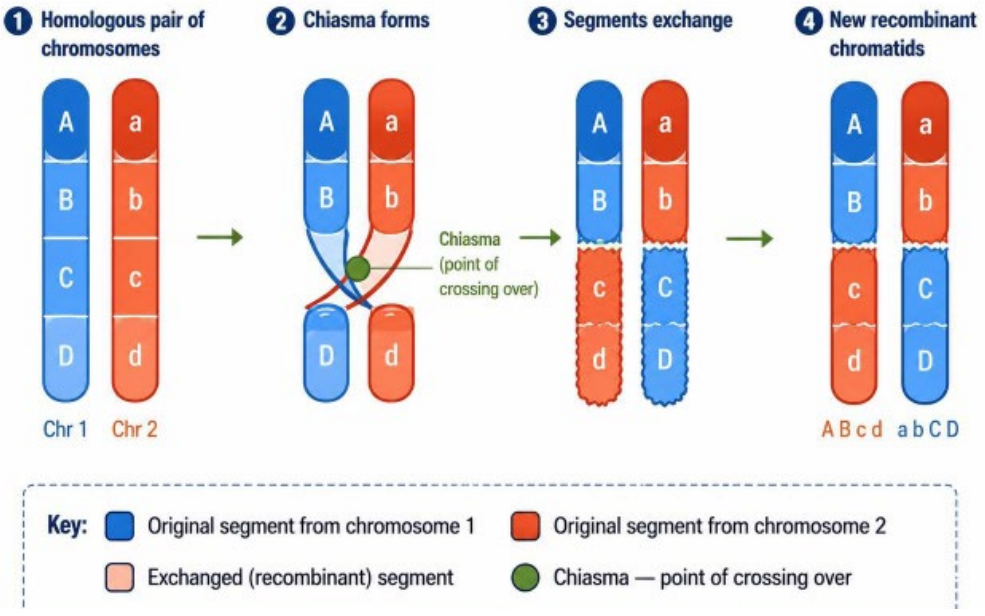


Figure 2.13: Illustration of crossing over

Note: During meiosis, homologous chromosomes pair up and exchange segments at points called chiasmata (singular: chiasma). This produces new combinations of alleles in the gametes, combinations that did not exist in either parent. Crossing over is a key source of genetic variation in sexually reproducing organisms. Genes on the same chromosome are said to be linked; crossing over can separate them.

3. Epistasis: This is the condition where the presence of one gene (**epistatic gene**) at a particular locus suppresses the effect of another gene (**hypostatic gene**) at another locus. Examples of epistasis are coat colour in mice and comb shape in poultry birds.
4. Polygenic characters: These are characters controlled by the combined effect of many alleles at different loci. The different alleles can combine in more ways than a single pair of alleles since different pairs of genes are involved. Examples are about four pairs of genes coding for the expression of melanin in the skin, about four pairs coding for eye colour, and about five pairs coding for height in humans.

Environmental Factors

1. Nutrition: This affects growth, development, and expression of traits. For example, identical twins raised with different diets may develop different heights.
2. Light Intensity affects the skin tone. High light intensity can lead to high production of melanin (dark pigment) in the skin.
3. Altitude affects the number of red blood cells in humans and, therefore, breathing in humans.
4. Exercise can help develop big muscles and keep the body healthy and resilient.
5. Pathogens cause diseases in humans, leading to changes in physical appearance in some cases, e.g. leprosy and elephantiasis.

Social interactions and migration patterns are also environmental factors that influence variation. For example, during mate selection, non-random mating may affect gene distribution, while certain cultural practices may encourage or discourage certain traits. Movement between populations also increases genetic diversity by introducing new alleles into the population.

APPLICATION OF PRINCIPLES OF VARIATION AMONG HUMANS TO IMPROVE LIFE

Genetic Disorders and Genetic Counselling

Genetic disorders result from abnormalities in an individual's genome. Examples include Down syndrome, sickle cell anaemia, cystic fibrosis, and Huntington's disease. They can be inherited (hereditary) or caused by new mutations.

Personalised Medicine and Genetic Variation

The medical approach tailors treatment to individual genetic makeup**.** It uses genetic information to predict disease susceptibility and drug response**.** Example: cancer treatment

based on tumour genetic history. Preventive measures may also be effective for individuals with a genetic predisposition to diseases

Forensic Applications of Human Variation

The study of variation has several applications in forensic science. Some applications are

1. DNA profiling/fingerprinting for identifying individuals.
2. Paternity and relationship testing.
3. Victim identification in mass disasters.
4. Tracking geographical ancestry through genetic markers.

How Variation Aids Forensic Investigations

a. Individual-specific DNA profiles due to genetic polymorphisms: This refers to variations in DNA sequences among individuals. These variations make each person's DNA profile unique, allowing forensic investigators to distinguish between individuals and link DNA evidence to a specific person.

b. Short Tandem Repeats (**STRs**) analysis for unique identification: STRs are repetitive DNA sequences that vary in length among individuals. By analysing multiple STR loci, forensic investigators can create a unique DNA profile for an individual, making it possible to identify individuals and match DNA evidence to a specific person.

c. Mitochondrial DNA analysis for maternal lineage tracing: mitochondrial DNA (**mtDNA**) is inherited maternally and remains relatively unchanged through generations. By analysing mtDNA, forensic investigators can trace maternal lineage and identify individuals or remains, particularly in cases where nuclear DNA is degraded or unavailable.

d. Y-chromosome analysis for paternal lineage tracing: Y-chromosome DNA is inherited paternally and can be used to trace paternal lineage. By analysing Y-chromosome DNA, forensic investigators can identify males and link DNA evidence to a specific paternal lineage.

Genetic Factors in Disease Susceptibility

a. **Single-gene disorders** are caused by a mutation in one specific gene.

   i. **Sickle cell anaemia:** Caused by a mutation in the gene responsible for haemoglobin production. The red blood cells become sickle-shaped, reducing their ability to carry oxygen efficiently.

   ii. **Cystic fibrosis:** Caused by a mutation in the CFTR gene. It leads to the production of thick, sticky mucus that affects the lungs and digestive system.

   iii. **Huntington's disease:** A hereditary disorder caused by a mutation in a single gene, leading to progressive damage to nerve cells in the brain.

b. **Polygenic disorders** are influenced by variations in many genes acting together.

i. **Type 2 diabetes:** Several genes affect insulin production and the body's response to insulin, increasing the risk of developing the disease.

ii. **Heart disease:** Multiple genes can influence blood pressure, cholesterol levels, and other factors that contribute to cardiovascular disease.

iii. **Hypertension (high blood pressure):** Results from the combined effects of many genes together with lifestyle factors.

c. **Gene–environment interactions** occur when genetic predispositions interact with environmental factors to influence disease development.

i. **Type 2 diabetes:** Individuals may inherit genes that increase susceptibility, but poor diet, obesity, and lack of physical activity often trigger the disease.

ii. **Lung cancer:** Some people inherit genetic variants that increase their susceptibility, but exposure to cigarette smoke or air pollution greatly increases the risk.

iii. **Asthma:** Genetic factors can make a person more prone to asthma, while environmental triggers such as dust, pollen, smoke, or respiratory infections can cause symptoms to develop.

Note: Genes can influence disease risk, but environmental factors such as diet, lifestyle, pollution, and infections often determine whether a disease develops and how severe it becomes.

Why an individual must understand the Principles of Variation

1. It is required for personal health monitoring and screening
2. Knowledge in genetics allows people to identify the causes of genetic diseases and their risk factors and to plan a targeted therapy.
3. It guides the individual to modify his or her lifestyle for a healthy living.
4. The individual becomes more knowledgeable in genetic concepts such as adaptation, speciation and biodiversity.

EVOLUTION AND THE EVIDENCE OF EVOLUTION

Evolution

Evolution is the gradual change in the heritable characteristics of biological populations over successive generations. These changes are influenced by the environment and passed from one generation to another. The changes allow organisms to adapt to their environment for better survival and reproduction. Evolution offers a clearer understanding of the diversity of life and how different species are related within a habitat.

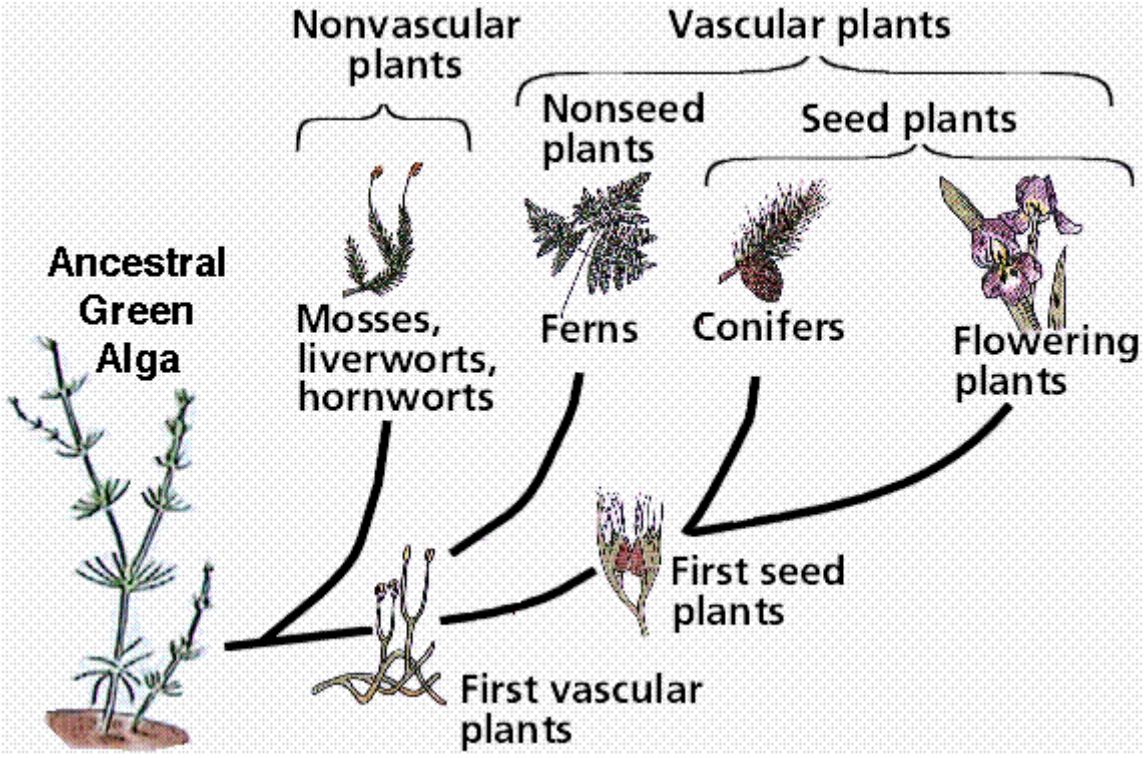


Figure 2.13: Evolution of plants

Types of Evolution

There are two main types of evolution. These are microevolution and macroevolution.

1. Microevolution refers to small-scale changes in allele frequencies in a population over a few generations. The following are examples of microevolution:
   a. The development of antibiotic resistance in bacteria.
   b. Pesticide resistance in insects.
   a. Changes in beak shape among Galapagos finches during drought periods.
   b. Sickle cell trait prevalence in malaria-endemic regions of Ghana and West Africa.
   c. Industrial melanism in peppered moths in response to pollution in industrial areas.
2. Macroevolution is the large-scale evolutionary changes that occur over huge geological time periods, often leading to speciation (formation of new species). Examples include the evolution of whales from land-dwelling mammals, the development of birds from dinosaur ancestors, the evolution of humans from ape-like ancestors, the transition of fish to amphibians and the evolution of flowering plants.

Evidence of Evolution

1. *Fossil Records:* Fossils are preserved remains or traces of ancient organisms. Fossil records show a progression from simple to complex organisms over a very long geological time frame. Fossils found in Ghana, particularly marine fossils in sedimentary rocks, provide local evidence of evolutionary changes.

2. *Comparative Anatomy:* This is the study of similarities and differences in anatomical structures across species. Structures studied include
    a. Homologous structures: These are structures with similar anatomy but different functions (e.g., human arm, whale flipper, bat wing)
    b. Analogous structures: They are structures with similar functions but different anatomy. Examples are insect wings and bird wings)
    c. Vestigial structures: These refer to the reduced or functionless remains of structures that were functional in the ancestors of an organism. Examples are the appendix in humans and the pelvic bones in whales)
3. *Embryological Evidence:* Embryos of different vertebrates look similar in the early stages of development. Human embryos temporarily develop gill pouches, a tail, and other features like other vertebrates. These similarities suggest common ancestry
4. *Molecular and Biochemical Evidence:* DNA and protein similarities between species give clues to the occurrence of evolution. This is supported by the universal genetic code among all organisms. For example, cytochrome C (a protein) similarities between humans and chimpanzees are approximately 99%. Mitochondrial DNA evidence also traces our first parents (early humans) from Africa.
5. *Biogeographical Evidence:* Biogeographical evidence is observed in the distribution of species across the globe. Also, endemic species are found only in specific geographic regions of the Earth. Similar ecological niches filled by different organisms in isolated areas. That is, when areas are geographically isolated, similar habitats can result in different organisms evolving to fill the same ecological roles. This is termed *convergent evolution*. For example, marsupials in Australia are like mammals in other parts of the world but with distinct differences due to Australia's isolation. Also, different species of desert-dwelling lizards have evolved similar traits (e.g. sand-digging abilities) in different desert regions around the earth.

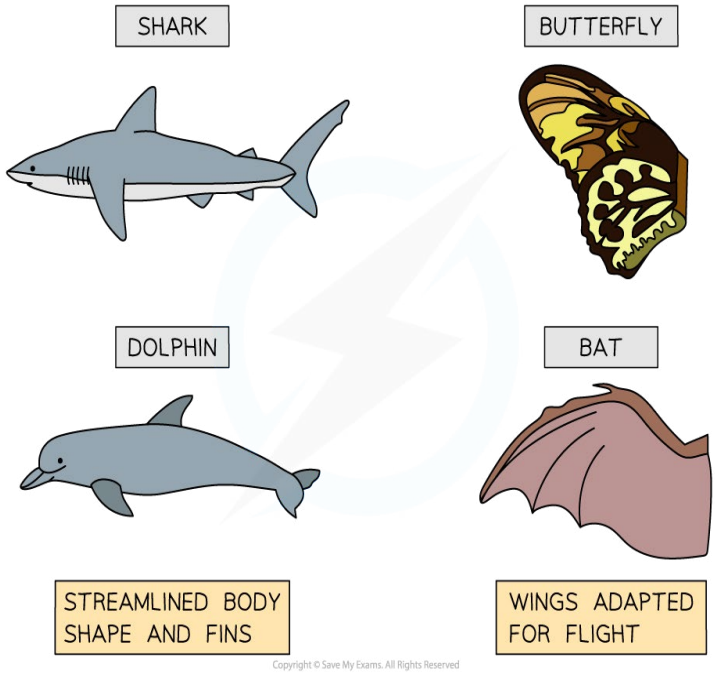
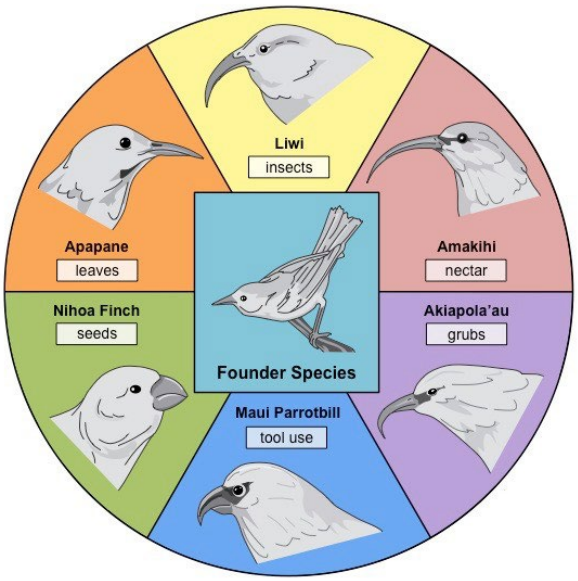


Figure 2.14: Convergent evolution

On the other hand, *divergent evolution* is where two or more related species become more dissimilar over time due to different habitats or ecological niches. The process leads to distinct characteristics and adaptations. A typical example of divergent evolution is the observation of Darwin's finches on the Galapagos Islands, where different beak shapes and sizes have evolved for specific food sources.



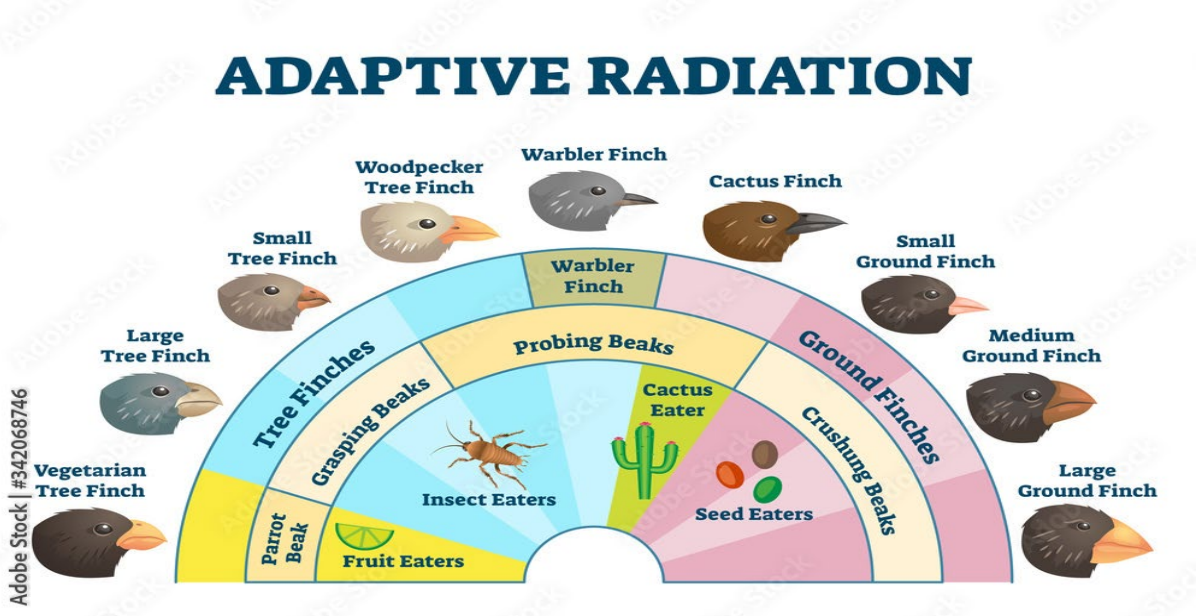


Figure 2.15: Divergent evolution

Theories of Evolution

Lamarck's Theory of Evolution

This theory was proposed by the French naturalist, Jean-Baptiste Lamarck (1744-1829). The essential components of his theory are;

a. Organisms can change their physical features during their lifetime in response to environmental challenges.

b. These acquired characteristics are passed on to their offspring.

c. Evolution occurs through the inheritance of acquired characteristics.

A typical illustration of this theory is observed in giraffes stretching their necks to reach high leaves. Eventually, they would develop longer necks, and this trait would be passed to offspring. Another illustration is the blacksmith's muscles, where the theory taught that the descendants of a blacksmith acquired muscles due to the blacksmith's arm muscles developing because of constant use.

This theory is also known as the theory of inheritance of acquired characteristics.

Criticisms of Lamarck's Theory

1. Acquired characteristics (like muscle development through exercise) are not inherited.
2. No mechanism was proposed for how acquired traits could affect reproductive cells.
3. Modern genetics has disproven the inheritance of acquired characteristics.

Darwin's Theory of Evolution

The British evolutionist, Charles Darwin (1809-1882), proposed the *theory of natural selection* as the basis of evolution. The components of the theory are:

1. Organisms produce more offspring than can survive
2. Variation exists among individuals in a population
3. Some variations are heritable
4. Individuals with favourable variations are more likely to survive and reproduce (survival of the fittest)
5. Over time, favourable traits become more common in the population.

Evidence Supporting Darwin's Theory

1. Observed instances of natural selection (e.g., antibiotic resistance).
2. Artificial selection demonstrating the principle (e.g., selective breeding of crops, livestock and dogs!!).
3. Fossil evidence showing gradual changes over time.
4. Geographical distribution of related species.

Modern Evolutionary Synthesis: This is a comprehensive theory that integrates.

a. Darwin's theory of evolution by natural selection

b. Mendelian genetics

c. Population genetics

In summary, it,

i. *combines Darwin's theory with modern genetics.*

ii. *recognises DNA as the mechanism for inheritance.*

iii. *includes concepts like genetic drift and gene flow.*

iv. *acknowledges punctuated equilibrium (periods of rapid evolutionary change).*

Factors that Influence Evolution

1. Natural Selection: Natural selection is the process by which organisms with favourable traits are more likely to survive and reproduce, passing those traits to the next generation. Example is Peppered moths in England during the Industrial Revolution. Dark-colored moths had a survival advantage in polluted areas, leading to an increase in their population.
2. Mutation is the random change in the DNA sequence. This is the primary source of new genetic variation and can be beneficial, harmful, or neutral. An example is the mutation in the haemoglobin gene leading to the sickle cell trait in West Africa
3. Genetic Drift: This refers to the random changes in the frequency of a gene or trait in a population over time. It is more significant in small populations. Examples of the bottleneck effect: When population size is dramatically reduced. Also, the founder effect, where a small group establishes a new population
4. Gene Flow: This refers to the exchange of genes between populations through migration and interbreeding. It reduces genetic differences between populations. An example is the migration patterns in human populations across Africa.
5. Non-random Mating: This includes positive assortative mating, where individuals with similar phenotypes mate together; negative assortative mating, where those with dissimilar characteristics mate; and sexual selection, where individuals with traits that increase mating success are favoured. An example is the peacock's elaborate tail feathers, where peacocks with brighter, elaborate tail feathers attract mates better than those with less elaborate tail feathers.

NOTE: ***Assortative mating*** occurs when individuals choose mates that are similar to themselves in certain traits, such as size, colour, or behaviour. Over time, this preference can reduce interbreeding between different groups and contribute to the formation of new species.

6. Geographic Isolation: This occurs when a group of organisms becomes separated from others by a physical barrier such as a mountain, river, desert, or lake. Because they can no longer mix and breed with the original population, they gradually develop different characteristics over many generations. For example, different species of cichlid fish found in separate crater lakes in Ghana evolved independently because the lakes isolated them from one another. Over time, each group adapted to its own environment, leading to the formation of distinct species.

Activity 2.10 Evolution - Types and Theories

Objective: To understand the two main types of evolution and examine Lamarck's and Darwin's theories.

Instructions

1. Team up with two or three of your classmates.
2. Discuss among yourselves the concepts of microevolution and macroevolution, citing relevant examples in your discussion.
3. Note down key points that emerge from your discussion.
4. Discuss how Lamarck's and Darwin's theories are supported by modern evolutionary trends.
5. Discuss how the two types of evolution relate to these theories.
6. Present your findings to the rest of the class.

CELL CYCLE, MITOSIS AND MEIOSIS

Cell Cycle

As a cell grows, it goes through stages that lead to its division into two daughter cells. Prokaryotes and Eukaryotes have comparable cell cycles, but the eukaryotic cycle is more clearly marked. It consists of a resting stage (Gap 0), an interphase (which includes the Gap1, Synthesis, and Gap 2 phases) and the cell division stage (Mitotic phase). These stages are in a sequential order of events (phases) that include the growth of the cell, duplication of its DNA (DNA replication) and some of its organelles. It is then followed by the partitioning of the cell's chromosomes, cytoplasm and other components into two daughter cells in a process called cell division. The cell cycle is an essential process for growth, development, and tissue repair in living organisms.

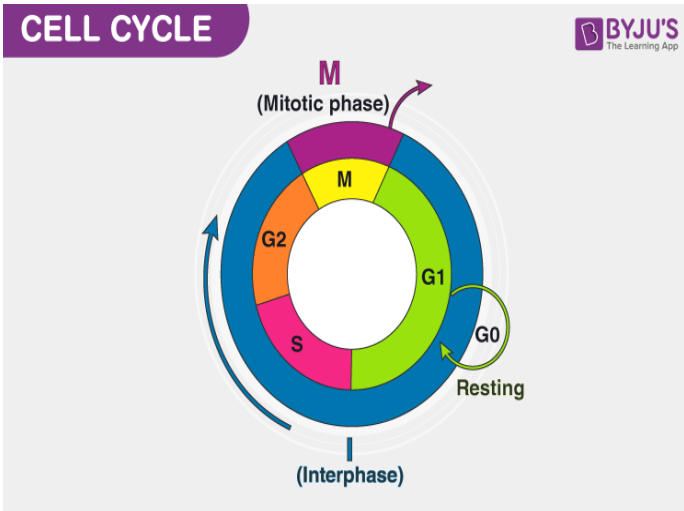


Figure 2.16: Illustration of the cell cycle

Stages and Phases of the Cell Cycle

The resting stage or Gap 0/G0 phase

This is a resting or inert stage in the cell cycle where cells exit the active cycle and enter a state of dormancy. Cells in this phase are not actively preparing to divide but may still carry out normal functions specific to their cell type. Cells in this phase can re-enter the cell cycle if conditions are favourable for growth and division, for instance, in response to growth factors or tissue repair needs. The G0 phase is important for maintaining cellular function and regulating the overall cell population in tissues.

The Interphase stage

This is the longest stage of the cell cycle, during which the cell prepares for division. It consists of three phases: Gap1, Synthesis, and Gap 2.

Phases of Interphase

a. *G1 Phase (Gap 1):* In this phase, the cell grows, increases in size and synthesises proteins and organelles. The cell assesses its environment and resources to ensure conditions are suitable for DNA replication.

b. *S Phase (Synthesis):* When all conditions are suitable, the cell duplicates its entire DNA content, resulting in two identical sets of chromosomes. The centrosomes also duplicate to prepare for mitosis.

c. *G2 Phase (Gap 2):* After the DNA duplication, the cell continues to grow and produce more proteins and organelles, checks for any DNA damage and ensures all DNA is properly replicated in preparation for mitosis. This ensures that errors are prevented during cell division, maintaining genetic stability.

Cell division stage: This is the stage in the cell cycle where the cell divides into two daughter cells. It consists of two main phases: mitosis and cytokinesis.

Mitotic Cell Division

Mitosis is the process where nuclear division occurs, resulting in two daughter nuclei (karyokinesis). Mitosis is further divided into:

Prophase: Chromosomes condense and become visible, and the nuclear envelope begins to break down. The mitotic spindle forms from centrioles.

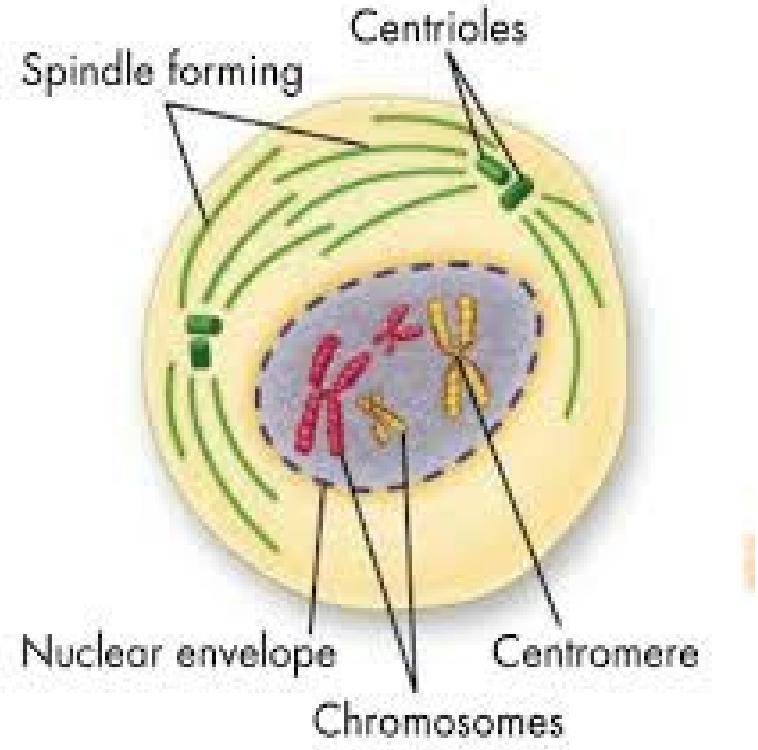


Figure 2.17: Prophase

Metaphase: Chromosomes align at the cell's equatorial plate (metaphase plate), and Spindle fibres attach to the centromeres of the chromosomes.

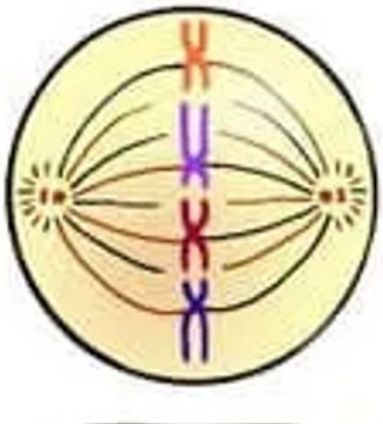


Figure 2.18: Metaphase

Anaphase: Sister chromatids are pulled apart and move toward opposite poles of the cell. The cell elongates as the sister chromatids separate to opposite poles.

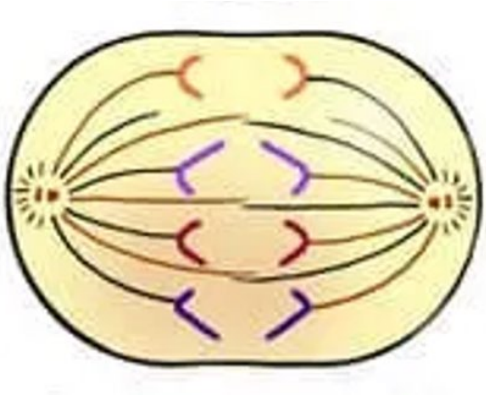


Figure 2.19: Anaphase

Telophase: Chromatids reach the poles and may decondense back into chromatin. The nuclear envelope reforms around each set of chromosomes. The chromosomes uncoil and assume their threadlike forms.

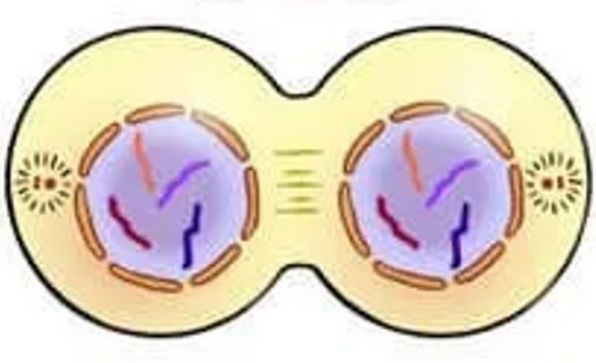


Figure 2.20: Telophase

Cytokinesis is the process by which the cytoplasm and organelles divide into two daughter cells. In animal cells, a cleavage furrow forms, pinching the cell into two, while in plant cells, a cell plate forms, eventually developing into a new cell wall.

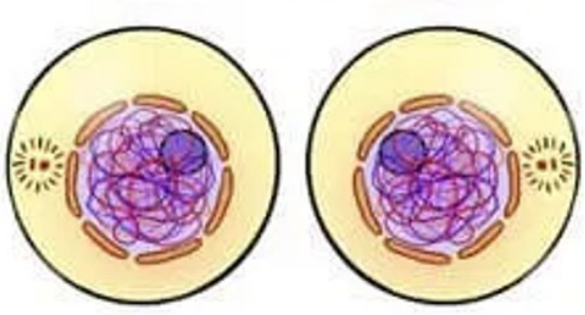


Figure 2.21: Two daughter cells resulting from mitosis

Importance of Mitosis

1. In multicellular organisms, mitosis is essential for growth and development, allowing them to increase in size by producing new cells.
2. Mitosis ensures that each daughter cell receives an identical set of chromosomes, maintaining genetic stability and continuity.
3. Mitosis ensures that worn-out or damaged cells are replaced with new healthy ones, thereby maintaining the integrity of tissues and organs.
4. In single-celled organisms and some multicellular organisms, mitosis is the primary means of producing new individuals.

Mitosis occurs in somatic cells and produces **two genetically identical daughter cells**. It is used for growth, repair, and replacement of body cells.

Meiotic cell division

Meiosis is a specialised type of cell division that reduces the chromosome number by half, resulting in four genetically distinct gametes (sperm or eggs).

Note: Because at fertilisation the original diploid number is continued. If this didn't happen, the chromosome number would double every generation. So after 24 generations, there would be 16,777,216 chromosomes in a cell!

This type of cell division results in four daughter cells from a single parent cell, with each daughter cell having half the number of chromosomes of the parent cell. It occurs in sexually reproducing organisms and is essential for sexual reproduction. Before meiosis begins, during the S phase of the cell cycle, the DNA of each chromosome is replicated so that it consists of two identical sister chromatids, which remain held together at the centromere.

Phases of Meiosis

Meiosis consists of two main stages: Meiosis I and Meiosis II, each with several sub-phases.

Meiosis I

Prophase I: Chromosomes condense and become visible, and similar (homologous) chromosomes pair up. In humans, there are 23 pairs of homologous chromosomes, accounting for the 46 chromosomes. Homologous chromosomes pair with each other and undergo genetic recombination, a programmed process in which DNA may be cut and then repaired, which allows them to exchange some of their genetic information with their homologous pair. The recombination events result in crossing over.

Metaphase I: Homologous chromosome pairs align at the equatorial plate. Spindle fibres attach to the centromeres of each pair.

Anaphase I: Homologous chromosomes are pulled apart to opposite poles of the cell. Sister chromatids remain attached at this stage.

Telophase I: Chromosomes reach the poles and may decondense. The nuclear envelope may reform, resulting in two haploid cells.

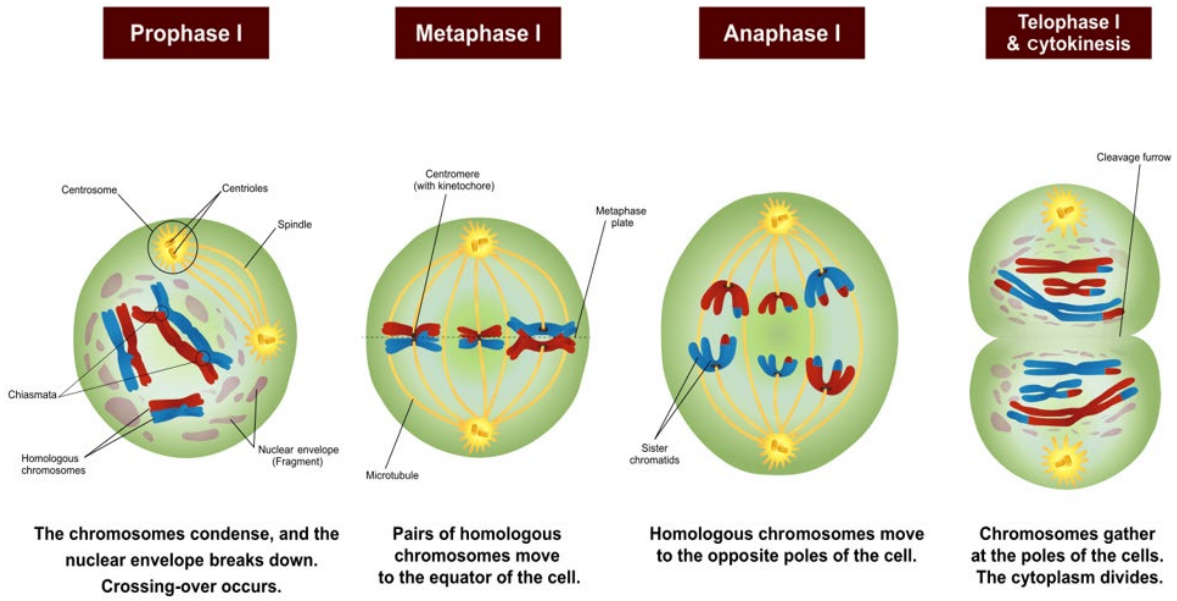


Figure 2.22: Stages of the first meiotic phase (meiosis I)

Meiosis II

Prophase II: Chromosomes condense again, and the nuclear envelope breaks down if it has reformed, and spindle fibres form.

Metaphase II: Chromosomes align at the equatorial plate. Spindle fibres attach to the centromeres of sister chromatids.

Anaphase II: Sister chromatids are pulled apart to opposite poles.

Telophase II: Chromatids reach the poles and decondense. The nuclear envelope reforms, resulting in four genetically diverse haploid cells.

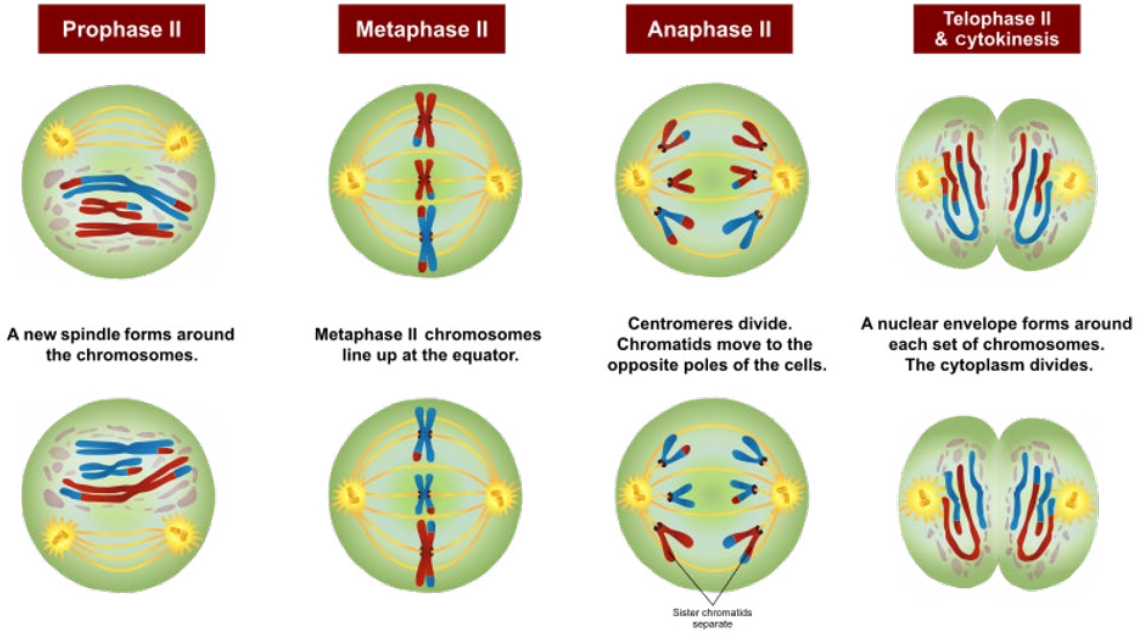


Figure 2.23: Stages of the second meiotic phase (meiosis II)

Importance of Meiosis

1. Meiosis is crucial for sexual reproduction, as it produces gametes with half the number of chromosomes.
2. It introduces genetic diversity through crossing over and independent assortment, which are essential for evolution and adaptation in populations.
3. Maintains species chromosome number from one generation to the next.

Activity 2.11 Comparing Mitosis and Meiosis to the Cell Cycle

Objective: To understand the differences between mitosis and meiosis in relation to the cell cycle.

Instructions

1. Create a table or diagram to compare mitosis and meiosis. Include the following stages
   a. Interphase
   b. Mitosis (prophase, metaphase, anaphase and telophase)
   c. Meiosis (meiosis I and II).
2. Highlight the differences between mitosis and meiosis in terms of:
   a. purpose (growth, repair, reproduction)
   b. number of cell divisions
   c. number of daughter cells produced
   d. genetic variation
3. Use different colours or symbols to distinguish between mitosis and meiosis.
4. Write a short reflection (100-150 words) on the significance of meiosis in genetic diversity and reproduction.
5. Create a concept map or flowchart illustrating the relationship between mitosis, meiosis and the cell cycle.

Hint: use online resources such as Khan Academy or Crash Course to review the cell cycle, mitosis and meiosis. Use different colours or symbols to make your diagrams and tables visually appealing and easy to understand.

Activity 2.12 Cellular Exploration

Objective: To understand the structure, function and processes of cells.

Instructions

1. Create a diagram or model of a cell, and label its components (e.g. cell membrane, nucleus, mitochondria).

2. Research and write a short essay (300-350 words) on a specific cellular process such as;
   a. cellular respiration
   b. cell division
3. Apply the concepts of cell structure, function and organelles, cell transport and cellular regulation or interaction which you learned in the previous years to any of the specific cellular processes in question 2.
4. Use these concepts to explain any of the processes in question 2.
5. Share with a classmate how errors in cell structure, function or regulation can lead to abnormalities in any of the cellular processes in question 2.

EXTENDED READING

- https://www.mayoclinic.org/tests-procedures/rh-factor/about/pac-20394960

- https://healthy.kaiserpermanente.org/health-wellness/health-encyclopedia/he.rh-sensitization-during-pregnancy.hw135942

- https://scienceofbiogenetics.com/articles/the-role-of-genetics-in-rh-factor-and-its-implications-for-human-health

- https://frontiersrj.com/journals/ijflsr/sites/default/files/IJFLSR-2023-0081.pdf

REVIEW QUESTIONS 2

***Scenario 1*: Blood Type Inheritance in a Ghanaian Family**

The Abena family lives in a small community in Ghana where they are well-known for their involvement in community health initiatives. Recently, Abena, the mother, learned about the importance of blood types and Rhesus factor, especially during medical emergencies. She recalls that her husband, Kojo, has blood type A, while she has blood type O. Their first child, Kofi, is blood type A, and their second child, Ama, is blood type O.

Questions

a. Genetic Analysis: Based on the blood types of Abena and Kojo, what are the possible blood types of their children? Explain how blood type inheritance works in this context.

b. Potential Complications: As Abena becomes pregnant with their third child, she learns that her Rhesus factor is negative, while Kojo's is positive. Discuss the implications of this for the pregnancy. What precautions should Abena take to ensure the health of her unborn child?

c. Community Awareness: Given the importance of blood type knowledge in medical emergencies, how can the Abena family use their situation to educate others in their community about the significance of knowing one's blood type and Rhesus factor?

d. Real-Life Application: Reflect on a situation where knowing blood type and Rhesus factor could save a life in a local hospital during an emergency. How can this knowledge impact patient care in your community?

***Scenario 2*: The Genetic Legacy of the Mensah Family**

The Mensah family in a rural Ghanaian community has a history of sickle cell anaemia. Mama Mensah is a carrier (AS), and her husband, Kwame, is also a carrier (AS). They have two children: Kojo, who is healthy (AA), and Abena, who has the sickle cell trait (AS).

Questions

a. Analyse the possible genotypes of the Mensah children. What are the chances of having another child with sickle cell anaemia?

b. Discuss how understanding genetic principles can help the Mensah family make informed decisions about future pregnancies.

c. Reflect on the importance of genetic counselling in helping families like the Mensahs understand their risks and options.

***Scenario 3*: The Blood Type Dilemma for the Nkansah Family**

The Nkansah family is preparing for a wedding, and the bride, Afia, has blood type AB. Her fiancé, Kofi, has blood type O. They are excited about starting a family but are concerned

about potential blood type issues, especially since Afia's mother had complications during pregnancy due to Rh incompatibility.

Questions

a. What are the possible blood types of Afia and Kofi's future children? Explain the inheritance patterns involved.

b. Discuss the implications of Afia being Rh-positive and Kofi being Rh-negative for their planned pregnancy.

c. How can the Nkansah family educate their community about the importance of knowing blood types and Rhesus factors in pregnancy?

***Scenario 4:* The Role of Genetics in the Adomako Community Health Initiative**

The Adomako community is launching a health initiative focusing on blood donation. They learn that many members do not know their blood types. The community leader, Nana Adomako, encourages everyone to get tested. He himself is blood type A, and his wife, Ama, is blood type O.

Questions

a. What are the implications of Nana and Ama's blood types for their children? What blood types can their children potentially inherit?

b. Discuss how genetic variation can affect the health of the community and the importance of blood type diversity in the donor pool.

c. How can the Adomako community utilise their blood donation initiative to raise awareness about genetics and health?

***Scenario 5:* The Impact of Genetics on the Boateng Family's Future**

The Boateng family has a history of diabetes and high blood pressure. Their daughter, Sika, is concerned about her risk factors, especially since she has learned about genetic predispositions. Her father has type 2 diabetes, and her mother has high blood pressure.

Questions

a. How do genetics and environmental factors contribute to Sika's risk of developing diabetes and high blood pressure?

b. Discuss lifestyle changes that Sika could adopt to mitigate her genetic risks based on the principles of genetic variation and environmental impact.

c. How can Sika use her knowledge of genetics to educate her peers about health management and the importance of regular check-ups?

1. How does natural selection contribute to the evolution of specific traits in a population? Provide examples of traits that have evolved due to environmental pressures.
2. Compare the mechanisms of evolution: natural selection, genetic drift, and gene flow. How do these processes interact to influence genetic variation within a population?

SECTION

3

DIVERSITY OF LIVING THINGS



DIVERSITY OF LIVING THINGS AND THEIR ENVIRONMENT

INTRODUCTION

In year 2, you explored selected insects like grain weevil, butterfly, housefly and honeybee, covering their life cycle, characteristics, economic importance and population control. This was to help you understand their impact on plant and animal life in ecosystems. You also learned about tropical habitats and adaptations of organisms within these environments.

Moving forward, you will be discussing specific organisms from the different classes of vertebrates, i.e. Tilapia (Osteichthyes), toad/frog (Amphibia), wall gecko (Reptilia) and domestic fowl (Aves), as well as interdependencies within ecosystems and ecological data analysis. Additionally, you will be studying diseases that affect humans, plants and animals from an ecological, economic and global perspective.

KEY IDEAS

- Changes in the environment, such as climate change, can disrupt the interdependencies among organisms, leading to decreased biodiversity and a compromised ecosystem.
- Domestic fowl are highly reproductive and adaptable to various environments. They are a crucial source of proteins and income for many households and industries worldwide.
- Emerging diseases are infectious diseases that have recently appeared in a population for the first time, or that previously existed but are rapidly increasing in incidence, expanding into new geographical areas, or affecting new host populations. Prevention of these diseases can be done by vaccination, watching for outbreaks, teaching people about hygiene and safety, and doing research to find better ways to diagnose and treat these illnesses.
- Frogs and toads have a unique life cycle transitioning between aquatic and terrestrial environments. Some species are economically important for food and scientific research.
- Organisms interact through food webs, where producers, consumers, and decomposers rely on one another for survival and energy flow.
- Tilapia is highly adaptable to different environments and can thrive in various water conditions, making it an excellent candidate for aquaculture. It is a significant source of food and income for many communities worldwide.
- Wall geckos have specialised toe pads that enable them to climb walls and ceilings. They are also important in the biological control of pests through their feeding.

CHARACTERISTIC FEATURES, LIFE PROCESSES AND ECONOMIC IMPORTANCE OF TILAPIA AND FROG/TOAD

Characteristic Features of Tilapia

Tilapia can grow well in various water conditions, including freshwater habitats such as lakes, rivers, ponds and to some extent, lagoons. They can tolerate changes in temperature, pH and salinity.

Tilapia has a streamlined (smooth, oval, curved surfaces that allow water to flow easily around it), laterally flattened body shape.

1. The body is covered with large smooth cycloid scales that are often greyish or brownish in colour. The cycloid scales protect it from injury and infection, reduce friction and aid movement in water.
2. It has both paired and unpaired fins, which provide stability and are used for its movement in water. The paired fins are the pelvic and pectoral fins. The unpaired fins are the dorsal, ventral/anal and caudal/tail fins.
3. The lateral line has tiny pits that are used for detecting changes in the pressure in the water
4. The operculum is a flat bony plate that covers and protects the gills.
5. The wide terminal mouth is used to feed on a wide range of food.

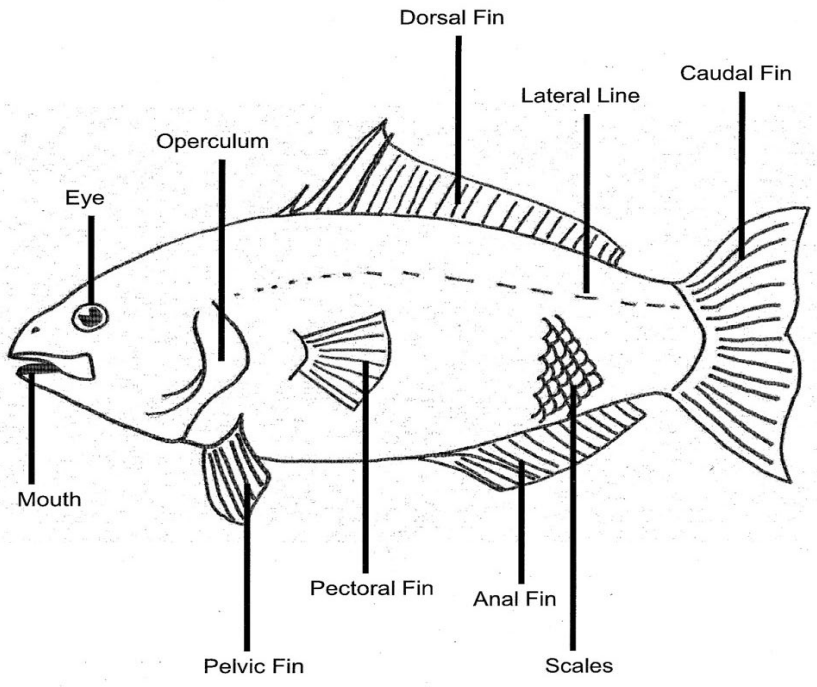


Figure 3.1: External features of Tilapia

Tilapia shows the tendency for rapid growth and reaches a marketable size in a matter of months. It can grow up to 2-3 feet (60-90 cm) in length and weigh up to 5-6 pounds (2.3-2.7 kg).

Tilapia is relatively disease-resistant and can survive in crowded conditions. It is a prolific breeder, with females capable of spawning multiple times in a year, coupled with its fast growth rate and disease resistance, making it the choice of many farmers in aquaculture.

Some life processes of tilapia

Nutrition

Tilapia is omnivorous, meaning it feeds on a variety of foods, which include algae, plankton, aquatic plants and small invertebrates. It uses its mouth to scrape algae from surfaces. During feeding, it takes in water through its mouth. The water passes over the gill rakers, which are bony or cartilaginous projections on the gill bar. The gill bar supports, protects and filters food from the water that passes over them in fish and in some other aquatic animals.

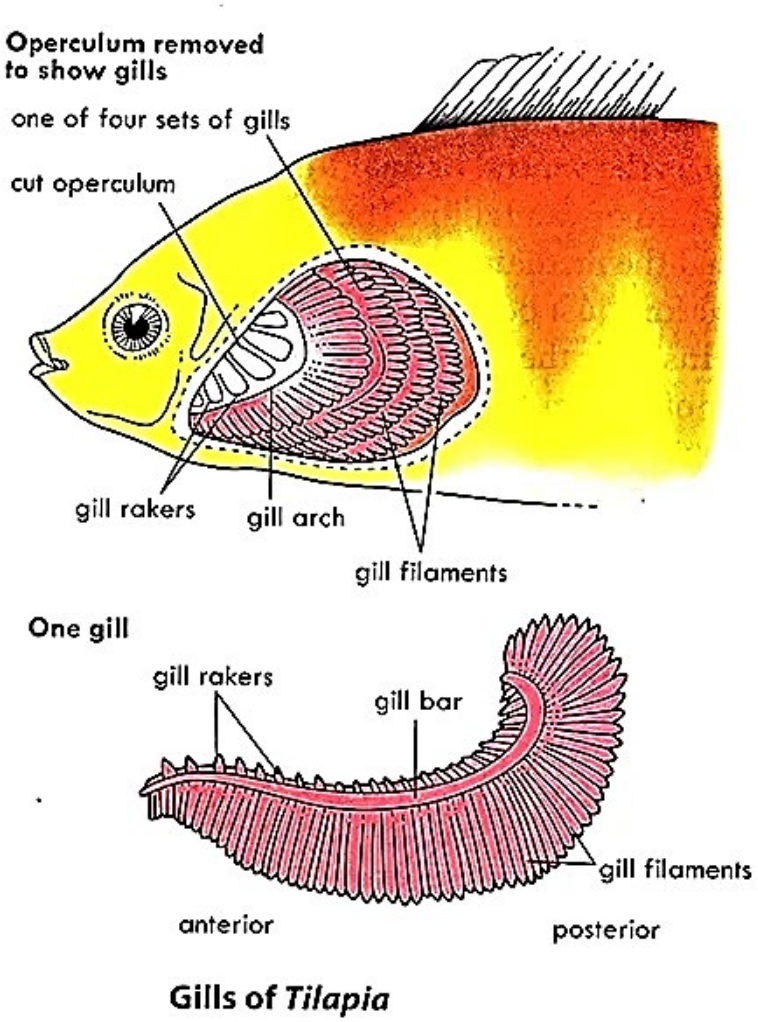


Figure 3.2: The gills of Tilapia

The filtered food particles are kept in the mouth or pharynx, which is behind the buccal cavity (the mouth), and swallowed. The filtered water is expelled through the gills or other openings. This process of feeding is known as filter feeding.

Excretion

Tilapia excretes ammonia (a nitrogenous waste), and carbon dioxide through its gills. Excess salts and water are excreted by the kidneys in the form of urine.

Note: The urine produced by Tilapia is not like human urine in that it is mostly ammonia-free. The gills handle most of the ammonia removal from its body.

Reproduction

Tilapia reproduces by spawning. This is where males fertilise eggs released by females in shallow pits in the bed of a pond or lake. This type of fertilisation is called external fertilisation. Some species of Tilapia also exhibit mouthbrooding, where the female incubates the eggs in her mouth until they hatch into larvae called fry. This show of parental care protects the young against predators.

Movement

1. The fins are used for movement through water.
    a. Driving the fish forward is brought about by the side-to-side lashing of the caudal fin. This rapid movement is controlled by the contraction of the well-developed muscle blocks on both sides of the body of the fish, especially in the tail region.
    b. During rapid movement, the paired fins are held close to the body, and when extended, they slow down or stop the movement of the fish.
    c. The caudal fin also works with the paired fins in steering (changing the direction) the fish through the water. The pectoral and pelvic fins are for steering, pitching and stability.
    d. The other unpaired fins, i.e. dorsal and anal fins, control yawing and rolling.
2. The streamlined body shape is for efficient movement in the water.
3. The slimy nature of the body surface, also known as the mucus layer, reduces drag and friction as it moves through the water.
4. The air or swim bladder provides buoyancy, i.e. makes it float in the water without swimming. This happens when gases diffuse from the blood into the bladder and inflate it, rendering the fish less dense and causing it to rise easily. When the bladder is deflated, the fish becomes denser and sinks.

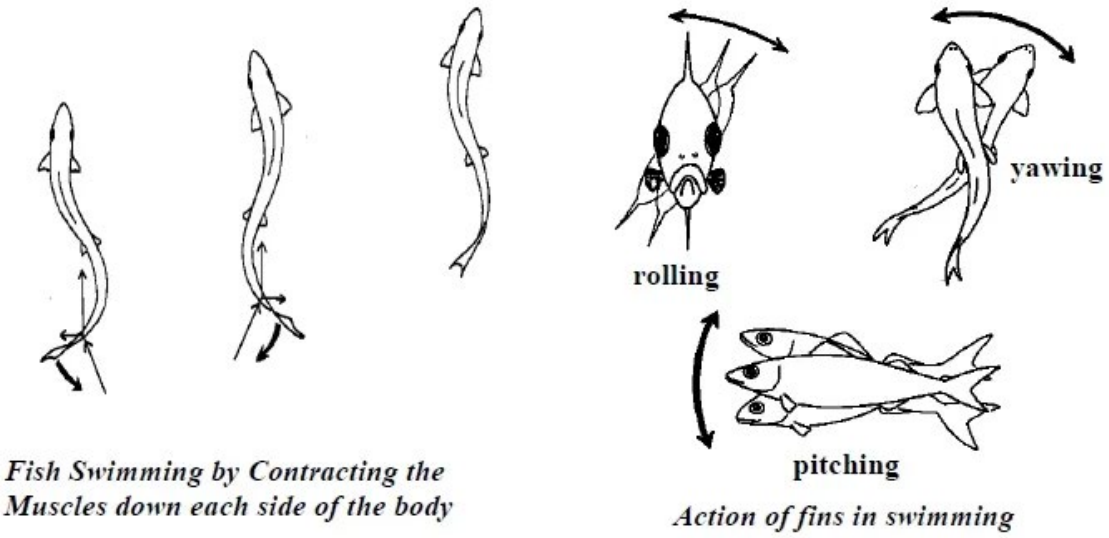


Figure 3.3: Different types of movement exhibited by Tilapia

Economic Importance of Tilapia

1. Tilapia is rich in protein and low in fat, making it a valuable source of nutrition. It offers numerous health benefits due to its high protein content, low saturated fat levels, rich omega-3 fatty acid profile and a good source of vitamins and minerals such as vitamin D, potassium and selenium.
2. Aquaculture practices provide a source of income for many people in the industry. Farming tilapia is possible due to its characteristics of rapid growth, disease resistance and ability to thrive in diverse conditions. It can be raised in environmentally sustainable ways, such as an integrated farming system that makes use of waste products for crop production as feed for the fish.
3. Tilapia farming, processing and distribution create jobs for people in rural areas, which contributes to local economies and livelihoods. In Ghana, the farming of Tilapia has created livelihood opportunities for many people in both rural and peri-urban areas. For example, the people of Weija, Akosombo and Ada trade in the fresh or dried tilapia.
4. Tilapia is exported to many countries, generating foreign exchange earnings for Ghana, hence supporting the national economy.
5. In many cultures, tilapia is associated with traditional fishing practices and culinary heritage. This promotes local customs and tourism. For example, in Ghana, Tilapia is a popular dish often served in hotels, restaurants, and other eating places and has become an important part of Ghanaian hospitality, reflecting the country's wealth of local cuisine.
6. The tilapia industry drives research in aquaculture practices, genetics, and nutrition, leading to new ways of improving fish farming efficiency and sustainability.

Activity 3.1 Exploring Characteristics and Economic Importance of Tilapia

Objective: Discuss the characteristics and economic importance of Tilapia.

Materials

- Pictures or videos of Tilapia
- Diagrams of Tilapia's body structure
- Large plain cards and markers
- Handouts with guiding questions
- Scenarios related to Tilapia farming.

Tilapia Farming in Ghana

Tilapia farming in Ghana is important for the economy and food supply. Kwaku Avitor's farm is in the Volta Region of Ghana. His farm sits on a 15-hectare land, dealing in freshwater Tilapia farming. The farm uses water from nearby lakes and rivers. He and his worker frequently check the water quality (like temperature and oxygen levels) to keep the fish healthy. The farm uses Nile tilapia, which grow quickly and adapt well to local conditions with about 6,000 fish placed in each hectare to ensure enough space for healthy growth. The fish eat a mix of local ingredients (e.g. plant parts, organic waste, food scraps from homes etc.) and commercial feed for good growth. They are fed twice a day, with careful monitoring of how much they eat. They regularly check the fish health to spot any problems early. Vaccines and approved medicines are used to treat common fish diseases. Diseases like 'Tilapia-lake-virus' can cause high fish death rates. Changes in water quality and temperature can also affect fish growth. Due to the poor roads and competition from imported fish, Mr Avitor at times struggles to sell his fish. He recently had support from an export company that has promised to buy his fish on a regular basis. Since Mr Avitor started his fish farm, he has employed five men from his village. The fish not sold after harvesting are dried by the wives of his workers and sold in the local market as koobi. Tilapia farming in Ghana has many benefits for the economy and nutrition. While there are challenges, such as managing diseases and accessing markets, better practices can help improve the success of tilapia farming in the country.

Instructions

1. Consider the scenario provided, discuss and write down on your large plain card:
   a. the features of Tilapia, such as its habitat, diet and adaptations.
   b. how Tilapia is farmed.
   c. its economic benefits
   d. challenges the farmers face.
2. Think about what you have learned about tilapia and share your knowledge with the class.
3. Share with the class how you will apply this knowledge in your daily life and in future.

Characteristic Features of Toad

1. Toads have a compact, rounded body shape.
2. The skin is dry, rough and warty with small bumps and ridges. The nature of the skin helps it conserve water.
3. On both sides of the head is a pair of prominent, bulging and golden or copper-coloured eyes which boost its vision and ability to spot predators. Behind the pair of eyes are a pair of visible circular membranes, called the tympanic membrane (eardrum), that detect sound vibrations.
4. The legs are relatively short compared to the body, which ends in webbed digits for swimming in water. The two pairs of limbs, i.e. fore and hind limbs, are for movement.

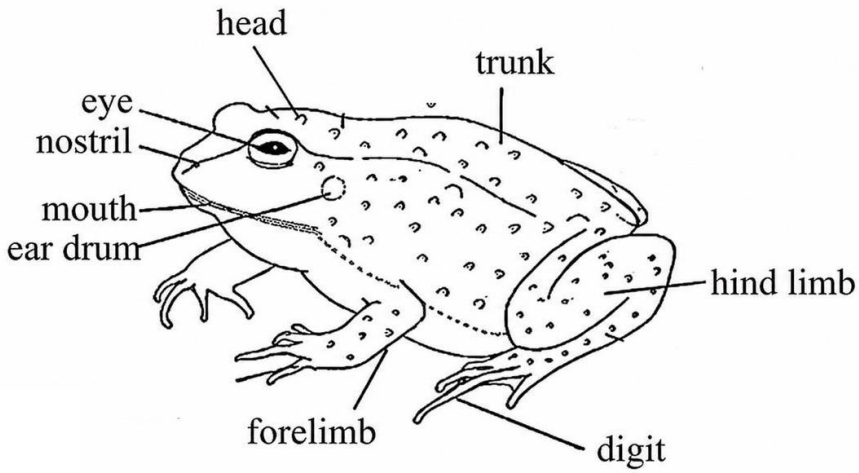


Figure 3.4: External features of the common African toad

Some life processes of the toad

Nutrition

Toads are carnivorous, with their nutrition consisting mainly of insects, invertebrates like worms, snails and small arthropods like spiders and centipedes. They have no teeth. They use their long sticky tongues to catch prey and swallow it whole.

Excretion

The primary waste product of toads is urea, which is excreted through their kidneys. Urea is a nitrogenous waste that is produced from the breakdown of proteins. The urea is passed out in a rather concentrated urine because much of the water is reabsorbed. Additionally, excretion of carbon dioxide occurs through the lungs, the mouth and the skin by diffusion.

Movement

Toads are known for their distinctive movement patterns, which include hopping or leaping, crawling and swimming.

1. They usually use their powerful hind legs to hop short or long distances. As the toad prepares to hop, its limb muscles and tendons store elastic energy.
2. The hind limbs rapidly extend, releasing the stored energy and propelling the toad into the air.
3. The toad lands on its front legs, which absorb the impact or shock and help to stabilise the body.
4. When in water, toads move by swimming. This is done using the webbed digits of the hind legs to paddle through the water while the fore limbs are used for steering.

Reproduction

The breeding season of *Sclerophrys regularis* usually occurs in the rainy period. During this time, males start croaking to attract females. Once a female responds, the male climbs onto her back and clasps her with its forelimbs, a mating position known as *amplexus*. This posture ensures the male fertilises the eggs as the female lays them.

Females deposit eggs in shallow water bodies like ponds or temporary pools. The eggs are released in long strands, with their number and pattern influenced by environmental conditions. As the female lays the eggs, the male simultaneously releases sperm over them, permitting external fertilisation.

The fertilised eggs develop into embryos and hatch within 3 to 14 days, depending on temperature and water quality. The hatched larvae, called tadpoles, are fully aquatic, equipped with gills and a tail for swimming.

Within several weeks or months, the tadpoles undergo metamorphosis where they gradually develop legs, lungs and lose their tails, moving from aquatic life to life on land. Once this transformation is complete, the young toads leave the water and begin their terrestrial life.

Sclerophrys regularis typically reaches reproductive maturity within 2 to 3 years, and the life cycle starts once again.

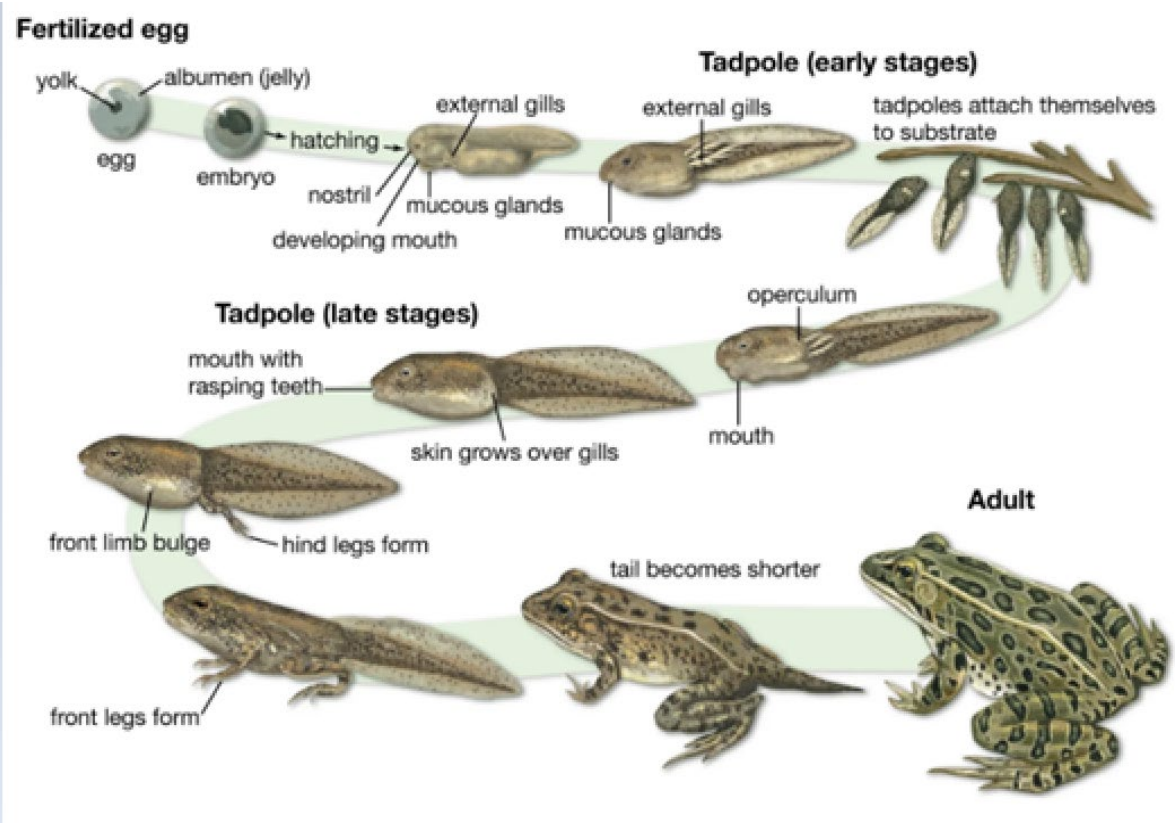


Figure 3.5: Reproduction in Toads

Economic importance of the toad

1. Frogs and toads help show how healthy an ecosystem is. Their presence or absence can indicate environmental changes, which help with conservation and land management.
2. They help control insect populations, including pests that harm crops. This benefits farmers by reducing the need for chemical pesticides.
3. Some frog species produce skin secretions that are being studied for their potential health benefits, like fighting infections and relieving pain.
4. Certain frogs and toads are popular as exotic pets because of their colourful appearance, which supports local economies through breeding and sales.
5. Frogs and toads are important in many cultures and stories, often symbolising fertility and change.
6. They attract nature lovers and researchers, helping to support ecotourism that brings money to local communities.
7. Their unique features make them valuable for scientific research, aiding educational programs in biology and environmental science.
8. In some cultures, frog legs are considered a tasty dish, providing protein and income for local people.

Activity 3.2 "Frog and Toad Explorers"

Objective: Explore and discuss the characteristic features of frogs and toads and their economic importance.

Materials

- Pictures or models of toads or frogs (station 1)
- Information on toad habitat and diet (station 2)
- Information on the economic importance of toads (station 3)
- White sheet of paper
- Markers or pens
- Guiding questions printouts (optional)

Instructions

1. Team up with two of your peers and visit each of the stations or themes
2. At each station, discuss with your peers and answer these questions.
   a. What are the characteristic features of toads?
   b. How do toads contribute to ecosystem balance?
   c. How does the toad's presence benefit humans or agriculture?
3. Note down all your answers on your white sheet of paper.
4. After rotation, share your insights with other groups in your class.

CHARACTERISTIC FEATURES, LIFE PROCESSES AND ECONOMIC IMPORTANCE OF WALL GECKO AND DOMESTIC FOWL

Characteristic Features of the Common Wall Gecko

The Common wall gecko, belonging to the *Hemidactylus* species, is a small lizard frequently seen on walls in urban areas, especially in warm climates. It coexists with humans and feeds on insects, spiders, and other small invertebrates. This reptile can grow up to 15 cm in length and is commonly found in rocky terrains, cliffs, rock fields, construction sites, ruins, building walls, and even inside homes. It is completely harmless and non-poisonous to humans. Primarily nocturnal, the wall gecko is known for its remarkable ability to climb vertical surfaces and ceilings.

1. Its body is robust with a flat head and large, bulging eyes that lack eyelids.
2. The skin is scaly and rugged, typically brownish-grey or brown with varying spots. Its colouration can shift in intensity depending on the lighting, helping it blend seamlessly into its surroundings.

3. One of its most distinctive features is its toes, which are equipped with specialised adhesive pads that allow it to grip and scale smooth surfaces.
4. The gecko has a detachable tail, which it can shed as a defence mechanism when threatened.



Figure 3.6: Wall gecko

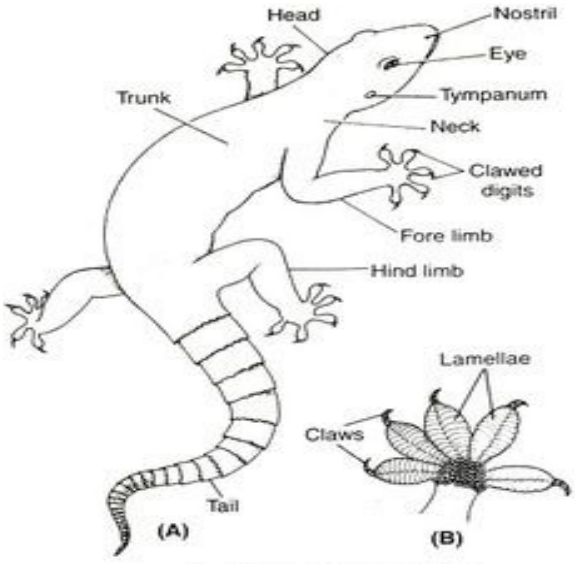


Figure 3.7: Drawing showing external features of the Wall gecko

The Life Processes of the Wall Gecko

Nutrition

Wall geckos are carnivorous insectivores that forage individually during warmer months. They feed on a variety of insects and small invertebrates. Most geckos hunt and feed during the night; they are often seen hunting nocturnal insects near artificial light sources such as streetlights and those in homes.

Excretion

Like most reptiles, wall geckos excrete nitrogenous waste in the form of uric acid, which conserves water more effectively than ammonia or urea. This uric acid is sometimes expelled along with a small amount of urine through the cloaca, a shared opening for the digestive, urinary and reproductive systems. Through this single opening, wall geckos eliminate faeces, urine and reproductive cells (sperm or eggs).

Movement

Wall geckos possess strong limb and trunk muscles that enable them to exert force against vertical surfaces. Their flexible bodies allow precise control of limb movements for efficient climbing. One important feature of the wall gecko is their special toe pads. These pads have millions of tiny hair-like structures called setae. These setae help the gecko stick to surfaces by creating a strong adhesive effect. This stickiness comes from very small forces called van der Waals interactions, which happen when molecules are extremely close to each other. This adaptation allows geckos to climb and hold onto various surfaces easily.

Their tails also play a crucial role in stabilising and controlling movement, especially during landings after a fall.

Reproduction

In warmer climates, wall geckos can reproduce all year round. During mating, the male grips the female's neck with his jaws and wraps his tail around hers, lining up their cloaca for intercourse. After mating, the female lays one or two eggs in a concealed location such as cracks, crevices, beneath rocks or corners of homes. The incubation period lasts between 30 and 50 days, depending on environmental conditions like temperature, humidity and oxygen levels. Hatchlings emerge at less than 5 cm in length and are fully independent from birth. They grow rapidly, reaching sexual maturity within 6 to 12 months.

Economic Importance of the Wall Gecko

Biological Pest Control

1. Wall geckos play a vital role in natural pest management. A single gecko can eat 50 to 100 insects per night, including mosquitoes, flies, cockroaches and termites. This reduces how much chemical pesticides are used and therefore lowers household pest control costs.
2. By feeding on vector mosquitoes that transmit, e.g. malaria and dengue parasites, wall geckos indirectly reduce healthcare expenses and productivity losses. In Ghana and other tropical regions, this ecosystem service holds substantial economic value.
3. In rural farm structures, geckos help protect stored grains and produce from insect damage, reducing post-harvest losses in traditional storage systems.

Research and Biotechnology

The gecko's extraordinary climbing ability has inspired biomimetic innovations worth millions in research and development. Gecko-inspired adhesives are being explored for use in the following:

a. Medical devices and bandages
b. Robotics and climbing technologies
c. Industrial materials handling
d. Space technology applications

Cultural and Tourism Value

1. Wall geckos play a role in boosting biodiversity tourism, particularly in tropical areas. This means that tourists are often interested in seeing these unique creatures as part of their experience in nature.
2. In many cultures, including in Ghana, wall geckos are viewed as helpful companions around the house. People appreciate them because they eat pests like insects. Additionally, these geckos are part of local traditions and stories, making them a significant part of the culture.

Structural and Food Contamination

Gecko droppings can pollute food and water, so it's important to keep storage areas clean. If there are a lot of geckos, you might need to clean walls and ceilings to prevent contamination. However, the costs of cleaning are usually small compared to the benefits of having geckos around, since they help control pests like insects.

Invasive Species Impacts

When geckos are introduced to non-native environments, some species may become invasive and displace local fauna and disrupt ecosystems. In such cases, control programs may be necessary, and this requires financial investment and ecological management.

Characteristic Features of the Domestic Fowl

The domestic fowl (*Gallus domesticus*) is a warm-blooded (homoiothermic) animal, meaning it maintains a constant internal body temperature regardless of external environmental conditions.

The body of the domestic fowl is divided into three main parts: the head, trunk and tail.

The head is small and rounded in shape

a. It features a skull that extends into two strong, pointed, horny structures known as the beak.
b. Has a pair of slit-like nostrils located on the beak.
c. Includes a pair of eyes with eyelids and a nictitating membrane (a transparent third eyelid).
d. Has ear openings, located behind each eye and are concealed by feathers.
e. bears a red, fleshy structure called the comb and beneath the beak hang a pair of fleshy lobes known as wattles. The comb and wattles are more prominent in males than in females.
f. is covered with feathers, except for the beak, comb and wattles.

Trunk and Limbs

The trunk supports both forelimbs and hindlimbs

a. The forelimbs are modified into wings
b. The legs and digits are covered with overlapping scales
c. Each leg has four digits ending in sharp, curved claws, three of which point forward and one backwards.

Tail

a. The tail is short and covered with long, strong quill feathers (also known as flight feathers)

b. At the base of the tail is the preen gland (also called the oil gland), which secretes oil used for preening, i.e. a grooming behaviour that keeps feathers glossy and waterproof.

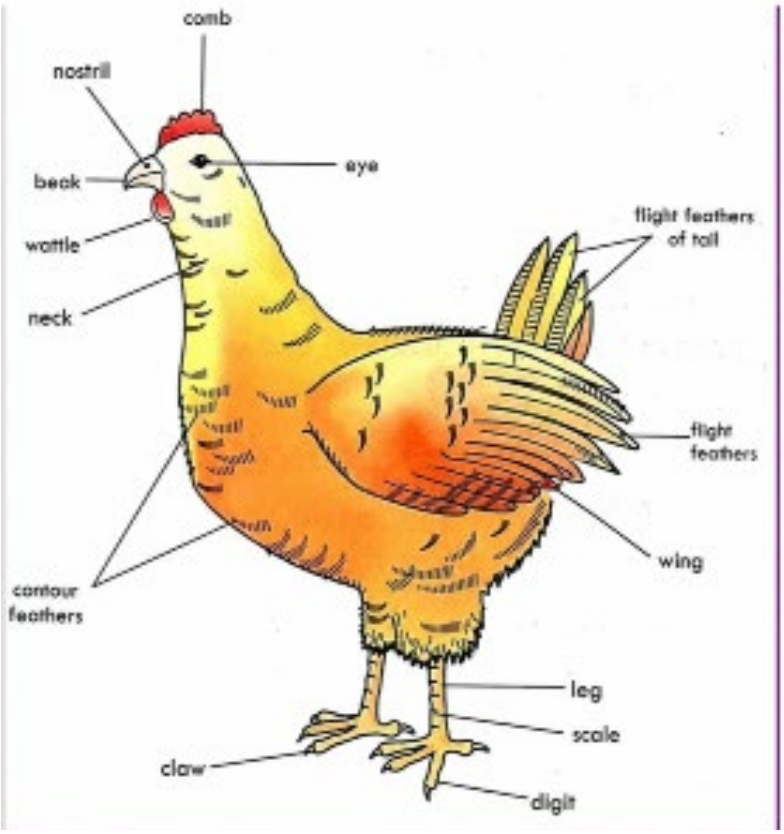


Figure 3.8: External features of the domestic fowl, Gallus domesticus

Selected Life Processes of the Domestic Fowl

Nutrition

The domestic fowl is omnivorous, feeding on a variety of food sources, including insects, worms and plant materials such as seeds and leaves. It uses its sharp, strong claws to scratch the ground in search of food, which is then picked up using its sharp, pointed beak.

The Digestive Process

a. The food is swallowed and passes through the oesophagus into the crop, where it is temporarily stored.

b. From the crop, the food moves into the proventriculus (the first part of the stomach), where digestive juices are secreted to begin chemical digestion.

c. The partially digested food then enters the gizzard (the second part of the stomach), where churning (mixing of food with small stones and digestive juices) and mechanical breakdown occur.

d. The presence of small, fine stones in the gizzard helps grind the food mechanically.

e. The food then moves into the intestine, where further digestion and nutrient absorption take place.

f. The caeca absorb water from the remaining food material.

g. The rectum transfers undigested food into the caeca, and it is finally eliminated as faeces through the cloaca

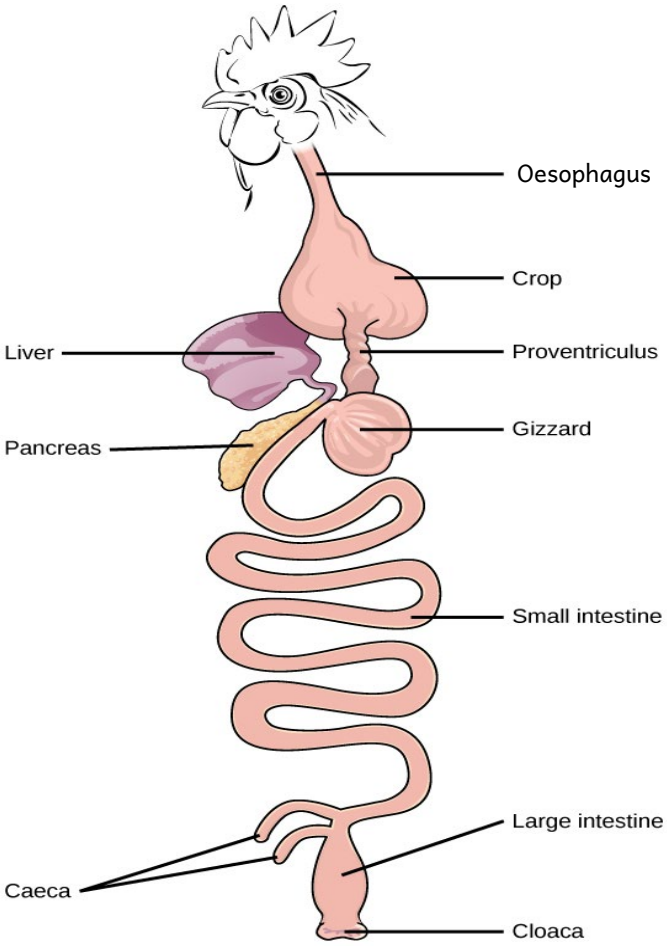


Figure 3.9: Digestive system of a Domestic fowl

Excretion

Excretion in domestic fowl involves the removal of waste products primarily through droppings. Unlike mammals, birds do not produce urea as the main nitrogenous waste. Instead, their kidneys filter waste and produce uric acid directly. This uric acid is in a thick, pasty form with very low water content and is excreted along with faeces and appears as a whitish or cream-coloured bit on the faeces.

Movement

Bird flight can be categorised into flapping, gliding or soaring. Several adaptations enable the domestic fowl to fly, even though it is not a strong flyer.

1. Large wing feathers provide a broad surface area for lift
2. Streamlined body shape reduces air resistance during flight

3. Wing and tail feather tips assist in steering
4. Large pectoral muscles depress the wings during flapping
5. A keel-like extension of the breastbone (sternum) serves as an anchor for these powerful muscles
6. A rigid skeleton offers a firm framework for muscle attachment
7. Hollow bones reduce overall body weight
8. The tail stabilises the bird in flight and aids in braking and landing
9. Eyes positioned on the sides of the head grant the bird wide and acute vision

Reproduction

Female domestic fowls, called hens, begin laying eggs at around six months of age. During courtship, the male (rooster or cockerel) performs a 'circle dance', lowers one wing and displays his colourful feathers to attract the female.

1. The male mounts the female, positions their reproductive openings together to transfer sperm into her oviduct, where internal fertilisation occurs.
2. As the fertilised egg travels down the oviduct, it becomes encased in albumen and a shell and is eventually laid in a nest.
3. Typically, one egg is laid per day, and incubation begins only after the full clutch has been laid.
4. The hen incubates the eggs, maintaining a temperature close to her body temperature by pressing them against her body to keep them warm and prevent water loss.
5. The embryo develops as its cells divide to form tissues and organs.
6. The yolk provides nutrients, while the albumen supplies both food and water.
7. The eggshell and membranes are permeable to air, allowing oxygen to diffuse in and be absorbed by capillaries over the yolk and the allantois.
8. Carbon dioxide diffuses out through the shell.
9. Once fully developed, after about three weeks, the eggs hatch (the chicks break out using their beaks).
10. Covered in down feathers, the chicks are mobile shortly after hatching but remain close to the mother hen.
11. The mother hen shelters them with her body and wings, protecting them from predators like cats and hawks.

The reproductive process in chickens is especially notable for its role in egg production, which is a key aspect of their economic and agricultural value.

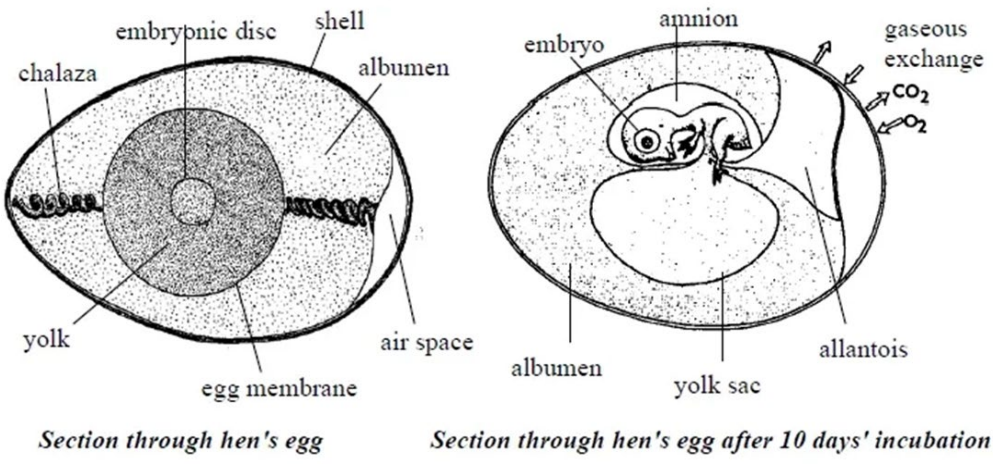


Figure 3.10: Longitudinal section through the hen's egg before and during incubation

Function of the Parts of an Egg

a. Amnion: a fluid-filled sac that suspends and protects the developing embryo.

b. Allantois: stores excretory waste and transports oxygen to the embryo through its extensive network of blood vessels.

c. Yolk Sac: shrinks as the embryo consumes its food reserve and is absorbed into the body at hatching.

d. Yolk: supplies proteins and lipids (fats) essential for the embryo's development.

e. Albumen: provides proteins and water to support the growth of the embryo.

f. Chalaza: a twisted strand of dense albumen that anchors the yolk in place.

g. Shell and Egg Membrane: permeable to air and serves as a protective barrier for the embryo.

Economic Importance of the Domestic Fowl

The domestic fowl (*Gallus domesticus*) is among the most economically valuable domesticated animals globally. Its significance spans food production, employment, agricultural sustainability, cultural practices and emerging opportunities in value-added products and environmental services. The economic importance of the domestic fowl includes, but is not limited to:

Food Production

1. Chicken meat is the second most consumed meat worldwide, offering high-quality protein and essential micronutrients such as B vitamins, iron, and zinc.
2. Eggs are a source of complete protein, essential fatty acids and vitamins A, D, E, and B-complex, along with minerals like iron and phosphorus.

Employment and Income Generation

1. Large-scale poultry enterprises create jobs across the value chain: from farm labour to processing and distribution.
2. Small-scale poultry keeping requires low initial investment and provides supplemental income for rural families.
3. Poultry farming supports employment in:
    a. Feed production
    b. Veterinary services
    c. Equipment manufacturing
    d. Transportation
    e. Slaughterhouses
    f. Egg processing
    g. Cold storage
    h. Retail and marketing

Integrated Agricultural Systems

1. Chicken manure is a rich fertiliser for crop production and contains approximately 4% nitrogen, 2% phosphorus and 2% potassium.
2. Free-range chickens help control pests by consuming insects and weed seeds.
3. Crop residues serve as feed for chickens, while poultry manure enriches soil, creating a cyclic farming system that reduces reliance on synthetic fertilisers and pesticides.

By -Products

1. Feathers are used in bedding and clothing for insulation.
2. Droppings are processed into organic manure.
3. Eggshells are utilised in calcium supplements, crafts and soil amendments.

Cultural and Social Importance

1. Domestic fowl play a role in traditional rituals and religious ceremonies across various Ghanaian cultures.
2. Live chickens are commonly given as gifts during major life events such as weddings, funerals and childbirth.
3. Chicken dishes are served to honoured guests as a gesture of respect and goodwill.

Activity 3.3 Create a Mind Map – Life Cycle of Wall Gecko and Domestic Fowl

Objective: Create a comparative mind map that summarises the life cycles of the wall gecko and the domestic fowl, highlighting key stages, processes, and adaptations.

Materials Needed

- A3 or A4 sheets
- Coloured pencils or markers
- Ruler (optional)
- Reference notes or textbooks

Instructions for Learners

1. At the centre of your page, write: "Life Cycle of Wall Gecko and Domestic Fowl"
2. From the centre, draw two large branches (lines):
    a. Label one Wall Gecko
    b. Label the other Domestic Fowl
3. Under each main branch, include the following sub-branches.
    a. Reproduction: Describe how each animal mates and lays eggs
    b. Development: Show how the young grow and mature
    c. Adaptations: Include special features that help them survive (e.g., tail use, feathers)
    d. Parental Care: Outline differences in the care of the young
4. Use Visuals and Colour
    a. Use colours to make your mind map clear and attractive
    b. Add simple drawings or icons like eggs, hatchlings or adult animals
    c. Use short phrases or keywords instead of long sentences
5. As you build your mind map, think about:
    a. What is similar between the wall gecko and the domestic fowl?
    b. What is different?
6. Be ready to present your mind map to the class and explain your ideas.

INTERDEPENDENCY OF LIVING AND NON-LIVING THINGS AND THEIR IMPORTANCE

Interdependency in Ghanaian Ecosystems

Ghana has many different ecosystems, from coastal mangroves to northern savannas. These ecosystems are shaped by the relationships between biotic, living things (like plants and animals) and abiotic, non-living things (like climate, soil, and water). These interactions affect the variety of life and how well the ecosystems work.

Energy Flow

Energy flow describes the one-way movement of energy through an ecosystem. It begins with producers (such as green plants) that capture sunlight through photosynthesis, and continues through various levels of consumers (herbivores, carnivores, and decomposers).

a. Energy moves in a single direction, from the sun to producers, then to consumers.

b. At each level, some energy is lost as heat, making the flow non-cyclic.

Nutrient Cycling

Unlike energy, nutrients cycle within ecosystems through biogeochemical processes. Nutrient cycling involves the movement and exchange of organic and inorganic matter, which is reused in the production of new biomass.

The Carbon Cycle

The carbon cycle is a key biogeochemical cycle that involves the exchange of carbon among the biosphere, pedosphere (soil), geosphere (land), hydrosphere (water), and atmosphere. The carbon is driven through when,

a. trees absorb carbon dioxide from the atmosphere during photosynthesis.

b. trees die or are burned (e.g., through slash-and-burn agriculture), and carbon is released back into the atmosphere.

Other sources of atmospheric carbon include

i. respiration by animals and plants

ii. decay of organic matter

iii. emissions from burning fossil fuels

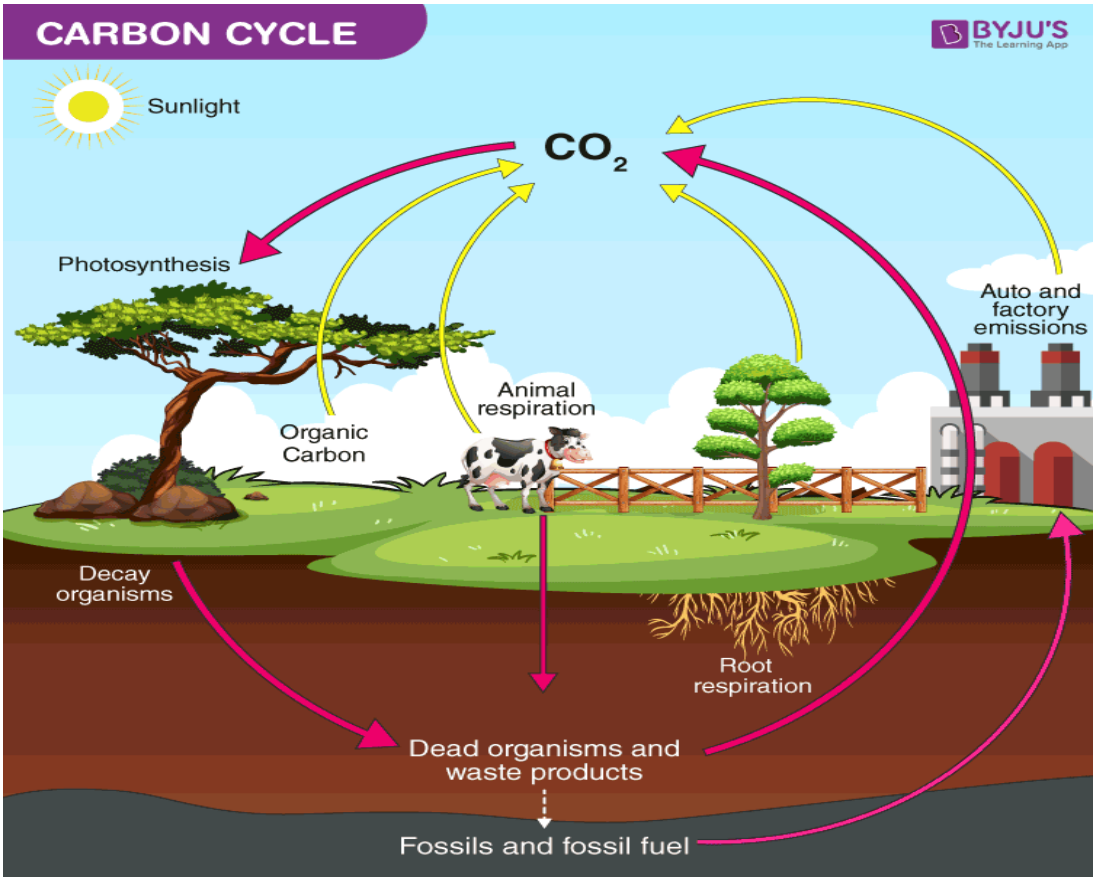


Figure 3.11: Carbon cycle

Nitrogen Cycle

The nitrogen cycle is a biogeochemical process through which nitrogen changes between different chemical forms as it moves through the atmosphere, land and aquatic ecosystems. In Ghanaian agriculture, leguminous crops such as groundnuts and cowpeas play a key role in this cycle. These plants form symbiotic relationships with nitrogen-fixing bacteria found in their root nodules. The bacteria convert atmospheric nitrogen into forms usable by plants, thereby naturally enhancing soil fertility.

The cycle begins with **nitrogen fixation**, where atmospheric nitrogen gas is converted into ammonia by nitrogen-fixing bacteria or lightning. Through **nitrification**, soil bacteria change ammonia into nitrites and then nitrates, which plants absorb through their roots. Animals obtain nitrogen by feeding on plants or other animals. When plants and animals die or produce waste, decomposers such as bacteria and fungi break down the organic matter through **ammonification**, releasing ammonia back into the soil. Finally, during **denitrification**, certain bacteria convert nitrates back into nitrogen gas, which returns to the atmosphere and completes the cycle.

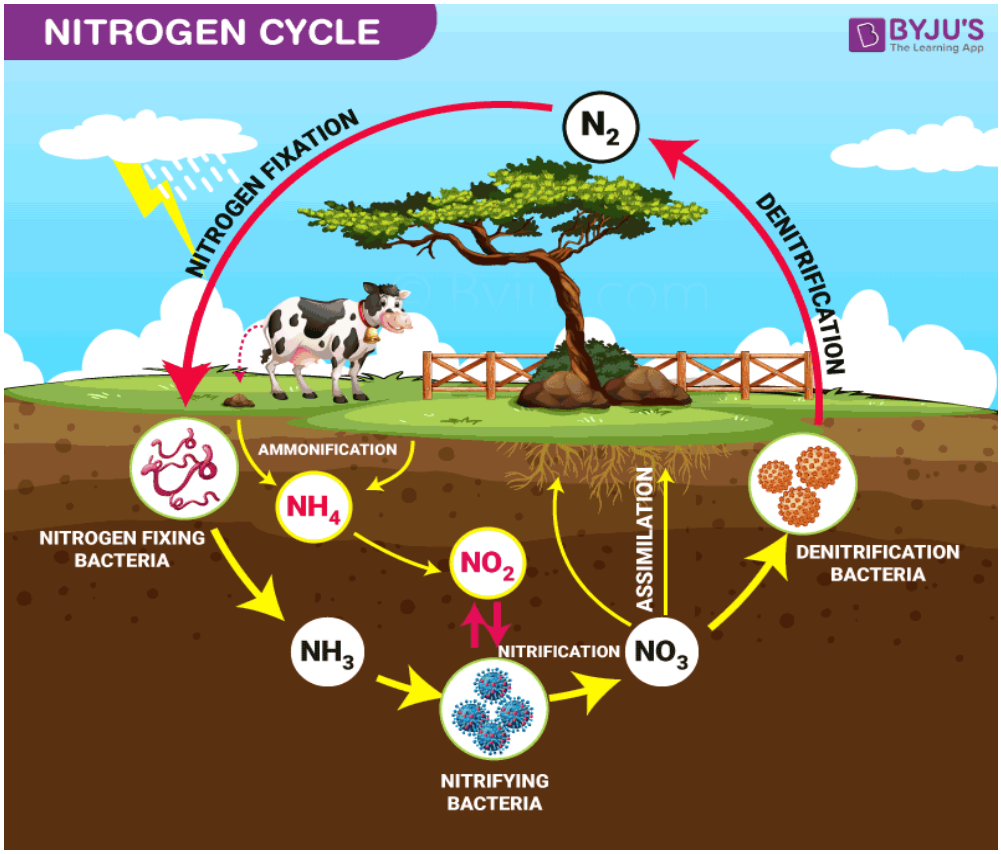


Figure 3.12: Nitrogen cycle

The Water Cycle

The water cycle is the continuous movement of water between the Earth's surface and the atmosphere. This cycle involves key processes.

1. **Evaporation**: During this process, heat from the sun changes liquid water from rivers, lakes, oceans, soil, and other surfaces into water vapour, which rises into the atmosphere. Together with transpiration from plants, this adds moisture to the air.
2. **Condensation**: In the cold atmospheric air, water vapour cools back to water and gathers to form clouds.
3. **Precipitation**: Here, the condensed water falls back to earth as rain, snow or hail (depending on how cold the air is).
4. Runoff is the water flowing over land into bodies of water like lakes and the sea.

Quick Investigation Exercise: Do you know why lakes are freshwater and the sea is salty?

In Ghana, seasonal rainfall patterns play a crucial role in determining how much water is available across ecosystems. These fluctuations affect both terrestrial (land) and aquatic (water) communities, influence biodiversity, plant growth and animal behaviour.

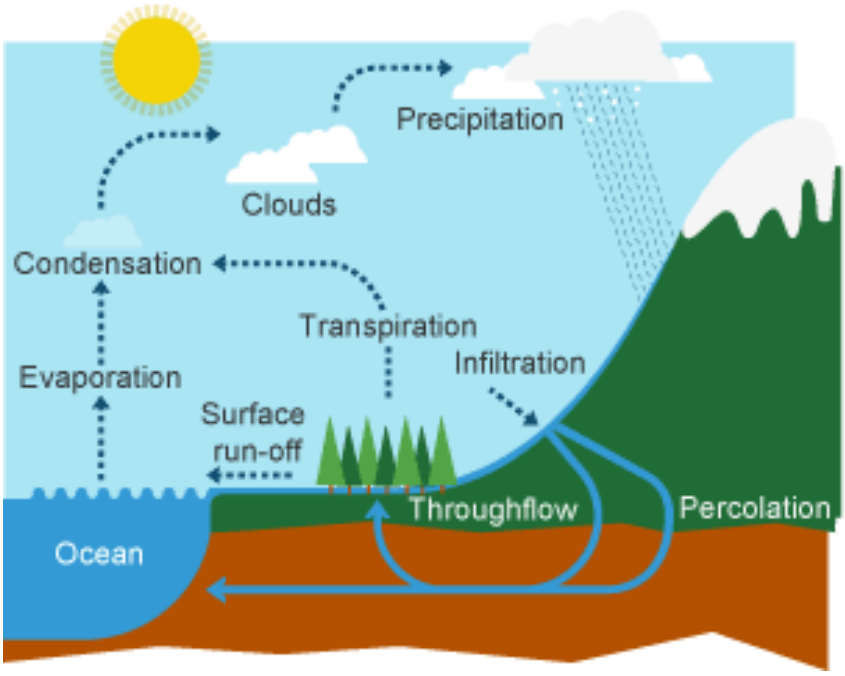


Figure 3.13: Water cycle

Food Chains, Food Webs and Decomposition

Food Chains

A food chain is a linear series of organisms through which energy and nutrients flow as one organism consumes another. It shows a single pathway of energy transfer within an ecosystem. Here are examples of food chains from various ecosystems in Ghana.

1. Forest Ecosystem (Kakum National Park): *Dead leaves → Termites → Agama lizard → African harrier hawk*
2. Savanna Ecosystem (Northern Ghana): *Grass → Grasshopper → Guinea fowl → Serval cat*
3. Coastal/Marine Ecosystem (Gulf of Guinea): *Phytoplankton → Anchovy → Sea bream → African Fish eagle*
4. Freshwater Ecosystem (Lake Volta): *Algae → Water insects → Tilapia → Nile perch → Kingfisher*
5. Wetland Ecosystem (Amanzuri Wetlands): *Water plants → Tadpoles → Mudfish → African fish eagle*

   Each link in a food chain represents a trophic level, which is the position an organism occupies in a food chain or ecological pyramid based on its feeding behaviour. The main trophic levels include:

   a. Producers – First trophic level
   b. Primary consumers – Second trophic level

c. Secondary consumers – Third trophic level

d. Tertiary consumers – Fourth trophic level

At each stage of energy transfer, approximately 90% of the energy is lost, mostly as heat, and through waste such as undigested food, uneaten parts, death, and decomposition. This significant energy loss explains why food chains typically consist of only 4 to 5 trophic levels.

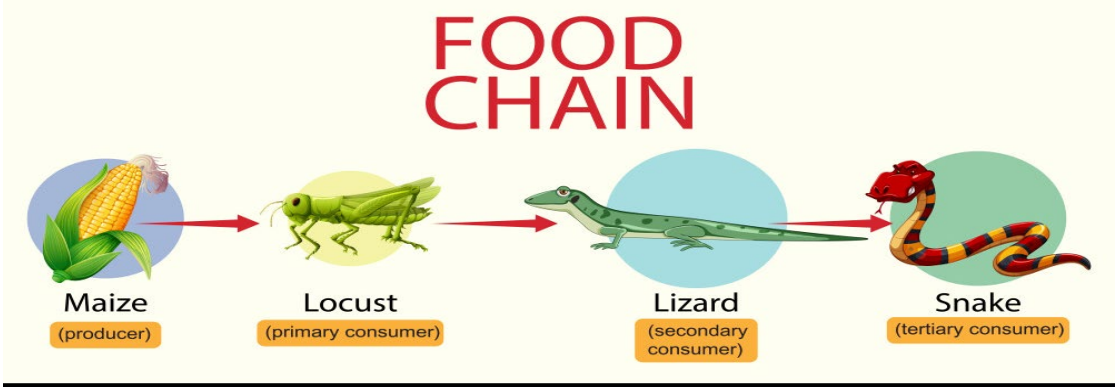


Figure 3.14: A terrestrial food chain

Food Webs

A food web is a system of interlocking and interdependent food chains, illustrating the complex feeding relationships within an ecosystem. In real ecosystems, energy transfer is more complex than in simple food chains. For example, in Ghana's forest ecosystems, one type of tree can support many herbivores (plant-eating animals). These herbivores, in turn, are hunted by different predators. This creates a rich and dynamic web of interactions among different species.

Food webs highlight

a. multiple feeding relationships among organisms

b. alternative energy pathways, allowing flexibility in energy flow

c. ecosystem's strength due to redundancy in species roles. This means that an ecosystem is stronger and more resilient when multiple species can perform similar roles.

Keystone Species and Ecosystem Stability

The removal of a keystone species (one that has an extremely large impact on its environment relative to its abundance) can lead to powerful shifts in ecosystem structure. For example, in Mole National Park, a decline in large predators like lions and leopards could result in a surge in herbivores like the duiker and hartebeest populations, ultimately causing significant vegetation changes and altering the balance of the ecosystem.

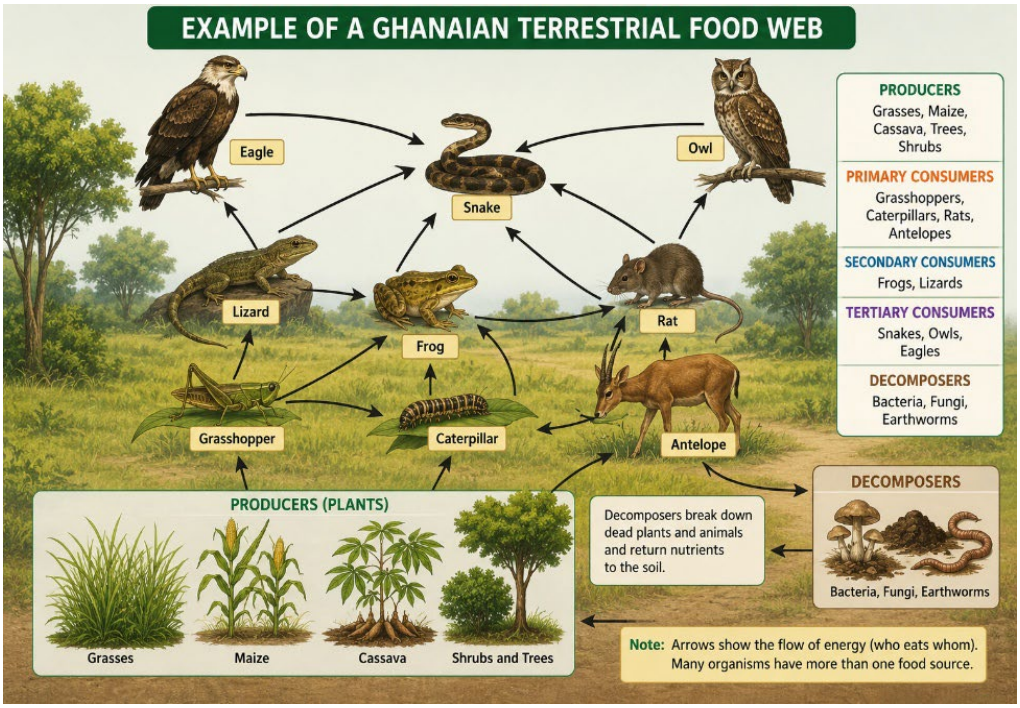


Figure 3.15: An example of a terrestrial food web

Decomposition

Decomposition is the process by which organic substances are broken down into simpler forms of matter, releasing nutrients back into the ecosystem.

Importance of Decomposition in Ecosystems

Decomposition plays a vital role in how an ecosystem functions by:

1. recycling nutrients in dead organic matter into forms usable by plants
2. preventing the accumulation of dead material in ecosystems
3. contributing to soil formation and enhancing soil fertility
4. completing biogeochemical cycles, such as the carbon and nitrogen cycles

Decomposers in Ghanaian ecosystems

In Ghana, decomposers include:

1. Fungi like mushroom species and mycorrhizal fungi are especially abundant in humid forest regions.
2. Bacteria are microscopic organisms that break down organic matter.
3. Invertebrates, such as termites, earthworms, and dung beetles.

Factors Affecting Decomposition

Several environmental factors influence the rate of decomposition.

1. Temperature: Decomposition occurs faster in warmer regions
2. Moisture: Seasonal changes affect decomposer activity
3. Oxygen availability: Aerobic conditions speed up decomposition
4. pH levels: Optimal pH supports microbial activity

In Ghana's cocoa-growing regions, effective management of organic matter decomposition is important for maintaining soil fertility and reducing reliance on chemical fertilisers.

Biological/Symbiotic Associations (Symbiosis)

Biological association refers to the relationship between different species living together in the same ecosystem. These relationships involve varying degrees of physical association and interdependence, which may be:

a. beneficial
b. harmful
c. neutral

Mutualism

Mutualism is a type of biological relationship in which both species benefit from the association. Common examples include the points mentioned below.

1. Mycorrhizal Symbiosis: A relationship between fungi and forest trees.
    a. Fungi provide minerals and enhance water absorption for the tree
    b. The tree supplies carbohydrates (food) to the fungus
2. Pollination
    a. Bees collect nectar from plants as food
    b. In return, they transfer pollen grains, aiding plant reproduction
3. Nitrogen-Fixing Bacteria in Legumes
    a. Bacteria in root nodules fix nitrogen for plant use
    b. The plant provides nutrients and shelter to the bacteria
4. Gut Microbiota in Ruminants
    a. Microorganisms in the digestive systems of animals like cattle and goats digest cellulose
    b. The microbes receive food and protection from the host animal



Figure 3.16: Honeybee on a coneflower

Mutualism is ecologically important because it:

a. creates interdependencies that promote ecosystem stability
b. allows organisms to access resources or habitats that would otherwise be unavailable
c. drives co-evolutionary processes, leading to increased biodiversity. This means that certain interactions between species can encourage them to evolve together over time. As they adapt to each other, new species may emerge, leading to greater biodiversity.
d. supports essential ecosystem functions, such as pollination and nutrient acquisition

These relationships are often highly specific and have evolved over long periods. Disruption of mutualistic interactions can lead to serious ecological consequences, including:

a. reduced agricultural productivity
b. decline in the ability of a forest to regenerate.

Such impacts are particularly relevant in Ghana's diverse ecosystems, where mutualism plays a key role in maintaining ecological balance.

Commensalism

Commensalism is a biological relationship between two different species in which one organism benefits, while the other is neither helped nor harmed.

1. The benefiting organism is called the commensal
2. The unaffected organism is referred to as the host

Some common examples observed in Ghanaian ecosystems include the following.

a. Cattle egrets feeding on insects stirred up by grazing livestock.
b. Epiphytic ferns growing on tree trunks in forested areas.
c. Small fish sheltering among mangrove roots along the coast.
d. Birds nesting in tree cavities.

e. Remora fish attach to sharks for access to food scraps, transport, and protection.



Figure 3.17: Egret feeding on insects stirred up by a grazing cow

Commensalism offers several ecological benefits, including:

a. making habitats more complex, which helps to support more types of plants and animals.

b. providing alternative survival strategies so that some organisms can adapt and find new ways to live and thrive.

c. encouraging new partnerships between species over time: As species interact, they can form helpful connections with each other.

In Ghana's farms, commensalism often supports beneficial organisms that aid in natural pest control, e.g. Spiders build webs near cocoa trees to capture pest insects without harming the trees. This helps farmers to reduce the use of chemical pesticides, saving money and protecting the environment.

Parasitism

Parasitism is a biological relationship in which one organism (the parasite) lives on or inside another organism (the host), causing harm to the host while benefiting from the interaction. In severe cases, the parasite may eventually lead to the host's death.

Quick Question: Why do parasites rarely kill their host?

Common Examples in Ghana

1. *Plasmodium* (a malaria parasite transmitted by *Anopheles* mosquitoes) in humans(host).
2. Mistletoe growing on shea and mango trees (hosts).
3. Intestinal worms affecting humans and livestock (hosts).
4. Parasitic fungi attacking cocoa and other crops (hosts).



Figure 3.18: Mistletoe on a tree



Figure 3.19: Dodder on a green-leafed plant

Ecological Importance of Studying Parasites

Understanding parasites in a habitat is crucial because:

a. they can sometimes help regulate host populations.
b. they drive the development of the host's defences.
c. they contribute to disease exposure in organisms.
d. scientists use parasite presence to assess ecosystem health.

In Ghanaian farms, controlling parasites like cocoa black pod disease or stomach worms in goats is essential. Without proper management, crops may fail, and animals may become ill, leading to financial losses for farmers.

However, in forests and grasslands, parasites can play a regulatory role, preventing any single species from dominating. This promotes species diversity and strengthens ecosystem resilience.

Saprophytism

Saprophytism is a mode of nutrition in which organisms obtain nutrients from dead and decaying organic matter. These organisms are known as saprophytes.

Examples of Saprophytic Relationships

1. Fungi decomposing fallen logs in forest ecosystems.
2. Bacteria breaking down leaf litter.
3. Termites consuming dead wood.
4. Mushrooms emerging after the rainy season.



Figure 3.20: Bracket fungi on a tree trunk

Ecological Importance

Saprophytism contributes to ecosystem health by:

a. driving nutrient cycling, essential for productivity.
b. improving soil formation and fertility.
c. preventing buildup of dead organic material.
d. supporting food webs based on detrital energy pathways (energy from dead plants and animals)

In Ghana, traditional farming practices often include fallow periods, i.e. resting intervals between planting seasons. These allow decomposition to replenish soil nutrients. Without saprophytes, nutrients would remain locked in dead matter, leading to infertile soils and reduced food production.

Note

Detrital: Relating to dead and decaying organic matter that serves as a source of food for decomposers and detritivores.

Example in Ghana

A fallen cocoa leaf decomposing on the forest floor is detritus. Earthworms and termites feed on it, making it part of a detrital food chain.

Example of a Detrital Food Chain

Dead leaves → Earthworm → Bird → Hawk

Epiphytism

Epiphytism is a biological relationship where one plant (the epiphyte) grows non-parasitically on another plant (the host), using it solely for physical support, not for nutrients.

Examples in Ghana's ecosystems

1. Orchids growing on trees in tropical forests
2. Mosses and lichens on tree trunks
3. Ferns nestled in tree crevices
4. Algae growing on aquatic plants



Figure 3.21: Bromeliad, an epiphyte growing on a tree trunk

Ecological Importance of Epiphytism

Epiphytism plays a vital role in maintaining ecosystem health and complexity. Its ecological benefits include the following.

1. Increasing structural complexity within forest ecosystems.
2. Creating microhabitats that support other organisms, such as insects and amphibians.
3. Enhancing canopy biodiversity, especially in tropical rainforests.
4. Participating in nutrient cycling, particularly by capturing nutrients from rainfall and air.

In Ghana's relic rainforests, epiphytes are especially diverse. They contribute to ecosystem complexity by forming habitats for other species and by capturing water and nutrients that might otherwise be lost, thereby supporting overall biodiversity and ecological balance.

Ecological Importance of Interdependency

Interdependency among living organisms is essential for the stability and sustainability of ecosystems. Its importance includes:

a. ensuring a stable ecosystem through mutual dependence among species.

b. providing critical services such as food, clean water, and fertile soil necessary for survival.

c. supporting ecosystem conservation, which depends on the interconnected relationships among all living things and not just individual species.

Healthy ecosystems thrive when species work together, forming networks of support that maintain balance, productivity, and resilience.

Activity 3.4 "Ecosystem Explorers: Discovering Symbiotic Relationships"

Objective: Identify, describe and classify examples of mutualism, commensalism, parasitism, saprophytism and epiphytism in the school compound or local environment and compile your findings into a collaborative field guide.

Instructions

1. Field exploration
    a. Work in pairs or small groups.
    b. Go around the school compound or the nearby area.
    c. Look for examples of these relationships in plants, animals, insects or fungi.
    d. For each type of biological association, write down one example you find.
    e. Describe what is happening in that relationship, i.e. who benefits, who does not but is not harmed, who is harmed and how.
    f. Draw or take a picture of each example if you can.
2. After your exploration, create a field guide that includes:
    a. A title and your group's name.
    b. A section for each relationship with your example, description and an illustration.
    c. Any interesting facts or local names of the species you found
3. Present your field guide to the class. Make sure your notes are clear and complete.

Caution: Be respectful of nature. Don't harm any organism.

Activity 3.5 Decomposition uncovered

Objective: Observe and compare how different plant materials decompose.

Materials

- Various plant materials (e.g., grass, leaves, fruit peels)
- Soil or compost
- Clear plastic containers/bags
- Water
- Notebook for observations
- Rulers (for measuring size changes)

Instructions

1. Choose three different plant materials.
2. Collect equal volumes of each material (e.g., a cup or handful).
3. Place the materials in separate clear containers/bags filled with equal amounts of soil/compost.
4. Lightly water the materials to keep them moist.
5. Check the containers/bags once a week for 3-4 weeks.
6. Measure and record any changes in size (using a ruler) and appearance (colour, texture).
7. At the end of the observation period, create a chart to show the changes observed for each material over time.
8. Discuss which materials decomposed the fastest and potential reasons for the differences.
    a. What factors influenced the decomposition rates?
    b. Why is decomposition important for soil health and ecosystems?

THE PLANT DENSITY OF A SCHOOL FIELD

Plant Density Sampling Techniques

Plant density is the number of individual plants per unit area in a habitat. Plant density gives us a better understanding of vegetation composition, ecosystem stability, and biodiversity. Instruments used for estimating plant populations and densities include quadrats and line transects. The plant density within a habitat is determined by the formula,

$$\text{Plant Density} = \frac{Total\ number\ of\ individuals\ species}{Total\ area\ sampled}$$

$$\text{Plant density} = \frac{N}{A}$$

$$= \frac{plants}{m^2} \text{ or } \frac{plants}{hectare}$$

Where

N = number of individual species counted,

A = total area sampled.

Steps for collecting data for calculating Plant Density

1. Define a clear study area and choose an appropriate sampling method (quadrat, transect, etc.).
2. Place the sampling instrument randomly or systematically within the area.
3. Count all individuals of the target plant species in each sampling unit.
4. Calculate the total number of plants and the total area sampled.

5. Divide the total number of plants by the total area to determine density (plants/m^2).

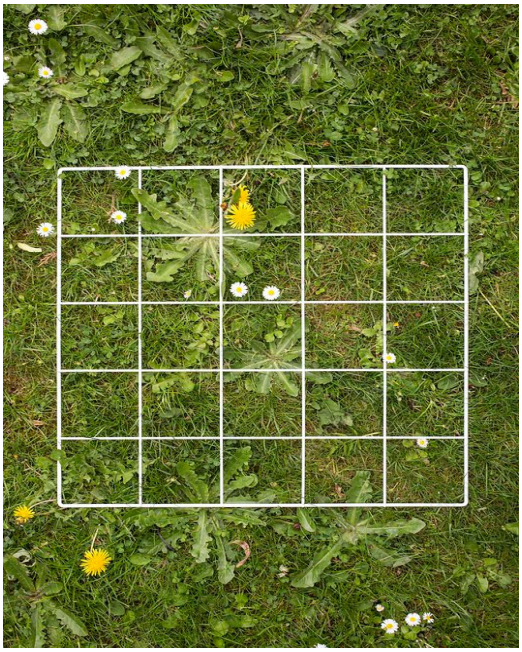


Figure 3.22: A frame quadrat in a school field

For example, if five different 1m^2 quadrats are randomly placed in a school field to estimate the density of *Tridax procumbens (*plant with white flowers in the figure*)*, and the number of *Tridax* in each quadrat is counted to be 12, 8, 14, 10, 6.

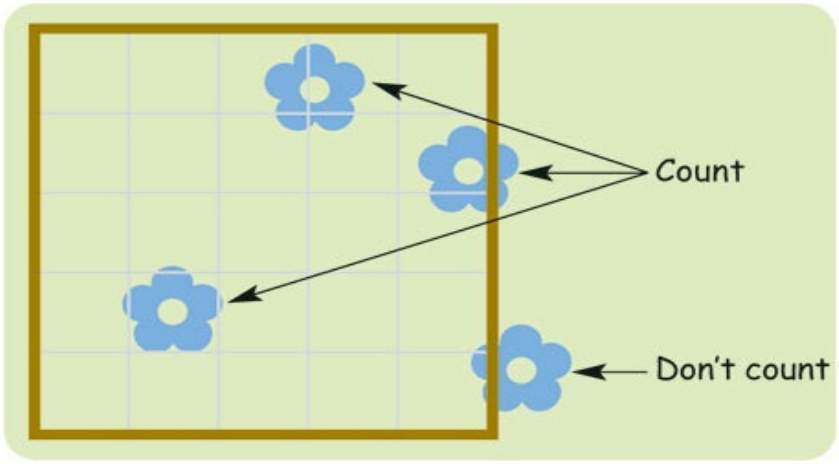


Figure 3.23: Using a quadrat to sample

Then the density of *Tridax* in this habitat is determined as follows:
Total number of *Tridax* = 12 + 8 + 14 + 10 + 6 = 50 plants
Total area sampled = 5 quadrats × 1m^2 = 5m^2

Plant density $= \frac{50\ plants}{5m^2}$

= 10 plants/m^2

The density of *Tridax procumbens* is therefore 10 plants per square metre in the school field.Top of Form

Precautions in estimating plant density in a habitat

1. Ensure truly random placement of sampling instruments to avoid bias.
2. Use an appropriate quadrat size (smaller for dense vegetation, larger for sparse).
3. Maintain a constant identification criterion for the target species.
4. Collect sufficient samples to ensure reliability (minimum 5-10 quadrats).
5. Consider seasonal variations in plant growth and flowering.

Relationships between plants in the environment and human health

1. The presence of green plants in the environment helps to reduce stress and boost the mood of an individual.
2. Plants clean the air by using up carbon dioxide and producing oxygen. This activity of plants helps to replenish oxygen levels and protect humans from respiratory illnesses.
3. Crops are grown in farms and gardens to provide food (nutrients) for growth and good health.
4. Many plants have medicinal properties and are used in traditional and modern medicine to treat various ailments.
5. Parks and gardens serve aesthetic purposes to improve human health in humans.

Activity 3.6 Plant Sampling and Density Calculation

Objective: Conduct plant sampling and calculate mean density.

Materials

- Quadrat frames (or tape measures)
- Data recording sheets

Instructions

1. Select a specific habitat area to sample.
2. Identify a specific plant species you want to sample
3. Place quadrats randomly within your area and count the number of plants identified in each quadrat.
4. Calculate the mean density of plants per unit area.
5. Repeat instructions 2 to 4 for different areas and determine variations in the density of the plant.
6. Research various factors that influence the plant's distribution.
7. Select a specific factor to focus on and gather data from your sampled areas to support your ideas.

8. Analyse how your chosen factor affects plant distribution within the sampled areas.
9. Share your results with the class

ESTIMATING/ANALYSING THE BODY MASS INDEX (BMI) OF LEARNERS IN A CLASS AND ITS IMPLICATIONS

Estimating and Analysing Body Mass Index (BMI) of a Person

Body mass index (BMI) is a simple measure used to classify individuals as underweight, normal weight, overweight, or obese and is a common health indicator of weight-related health risks. The BMI value is calculated by dividing the mass or weight (Kg) of a person by the height squared (m^2).

The formula is

$$\text{BMI} = \frac{weight(kg)}{height^2\ (m^2)}$$

Remember, BMI doesn't distinguish between muscle and fat mass.

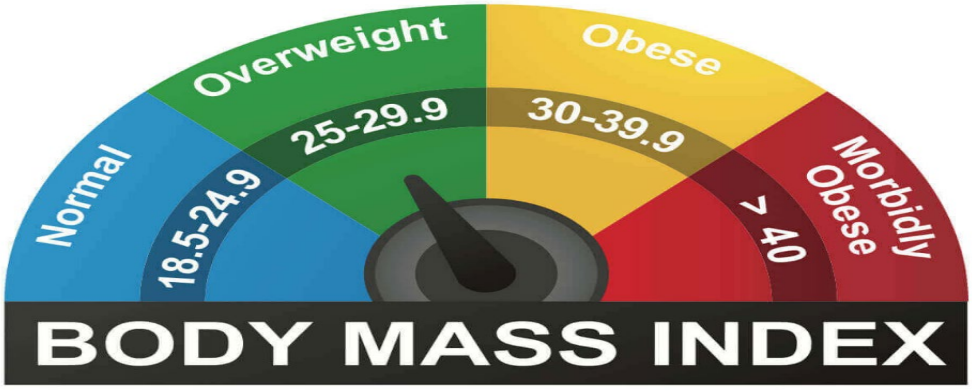


Figure 3.24: The BMI scale for adults

The table below provides the category for BMI.

Table 3.1: Categorisation of BMI

BMI Range/kg/m^2	Category
Below 18.5	Underweight
18.5 - 24.9	Normal weight
25.0 - 29.9	Overweight
30.0 – 39.9	Obese
40.0 and more	Morbidly obese

Top of FormSteps for Calculating BMI

1. Measure body mass (weight) in kilograms.
2. Measure height in metres.
3. Find the square of the height measured
4. Divide the weight by the squared height value.

Quick Exercise

For example, the following data were collected from five mechanics in a shop in Kasoa. Calculate the BMI

Mass and height of five mechanics in a shop at Kasoa.

Mechanic	Mass/kg	Height/m	Height^2/m^2
Kofi	65	1.70	
Musa	55	1. 65	
Kwame	80	1.85	
Akosua	50	1. 65	
Yaw	85	1.75	

Interpret the BMI values in the table below as a summary of the results of the five mechanics.

Mechanics	BMI	Category
Kofi		
Musa		
Kwame		
Akosua		
Yaw		

Common precautions to take when estimating BMI

1. Use calibrated scales and measure height with the person standing straight against a wall.
2. Take measurements without shoes and in light clothing only.
3. Do not calculate BMI for pregnant women or very muscular individuals.
4. Use age-specific BMI charts for children and adolescents.Top of Form

Limitations of using the interpretations of BMI

1. The method does not distinguish between muscle and fat.
2. It may not be appropriate for athletes, pregnant women and the elderly.
3. Ethnic variations exist in body composition.
4. Children and adolescents require a different interpretation using age-specific charts.

Activity 3.7 Investigating Body Mass Index

Objective: Calculate and analyse BMI data and errors.

Materials

BMI calculation worksheets, graph paper or digital tools for creating tables, a weighing scale and a tape measure (to be provided by the teacher or visit any health post for measurement to be taken)

Sample worksheet

Body mass compares your mass to your height using the following equation: BMI=

Your task

1. Collect data on age, weight and height from volunteers to fill the rows in the tables.
2. Calculate the BMI of each volunteer.

Age	
Weight/Kg	
Height/m	
BMI	
category	

Age	
Weight/Kg	
Height/m	
BMI	
category	

Age	
Weight/Kg	
Height/m	
BMI	
category	

Instructions

1. Measure your height and weight
2. Share your values with as many classmates as possible while you collect their values as well (minimum of 10)
3. Calculate your BMI and that of the others, using the formula:

$$\text{BMI} = \frac{Weight\ (Kg)}{Height^2\ (m^2)}$$

4. Create a frequency table categorising BMI into underweight, normal weight, overweight, and obese.
5. Draw a bar graph to represent the number of classmates in each category.
6. Analyse findings for possible errors and suggest solutions to minimise these errors.
7. Present findings focusing on strategies for accurate measurements.

EMERGING HUMAN DISEASES, TRANSMISSION AND CONTROL MECHANISMS: SARS-COV, COVID-19, EBOLA, BURULI ULCER, SWINE FLU/ H1N1 FLU AND MONKEYPOX

Emerging Human Diseases: Transmission and Prevention

Emerging diseases are infections that have newly appeared in a population or have existed but are rapidly increasing in occurrence or geographic range. Examples of these diseases are SARS-COVID-19, Ebola, Buruli ulcer, Swine flu/H1N1 flu and Monkeypox. Emerging diseases are identified by the following characteristics:

a. They are either new or old diseases
b. The number of new cases recorded in the population (incidence) keeps increasing rapidly.
c. They spread to new geographic locations and populations.
d. They pose a huge threat to the public and can re-emerge after a period of decline.

Common Emerging Diseases

SARS (Severe Acute Respiratory Syndrome)

This is a serious respiratory illness that can lead to severe pneumonia and respiratory failure. It was first recorded in 2002 in Guangdong Province in China. Bats are believed to be natural reservoir hosts, suspected to be carrying the virus (bats are considered the vectors).

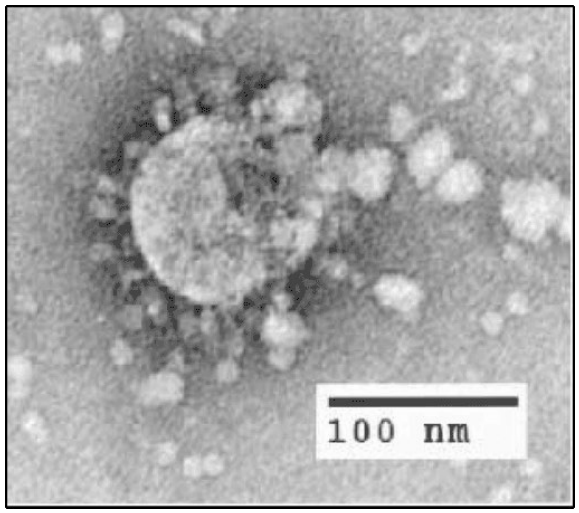


Figure 3.25: Electron micrograph of SARS-CoV

Causative Organism: Coronavirus (SARS-CoV)

Transmitted through;

a. respiratory droplets that are released when an infected person coughs or sneezes. The virus in the droplets may be inhaled by other individuals nearby.
b. close person-to-person contact.
c. touching surfaces or objects contaminated with the virus and then touching the mouth, nose, or eyes.

Signs and symptoms include high fever, headaches, body pains, dry cough and shortness of breath.

Control and Preventive Measures

a. Wear a nose mask and personal protective equipment (PPE).
b. Practice good personal hygiene (such as handwashing).
c. Isolate infected persons.
d. Use vaccines.
e. Implement strong travel restrictions and screening protocols.
f. Quarantine suspected persons.
g. Educate the public.



Figure 3.26: Personal protective equipment (PPE)

COVID-19 (Coronavirus Disease 2019)

This is a respiratory disease that can have mild to severe forms. It was first identified in Wuhan, China, in December 2019. Bats are believed to be the natural reservoir and are considered to be vectors for the disease.

Causative Organism: SARS-CoV-2 (virus)

Transmitted through;

a. respiratory droplets that are released when an infected person coughs or sneezes. The virus in the droplets may be inhaled by other individuals nearby.

b. touching surfaces or objects contaminated with the virus and then touching the mouth, nose, or eyes.

c. possible airborne transmission in enclosed spaces.

Signs and Symptoms include fevers, coughs, shortness of breath (difficulty in breathing), fatigue, headaches, sore throats and runny or stuffy nose.

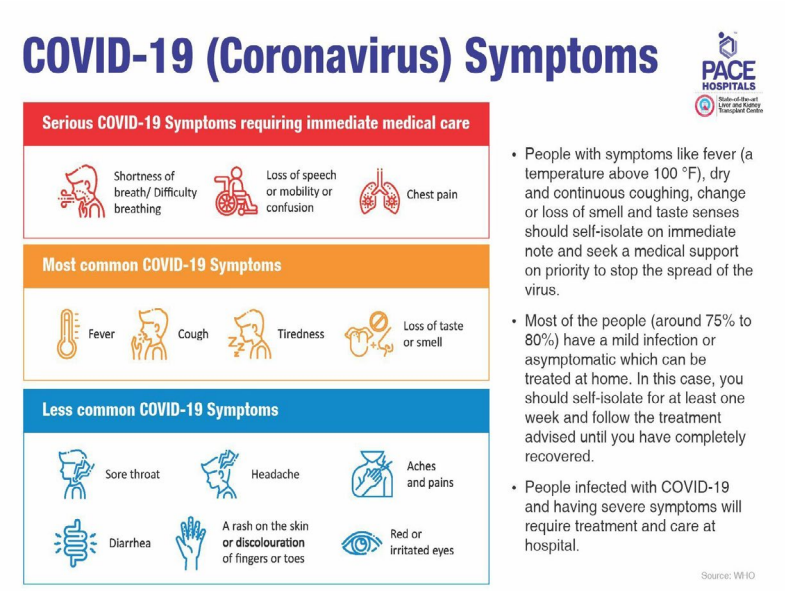


Figure 3.27: Mild to severe symptoms of COVID-19

Control and Preventive Measures

a. Vaccination
b. Wear a mask in public places
c. Practise social distancing (at least six feet apart)
d. Frequent handwashing
e. Avoid touching face
f. Isolate suspected infected persons
g. Avoid going out as much as possible, especially when feeling sick
h. Quarantine suspected individuals
i. Educate the public about preventive measures

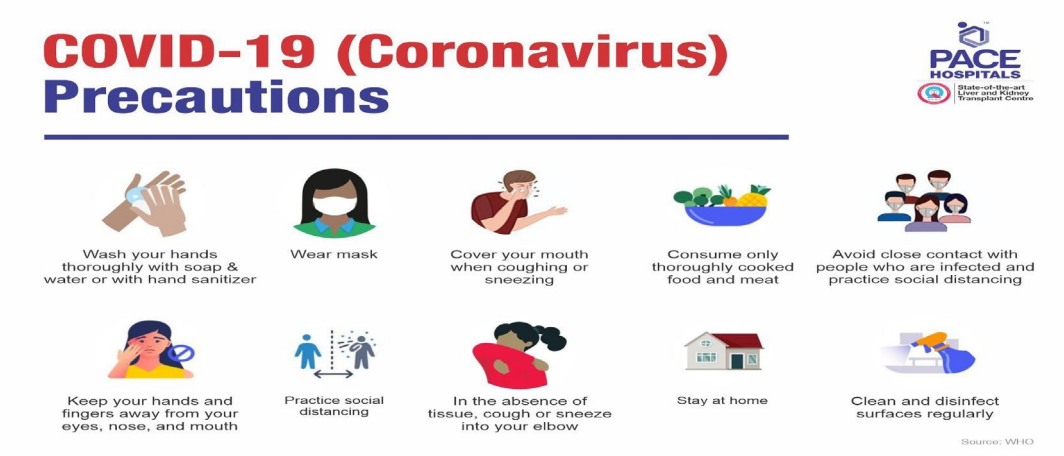


Figure 3.28: Preventive measures for COVID-19

Ebola Virus Disease

This is a severe and deadly viral disease which causes widespread bleeding and organ failure among infected individuals. It was first recorded in 1976, in the now Democratic Republic of Congo (DR Congo). The virus is believed to have originated from fruit bats.

Causative organism: Ebola virus (family *Filoviridae*).



Figure 3.29: The Ebola virus

Transmitted through;

a. direct contact with blood, body secretions, or other bodily fluids of infected persons
b. contact with contaminated objects, fomite (e.g., needles)
c. handling or consuming infected wild animals (e.g., fruit bats, monkeys)

Signs and Symptoms include fever, vomiting, diarrhoea, abdominal pain, muscle and joint pain and bleeding.

Control and Preventive Measures

a. Wearing PPE such as masks, gloves and gowns.
b. Practice good personal hygiene such as handwashing.
c. Isolate infected persons.
d. Implement contact tracing strategies used to identify and monitor individuals who have been in close contact with someone diagnosed with the disease.
e. Use vaccines
f. Ensure safe burial of individuals who died from the disease.
g. Educate the public.

Buruli Ulcer

This is an infection caused by a slow-growing aerobic bacterium, which causes severe skin and bone tissue damage when left untreated. It occurs in tropical and sub-tropical regions of the world, especially in Africa, Australia and Southeast Asia. It is believed to be associated with stagnant waters.

The causative organism is *Mycobacterium ulcerans*

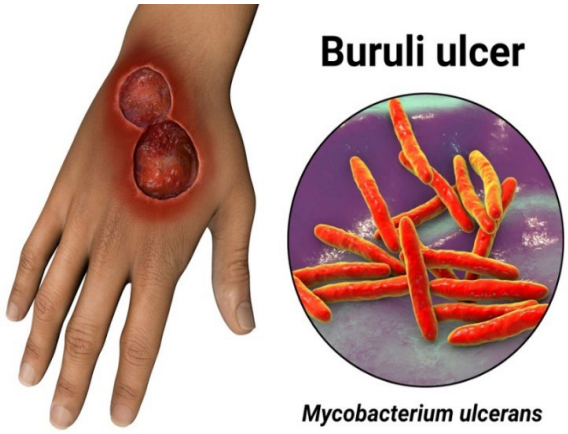


Figure 3.30: (left) hand affected by Buruli ulcer, (right) electron micrograph of the causative organism

The exact mode of transmission is not fully understood, but possibly through contaminated water, soil, or insect bites (in aquatic environments).

Signs and symptoms include painless nodules or lumps under the skin, swelling of the affected area, skin lesions or plaque and destruction of the skin and underlying tissues.

Control and Preventive Measures

a. Early detection and treatment with antibiotics.
b. Wearing protective clothing (e.g. long sleeves, pants, etc.)
c. Avoid contact with contaminated water.
d. Ensure personal hygiene and improve wound care.
e. Educate people.

Swine Flu (H1N1 Influenza)

It is a type of respiratory illness that can range from mild forms to severe forms. It was first recorded in Mexico and the United States in 2009. The virus is believed to have been carried by pigs.

Causative organism: H1N1 influenza virus (a subtype of Influenza A)

Transmitted through;

a. respiratory droplets that are released when an infected person coughs or sneezes. The virus in the droplets may be inhaled by other individuals nearby.
b. touching surfaces or objects contaminated with the virus, i.e, fomite, and then touching the mouth, nose, or eyes.
c. Human-to-human contact is common

Signs and Symptoms include fever, cough, sore throat, runny or stuffy nose, headaches, fatigue, muscle or body aches and chills (feeling cold).

Control and Preventive Measures

a. Vaccination.
b. Practice good hygiene such as handwashing.
c. Use a mask in public places.
d. Use prescribed antiviral medications.
e. Stay home when sick.

Monkeypox

This is a viral disease that causes symptoms like smallpox. It was first identified in monkeys in 1958, primarily in Central Africa and West Africa. The virus is believed to be carried by rodents (which are vectors for this virus).

Causative organism: Monkeypox virus (a member of the *Orthopoxvirus* genus)

Transmission

a. Close contact with infected individuals or animals.

b. Contact with body fluids, lesions, or contaminated materials (e.g., bedding).

c. Respiratory droplets during prolonged face-to-face contact.

Signs and Symptoms include fever, headache, muscle pains, back pain, swollen lymph nodes and rashes or skin lesions which progress from flat red spots to pus-filled blisters.

Control and Prevention Measures

a. Vaccination.

b. Avoid contact with infected animals (rodents and primates).

c. Wear PPE when caring for infected persons.

d. Practice good hygiene.

e. Isolate infected persons.

f. Educate the public about the disease and its consequences.

Activity 3.8 Scenario: Outbreak of "Phluokona Virus"

Objective

Create a plan for responding to a new infectious disease outbreak to gain a deeper understanding of disease transmission and public health response strategies.

Instructions

1. Read the fictional scenario about an outbreak of a new infectious disease carefully.

   Scenario

   In the coastal town of Telwater, a new infectious disease known as Phluokona Virus has emerged. The virus was first identified in the latter part of the rainy season and has rapidly spread among the local population. Initially, reports indicated that Phluokona Virus causes flu-like symptoms, but it can lead to severe respiratory complications in vulnerable individuals. Other symptoms are fever, cough, fatigue, body aches and severe respiratory distress (in advanced cases). The Phluokona virus is primarily thought to be transmitted through respiratory droplets when an infected person coughs or sneezes and through direct contact with contaminated surfaces. It is highly common in older adults (65 and older), individuals with pre-existing health conditions (e.g., asthma, hypertension) and young children under 5 years of age. As of now, there have been 150 confirmed cases in Telwater, with 20 hospitalisations. The local health department has initiated 'contact tracing' but is struggling to keep up with the rapid rise in cases. There are reports of community panic, with many residents avoiding public places. The assemblymen in the area have called for an emergency town hall meeting to

discuss the outbreak and potential response measures. Local schools have been closed for three weeks as a precaution, and the health department is considering implementing a temporary quarantine for affected areas.

2. Organise into teams of 4-5 learners or as an individual and choose a role (e.g. epidemiologist, public health official, communicator).

   Task for a group/individual

3. Consider the following as the (e.g. communicator)
   a. Determining factors: justify if it is an emerging disease.
   b. Surveillance: How will you track the spread of the virus and monitor new cases?
   c. Containment Strategies: What actions will you take to prevent further transmission?
   d. Public Communication: How will you inform the community about the outbreak and encourage preventive behaviour?
   e. Resource Allocation: What resources (e.g., medical supplies, healthcare personnel) will you need to manage the outbreak effectively?
4. Outline your plan
5. Create and share a written document or presentation slide summarising your plan.

PLANT AND ANIMAL DISEASES: THEIR CONTROL AND PREVENTION

Plant Diseases: Control and Prevention

Blight diseases

Blight is the general term for plant diseases caused by fungal or bacterial pathogens. These pathogens cause cell death (necrosis) in large areas of plants. Blight causes rapid and complete chlorosis (yellowing), browning and death of plant tissues like leaves, branches, twigs, or floral organs, completely damaging the plant. Common plants that are affected are potatoes, tomatoes, capsicum/bell peppers and eggplants. Different types of blight can affect edible and ornamental plants.

A table of blight diseases, causative organisms, plants and their parts affected, and symptoms is provided below.

Table 3.2: Blight diseases, causative organisms, plants and their parts affected, and symptoms.

Diseases	Causative organism	Plants and their parts affected	Symptoms
Early/target spot blight	Fungus: Alternaria solani	Tomatoes: leaves, stem, flowers, potatoes: leaves,	Distorted, dark brown to black spots on the leaves with a distinct concentric ring pattern.
Halo blight	Bacteria: Pseudomonas savastanoi pv. Phaseolicola	Beans: leaves, pods,	Brown spots with a light-green or yellow ring around spots
Late blight	Fungus: Phytophthora infestans	Potato: leaves Tomato: leaves	Rapid leaf rot.
Fire blight	Bacteria: Erwinia amylovora	Apples and pears: flowers, stems and leaves	Dark orange-brown (apples) or black (pears) patches or whole areas giving it a burnt appearance.



Figure 3.31: Late Blight disease on tomato plant



Figure 3.32: Early blight disease on a leaf



Figure 3.33: Halo blight on bean leaves



Figure 3.34: Fire blight on an apple tree

Mode of Transmission of Blight

The disease is transmitted through the air over long distances by the dispersal of the spores that are produced by the pathogen in moist and humid environments. The spread of these spores can be aided by:

a. water splash.
b. high humidity.
c. conducive temperatures.
d. human activities such as using contaminated tools or equipment.
e. humans moving between fields without proper sanitation.

Control and prevention

Pathogens can stay in infested soil, old plant materials or on other 'host' plants, like nearby weeds, for up to a year. This makes it difficult to treat once the plants are affected. Some actions can be taken to prevent and control the disease.

a. Cultural Practices: Maintaining optimal growing conditions, removing (burning) infected plant parts, and crop rotation can help manage blight. Plant disease-free seeds and only save seeds from disease-free plants. Water the soil, avoid crown and root injuries, and feed plants regularly to keep them growing well – healthy plants can better resist pests and diseases.
b. Chemical control: Depending on the specific blight, fungicides can be used to protect healthy tissues from infection.
c. Other measures: Soil solarisation involves tightly covering the area of soil with clear plastic and letting the sun heat the soil for a couple of weeks to reduce the amount of fungus in the soil. After solarisation, reintroduce beneficial fungi and bacteria into the soil before planting.

Wilt diseases

Wilt diseases are a group of plant diseases characterised by the wilting of leaves and stems, often leading to plant death. Wilt diseases are mainly caused by pathogens that infect the vascular system of plants and disrupt the transportation of water and nutrients.

A table of wilt diseases, causative organism, plants and their parts affected, and symptoms is provided below.

Table 3.3: Wilt diseases, causative organism, plants and their parts affected, and symptoms

Wilt disease	Causative organism	Plants and their parts affected	Symptoms
Fusarium Wilt	Fungus: *Fusarium oxysporum*	Tomatoes (stems, leaves) Cotton (stems, roots), etc.	Wilting of leaves, often starting with the lower leaves Yellowing of leaves (chlorosis) Stunted growth Brown discolouration in vascular tissues when cut open

Verticillium Wilt	Fungus: *Verticillium dahliae*	Eggplants (stems, leaves) Strawberries (roots, stems), etc.	Wilting of leaves and stems Yellowing and browning of leaves Stunted growth Discolouration in the vascular system
Bacterial Wilt	Bacterium: *Ralstonia solanacearum*	Tomatoes (stems, roots) Potatoes (stems, tubers), etc.	Sudden wilting and collapse of plants Yellowing of leaves Brown discolouration in vascular tissues Water-soaked lesions on stems



Figure 3.35: Fusarium wilt in okra stem



Figure 3.36: Verticillium wilt in eggplant

Mode of transmission

Conditions such as drought or poor drainage can increase the effects of wilt diseases, making plants more prone to infection and affecting crop yields and plant health. The disease is transmitted through:

a. contaminated soil
b. plant debris or infected plant parts
c. water
d. human activity, such as using contaminated tools

Control and prevention

Soilborne spores can stay in the soil for years and infect plants through the roots. Managing wilt diseases successfully is key to protecting crops and ensuring agricultural productivity. Some measures can be taken to prevent and control the disease.

a. Cultural Practice
    i. To reduce the pathogen load in the soil, practise crop rotation with non-host plants or plant varieties that are resistant to specific wilt diseases.

ii. Add organic matter to the soil to improve soil health and structure to promote beneficial microbial activity that can outcompete pathogens.

iii. Remove and destroy infected plant debris to prevent the spread of pathogens.

iv. Regularly clean tools and equipment to avoid contamination.

v. Avoid over-watering and ensure good drainage to reduce waterlogged conditions, which can enable fungal growth.

vi. Use drip irrigation to minimise leaf wetness.

b. Biological Control involves introducing beneficial bacteria and fungi that can suppress wilt pathogens. These microorganisms can help protect plants by outcompeting or directly inhibiting pathogens.

c. Chemical Control involves the use of fungicides and bactericides, treatments that carefully target specific pathogens.

d. Regularly monitor plants for early signs of wilt diseases to take early action to reduce the spread of the disease.

Activity 3.9 Plant Power: Awareness Campaign Extravaganza!

Objective: Design an awareness campaign for a plant disease (e.g., late blight, verticillium wilt)

Materials: Art supplies, digital tools for creating posters, social media mock-ups, brochures

Instructions

1. Research a selected plant disease, focusing on its impact and prevention strategies
2. Brainstorm for campaign ideas targeting a specific audience (e.g. farmers, gardeners)
3. Develop campaign materials (e.g. posters, brochures, social media posts)
4. Present your target audience and intended message.
5. Display the campaigns around the school or community to raise awareness.

Animal Disease: Control and Prevention

Brucellosis

Brucellosis is a contagious disease in livestock caused by various bacteria of the genus Brucella. It is a zoonotic disease, which means it can be transmitted from animals to humans. In animals, it is characterised by abortions and reproductive failure. It can affect cattle, pigs, sheep, goats, camels, horses, and dogs. The specific causative organisms are *B. abortus* (in cattle), *B. melitensis (*in sheep and goats) and *B. suis* (in pigs).

Mode of transmission

a. Brucellosis is mainly spread when the animal aborts or gives birth with high levels of the bacteria in the birth fluids.

b. The bacteria can also take over the udder and contaminate the milk.

c. The bacteria survive in cool, moist environments for several months and remain infectious to other animals that ingest them.

d. It infects animals and humans through cuts in the skin and mucous membranes.

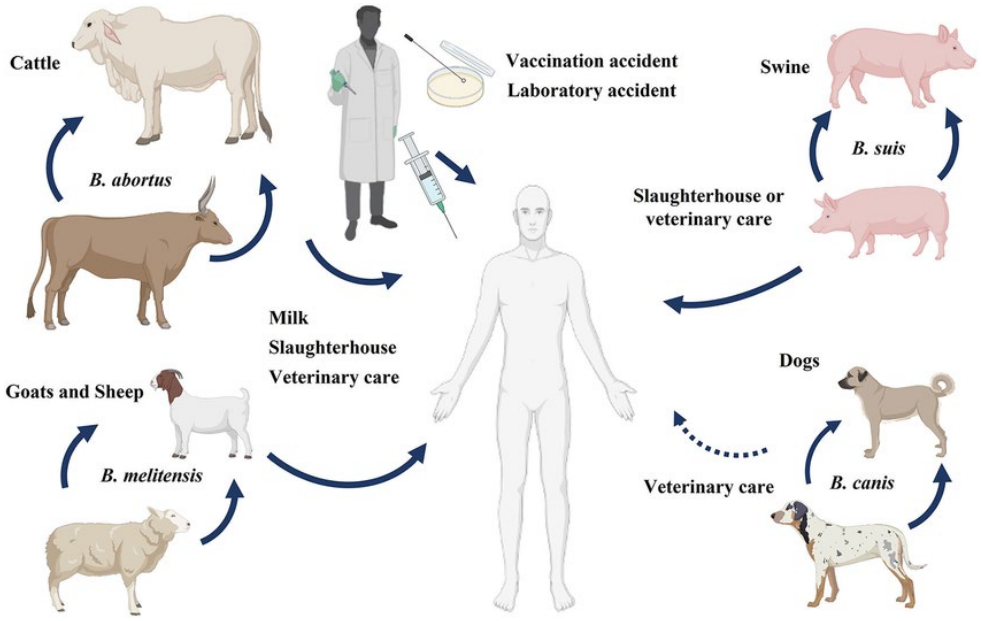


Figure 3.37: Transmission of Brucellosis

Symptoms of infected animals

a. Show few signs until abortions, retention of placenta, stillbirth, birth of weak offspring or infertility occurs.

b. Skin lesions

c. Swelling of the testicles in males.

d. The bacteria are found in the joints, causing arthritis.

Symptoms in humans may include fever and chills, sweats, fatigue and discomfort, joint and muscle pain and headache.

Control and prevention

a. *Vaccination* is often used to reduce the occurrence of infection. Several vaccines are available that use modified live bacteria.

   i. Vaccinate livestock (especially cattle, sheep, and goats) with appropriate vaccines (e.g. *Brucella abortus* strain 19 for cattle) to reduce the incidence of infection.

ii. Human vaccination is currently not available, but research is ongoing.

b. *Hygiene and Sanitation*

i. Implement strict hygiene practices on farms, including regular cleaning and disinfection of facilities and equipment.

ii. Use PPE like gloves, masks, and protective clothing when handling animals or animal products to prevent exposure.

c. *Testing and Surveillance*

i. Conduct routine testing of animals for early detection and treatment of Brucella infections.

ii. Isolate and treat infected animals to prevent the spread of the disease within herds.

iii. Implement controls on the movement of animals from infected areas to prevent transmission.

d. *Public Awareness and Education*

i. Educate farmers and livestock handlers about Brucellosis, its transmission, and prevention measures.

ii. Raise awareness in communities about the risks of consuming unpasteurised dairy (milk) products and the importance of reporting suspicious cases.

e. *Food Safety Practices*

i. Promote the pasteurisation of milk and dairy products to kill any potential bacteria.

ii. Practice safety protocols when handling and processing animal products, including thorough cooking of meat.

Tuberculosis

Tuberculosis (TB) is a contagious disease caused by bacteria of the genus *Mycobacterium*, primarily *Mycobacterium bovis* in cattle and *Mycobacterium avium* in birds. It can also affect other animal species, including humans (*Mycobacterium tuberculosis*). It is a zoonotic disease because it can be transmitted from animals to humans (zoonosis) and from humans to animals (reverse zoonosis).

Mode of transmission

TB is primarily spread through;

a. inhalation of airborne droplets from infected animals and humans

b. direct contact with infected tissues of humans and animals

c. consumption of milk and meat from infected animals.

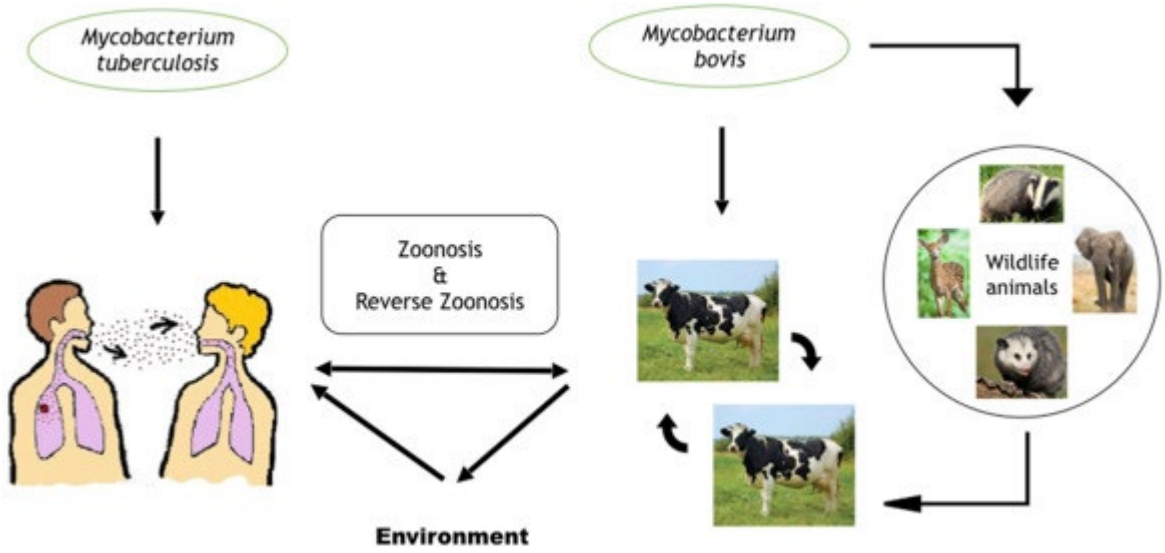


Figure 3.38: Transmission of Tuberculosis

Symptoms

a. Cattle and pigs exhibit chronic cough, weight loss, fever, lethargy, and swollen lymph nodes.

b. Humans exhibit the following.

i. Cough lasting more than three weeks, sometimes with blood or sputum.
ii. Discomfort or pain in the chest with difficulty in breathing, especially when coughing.
iii. Unusual tiredness or weakness
iv. Low-grade fever that may come and go
v. Excessive sweating during the night, often soaking through clothing or sheets.
vi. Decreased desire to eat, leading to weight loss.

Control and Prevention

a. Regular testing and culling of infected animals.

b. Pasteurisation of milk and proper meat inspection.

c. Vaccination (e.g., BCG vaccine) in some regions, though not widely used in cattle.

d. Regular screening helps promote early detections and treatment.

e. Treatment requires completing the full course of prescribed antibiotics.

f. Use nose masks when infected to prevent and control its spread.

g. Educate the public about TB transmission, symptoms, and the importance of seeking care.

h. Address the issue of stigmatisation associated with TB to encourage individuals to seek testing and treatment.

Activity 3.10 Mission Control: Crafting a Disease Defence Strategy!

Objective: Create a comprehensive management plan for a chosen disease (e.g. bacterial wilt, brucellosis).

Materials: Sample management plan template

Disease Management Plan Template

Disease Overview
Disease Name: *Pathogen:* (Bacterium, virus, fungus, etc.) *Host(s):* (Plants/animals affected) *Description:* Brief description of the disease.
Symptoms
Transmission *Modes of Transmission:* (E.g., airborne, waterborne, direct contact, etc.) *Environmental Factors:* (Conditions that promote transmission)
Impact *Economic Impact:* (Cost to agriculture, livestock, etc.) *Ecological Impact:* (Effects on ecosystems) *Public Health Impact:* (where needed)
Current Management Practices *Prevention Strategies:* (E.g., sanitation, quarantine, resistant varieties) *Control Measures:* (E.g., chemical treatments, biological control)
Proposed Management Plan *Short-term Goals:* (Immediate actions to take) *Long-term Goals:* (Sustainable practices to implement) *Action Steps:* (List specific actions required to achieve goals) *Roles and Responsibilities*: (Who will carry out each action?)
Monitoring and Evaluation *Monitoring Methods:* (How will progress be tracked?) *Evaluation Criteria:* (How will success be measured?)
Conclusion Summary of Key Points: Final Recommendations:
References: (List of sources used for research)

Note: Search for relevant internet resources on case studies of learner's choice.

Instructions

- Select one disease and research current management practices.
- Using the provided template, outline your management plan.
- Share your plan with a peer for review and provide constructive feedback for the work you reviewed.
- Revise the plan based on feedback
- Present the plan to the class.

Activity 3.11 Assessing Organism Health and Its Impact

Objective: To understand the health of specific organisms, the diseases that affect them, and the impacts on agriculture, the economy, and the nation.

Materials

- Paper and pencils
- Access to research materials (books, internet)
- Worksheets for data collection
- Chart paper for presentations

Steps

1. Pick an organism that plays a big role in farming here in Ghana. It could be a crop like cocoa or maize, or livestock like cattle or domestic fowl.
2. Research into
    a. what a healthy version of your chosen organism looks like.
    b. what diseases can affect it?
    c. what are the signs that something is wrong?
3. Think about how the health of your organism impacts:
    a. Agriculture: How does it affect how much food we can grow?
    b. Economy: What happens to farmers' income and food prices?
    c. Nation: Why is this important for food security and exports?
4. Gather information from surveys or find existing data to see how common these diseases are and their effects. (ask your teacher for existing data or use online sources)
5. Create some charts or graphs to show your findings.
6. Prepare a short presentation to share what you learned with the class. Include your research, the impacts, and any solutions you think could help improve organism health.

EXTENDED READING

- https://www.khanacademy.org/science/biology/ecology/community-ecosystem-ecology/a/ecological-interactions



- https://www.woah.org/en/what-we-do/animal-health-and-welfare/animal-diseases/



- https://www.youtube.com/watch?v=yGYnwMSflBU



REVIEW QUESTIONS

1. Describe the reproductive process of tilapia. How do they care for their young?
2. What implications do the breeding habits of tilapia have for their populations in both wild and farmed environments?
3. Describe the life cycle of a frog/toad, including the stages from egg to adult.
4. What strategies could be implemented to ease the effects of environmental changes on frog and toad populations?
5. What adaptations do wall geckos have that allow them to thrive in their environments?
6. Describe the feeding habits of wall geckos.
7. How does tilapia farming contribute to local economies?
8. Discuss the role of frogs/toads in ecological research and their importance in biodiversity.
9. What are the economic impacts of poultry farming on rural communities?
10. Describe how sunlight is a vital non-living component in a food web.
11. Explain the role of decomposers in an ecosystem and how they contribute to the food web.
12. Compare and contrast mutualism and parasitism with examples from nature.
13. Illustrate a simple food web that includes at least three producers and three consumers from a Ghanaian ecosystem. Explain the interdependency shown in your web.
14. Analyse how the removal of a top predator from an ecosystem might affect both living and non-living components.
15. What are the potential consequences of climate change on the interdependency of living and non-living things in a specific ecosystem?
16. Given the weight (kg) and height (m) of five adults,

Learner	Weight/Kg	Height/m
A	70	1.75
B	50	1.60
C	90	1.80
D	60	1.65
E	80	1.70

a. Calculate their BMI.

b. Create a frequency table showing how many learners fall into each BMI category.

c. Identify three potential sources of error in measuring BMI.

d. Explain how each error could affect the results.

e. What best practices should be followed to minimise the errors?

17. After sampling, you counted 150 plants in a 10 m^2 area. Calculate the mean density of plants per square metre.

18. An area of grassland is surveyed to estimate the population of snails in the area. The grassland measured 30m by 100m, and quadrats measuring 50cmx50cm were used. 16 quadrats were laid down in the area at random, and the number of snails in each was counted. The number of snails counted is given below. 12, 14, 8, 3, 4, 13, 8, 9, 2, 7, 3, 14, 5, 7, 2, 1. Estimate the population of snails in the grassland.

a. Discuss at least three factors that affect plant distribution in a habitat, providing examples of how each factor influences the types of plants found in that area.

b. Analyse how changes in one of the identified factors (e.g., water availability) could have ecological consequences in the habitat.

19. State an example of an emerging disease and justify why it fits this classification.

20. What environmental, social, or biological factors influence the spread of emerging diseases?

21. Which preventive measures have proven most effective in controlling emerging diseases, and why?

22. What role does communication play in managing the outbreak of a disease?

23. Explain how environmental factors can influence the spread of a selected plant disease.

24. Analyse how an outbreak of a specific animal disease can impact local agriculture and farmers.

25. Investigate the effectiveness of different management strategies for controlling a specific plant disease.

SECTION

4

ANIMAL AND PLANT SYSTEMS



SYSTEMS OF LIFE

INTRODUCTION

In year 2, you learnt about some of the systems of mammals and plants and how their function are crucial to the overall function and well-being of the organism.

In this section, we continue to explore how the various biological systems work together to sustain life in both mammals and flowering plants. In mammals, the respiratory, reproductive, musculoskeletal, and hormonal systems each perform essential functions such as breathing, movement, growth, and reproduction. These systems are interconnected, ensuring the body functions smoothly and maintains healthy living.

We will also study flowering plants, focusing on sexual reproduction, which promotes genetic diversity and species survival. Additionally, we will learn how plants carry out excretion, removing waste through structures like stomata and lenticels.

Understanding these systems reveals how life is maintained through cooperation between organs and processes. Whether in animals or plants, each system plays a vital role, and their coordination is key to survival and well-being.

KEY IDEAS

- Bones and muscles work together to support the body and enable movement, essential for survival and interaction with the environment.
- Hormones regulate vital functions such as growth, metabolism, and reproduction, ensuring coordination between different body systems.
- Plants eliminate waste gases and substances through structures like stomata, lenticels and root exudation, maintaining internal balance.
- Sexual reproduction in flowering plants promotes genetic variation, helping species adapt and survive across generations.
- The respiratory system supplies oxygen for energy production and removes carbon dioxide, a waste product of respiration.
- The respiratory, reproductive, musculoskeletal, and hormonal systems work together to maintain health and support life processes like movement, growth and reproduction.

HOW THE RESPIRATORY SYSTEM IN MAMMALS FUNCTIONS AND WORKS WITH OTHER SYSTEMS TO ENSURE HEALTHY LIVING

The Human Respiratory System

Living organisms require energy to carry out essential life processes, and most obtain this energy by breaking down food. This breakdown occurs through a series of biochemical reactions known as respiration, which requires oxygen to release energy from food molecules.

In animals, the respiratory system is responsible for the exchange of gases, primarily oxygen and carbon dioxide. While all animals share the same basic function of respiration, the structure and operation of their respiratory systems can vary significantly. In humans and many other animals, the respiratory system operates under involuntary control, meaning breathing happens automatically without conscious effort.

The brain's respiratory centres, located in the medulla oblongata and pons, regulate the rate and depth of breathing. These centres receive input from:

a. Chemoreceptors, which monitor oxygen and carbon dioxide levels in the blood
b. Mechanoreceptors, which detect lung stretch and volume

Based on these signals, the brain adjusts breathing to meet the body's needs. Although humans can voluntarily hold their breath for short periods, the nervous system eventually overrides this control to resume breathing, an essential function, as prolonged interruption can lead to death.

Structure of the Human Respiratory System

1. Nasal cavity: air enters through the nose and passes into the pharynx and larynx, leading to the trachea.
2. Lungs: Each lung contains the following.
   a. bronchi (singular: bronchus)
   b. bronchioles
   c. alveoli (singular: alveolus), where gas exchange occurs
3. Pleural Membrane: A double-layered membrane covering each lung, with pleural fluid between the layers to reduce friction during breathing.
4. Thoracic Cavity: The lungs are housed in this cavity, which is bordered by:
   a. the vertebral column at the back (dorsal surface)
   b. the sternum at the front (ventral surface)
   c. the ribs on the sides

d. the diaphragm at the bottom

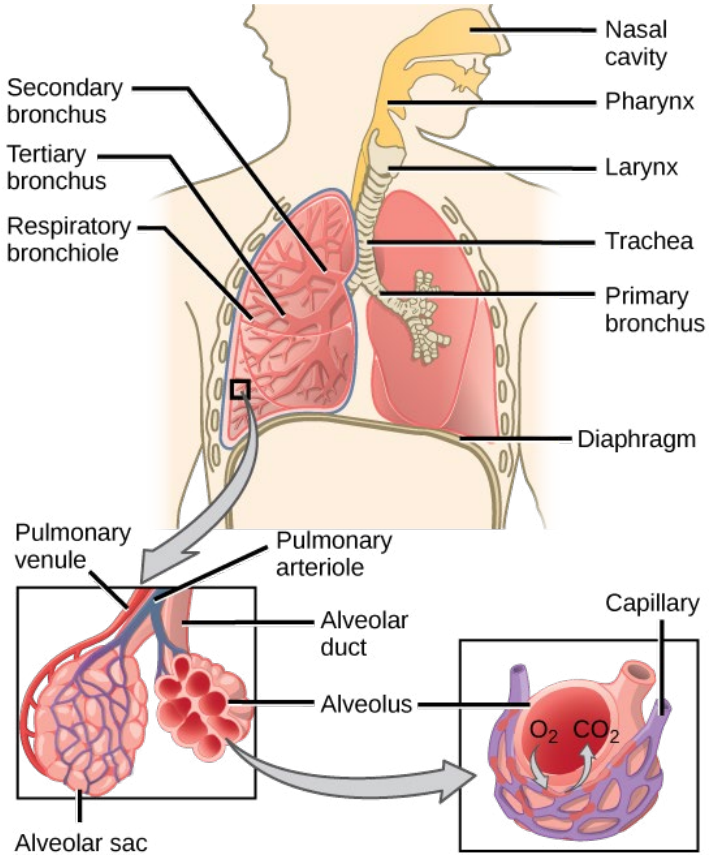


Figure 4.1: Structure of the human respiratory system

Human Respiration and Breathing Mechanism

The coordinated actions of all parts of the respiratory system enable the process of respiration to occur. Respiration begins with the inhalation of air into the alveoli, followed by the diffusion of oxygen (O_2) and carbon dioxide (CO_2) across the alveolar membrane. The blood transports these gases, allowing for further diffusion between blood and body tissues. Finally, oxygen is used to break down food molecules, releasing energy and producing carbon dioxide as a waste product.

Breathing Mechanism

Inspiration (Inhalation)

a. The diaphragm, a dome-shaped muscle beneath the lungs, contracts and moves downward, increasing the volume of the chest cavity.

b. The intercostal muscles (located between the ribs) also contract, pulling the ribs upward and outward.

c. This expansion creates low pressure inside the lungs compared to the atmosphere, causing air to flow in through the nose or mouth.

Pulmonary Gas Exchange

a. Air travels down the trachea (windpipe) into the bronchial tubes, which branch into smaller bronchioles.

b. These bronchioles lead to tiny air sacs called alveoli, surrounded by capillaries.

c. Oxygen from inhaled air diffuses across the thin walls of the alveoli and capillaries into the bloodstream, while carbon dioxide moves from the blood into the alveoli to be exhaled.

Expiration (Exhalation)

a. The diaphragm relaxes and moves upward, and the intercostal muscles relax, reducing the volume of the chest cavity.

b. This causes increased pressure inside the lungs, forcing air out through the airways and out of the body.

Gaseous Exchange

The exchange of oxygen and carbon dioxide is vital for respiration. Oxygen is required by all animals to release energy, while carbon dioxide is a waste product that must be removed.

Air Pathway During Inhalation

The pathway of air during inhalation is summarised as follows.

Nostrils → Nasal Cavity → Pharynx → Larynx → Trachea → Primary Bronchi (Right and Left) → Secondary and Tertiary Bronchi → Respiratory Bronchioles → Alveoli.

a. The pharynx serves as a common passage for food and air.

b. The larynx, also known as the voice box or soundbox, is protected by the epiglottis, which prevents food from entering the airway.

c. The alveoli and alveolar ducts are the primary sites for gas exchange.

Sites of Gas Exchange

1. External Respiration occurs in the alveoli, where oxygen diffuses into the blood and carbon dioxide diffuses out.
2. Internal Respiration occurs in the body tissues, where oxygen diffuses out of the blood and carbon dioxide diffuses in.

As blood rich in carbon dioxide reaches the alveoli, CO_2 diffuses into the alveolar air and is expelled during exhalation. This exchange happens through simple diffusion, driven by pressure gradients. The structure of the lungs is specially adapted to optimise gas diffusion. The respiratory membrane is highly permeable to gases, allowing efficient exchange. Both the respiratory membrane and the capillary walls are extremely thin, which facilitates rapid diffusion. Additionally, the lungs possess a large surface area, ensuring that a maximum amount of gas exchange can occur throughout the organ.

Adaptations for Efficient Gas Exchange

The lungs are specially adapted to maximise gas exchange in the following ways:

1. the respiratory membrane is highly permeable to gases.
2. both the respiratory and capillary membranes are extremely thin.
3. the lungs have a large surface area, allowing for efficient diffusion of gases.

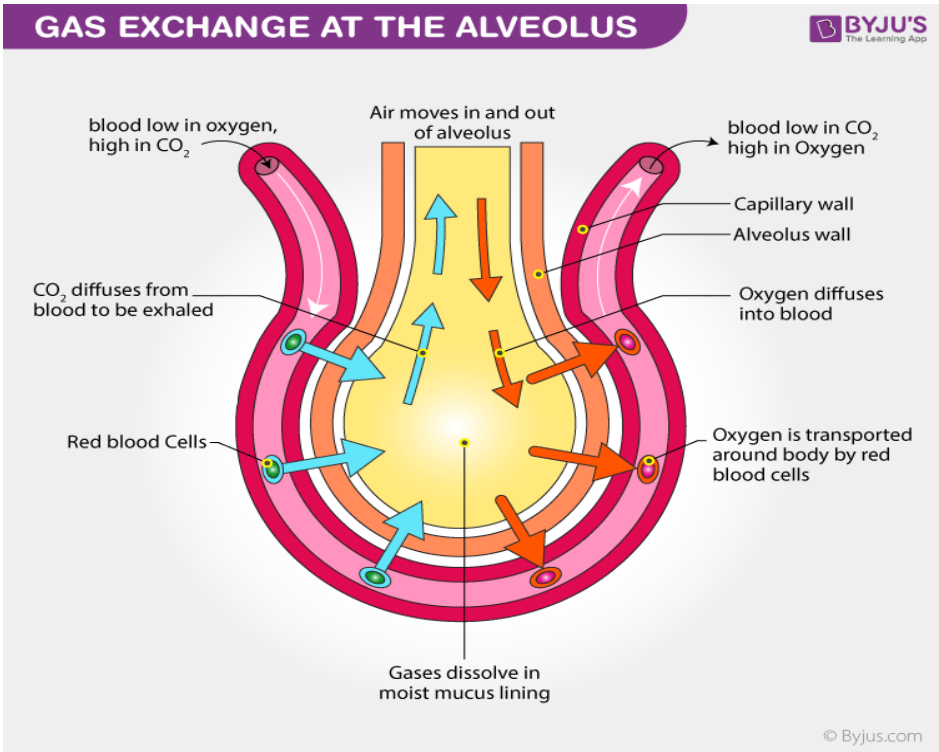


Figure 4.2: Gas exchange in the alveolus

Interesting facts

1. The surface area of the lungs is said to come close to that of a tennis court, which is enormous. Why? Because it is composed of millions of tiny alveoli rather than one big bag.
2. Carry out a simple arithmetic exercise with a cube as follows.
   a. Imagine one cube which is 10x10x10. Its surface area is 600. Divide it into eight cubes.
   b. Each of the eight cubes will have a surface area of 5x5x6 = 150.

      8x150 = 1200. So total surface area has doubled, yet it takes up the same space!!
3. And why do breathing surfaces have to have such a huge surface area? Simply because diffusion is a VERY SLOW process

Internal Respiration

Gas exchange is a continuous process in animals; however, oxygen and carbon dioxide are transported through different mechanisms within body tissues.

Transport of Oxygen in the Blood

While oxygen can dissolve directly in the blood, only about 1.5% is transported this way. The remaining 98.5% is carried by a specialised protein found in red blood cells called haemoglobin.

Haemoglobin (Hb)

Haemoglobin is a protein molecule located in erythrocytes (red blood cells). Each haemoglobin molecule can bind with four oxygen molecules. The amount of oxygen bound to haemoglobin affects the colour of the blood:

a. oxygen-rich haemoglobin (fully saturated with four oxygen molecules) gives arterial blood its bright red colour.

b. deoxygenated haemoglobin, found in venous blood, appears darker red due to fewer oxygen molecules being bound.

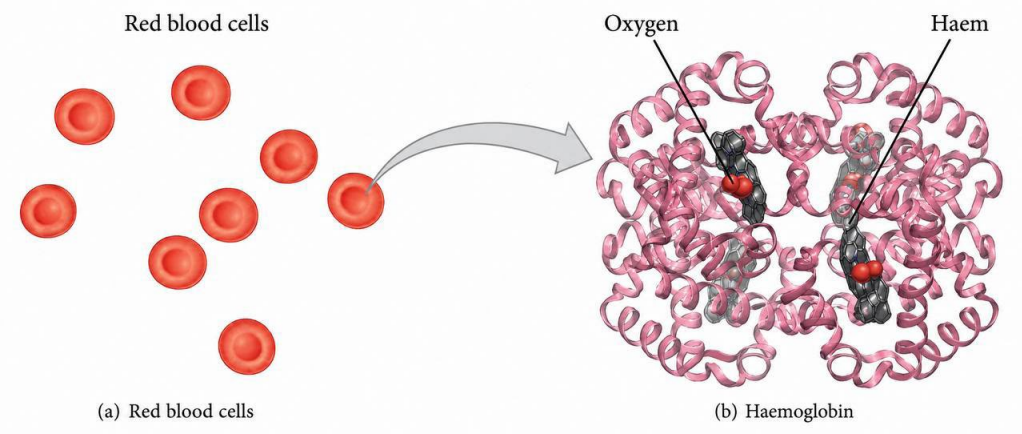


Figure 4.3: (a) Red blood cell (erythrocytes) (b) Haemoglobin, a protein

Haemoglobin and Oxygen Transport

Figure 4.3 illustrates

a. red blood cells, which transport oxygen to body cells and carbon dioxide to the lungs.

b. Haemoglobin, the key protein responsible for this gas exchange.

Binding oxygen to haemoglobin (Hb) becomes gradually easier after the first oxygen molecule attaches. This is due to a change in the haemoglobin's shape (conformation), which increases its affinity (chemical attraction) for oxygen. However, this affinity is not fixed; it can be influenced by environmental conditions.

Factors Affecting Oxygen Binding to Haemoglobin

The oxygen-carrying capacity of haemoglobin determines how much oxygen is transported in the blood. Several factors, including environmental changes and certain diseases, can affect this capacity and the efficiency of oxygen delivery. Other factors that influence the oxygen-carrying capacity of haemoglobin include:

Carbon Dioxide levels and blood pH

a. When carbon dioxide (CO_2) enters the blood, it reacts with water to form bicarbonate ions (HCO_3^-) and hydrogen ions (H^+).

b. As CO_2 levels rise, more H^+ ions are produced, leading to a decrease in blood pH.

c. This low pH reduces haemoglobin's affinity for oxygen, causing oxygen to dissociate from the Hb molecule.

d. As a result, more oxygen is required to achieve the same haemoglobin saturation level compared to conditions with a higher pH.

Note: the pH of the blood dictates breathing rate, not the oxygen content.

Body Temperature

a. An increase in body temperature, such as during intense skeletal muscle activity, also lowers haemoglobin's affinity for oxygen.

b. This means oxygen is released more readily to meet the body's increased demand.

Diseases Affecting Oxygen Transport

1. **Sickle Cell Anaemia**: this is a genetic disorder which results in red blood cells becoming crescent-shaped, elongated and stiff. These abnormal cells struggle to pass through capillaries, thereby reducing oxygen delivery and causing pain when blockages occur.
2. **Thalassemia**: A genetic disorder caused by defects in either the *alpha* (α) or *beta* (β) subunit of haemoglobin. With this condition, patients produce many red blood cells, but these cells contain less haemoglobin than normal. This leads to a reduced oxygen-carrying capacity in the blood.

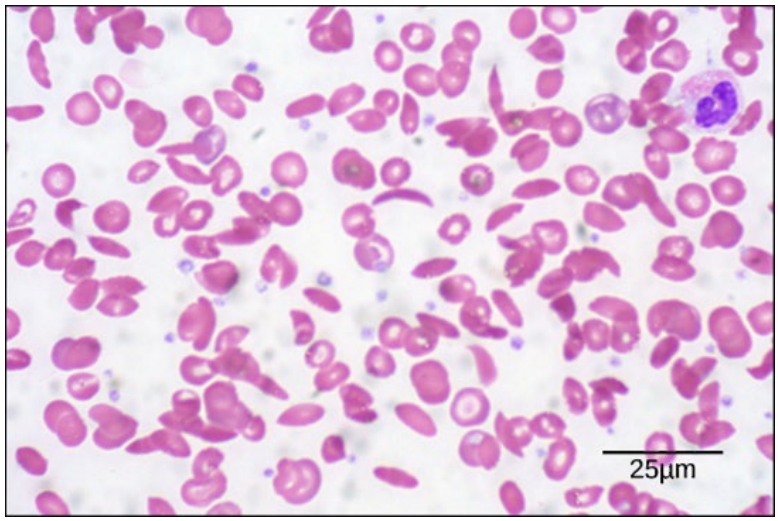


Figure 4.4: Blood sample showing crescent-shaped red blood cells.

Transport of Carbon Dioxide in the Blood

Carbon dioxide is transported from body tissues to the lungs through three main mechanisms:

1. Dissolution in Blood: Carbon dioxide is more soluble in blood than oxygen, allowing 5 - 7% of it to dissolve directly in the plasma.
2. Binding to Haemoglobin and Plasma Proteins: About 10% of carbon dioxide is transported by binding to haemoglobin and plasma proteins. When carbon dioxide binds to haemoglobin, it forms carbaminohaemoglobin. This binding is reversible, so when the blood reaches the lungs, carbon dioxide dissociates from haemoglobin and is expelled from the body.
3. Transport as bicarbonate ions: The majority, around 85% of carbon dioxide is carried in the blood as bicarbonate ions (HCO_3^-). Upon reaching the lungs, these ions are converted back into carbon dioxide, which is then exhaled.

Phases of Respiration in Organisms

Respiration occurs in different parts of the cell depending on the type of organism.

1. In prokaryotic cells, respiration takes place in the cytosol and around the plasma membrane.
2. In eukaryotic cells, respiration occurs in the mitochondria, often referred to as the "powerhouse" of the cell due to its role in energy production.

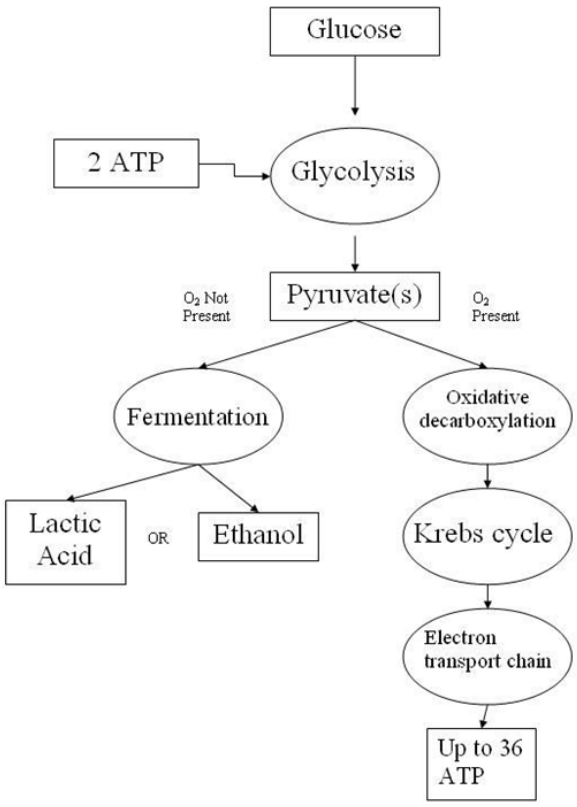


Figure 4.5: Flowchart of respiration

Glycolysis

Glycolysis is the first stage of cellular respiration, where glucose is broken down to release energy. This process begins with the use of two ATP molecules and results in the production of:

a. Two pyruvate molecules
b. 2 ATP
c. NADH
d. Water

Glycolysis takes place in the cytoplasm of the cell and does not require oxygen, making it common to both aerobic and anaerobic respiration.

In aerobic respiration, glycolysis is followed by the Krebs cycle, which further breaks down pyruvate (a 3-carbon compound) to generate more energy. In anaerobic conditions, where oxygen is absent, glycolysis is followed by fermentation, which produces lactic acid and a small amount of ATP in animals. In plants, ethanol and carbon dioxide are produced. Anaerobic respiration leads to cells producing small amounts of ATP.

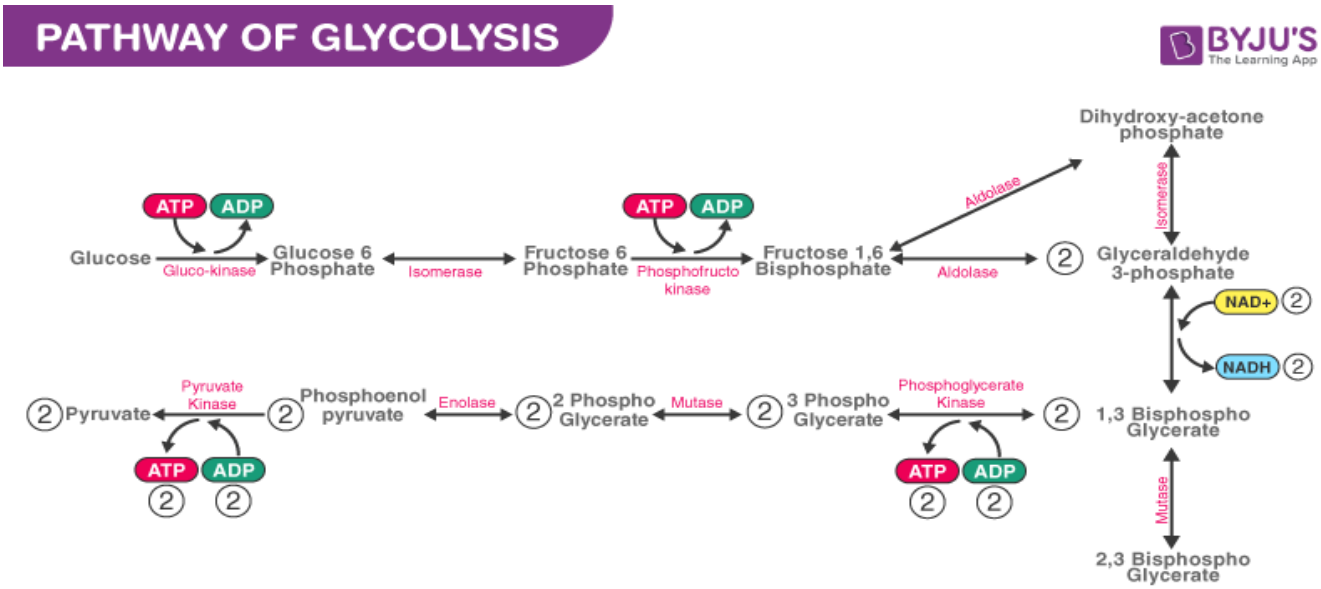


Figure 4.6: Pathway of glycolysis

Stages involved in glycolysis

1. A phosphate group is transferred from ATP to glucose, forming glucose-6-phosphate in the cytoplasm. This reaction is catalysed by the enzyme hexokinase.
2. Glucose-6-phosphate is converted into fructose-6-phosphate. This is a molecular rearrangement catalysed by the enzyme phosphoglucose isomerase.
3. Another ATP molecule donates a phosphate group to fructose-6-phosphate, forming fructose-1,6-bisphosphate. This reaction is catalysed by phosphofructokinase-1.

4. Aldolase, an enzyme, splits fructose-1,6-bisphosphate into glyceraldehyde-3-phosphate and dihydroxyacetone phosphate, which are isomers (molecules that have the same molecular structure but different structural formulas).
5. Triosephosphate isomerase converts dihydroxyacetone phosphate (DHAP) into glyceraldehyde-3-phosphate, the substrate for the next steps.
6. Two reactions occur:
    a. Glyceraldehyde-3-phosphate dehydrogenase transfers hydrogen to NAD^+, forming NADH and H^+.
    b. The same enzyme adds a phosphate to the oxidised glyceraldehyde-3-phosphate, forming 1,3-bisphosphoglycerate.
7. Phosphoglycerokinase, another enzyme, transfers a phosphate from 1,3-bisphosphoglycerate to ADP, forming ATP and 3- phosphoglycerate.
8. Phosphoglyceromutase, yet another enzyme, relocates the phosphate from the third (i.e., 3-phosphoglycerate) to the second carbon, forming 2-phosphoglycerate.
9. Enolase removes a water molecule from 2-phosphoglycerate, forming phosphoenolpyruvate (PEP).
10. Pyruvate kinase transfers a phosphate from PEP to ADP, forming pyruvate and ATP.

At the end of glycolysis, two molecules of pyruvate, 2 ATP and 2 NADH are produced.

Aerobic Respiration

Aerobic respiration is a continuous process that occurs in the presence of oxygen within the cells of animals and plants. The chemical equation for the reaction is:

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + ATP$ (*Glucose + Oxygen → Carbon dioxide + Water + Energy*)

In aerobic conditions, respiration proceeds through:

1. Pyruvate oxidation
2. Krebs cycle (also known as the Citric Acid Cycle or tricarboxylic acid cycle)
3. Electron Transport Chain (Oxidative Phosphorylation)

Pyruvate Oxidation

This step connects glycolysis to the citric acid cycle and occurs in the mitochondrial matrix of eukaryotic cells. The process involves:

a. Transporting pyruvate from the cytoplasm into the mitochondria
b. Decarboxylation of pyruvate (removal of one carbon as CO_2)
c. Formation of acetyl-CoA by attaching the remaining two-carbon unit (formed from the decarboxylation of pyruvate) to coenzyme A.
d. Electron transfer from pyruvate to NAD^+, forming NADH.

The resulting acetyl-CoA enters the Krebs cycle.

Citric Acid Cycle (Krebs Cycle / TCA Cycle)

Also known as the tricarboxylic acid (TCA) cycle, this stage occurs in the mitochondrial matrix and involves a series of reactions that oxidise acetyl-CoA to produce energy. Key steps are mentioned below.

1. Acetyl-CoA combines with oxaloacetate (a 4-carbon compound) to form citrate (a 6-carbon compound).
2. Citrate is converted to isocitrate through water loss and gain.
3. Isocitrate loses a carbon as CO_2, forming α-ketoglutarate (5C compound) and reducing NAD^+ to NADH.
4. α-ketoglutarate is oxidised, releasing CO_2 and forming succinyl-CoA (4C compound). The reaction is catalysed by α-ketoglutarate dehydrogenase.
5. Succinyl-CoA donates a phosphate to ADP, forming ATP and succinate.
6. Succinate is oxidised to fumarate, producing $FADH_2$.
7. Fumarate is hydrated to form malate.
8. Malate is oxidised to regenerate oxaloacetate, producing another NADH.

At the end of each cycle:

a. 6 NADH
b. 2 ATP
c. 4 CO2
d. 2 $FADH_2$ are produced.

Oxidative Phosphorylation / Electron Transport Chain

This final stage occurs in the inner mitochondrial membrane. Electrons from NADH and $FADH_2$ are transferred through a series of electron carriers, releasing energy to pump protons into the intermembrane space, creating a proton gradient. In this reaction,

a. Protons flow back into the mitochondrial matrix through ATP synthase, generating ATP.
b. Oxygen acts as the final electron acceptor, forming water.

This process produces approximately 34–36 ATP molecules and water.

When oxygen is unavailable, cells undergo anaerobic respiration. The pyruvate produced from glycolysis is converted through fermentation, allowing organisms to generate energy without oxygen.

Although less efficient, this process enables survival in low-oxygen environments by producing small amounts of ATP.

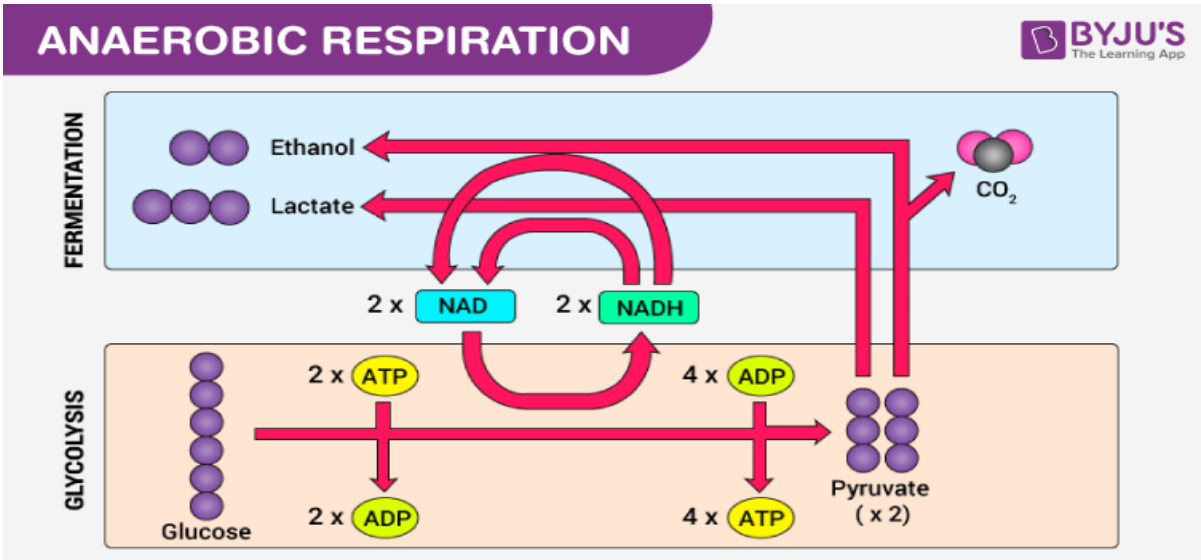


Figure 4.7: Pathway for anaerobic respiration (fermentation) in plants and animals.

Anaerobic Respiration

Anaerobic respiration typically occurs in lower plants and microorganisms. In the absence of oxygen, glucose derived from food is broken down into alcohol and carbon dioxide, along with the release of energy. The chemical equation for this process is:

$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2 + ATP$ (*Glucose* → *Alcohol* + *Carbon dioxide* + *Energy*)

Anaerobic respiration also takes place in multicellular organisms as a temporary response to oxygen-deficient conditions. During intense physical activities such as running, sprinting, cycling or weightlifting, the body's demand for energy increases. When oxygen supply is limited, muscle cells switch to anaerobic respiration to meet energy needs.

This process leads to the production of lactic acid, and its accumulation causes muscle cramps. A hot shower after strenuous exercise helps relieve cramps by improving blood circulation, which enhances oxygen delivery to the muscle cells.

Compared to aerobic respiration, anaerobic respiration produces less energy, as glucose is not completely broken down in the absence of oxygen.

Disorders of the Respiratory System

Asthma

Asthma is a respiratory condition where the air passages become inflamed, narrowed, swollen, and produce excess mucus, making breathing difficult. Symptoms include chest pain, coughing, and wheezing. Triggers include pollen, dust, cold air, and smoking. Treatment involves rescue inhalers, antibiotics and vaccinations. The best prevention is to avoid allergens and other triggers.

Bronchitis

Bronchitis is the inflammation of the bronchial tube lining, which carries air to and from the lungs. Causes include smoking (active or passive), pollution, and bacterial infections. It can be acute or chronic, often accompanied by persistent coughing due to swelling. Treatment includes the use of antibiotics, medication to reduce inflammation and lifestyle changes. Avoiding smoking and pollutants is key to prevention.

Emphysema

Emphysema is a chronic respiratory disease that reduces the surface area for gas exchange due to damage to the alveolar walls in the lungs. It is mainly caused by smoking, but other factors include chemical inhalation, toxins, dust and smoke exposure. Symptoms include shortness of breath and coughing. Treatment involves the use of antibiotics and bronchodilators to manage symptoms.

Lung Cancer

Lung cancer can develop in any part of the lungs and is commonly caused by smoking, exposure to asbestos, rubber, toxic gases and traffic fumes. Symptoms include difficulty breathing, wheezing, chest pain, and trouble swallowing. Treatment options include surgery, chemotherapy, and radiation therapy. Prevention involves avoiding smoking and exposure to pollutants.

Pneumonia

Pneumonia is a serious lung infection that affects individuals with weakened immune systems, such as infants, young children and the elderly. It is caused by bacteria, viruses and fungi. Symptoms include shortness of breath, chest pain, coughing, and nausea. Treatment includes antibiotics and vaccination. Preventive measures include maintaining hygiene, avoiding smoking and alcohol and strengthening immunity through a balanced diet.

Activity 4.1 "Fuelling Life: Exploring How Mammals Respire"

Objectives: To identify and explain the forms and processes of respiration in mammals, demonstrate and interpret aerobic respiration and fermentation through hands-on tasks and group collaboration.

Materials

For the Aerobic Respiration Test

- Stopwatch or timer (1 per group or use a phone)
- Pen and paper (for recording breathing rates)
- Space for light physical activity (e.g., jumping jacks)

For the Fermentation Experiment

- Transparent plastic bottle (small size, e.g. 500ml)
- Balloon
- Warm water (not boiling)
- Active dry yeast (1 tsp)
- Sugar (1 tsp)
- Spoon (for mixing)
- Funnel, for pouring ingredients into the bottle (optional)
- Marker or tape (to label bottle)

For the Concept Mapping Task

- A3 or A4 sheets of paper
- Coloured markers or pens
- Ruler for neat lines (optional)

For the Presentation

- Chart paper or whiteboard (optional) for displaying concept maps
- Tape or pins (to hang concept maps if needed)

Instructions

1. Form Your Team of 4 members, and choose your roles:
   a. Researcher – finds and shares key facts
   b. Recorder – writes down your group's ideas
   c. Presenter – shares your findings with the class
   d. Experiment Lead – guides your group through the experiment
2. Draw a concept map that shows
   a. The two forms of respiration are aerobic and anaerobic (fermentation)
   b. The organs involved in respiration (e.g., lungs, heart, muscles)
   c. The differences between aerobic and anaerobic respiration:
      i. Oxygen use
      ii. Energy produced
      iii. Waste products (e.g., CO_2, lactic acid, ethanol)

Use arrows, diagrams, and keywords to make your map clear and creative.

3. Carry out an aerobic respiration test by doing the following:
   a. Measure your breathing rate at rest (count breaths in 1 minute).
   b. Do 30 seconds of jumping jacks.
   c. Measure your breathing rate again.
   d. Discuss: Why did your breathing change? What does this tell you about oxygen and energy?

4. Carry out a fermentation test by doing the following:
   a. Mix 1 tsp yeast, 1 tsp sugar, and warm water in a bottle.
   b. Stretch a balloon over the bottle opening.
   c. Wait and observe for 10–15 minutes.
   d. Discuss: What gas is filling the balloon? What does this show about fermentation?
5. Share your discoveries.
   a. Present your concept map and experiment results to the class.
   b. Explain
      i. what each type of respiration does.
      ii. why your body uses aerobic respiration most of the time.
      iii. when and why fermentation happens (e.g. during intense exercise or in yeast)

HOW THE REPRODUCTIVE SYSTEM IN MAMMALS FUNCTIONS AND WORKS TOGETHER WITH OTHER SYSTEMS

Reproductive System of Humans

In humans, reproduction is sexual, meaning it involves the fusion of male and female gametes to form a zygote. Mammals are unisexual, with separate male and female individuals, each having a reproductive system designed for producing sex cells and supporting reproduction.

Both male and female reproductive systems.

a. gonads, where gametes (sex cells) are formed.
b. glands, which secrete hormones and fluids essential for development and reproduction.
c. internal genitalia, located inside the abdominal cavity.
d. external genitalia, found in the groin area.

Parts of the Male Reproductive System and Their Functions

The parts of the male reproductive system include the following mentioned below.

1. **Testes**: are two oval-shaped structures located in the scrotum. They are the primary male reproductive organs and produce sperm. The testes also secrete the hormone testosterone, which controls the development of male secondary sexual characteristics like a deeper voice, facial hair and muscle growth. The scrotum hangs outside the body to keep the testes cool for healthy sperm production.

2. **The epididymis** is a coiled tube attached to the testes where sperm mature and are stored before ejaculation.
3. **Vas Deferens**: is a muscular duct that transports mature sperm from the epididymis to the ejaculatory duct.
4. **Seminal Vesicles**: are glands that secrete a nutrient-rich fluid that mixes with sperm to form semen, helping to nourish the sperm.
5. **Prostate Gland**: secretes a milky fluid that enhances sperm motility and protects them in the female reproductive tract.
6. **Bulbourethral Glands**: also called Cowper's glands, they release a lubricating fluid before ejaculation to clean and prepare the urethra.
7. **Penis**: the external organ that delivers sperm into the female reproductive system. Contains the urethra, which carries both urine and semen. Since the urethra transports both urine and semen, the penis is called a urinogenital organ.

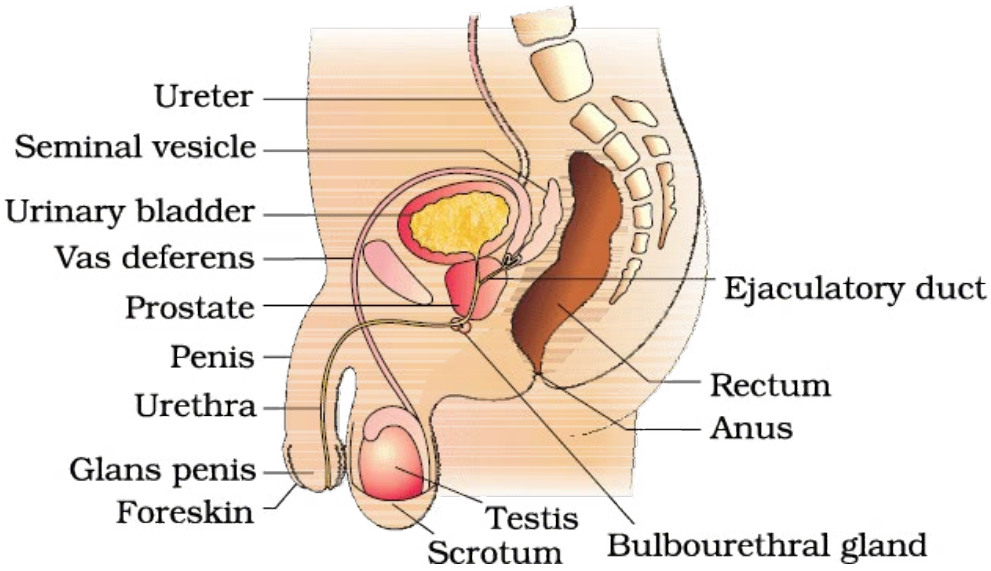


Figure 4.8: The male reproductive system

Parts of the Female Reproductive System and Their Functions

The female reproductive system is made up of internal and external organs that work together to produce eggs, support fertilisation and allow for the development of a baby. The parts include:

1. **Ovaries** are the female gonads. They produce ova (eggs) and secrete the female hormones oestrogen and progesterone, which control the menstrual cycle and support pregnancy.
2. **Fallopian tubes** are two narrow, muscular tubes that connect the ovaries to the uterus. These tubes carry the egg from the ovary to the uterus. Fertilisation of the egg usually occurs here. Tiny hair-like structures called cilia move the egg along the tube.
3. The **uterus** is a strong, hollow, muscular organ where a fertilised egg implants and grows into a foetus. It expands during pregnancy and contracts during childbirth.

4. **Endometrium** is the inner lining of the uterus. In humans, it thickens each month to prepare for possible pregnancy. If no pregnancy occurs, the thickened lining is shed during menstruation.
5. **The cervix** is the lower part of the uterus that opens into the vagina. It allows the passage of sperm into the uterus and menstrual fluid out of the uterus and dilates during childbirth to allow the baby to pass through.
6. **Vagina**: is a muscular canal that connects the cervix to the outside of the body. It serves as the birth canal, exit for menstrual flow and the receptacle during intercourse.

***Note** that, unlike in males, the urinary and reproductive passages in human females are separate and have separate openings. Urine is passed through the urethra, which opens just above the vaginal opening to the outside through the vulva.*

7. **External Genitalia (Vulva):** This is the external part of the female reproductive system. it includes the labia, clitoris and opening of the vagina. It protects the internal organs and plays a role in sexual sensation.

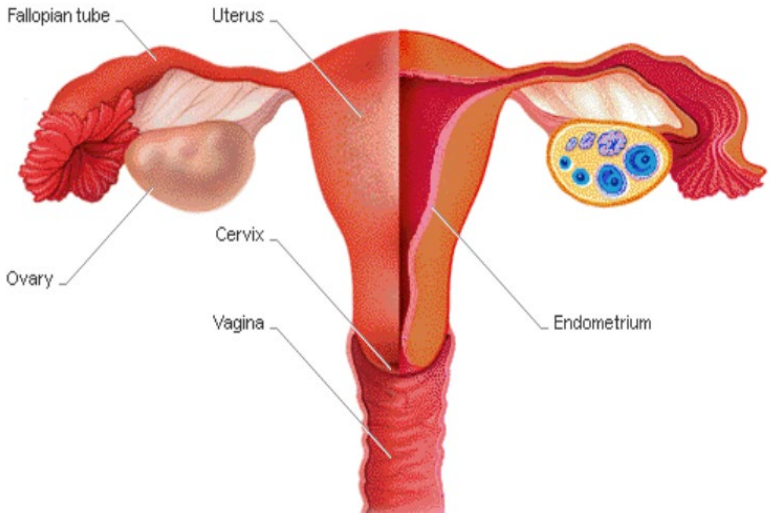


Figure 4.9: The female reproductive system

Human Reproduction: Key Processes

Human reproduction involves four main stages: gametogenesis, fertilisation, gestation, and childbirth.

Gametogenesis

Gametogenesis is the process of forming egg and sperm cells in the ovaries and testes, of females and males, respectively. The process occurs in males as follows:

1. The testes (*singular*: testis) produce sperm and sex hormones.
2. Sperm cells (spermatozoa) are formed through cell division in the seminiferous tubules of adult testes.
3. Hundreds of millions of sperm mature daily in the epididymis and are stored in the vas deferens.

4. Sperm are released during ejaculation; unused sperm are reabsorbed.
5. The luteinising hormone (LH) from the brain stimulates the testes to produce testosterone, which controls secondary sexual characteristics.

In females, the process of gametogenesis is called oogenesis, and it takes place in the ovaries. In the foetus, cells in the ovaries begin dividing to form primary oocytes.

1. The ovaries (*singular*: ovary) produce eggs (ova) and sex hormones.
2. At birth, a female has about 2 million immature eggs (oocytes) in her ovaries.
3. At puberty, the brain releases follicle stimulating hormone (FSH) and luteinizing hormone (LH), which trigger the maturation of one egg approximately every 28 days.
4. Each egg matures inside a sac-like structure called the Graafian follicle in the ovary.
5. The follicle also produces oestrogen, which prepares the uterus for possible pregnancy.
6. Ovulation occurs around day 14 of the menstrual cycle. This involves the release of a mature egg from the ovary into the fallopian tube. The female experiences a menstrual cycle, which causes changes in both the ovaries and uterus, regulated by the hormones FSH, LH, oestrogen and progesterone. The typical range of the menstrual cycle is 21 to 35 days, with an average of 28 days.

Phases of the Menstrual Cycle

The menstrual cycle is a series of changes in a woman's body that happen every month and prepare the female body for pregnancy. It is divided into four main phases, each with distinct roles and changes in the level of hormones in the body. The phases are:

1. ***Menstruation (Days 1–7):*** The endometrium (uterine lining) sheds, causing menstrual bleeding. During this phase, oestrogen and progesterone levels are low. The purpose is to clear out the previous cycle's endometrial lining to start afresh.
2. ***Follicular Phase (Days 1–13)***
    a. Follicles in the ovaries (Graafian follicles) begin to mature, especially one dominant follicle. FSH rises, as oestrogen also rises gradually.
    b. The follicular phase prepares an egg for ovulation and rebuilds the uterine lining.
3. ***Ovulation (Around Day 14):*** A mature egg is released from the ovary and travels through the fallopian tube toward the uterus. A rise in LH triggers ovulation. Ovulation makes an egg available for fertilisation.
4. ***Luteal Phase (Days 15–28):*** The ruptured follicle becomes the corpus luteum, which secretes the hormone progesterone. During this phase, the body produces more progesterone than any other hormone, though oestrogen is still present but in smaller amounts. In other words, progesterone dominates; oestrogen remains present. If fertilisation occurs, the egg may implant in the uterine lining. If not, the endometrium breaks down, and the cycle begins again.

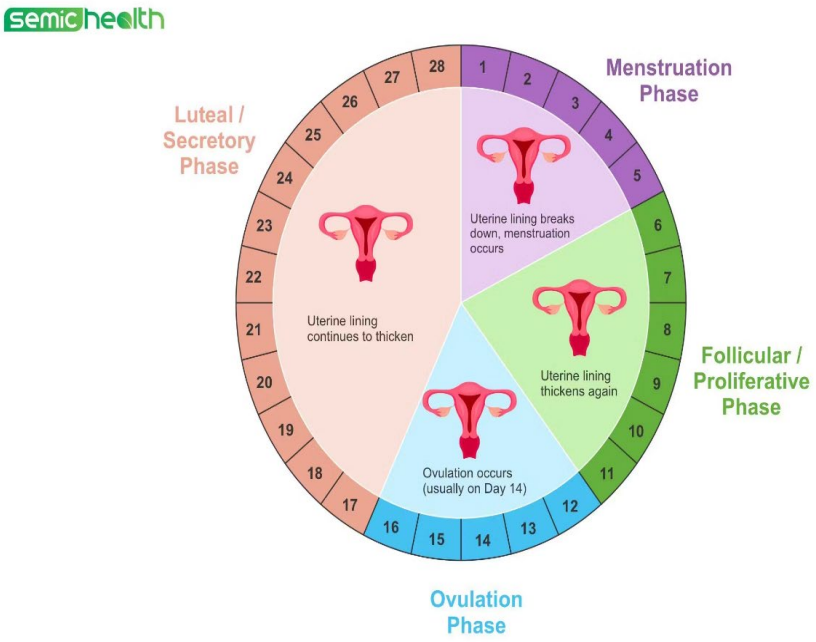


Figure 4.10: The female menstrual cycle in humans

Human reproduction involves several coordinated processes, all regulated by hormones to ensure the successful development of new life.

Hormonal Regulation of the Menstrual Cycle

Several hormones work together to control the phases of the menstrual cycle:

a. Oestrogen: produced by the ovaries, it helps develop the Graafian follicle and thickens the uterine lining.

b. Progesterone: also produced by the ovaries, it prepares the uterus for implantation and maintains the endometrial lining.

c. Luteinising Hormone (LH) and Follicle Stimulating Hormone (FSH): these are released from the pituitary gland in the brain and regulate the ovarian cycle.

This monthly cycle continues until a woman reaches her 50s, when the reproductive cycle naturally ends, a stage known as menopause.

Fertilisation

Fertilisation is the natural process where the male and female gametes fuse to form a zygote.

1. During coitus, semen containing thousands of sperm is released into the female's vagina.
2. The sperm swim through the vagina, the cervix and the uterus to reach the fallopian tubes, where only a few succeed in reaching the egg.
3. Fertilisation occurs in the fallopian tube when a sperm fuses with an egg (ovum).
4. A sperm can survive for only a few hours in the vagina because the environment is acidic, which is not ideal for it. However, sperm can survive up to 48–72 hours (2-3 days) in the female reproductive tract, while an egg lives for about 24 hours.

All genetic information from both parents is passed to the child at fertilisation. The father determines the sex of the child:

a. If the sperm carries a Y chromosome, the child will be a boy.

b. If the sperm carries an X chromosome, the child will be a girl.

Once fertilisation occurs:

i. The zygote begins to divide within 24 hours.

ii. After 3–4 days, it travels to the uterus and becomes an embryo.

iii. The embryo attaches to the endometrial lining in a process called implantation.

iv. It then develops over 9 months through a process called gestation.

Gestation

Gestation is the period from conception to birth, lasting about nine months in humans. It is divided into three trimesters.

1. For the first eight weeks, the developing baby is called an embryo.
2. After eight weeks, it is referred to as a foetus.
3. During gestation, embryonic cells grow and divide, forming specialised tissues and body organs.
4. For example, the heart, blood vessels and blood begin developing within the first month.

Conditions Necessary for Embryo Development

1. **Placenta**
   a. A special organ that forms between the embryo and the uterine wall.
   b. It allows selective exchange of materials:
      i. Oxygen, nutrients, water, salts, antibodies and hormones pass from the mother to the foetus to nourish and protect the foetus.
      ii. Waste products like carbon dioxide and urea are removed from the foetus to the mother.
   c. It also produces hormones that help the mother adapt to pregnancy.
2. **Amniotic Fluid**
   a. It surrounds the foetus and protects it from shock and movement.
   b. It maintains a stable internal temperature.
   c. The fluid is enclosed by the chorion, amnion and allantois membranes.
3. **Umbilical Cord**
   a. It connects the foetus to the placenta.
   b. It contains;
      i. two umbilical arteries that carry deoxygenated blood from the foetus to the placenta.

ii. one umbilical vein that carries oxygenated blood and nutrients from the placenta to the foetus.

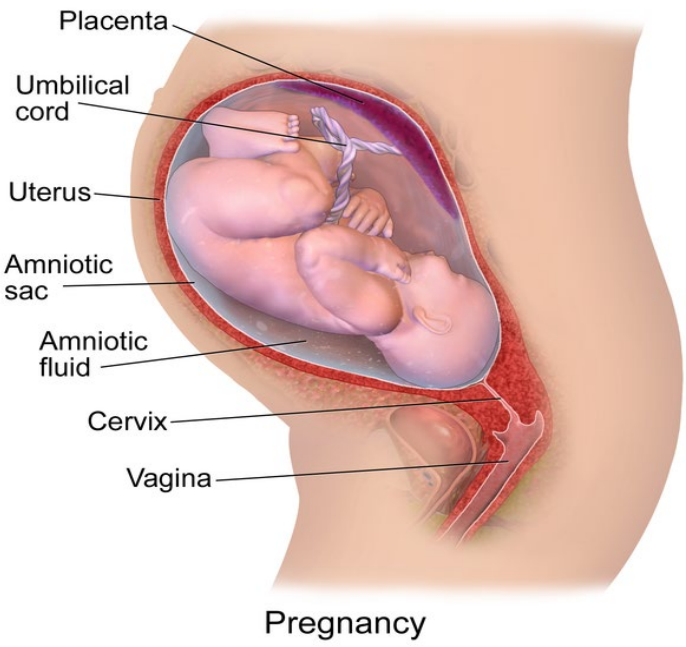


Figure 4.11: A developing foetus in the uterus (womb)

Childbirth

1. Childbirth, also called parturition, is the process by which a fully developed baby is delivered from the mother's uterus into the outside world. Childbirth usually occurs at the end of nine months (about 40 weeks) of gestation, by which time the foetus is fully formed and ready to be born. During childbirth, the foetus naturally turns so that its head is positioned downward, just above the cervix (lower part of the uterus). The muscle of the uterus starts to contract (tighten) and relax. These contractions help to push the baby downward toward the birth canal. The cervix opens (dilates) to allow the baby to pass through. The baby then moves through the vagina, also called the birth canal and is born. After the baby is born, the placenta is also expelled from the uterus. This is called the afterbirth. The key hormones involved in childbirth are:
   a. Oxytocin: triggers uterine contractions and helps with milk release after birth.
   b. Prostaglandins: help soften the cervix and support contractions.

Diseases and Problems of the Human Reproductive System

The reproductive system can be affected by various health conditions. These may involve infections, abnormal growths, hormonal imbalances or structural problems.

Sexually Transmitted Infections (STIs)

Sexually transmitted infections (STIs) are infections caused by bacteria, viruses, or parasites that are passed from one person to another primarily through sexual contact. STIs are a

major public health concern in Ghana and globally, affecting people of all ages. Many STIs can be treated or managed effectively when detected early, making awareness and education essential. Examples include;

1. **Gonorrhoea** is a bacterial STI caused by the bacterium *Neisseria gonorrhoeae*. It is one of the most common STIs worldwide and can infect the genitals, rectum, and throat.

   Transmission: It is spread through unprotected vaginal, anal, or oral sexual contact with an infected person. It can also be passed from a mother to her baby during childbirth, potentially causing eye infections in the newborn.

   Signs and Symptoms

   a. In males: a burning sensation during urination, and a thick yellow or green discharge from the penis
   b. In females: increased vaginal discharge, burning during urination, and bleeding between periods. Many females have no symptoms at all, making the infection easy to miss
   c. In both sexes: rectal pain, discharge, or bleeding if the rectum is infected; sore throat if the throat is infected

   Complications if Untreated

   a. In females: pelvic inflammatory disease (PID), which can cause infertility
   b. In males: inflammation of the epididymis, which can also lead to infertility
   c. Increased risk of HIV infection
   d. In newborns: blindness from eye infection

   Treatment: Gonorrhoea is treated with antibiotics. However, antibiotic-resistant strains are increasingly common, making prevention particularly important.

2. **Syphilis**

   Syphilis is a bacterial STI caused by the bacterium *Treponema pallidum*. It progresses through distinct stages if left untreated and can cause serious long-term complications.

   Transmission: Syphilis is spread through direct contact with a syphilis sore (chancre) during vaginal, anal, or oral sex. It can also be transmitted from mother to unborn child during pregnancy, causing congenital syphilis.

   Signs and Symptoms (Stages of Infection)

   Primary stage: A single painless sore (chancre) appears at the site of infection — on the genitals, anus, lips, or mouth. The sore heals on its own within 3–6 weeks, but the infection remains.

   Secondary stage: A skin rash appears, often on the palms of the hands and soles of the feet. Other symptoms include fever, swollen lymph nodes, sore throat, and fatigue. These symptoms also resolve without treatment, but the disease progresses.

Latent stage: No visible symptoms, but the bacteria remain in the body. This stage can last for years.

Tertiary stage: The most serious stage, affecting the heart, brain, and other organs. Can cause paralysis, blindness, dementia, and death.

Complications if Untreated

a. Serious damage to the heart, brain, and nervous system
b. Congenital syphilis in newborns, causing stillbirth, deformity, or death
c. Significantly increased risk of HIV infection

Treatment: Syphilis is effectively treated with penicillin antibiotics, particularly in the early stages. Later stages require more intensive treatment.

3. **HIV (Human Immunodeficiency Virus)**: a virus that attacks the immune system, progressively destroying the body's ability to fight infection. Without treatment, it leads to AIDS (Acquired Immunodeficiency Syndrome). HIV is transmitted through unprotected sex, sharing needles, blood transfusion with infected blood, and mother-to-child during pregnancy, birth, or breastfeeding. There is no cure, but antiretroviral therapy (ART) allows people with HIV to live long, healthy lives.
4. **HPV (Human Papillomavirus)**: the most common STI globally. Most infections clear on their own, but certain strains can cause genital warts or lead to cervical cancer in females. A vaccine is available and recommended for adolescents before sexual activity begins.
5. **Herpes (HSV)**: caused by the herpes simplex virus. Produces painful blisters or sores around the genitals or mouth. There is no cure, but antiviral medications reduce symptoms and transmission risk.
6. **Chlamydia**: a bacterial infection caused by *Chlamydia trachomatis*. Often has no symptoms, particularly in females, but can cause infertility if untreated. Easily treated with antibiotics when detected.
7. **Pelvic Inflammatory Disease (PID)**: not itself an STI but a complication that develops when STIs such as gonorrhoea or chlamydia spread to the female reproductive organs, including the uterus, fallopian tubes, and ovaries. PID can cause chronic pelvic pain, ectopic pregnancy, and infertility.

Prevention of STIs

The most effective ways to prevent STIs include:

1. Abstinence is the only 100% effective prevention
2. Consistent and correct use of condoms: male and female condoms provide a physical barrier that significantly reduces the risk of transmission of most STIs, including HIV, gonorrhoea, chlamydia, and syphilis. It is important to note that condoms reduce but do not eliminate the risk of STIs spread through skin contact, such as herpes and HPV
3. Vaccination: The HPV vaccine protects against the strains most likely to cause cervical cancer and genital warts

4. Regular STI testing is particularly important for sexually active individuals, as many STIs have no visible symptoms
5. Limiting sexual partners reduces exposure risk
6. Antiretroviral Pre-Exposure Prophylaxis (PrEP) a daily medication that significantly reduces the risk of HIV infection in high-risk individuals

Cancers

These are abnormal and uncontrolled growths of cells. Examples are:

1. Testicular Cancer
2. Cervical Cancer
3. Prostate Cancer

Reproductive Disorders

These are conditions that affect the normal function of the reproductive system. They include the following.

1. Erectile Dysfunction (ED) – difficulty in maintaining an erection
2. Polycystic Ovary Syndrome (PCOS) – hormonal imbalance in females
3. Menstrual Disorders
    a. Amenorrhea – absence of menstruation
    b. Dysmenorrhea – painful periods
    c. Menorrhagia – heavy menstrual bleeding

Hormonal Imbalances

These occur when the body produces too much or too little of certain reproductive hormones. It can affect fertility, menstrual cycles and sexual development.

Infertility

This is the inability to conceive a child after regular, unprotected sexual intercourse for a period of 12 months. Infertility applies to both men and women.

Abnormal Growths

These are unusual tissue formations in or around reproductive organs that may or may not be cancerous. They include:

- Benign Prostatic Hyperplasia (BPH) is a non-cancerous enlargement of the prostate.
- Varicocele – enlarged or swollen veins in the scrotum.
- Endometriosis – tissue like the uterine lining grows outside the uterus.
- Uterine Fibroids – are non-cancerous growths in the uterus.

Activity 4.2 Mapping the Human Reproductive System

Objective: To create a visual map showing the parts of the human reproductive system and their functions.

Materials

- A3 or A4 drawing paper
- Coloured markers, pens
- Ruler for neat lines and structure (optional)
- Reference textbooks or printed diagrams
- Tape or pins (optional) to fix on the classroom wall.

Instructions

1. Form a group of 4–5 members and assign yourselves to these specific roles:
    a. Artist: to draw the diagrams
    b. Researcher: to find the correct information
    c. Writer: to add labels and descriptions
    d. Presenter: to explain your map to the class
2. Choose either the male or female reproductive system for your visual map.
3. List all the parts on your sheet of paper (e.g., testes, ovaries, uterus, penis).
4. Write down the function of each part in simple terms.
5. Decide how you will show the parts and their functions visually.
6. Create your visual map, using A3 paper and coloured markers to draw your diagram. Include:
    a. labels for each part
    b. short descriptions of what each part does
    c. arrows or symbols to show how parts work together

Note: Make your map clear, creative, and easy to understand.

7. Present your visual map to the class. You may choose to display it on your classroom wall while explaining:
    a. what each part is and what it does.
    b. how the parts work together in reproduction.
    c. any interesting facts or differences between male and female systems.

Activity 4.3 "Break the Stigma: Talk About Reproductive Health"

Objective: To design a campaign that promotes reproductive health and creates awareness about sexually transmitted infections (STIs).

Materials

- Pens and notebooks (for jotting down ideas)
- Printed discussion questions (optional, for guidance)
- A3 or A4 sheets of paper (for posters or planning)
- Coloured markers and pens
- Glue, scissors and rulers (optional for poster design)
- Magazines or newspapers (for cut-out visuals or inspiration)
- Cardboard, mounting boards or placards (optional for displaying posters)
- A space to present or display a designed campaign
- Tape or pins
- Phone or speaker (optional)

Instruction

1. Engage in a group discussion on the following questions with four of your classmates. ***Note:*** Everyone should share their thoughts. Your teacher will help guide the conversation.
    a. What does reproductive health mean?
    b. Why is reproductive health important for young people?
    c. What are STIs, and how can they be prevented?
    d. What are some common myths or misunderstandings about STIs?
    e. How can we encourage others to make healthy choices?

Hint: Take notes during your discussion. These ideas will help you design your campaign.

2. Use your discussion notes to plan your campaign. Your campaign should include:
    a. A strong slogan or theme (e.g., "Stay Safe, Stay Smart")
    b. Key messages about reproductive health and STI prevention
    c. A plan for how to share your message (e.g. posters, drama, radio ad, social media)

Note: Your goal is to educate and inspire others to make healthy choices.

3. Choose any one or more of the following ways to present your campaign:
    a. Create a poster with drawings, slogans and facts.
    b. Write a speech or radio ad script.
    c. Design a social media post with hashtags and visuals.

Hint: *Be creative! Make your campaign clear, powerful, and informative.*

4. Present your campaign to the class. Be attentive as other groups also present their campaign poster to the class.

HOW THE MUSCULOSKELETAL SYSTEM IN MAMMALS FUNCTIONS AND WORKS TOGETHER WITH OTHER SYSTEMS TO ENSURE HEALTHY LIVING

Structure of The Human Skeleton and The Importance Of The Various Parts

The Human Skeleton

The human skeleton is a complex framework made up of bones, cartilage, ligaments and joints. It has about 206 bones in total.

The skeleton has several important functions.

a. It gives shape and support to the body.

b. It helps the body move when working together with the muscles.

c. It protects vital organs like the brain, lungs and heart, especially the skull and rib cage.

d. Inside the bones, there is red marrow, which makes red blood cells, white blood cells and platelete too. These cells carry oxygen to all parts of the body.

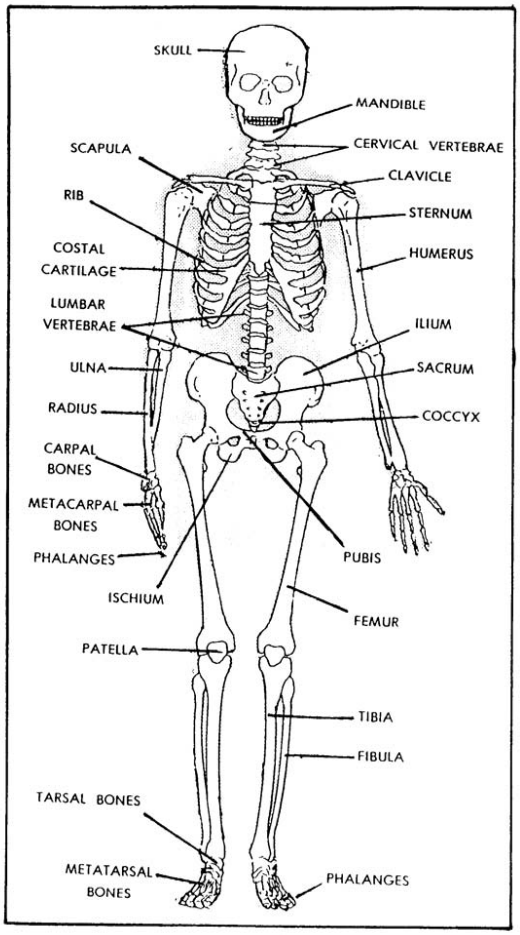


Figure 4.12: The Human Skeleton

Parts of the Human Skeleton

The human skeleton is divided into two main parts. These are:

Axial Skeleton

This part includes the skull, vertebral column (spine) and rib cage.

Functions of the Axial Skeleton

a. protects vital organs like the brain, heart and lungs.

b. supports the body's structure.

c. acts as an anchor for muscles to help with movement

The functions of the skull include:

a. Protects the brain

b. Houses sensory organs (eyes, ears, nose)

The skull is made up of the cranial bones, which surround the brain and the facial bones, which form the face.

The vertebral column, also called the spine, is a flexible, bony structure that runs down the back. It is made up of 33 vertebrae. It supports the body, allows flexibility, protects the spinal cord and connects different parts of the skeleton. The classification of the bones of the vertebral column is summarised in ***Table 4.1*** below.

Table 4.1: Sections of the Vertebral Column

Section	Number of Vertebrae	Key Functions
Cervical (C1–C7)	7	Supports the head; allows neck movement
Thoracic (T1–T12)	12	Supports the rib cage; protects the lungs and heart
Lumbar (L1–L5)	5	Bear's body weight
Sacral (S1–S5)	5 (fused into one)	Connects the spine to the hip bones; forms the pelvic girdle
Coccygeal	4 (fused into one)	Forms the tailbone

Details to Remember

- C1 (Atlas): Connects with the skull; allows nodding ("yes" movement.)
- C2 (Axis): Works with C1 to allow side-to-side ("no" movement).
- Thoracic vertebrae: Connect to 12 pairs of ribs at the back.
- Lumbar vertebrae: Are larger to support more weight.
- Sacral vertebrae: Fused to form the sacrum, part of the pelvic girdle.
- Coccygeal vertebrae: Fused to form the coccyx or tailbone.

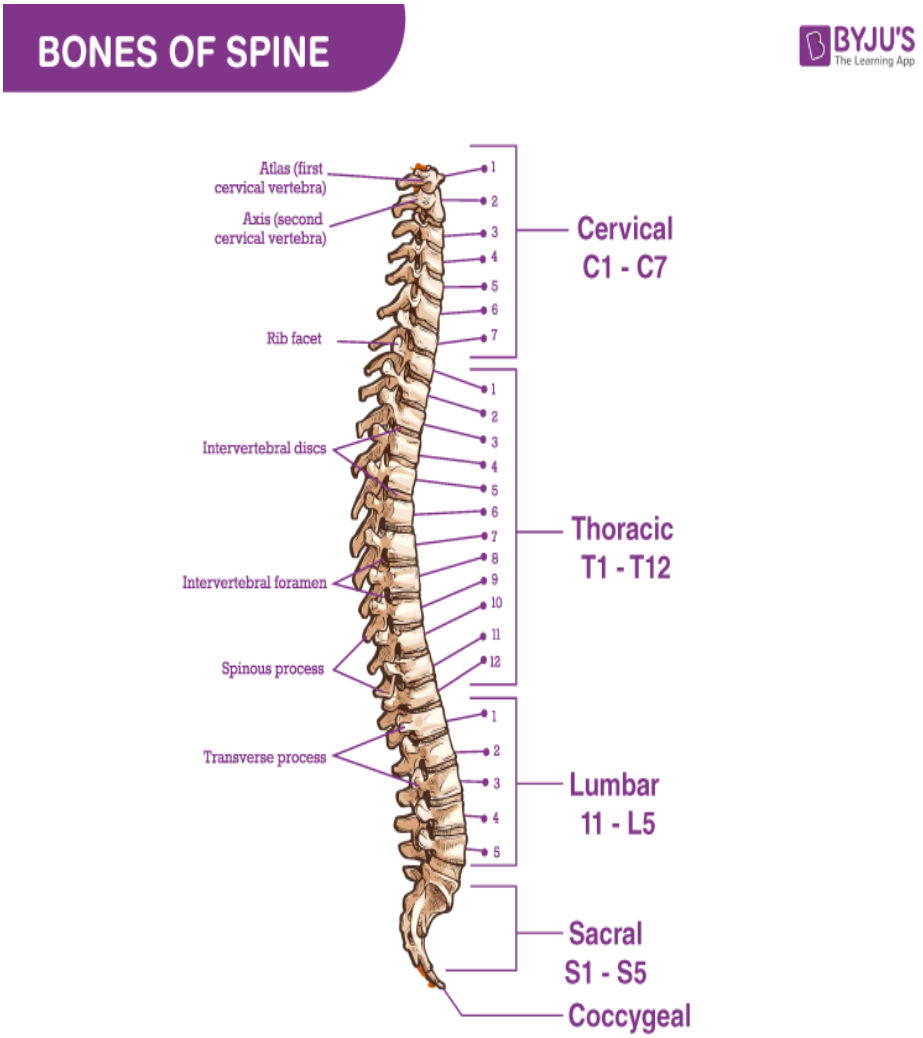


Figure 4.13: The Vertebral Column (spine)

Vertebrae and Spinal Canal

The central portion of each vertebra is hollow, forming the spinal canal. This canal encloses and protects the spinal cord, a vital part of the nervous system. Attached to the front of the vertebral column is the ribcage.

Rib Cage: This is a bony structure in the chest made up of:

1. 12 pairs of ribs (The first 7 pairs are directly attached to the sternum by the costal cartilage; the 8th to 10th pairs are indirectly attached to the sternum. Their cartilage connects to the seventh rib's cartilage. The 11th and 12th pairs are known as floating ribs, meaning they are not attached to the sternum.
2. The sternum (breastbone)
3. The thoracic vertebrae (backbone)

Adaptive Features of the Rib Cage

a. Curved and form a cage-like structure that protects vital organs like the heart and lungs from injury.

b. The costal cartilage provides flexibility and allows the rib cage to expand during breathing.

c. It supports efficient airflow by enabling chest expansion and contraction.

Sternum (Breastbone): This is a flat bone located in the centre of the chest. It forms the front part of the rib cage and connects the clavicles (collarbones) and the first seven pairs of ribs.

1. Manubrium (upper section): It connects to the clavicles and the first pair of ribs.
2. Body (middle section): the main part where most ribs attach.
3. Xiphoid process (lower section): a small cartilaginous tip that may ossify (turn to bone) with age.

Adaptive Features of the Sternum

The sternum

a. Serves as a central point for rib attachment, strengthening the rib cage.

b. It is broad and flat, which helps protect the heart, lungs, and major blood vessels like the aorta and pulmonary arteries.

Works with the ribs to form a flexible thoracic cage that expands and contracts, aiding breathing.

Thoracic vertebrae

1. They form part of the vertebral column and are in the upper and middle back.
2. There are 12 thoracic vertebrae, which are labelled T1 to T12.
3. They are found below the cervical vertebrae and above the lumbar vertebrae.
4. Each thoracic vertebra connects to a pair of ribs at the back.
5. They form the back portion of the rib cage.

Adaptive Features of the Thoracic Vertebrae

Thoracic vertebrae have a long neural spine, which provides a surface for the attachment of large thoracic muscles. This helps;

a. Support the rib cage.

b. Protect the heart and lungs.

c. Allow limited movement to maintain stability.

d. Help form the thoracic cavity, which houses vital organs.

Appendicular Skeleton

This is the part of the human skeleton that includes the upper limbs, lower limbs, pectoral (shoulder) girdle, and pelvic girdle. It is specialised for movement, support and balance.

Functions of the Appendicular Skeleton

The appendicular skeleton is the part of the human skeleton that includes the limbs (upper and lower) and the girdles (pectoral and pelvic) that attach them to the body. It is specialised for movement, support, and balance. The appendicular skeleton;

a. enables walking, running, lifting, and grasping.
b. provides support for body movement and weight-bearing.
c. allows for a wide range of motion in the arms and legs.
d. helps maintain balance and posture.

The main parts of the appendicular skeleton are summarised in ***Table 4.2*** below.

Table 4.2: Parts of the Appendicular Skeleton

Section	Components and functions
Upper Limbs	Humerus, radius, ulna, carpals (wrist), metacarpals (hand), phalanges (fingers). They are essential for grasping, holding, and lifting movements.
Lower Limbs	Femur, tibia, fibula, tarsals (ankle), metatarsals (foot), phalanges (toes). The lower limbs are essential for support, walking, running, and balance.
Pectoral (shoulder girdle)	Clavicle (collarbone), scapula (shoulder blade). It connects arms (forelimbs) to the axial skeleton.
Pelvic Girdle (hip girdle)	Hip bones (ilium, ischium, pubis) connect the legs to the axial skeleton and support body weight. It connects the lower limbs to the axial skeleton and supports the weight of the upper body when sitting or standing. Together, these bones form a bowl structure that protects the organs of the lower abdomen.

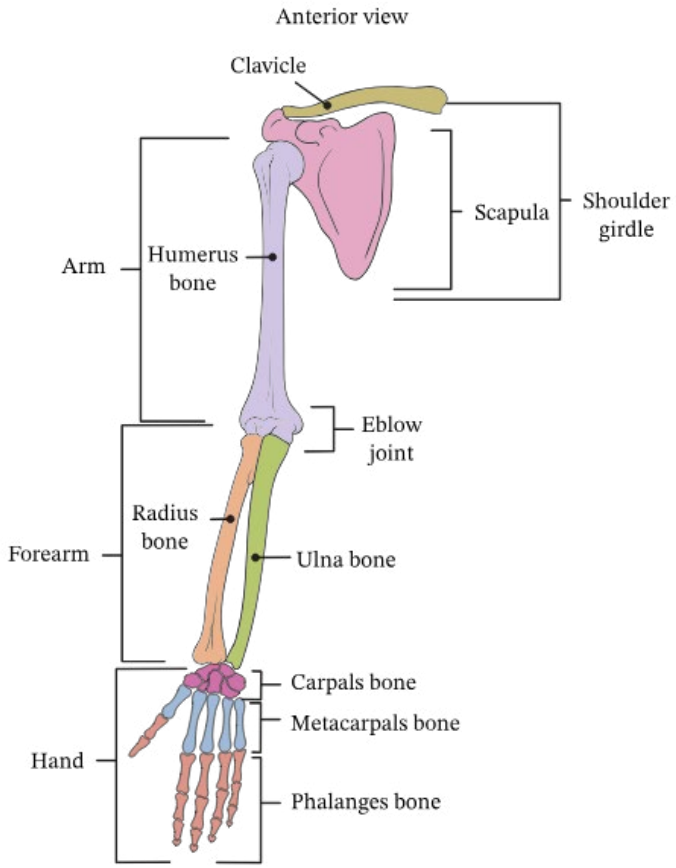


Figure 4.14: Pectoral girdle and upper limb

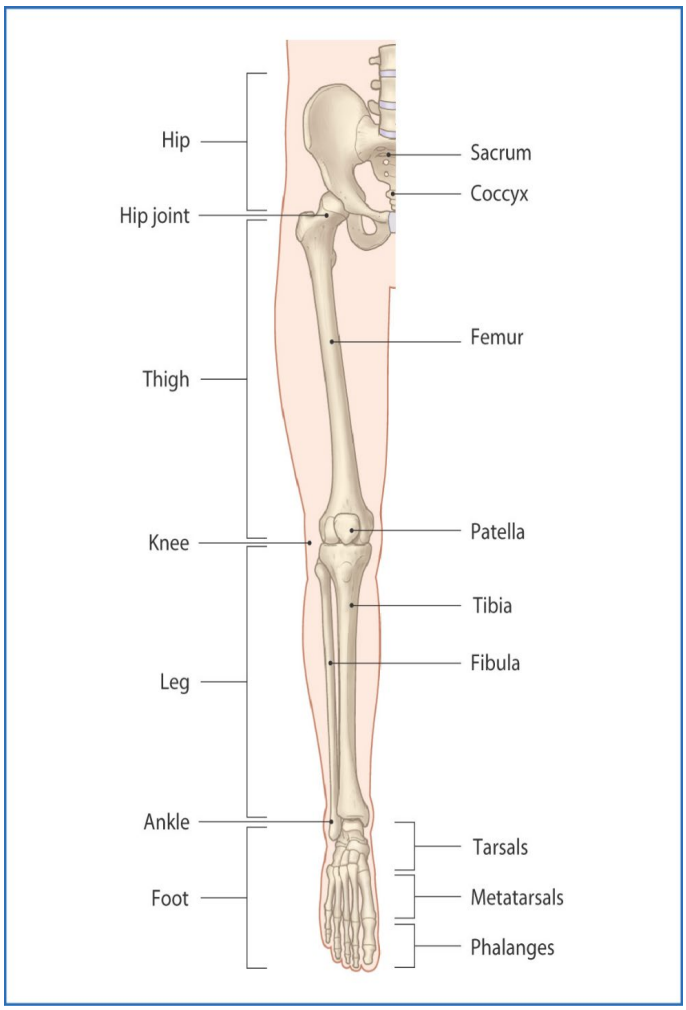


Figure 4.15: Pelvic girdle and the bones of the lower limbs

Adaptive Features of the Appendicular Skeleton

a. Clavicle (Collarbone): connects the arm to the body and helps stabilise the shoulder.

b. Scapula (Shoulder Blade): provides a broad surface for muscle attachment and allows for a wide range of motion.

c. Humerus, Radius and Ulna: these arm bones are designed for lifting, reaching and throwing.

d. Hand Structure: fine motor control and opposable thumb and fingers allow for grasping, holding and manipulating objects.

e. Pelvic Girdle: offers a stable base for the lower limbs, supports body weight during standing, and aids in bipedal movement.

f. Femur (Thigh Bone): The longest bone in the body is adapted for weight-bearing and mobility.

g. Knee Joint: allows bending and straightening while providing stability.

Joints in the Human Body

A joint is where two or more bones connect. Joints are essential for motion and structural support. The types of joints in the human body and their functions are summarised in ***Table 4.3*** below.

Table 4.3: Types of Joints and Their Functions

Joint	Example	Movement Allowed
Sutures	Skull	No movement: bones are tightly joined
Symphyses	Intervertebral discs, pubic symphysis	Slight movement: bones are joined by cartilage
Ball-and-Socket	Shoulder, hip	Rotational movement; wide range of motion in many planes
Hinge	Knee, elbow	Movement in one plane; strong and stable
Pivot	Atlantoaxial joint (neck)	Rotation around a single axis
Condyloid	Wrist	Movement in two planes
Saddle	Thumb	Wide range of movement
Gliding	Between carpal bones	Sliding movements

Muscles and Movement

There are over 600 muscles in the human body. Muscles are made of tiny fibres that contract (shorten) and relax (lengthen) to move body parts.

How Muscles Work with Bones

1. Muscles are attached to bones by tendons.
2. When a muscle contracts, it pulls on the bone, causing movement.
3. When it relaxes, the bone returns to its original position.
4. The brain and spinal cord send signals through motor neurons to control these actions.
5. Sensory receptors in muscles and joints give feedback about body position and help adjust movements.

Types of Muscle Tissue

The types, location and function of the muscles in the body are summarised in ***Table 4.4*** below.

Table 4.4: Types of Muscles in the Human Body

Muscle Type	Location & Function	Voluntary?
Skeletal Muscle	Attached to bones, supports body weight and movement; worked by tendons	Yes
Cardiac Muscle	Found only in the heart, it pumps blood through the body	No
Smooth Muscle	Found in organs like the intestines, arteries, iris, lungs, and reproductive system; helps with internal movements	No

Muscles are essential for moving body parts. They work together with bones, joints and nerves to make movement possible. Muscles cause movement in several ways listed below.

a. Muscle contraction: When a muscle contracts (shortens), it pulls on the bone it's attached to through tendons, causing movement.
b. Muscle relaxation: When the muscle relaxes (lengthens), the bone returns to its original position.
c. Nerve Signals: The brain and spinal cord send signals through motor neurons to control when muscles contract or relax.
d. Sensory feedback: Muscles and joints have receptors that send information back to the brain about body position and movement, helping with balance and coordination.

The muscle pairs in action during movement are:

a. Agonist (Prime Mover): This is the main muscle responsible for a movement (e.g. biceps during arm flexion).
b. Antagonist: this is the muscle that opposes the agonist (e.g. triceps during arm flexion).
c. Synergists: muscles that assist the agonist, helping to stabilise joints and improve movement efficiency.

The action of these muscle pairs is summarised below.

Table 4.5: Agonist and Antagonist Muscles

AGONIST = prime mover (working muscle). **ANTAGONIST** = relaxing muscle

	Agonist muscle	Antagonist muscle
Flexion at the elbow	Biceps	Triceps
Extension at the elbow	Triceps	Biceps
Flexion at the knee	Hamstrings	Quadriceps
Extension at the knee	Quadriceps	Hamstrings

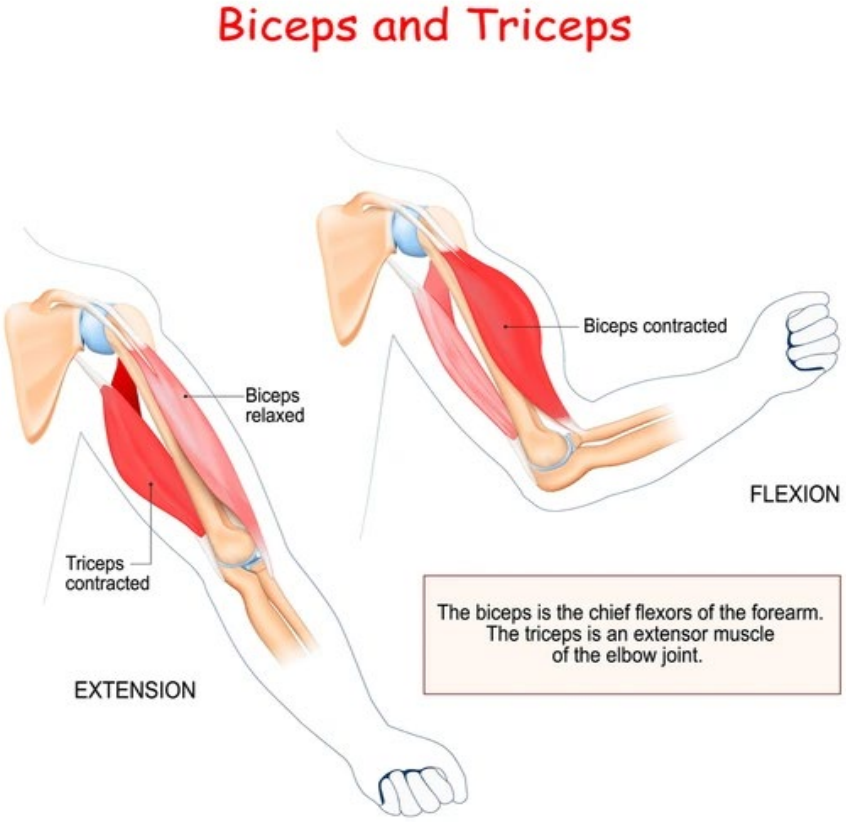


Figure 4.16: Movement of the forelimb

Activity 4.4 Build, Move and Describe the Human Skeleton

Objective: To identify and illustrate key skeletal structures and their functions and demonstrate how muscles interact with bones to move through creative drawing and physical demonstration.

Materials

- A3 drawing paper or cardboard
- Coloured pencils or markers
- Labels/stickers
- String or elastic bands (for muscle simulation)
- Simple props (e.g., rolled paper tubes for bones)
- Diagrams or reference charts (optional)

Instructions

Part 1: Creative Drawing & Annotation

1. Individually or in pairs, draw the following skeletal structures:

a. The skull
b. The vertebral column
c. The upper and lower limbs with their girdles (pectoral and pelvic)
d. The rib cage with the sternum

2. Label each part clearly and write short annotations beside them describing their specific functions (e.g., "Skull protects the brain"; "Femur supports body weight").
3. Use colour coding to highlight different regions (e.g., axial vs appendicular skeleton).
4. Show your drawing to your teacher for comments.

Part 2: Muscle Movement Demonstration

1. In small groups, act out how muscles move bones using your own arms.
2. Choose one learner to be the "biceps" and another to be the "triceps."
3. Demonstrate antagonistic movement:
   a. When the biceps contract, the arm bends (flexion)
   b. When the triceps contract, the arm straightens (extension)
4. Use string or elastic bands to simulate muscle tension and show how tendons pull on bones.
5. Explain the movement to the class using correct terms like agonist and antagonist.

HOW THE NERVOUS AND HORMONAL SYSTEMS IN MAMMALS FUNCTION AND WORK TOGETHER WITH OTHER SYSTEMS TO ENSURE HEALTHY LIVING

Structure of the Nervous and Hormonal Systems In Mammals and How The Parts Relate To Their Functions

Control Systems in Humans: Nervous and Endocrine Systems

Like all complex multicellular organisms, mammals need advanced control systems to manage body functions and respond to changes in their environment. These systems help maintain homeostasis and support survival. The two main control systems are:

a. Nervous System: uses electrical impulses for fast, precise responses.
b. Endocrine System: uses hormones (chemical messengers) for slower, long-lasting effects

Together, these two systems allow mammals to stay stable inside while adapting to the outside world.

The Nervous System

This system controls and coordinates body functions such as:

1. Movement
2. Sensation
3. Perception
4. Cognition
5. Behaviour

It is divided into:

a. Central Nervous System (CNS)

b. Peripheral Nervous System (PNS).

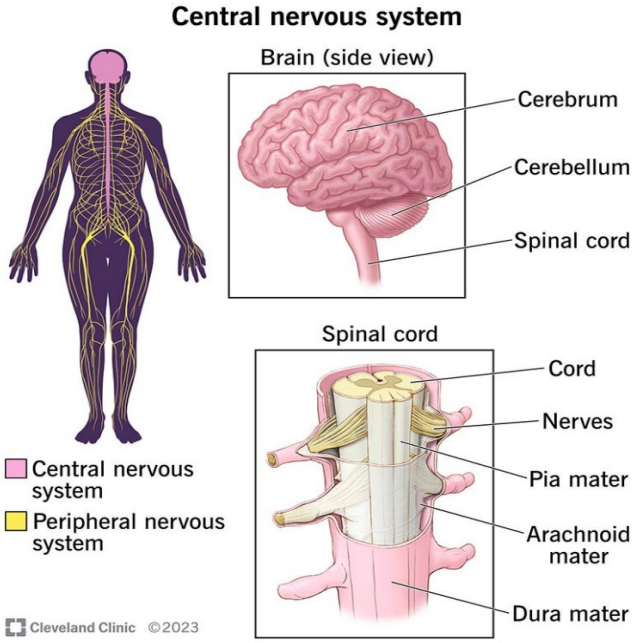


Figure 4.17: The Nervous System

Central Nervous System (CNS)

The Central Nervous System (CNS) is the main control centre of the body. It is responsible for processing information, coordinating responses and regulating both voluntary and involuntary actions. The main components of the CNS are:

a. Brain: responsible for the control of thoughts, emotions, memory, movement and vital functions.

b. Spinal cord: responsible for transmitting signals between the brain and body and controls reflexes. The parts of the brain and their functions are summarised in ***Table 4.5*** below.

Table 4.5: Parts of the Brain and Their Functions

Brain Part	Function
Cerebrum	Handles conscious thought, learning, and sensory interpretation.
Cerebellum	Coordinates movement, posture and balance
Medulla Oblongata	Controls vital functions like breathing and heartbeat
Cerebral Cortex	Outer layer of the cerebrum; divided into sensory, motor, and association areas
Hypothalamus	Regulates homeostasis and links the nervous system to the endocrine system

Peripheral Nervous System (PNS)

The PNS connects the CNS to the muscles, organs and sensory receptors of the body. This allows communication between the brain/spinal cord and the rest of the body. It has two subdivisions: the somatic nervous system (SNS) and the autonomic nervous system (ANS).

Somatic Nervous System (SNS)

The SNS controls voluntary movements and sensory input from the external environment. It also has voluntary control over skeletal muscles.

Autonomic Nervous System (ANS)

Controls involuntary functions like heartbeat, digestion, and breathing and regulates internal organs like the heart, lungs, stomach, smooth muscles and glands. The ANS is subdivided into the sympathetic and parasympathetic nervous systems.

Divisions of the ANS

1. Sympathetic Nervous System
    a. Prepares the body for physical activity, stress or danger (fight or flight) and emergencies.
    b. Increases heart rate, blood pressure and breathing.
2. Parasympathetic Nervous System
    a. Helps the body relax and recover.
    b. Decreases heart rate and blood pressure.
    c. Increases digestive activity and conserves energy.

        The PNS is important for the following reasons.

        i. It allows us to feel.
        ii. It helps us move our body.
        iii. It keeps our organs working properly.

Neurones (Nerve Cells)

Neurones are specialised cells in the nervous system that receive, process and transmit information using electrical and chemical signals. They are the basic units or building blocks of the nervous system.

Functions of Neurones

Neurones;

a. receive signals from other cells.
b. integrate information from multiple sources.
c. generate and transmit electrical impulses.
d. release neurotransmitters to communicate with other neurones or target cells.

Structure of a Neurone

1. **Cell body (soma):** contains the nucleus and organelles that maintain the cell and produce proteins essential for nerve function
2. **Dendrites**: short, branched extensions that receive incoming signals from other neurones or sensory receptors and carry them toward the cell body
3. **Axon**: a long, slender projection that conducts electrical impulses away from the cell body toward other neurones, muscles, or glands
4. **Myelin sheath**: a fatty insulating layer formed by Schwann cells that wraps around the axon, insulating it and significantly increasing the speed of impulse transmission
5. **Nodes of Ranvier**: small gaps in the myelin sheath where the axon membrane is exposed, allowing the impulse to jump between nodes in a process called saltatory conduction
6. **Axon terminals (synaptic knobs)**: the branched endings of the axon that release neurotransmitters into the synapse to communicate with the next cell

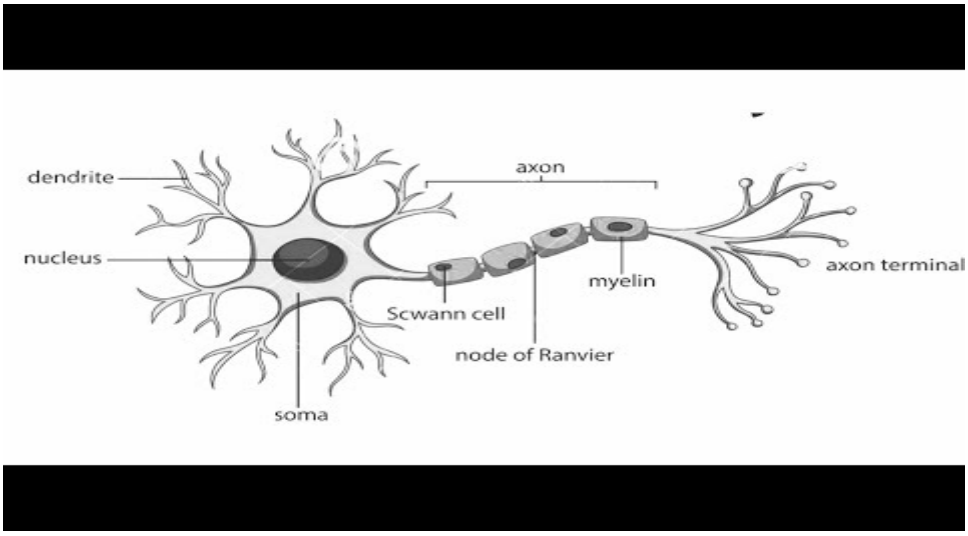


Figure 4.18: A Neuron

How Neurones Work

Neurones receive information from the environment or other neurons through dendrites, which are branch-like structures. For example, sensory neurones detect heat when you touch a hot object. The cell body (soma) processes incoming signals and decides whether to pass them on. It acts like a control centre, combining signals from different sources. If the signal is strong enough, it travels down the axon as an electrical impulse called an action potential. The axon carries the signal quickly, and at the end of it, the signal reaches the synapse. This is a tiny gap between neurones. The neurone releases neurotransmitters (chemical messengers) to pass the signal to the next cell.

Note: Neurones can change and adapt based on experience, a phenomenon called neuroplasticity. It is how we learn new things and form memories.

Types of Neurones

1. Sensory Neurones: Carry signals from sensory receptors, e.g. eyes, to the CNS.
2. Motor Neurones: Transmit signals from the CNS to muscles and glands to cause movement.
3. Interneurons (Intermediate Neurones): Connect sensory and motor neurones within the brain and spinal cord (CNS).

The Hormonal (Endocrine) System

The endocrine system is a network of glands and organs that produce and release hormones (chemical messengers) that travel through the blood to organs and tissues to regulate many body functions.

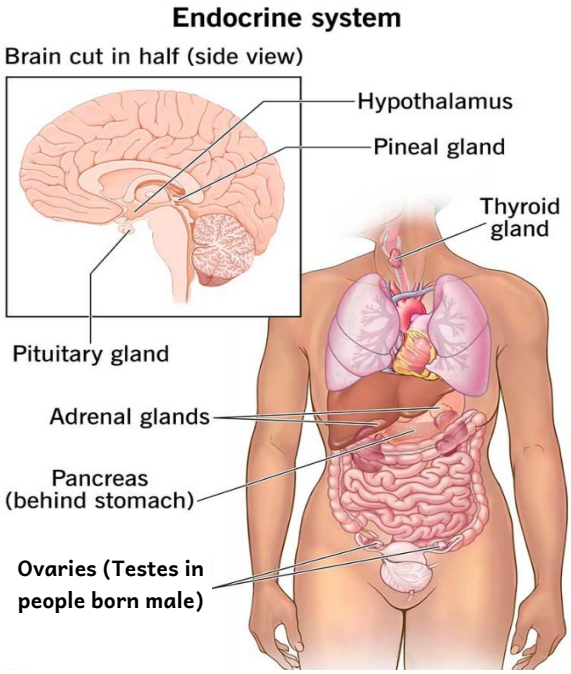


Figure 4.19: The Endocrine System

Functions of the endocrine system

The functions of the endocrine system include:

a. maintaining homeostasis (balance in the body).
b. control of metabolism (how the body uses energy).
c. regulating growth and development.
d. managing sexual function and reproduction.
e. controlling sleep-wake cycles.
f. regulating water and electrolyte balance.
g. influencing mood and stress response.

Table 4.6: Major Endocrine Glands and Their Functions

Gland	Location	Hormone(s) Produced	Function
Pituitary	Base of the brain	Growth hormone, prolactin, and trophic hormones	Controls other glands; regulates growth
Thyroid	Front of the neck	Thyroxine (T4), Triiodothyronine (T3) and calcitonin	Controls metabolism and energy use as well as calcium levels.
Parathyroid	Behind the thyroid	Parathyroid hormone (PTH)	Regulates calcium levels in blood and bones
Adrenal	On top of the kidneys	Adrenaline, noradrenaline and cortisol	Manage stress, blood pressure, and metabolism
Pancreas	Behind the stomach	Insulin, glucagon (from *Islets of Langerhans*)	Control blood sugar levels
Pineal	Deep in the brain	Melatonin	Regulates the sleep-wake cycle
Ovaries	In females	Oestrogen, progesterone	Controls female reproduction and menstruation
Testes	In males	Testosterone	Controls male reproduction and development

Note

1. Tropic hormones stimulate other endocrine glands to secrete their own hormones, while trophic hormones stimulate growth, development, and nourishment in target tissues.
2. Tropic Hormones

   Tropic hormones are primarily secreted by the anterior pituitary gland and the hypothalamus to regulate hormone axes.

   a. Thyroid-Stimulating Hormone (TSH): Stimulates the thyroid gland to release thyroid hormones.
   b. Adrenocorticotropic Hormone (ACTH): Stimulates the adrenal cortex to secrete cortisol.

   c. Luteinising Hormone (LH) & Follicle-Stimulating Hormone (FSH): Stimulate the gonads (ovaries and testes) to release sex hormones.

3. Trophic Hormones
   a. Trophic hormones act directly on tissues to increase their size, mass, or cell count.
   b. Growth Hormone (GH): Promotes skeletal and muscular growth.
   c. Prolactin: Stimulates mammary gland growth and development

How Hormones Work

Hormones are produced by glands in the endocrine system. Here is how they carry out their function.

1. Secretion: a gland releases a hormone into the bloodstream.
2. Transport: the hormone travels through the blood to target cells or organs.
3. Reception: target cells have specific receptors that recognise and bind to the hormone.
4. Action: once bound, the hormone triggers a response, like growth, metabolism changes or mood shifts.

Note: Hormones often work in feedback loops to maintain balance.

   a. Negative feedback: When enough of a hormone is produced, the body signals the gland to stop secreting more.
   b. Positive feedback: This is less common, but it intensifies the body's response (e.g., oxytocin during childbirth).

Integration of Nervous and Endocrine Systems

The hypothalamus in the brain acts as the main link between the nervous and endocrine systems. It receives signals from the nervous system and responds by releasing hormones that control the pituitary gland. The pituitary gland releases hormones that regulate other endocrine glands (e.g., the thyroid, adrenal glands, and reproductive organs). It's often called the "master gland," but it takes "orders" from the hypothalamus. In the stress response, for example, when danger is perceived, the nervous system activates the "fight or flight" response through adrenaline. At the same time, the endocrine system releases cortisol to sustain alertness and energy over time. In maintaining homeostasis, both systems constantly monitor and adjust body functions to maintain internal balance. For example, blood sugar regulation involves nervous input and hormonal control (e.g. insulin and glucagon from the pancreas). Again, both systems regulate body temperature, water balance, sensory organs and coordination ihumans.

Other real-life integration examples of the nervous and endocrine systems.

1. At puberty, the brain signals trigger hormone release that drives physical changes.
2. During sleep, light detected by the eyes signals the brain to release melatonin.
3. In reproduction, regions of the brain regulate hormones like oestrogen, progesterone, and testosterone.

Mammals interact with their environment using sensory organs that detect external stimuli and convert them into nerve impulses. These impulses are processed by the central nervous system (CNS), which coordinates appropriate responses. This pathway i.e. stimulus → sensory receptor → CNS → response, helps mammals:

a. navigate their surroundings
b. locate food
c. avoid predators
d. find mates
e. maintain homeostasis

Sensory Receptors and Organs

The Eye (Vision)

The human eye is a sensory organ that allows us to see. It detects light and sends signals to the brain, which then creates the images we see. **Figure 4.20** shows the anatomy of the human eye.

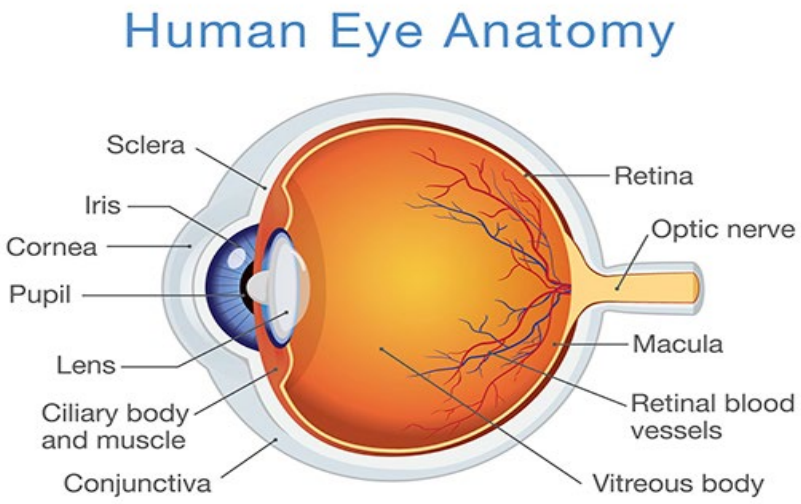


Figure 4.20: Anatomy of the Human Eye

The main parts of the eye and their functions are summarised in ***Table 4.7*** below.

Table 4.7: Main Parts of the Eye and Their Functions

Part of the Eye	Function
Cornea	Transparent front outer layer, which bends (refracts) light rays into the eye.
Pupil	Opening in the centre of the iris. It controls how much light enters.
Iris	The coloured part adjusts the size of the pupil.
Lens	Focuses light onto the retina.

Retina	light-sensitive layer, which contains rods and cones that detect light.
Optic Nerve	Carries visual signals from the retina to the brain.
Sclera	A white outer layer that protects and gives shape to the eye.
Choroid	Contains blood vessels and nourishes the retina
Vitreous humour	Jelly-like substance; maintains eye shape & allows light transmission
Aqueous humour	Maintains pressure, nourishes the eye, and keeps the eye inflated.

How the Eye Works

1. Light enters through the cornea and pupil. The curvature of the cornea causes most of the refraction of the light into the retina
2. The lens focuses and fine-tunes between near and distant vision onto the retina.
3. The retina converts light into electrical signals using:
   a. Rods, which detect dim light and black-and-white vision.
   b. Cones, which detect bright light and colour.
4. The optic nerve sends these signals to the brain.
5. The brain interprets the signals as images.

Fun facts

a. *The eye can detect over 10 million colours.*
b. *Your pupil size changes based on light and emotion.*
c. *The blind spot is where the optic nerve exits the eye, i.e. no light is detected there.*

Activity 4.5 Finding Your Own Blind Spot

Objective: To demonstrate the existence of the blind spot by making an object appear to disappear using only your eyes

Materials

- This page (or a piece of paper)
- A pen or pencil
- Your eyes!

Instructions

1. On a plain piece of paper, draw a small bold **X** on the left side and a small bold ● (filled circle) on the right side, approximately 6–8 cm apart, both on the same horizontal line.

X ●

2. Hold the paper at arm's length in front of you.

1. Close your right eye and focus your left eye directly on the **X**. Do not look at the dot, keep your gaze fixed on the X only.
2. Slowly bring the paper closer toward your face, keeping your left eye fixed on the X the whole time.
3. At a certain distance; usually about 25–30 cm from your face the dot on the right will completely disappear!
4. Continue moving the paper closer and the dot will reappear.

Discussion Questions for the Class

a. At what distance did the dot disappear for you? Was it the same for everyone in the class?

b. Why do you think we do not normally notice our blind spot in daily life?

c. What does this tell us about the role of the brain in vision?

d. Would the result be different if you used your right eye instead? Try it and find out!

e. People who are blind in one eye sometimes struggle with tasks like judging distance. Based on what you have just learned, can you suggest why?

Eye Defects

Eye defects are problems with vision caused by the shape of the eye, the lens or other parts that affect how light is focused. These defects can make it hard to see clearly and may require glasses, contact lenses or surgery to correct.

Common Refractive Defects of Vision

These occur when light does not focus properly on the retina.

1. ***Myopia (Near-sightedness):*** This results when the eyeball is too long, or the lens is too curved. When this happens, light focuses in front of the retina. People with this defect can see nearby objects clearly, but distant objects appear blurry. Correction is using concave lenses (diverging light rays).
2. ***Hypermetropia (Far-sightedness):*** This results when the eyeball is too short or the lens is too flat. In this situation, light focuses behind the retina. People with this defect can see distant objects clearly, but nearby objects are blurry. Convex lenses (convergent light rays) are used to correct this defect.
3. ***Astigmatism:*** This is caused by irregular curvature of the cornea or lens. It results in blurred or distorted vision at all distances. Correction is by using cylindrical lenses.
4. ***Presbyopia:*** results from loss of flexibility in the lens with age. Common in older adults, where they have difficulty seeing close objects. Correction is by using bifocal or reading glasses.

The Ear (Hearing and Balance)

The human ear is a sensory organ responsible for two main functions.

1. Hearing (detecting and interpreting sound waves).
2. Balance (helping with uprightness and coordination).

It's made up of three main parts: the outer ear, middle ear and inner ear

Parts of the Human Ear and Their Functions

1. Outer Ear: This is made up of the auricle (pinna), the visible part of the ear and the ear canal. It collects and channels sound waves into the ear.
2. Middle Ear: made up of the tympanic membrane (eardrum), which vibrates when sound waves hit it and the ossicles (three tiny bones) - *malleus* (hammer), *incus* (anvil) and *stapes* (stirrup). The middle ear amplifies and transfers sound vibrations to the inner ear.
3. Inner ear: made up of the cochlea (a spiral-shaped organ that converts vibrations into electrical signals), semicircular canals (which help with balance by detecting head movement), the vestibular nerve (which sends balance information to the brain) and the auditory nerve (which sends sound signals to the brain)

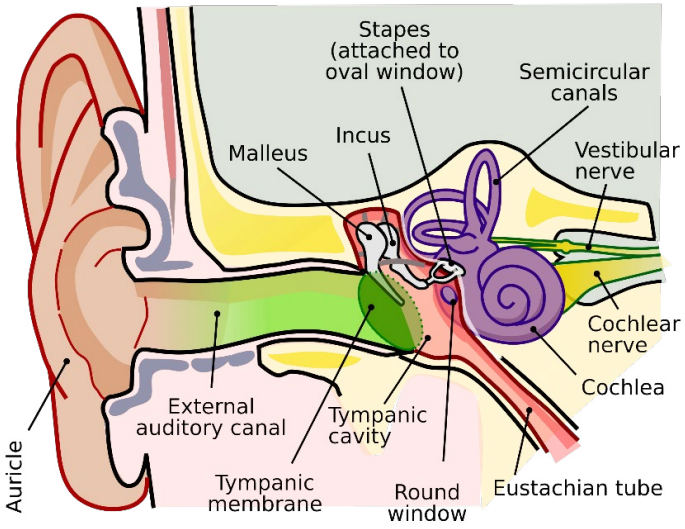


Figure 4.21: Anatomy of the Human Ear

How Hearing Works

1. Sound waves enter the ear canal.
2. They hit the eardrum, causing it to vibrate.
3. Vibrations pass through the ossicles to the cochlea.
4. The cochlea then converts the vibrations into electrical signals.

Signals travel via the auditory nerve to the brain, which interprets them as sound.

How Balance Works

1. The semicircular canals contain fluid and tiny hairs.
2. When you move your head, the fluid shifts and bends the hairs.
3. This sends signals to your brain to help you stay balanced.

Ear defects

These may be either congenital, e.g. Anotia (complete absence of the external ear) or acquired later in life, e.g. otitis media (infection of the middle ear).

Symptoms of Ear Defects

a. Hearing loss or muffled hearing.
b. Ear pain or discomfort.
c. Fluid discharge from the ear.
d. Ringing or buzzing sounds (tinnitus).
e. Dizziness or balance problems.

The Nose (Smell and Breathing)

The nose is a sensory organ that serves as the main entrance to the respiratory system and plays a key role in smell, breathing and speech. It is made of bone, cartilage, soft tissue and lined with mucous membranes and cilia (tiny hairs).

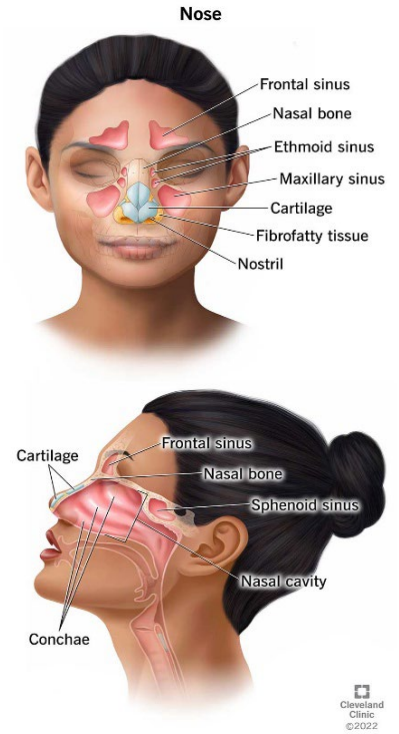


Figure 4.22: Anatomy of the Nose

The functions of the Nose are summarised in ***Table 4.8*** below.

Table 4.8: Functions of the Nose

Function	Description
Breathing	Allows air to enter the respiratory system.
Filtration	Nose hairs and mucus trap dust, germs, and particles.
Warming & Moistening	Air is conditioned before reaching the lungs.
Smell (Olfaction)	Olfactory cells detect odours and send signals to the brain.
Speech	Sinuses and nasal passages help produce nasal sounds.
Defence	Sneezing expels irritants and pathogens from the nose.

Key Structures of the Nose

1. Nasal cavity, nostrils, septum.
2. Turbinate bones: Increase surface area.
3. Olfactory epithelium: Contains olfactory receptors and neurones.
4. Mucous membranes: Trap particles and moisten air.

Defects of the nose

These may be congenital, e.g. choanal atresia (blockage of the nasal passage, causing breathing difficulties in newborns) or acquired in later life, such as sinusitis (infection or inflammation of the sinuses, leading to nasal congestion and pain.

Fun Facts

a. *The nose can detect over 1 trillion scents.*
b. *Sneezing is a reflex to clear the nose of irritants.*
c. *The shape of your nose is determined by bones and cartilage.*

The Tongue

The tongue is a muscular organ in the mouth that helps with chewing and swallowing, speaking and forming words, tasting and cleaning the mouth and teeth.

Functions of the Tongue

1. Taste: detects sweet, salty, sour, bitter and umami flavours.
2. Speech: shapes sounds and words.
3. Chewing & swallowing move food around and push it down the throat.
4. Cleaning helps remove food particles from teeth.
5. Breathing keeps the airway open during rest.

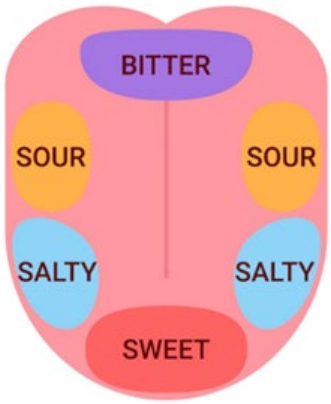


Figure 4.23: Taste areas of the tongue

The Skin

The skin is the largest organ of the human body and forms the outer covering. It belongs to the integumentary system and serves as a protective barrier between your internal organs and the outside world. It covers about 1.5 to 2.0 square meters in adults and varies in thickness depending on location, age and sex. The skin is made up of three main layers, each with specific roles.

1. Epidermis: the outermost layer, it contains protective cells and melanin (skin pigment)
2. Dermis: the middle layer, it houses blood vessels, nerves, sweat glands and hair follicles.
3. Hypodermis: deepest layer; made of fat and connective tissue. It insulates and cushions.

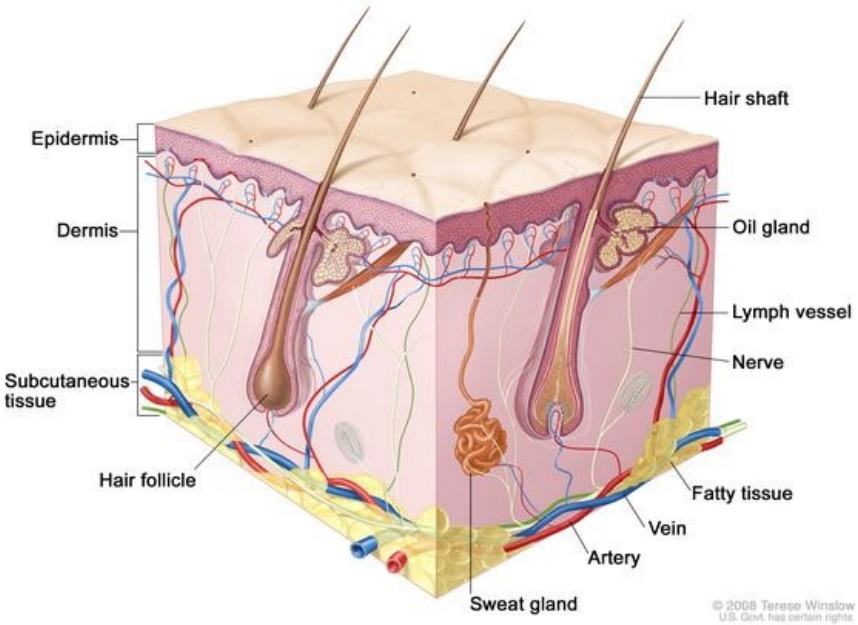


Figure 4.24: Anatomy of the Human Skin

Functions of the Skin

The skin performs several vital functions.

1. Protection: Shields against pathogens, UV radiation, and physical injury.
2. Sensation: It detects touch, pain, temperature and pressure via nerve endings.
3. Temperature regulation: The skin uses sweat and blood flow to maintain body temperature.
4. Vitamin D production: Synthesises vitamin D when exposed to sunlight.
5. Water retention: It prevents dehydration by keeping moisture inside the body.
6. Immune defence: Acts as a first line of defence against infections.

Fun Facts

a. *The skin renews itself every 28–30 days.*

b. *It hosts around 1,000 species of bacteria from 19 different phyla.*

c. *Goosebumps are a vestigial response meant to trap heat when cold.*

Coordination of Sensory Information in Mammals

Humans rely on complex systems to process sensory information, coordinate motor responses, and adapt to their environments. This coordination involves the nervous system, sensory organs, motor centres, and hormonal signals working together.

Sensory Processing

Sensory processing refers to how the nervous system receives, interprets and integrates sensory information from the body and environment. It involves sensory inputs, signal transmission, processing and response. The key components involved in this process are:

1. Sensory receptors
2. Neural pathways
3. Brain regions (e.g., visual cortex, auditory cortex)
4. Neurotransmitters and hormones

Integration Centres

These are specialised regions of the CNS, particularly in the brain. These centres receive input from various sensory organs (e.g., eye, ear, etc) and combine the signals to create a single, organised picture of what is happening around us. The integration centres include:

a. Association areas which integrate information from multiple senses (e.g., sight, sound, touch).

b. The thalamus, which relays and filters sensory signals (except smell).

c. Limbic System, which links sensory input to emotions and memory.

Motor Coordination

Motor coordination is the ability of the body to smoothly and efficiently combine movements from different muscles and body parts to perform a specific action. It allows you to walk, write, speak, play sports, and even pour water, all well controlled. The brain region involved in motor coordination includes:

1. Cerebellum: Coordinates movement, posture, and balance by comparing intended actions with sensory feedback

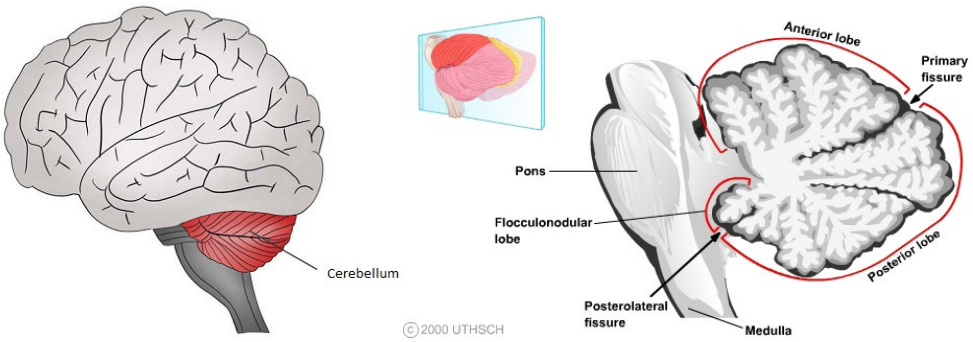


Figure 4. 25: Cerebellum

2. Motor Cortex: Initiates voluntary movements, plans and executes actions

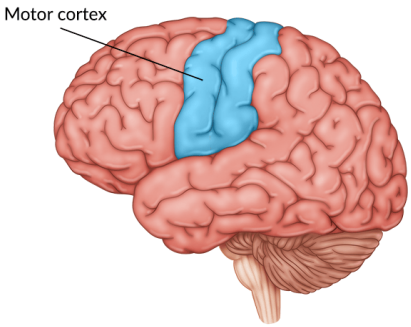


Figure 4.26: Motor cortex

3. Basal Ganglia: Regulate movement initiation and termination

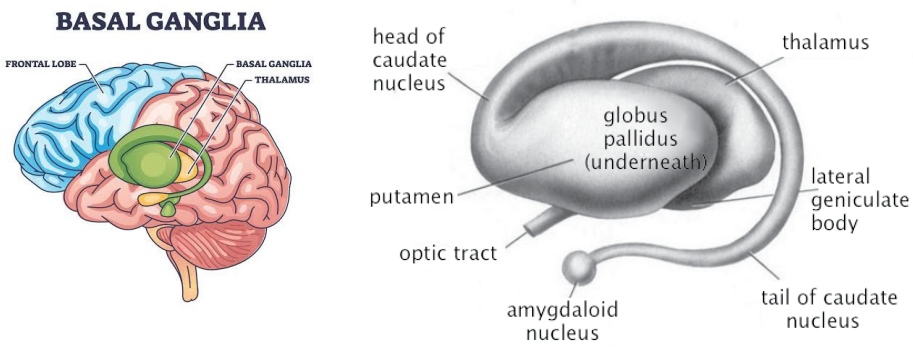


Figure 4.27: Basal Ganglia

4. Brainstem: Controls reflexive movements and coordinates vital functions

Sensorimotor Integration

Sensorimotor integration is the process by which the central nervous system (CNS) combines sensory inputs (like sight, touch and balance) with motor commands to produce smooth, adaptive movements. It is how the body knows where it is in space and how to respond appropriately.

Key Mechanisms

1. Feedback loops which adjust movements based on sensory feedback.
2. Proprioception i.e. an awareness of body position through muscle spindles and joint receptors.
3. Reflex arcs, which are fast, involuntary responses that bypass conscious control.

Hormonal Influence on Coordination

Hormones also affect how humans respond to sensory input and coordinate movement. Summarised in ***Table 4.9*** below are some hormones and their role in coordination.

Table 4.9: Hormones and their role in coordination

Hormone	Role in Coordination
Adrenaline & Noradrenaline	Enhance sensory perception during stress
Sex Hormones	Influence sensory preferences and behaviours, especially during mating
Melatonin	Regulates circadian rhythms and affects sensory sensitivity

Adaptations in Different Mammalian Species

Different mammals have evolved specialised sensory and motor adaptations based on their environments and lifestyles. The following summary shows mammal type and their adaptation.

Table 4.10: Adaptation of Different Mammalian Species

Mammal Type	Adaptation
Nocturnal Mammals	Enhanced smell and hearing; specialised night vision
Aquatic Mammals	Modified ears for underwater hearing; echolocation in cetaceans
Bats	Use echolocation with specialised auditory structures
Moles	Reduced vision; enhanced touch sensitivity via specialised snout

Activity 4.6 "The Body's Command Centre: Coordinating for Balance"

Objective: To explain how the nervous and hormonal systems work together to maintain homeostasis.

Instructions

1. Warm-Up Discussion
    a. Pair up with a classmate.
    b. Discuss this question: "What happens in your body when you run a race?"
    c. Think about changes like sweating, breathing faster, or feeling nervous.
    d. Be ready to share your ideas with the class.
2. Group Role-Play
    a. Form a group of 4–5 members.
    b. Choose a scenario where the body needs to maintain balance (homeostasis), such as:
        i. Responding to heat
        ii. Dealing with stress
        iii. Regulating blood sugar
    c. Assign roles in your group
        i. Brain (nervous system)
        ii. Glands (hormonal system)
        iii. Organs (effectors)
        iv. Stimulus (e.g., heat, stress)
    d. Create a short role-play showing how the nervous and hormonal systems work together to respond to the stimulus and restore balance.
    e. Use movement, dialogue, and props if helpful.
    f. Perform your role-play for the class.
3. Peer Teaching Carousel
    a. After performing, rotate to another group.
    b. Each group explains their scenario to the other.
    c. Make sure each person in your group speaks during the explanation.
    d. Use these guiding questions.
        i. What triggered the response?
        ii. Which system acted first?
        iii. How was balance restored?
4. Reflection
    a. On your own, write a short paragraph on: *"How do the nervous and hormonal systems work together to maintain homeostasis"*
    b. Be ready to read your answer aloud if asked.

METHODS OF REPRODUCTION IN FLOWERING PLANTS WITH EMPHASIS ON SEXUAL REPRODUCTION

Types of Reproduction

Reproduction is a biological process by which organisms produce new individuals or offspring. It is fundamental for the survival of species and is in two main types:

Asexual reproduction

1. This involves only one parent.
2. Offspring are genetically identical to the parent.
3. There is no fusion of gametes.
4. The method can be either natural or artificial.
    a. Some forms of natural asexual reproduction include binary fission (e.g., in bacteria such as *Escherichia coli*), budding (e.g. in Cnidarians such as the hydra, and fungi like yeast), regeneration (as in Planarians or flatworms, and Echinoderms such as starfish, brittle star and sea urchins) and parthenogenesis (examples are found in insects such as bees, aphids and some species of wasps).
    b. Artificial methods include cuttings (e.g. in roses and grapevines), grafting (e.g. in citruses and apples), layering (e.g. in strawberries and raspberries and tissue culture (e.g. in orchids, bananas and potatoes).

Sexual reproduction

1. It involves two parents.
2. It involves the fusion of a male and female gamete to produce offspring.
3. Offspring have varied genetic combinations.
4. Some natural forms of sexual reproduction include oviparity (e.g. in birds, reptiles, amphibians and many fishes), viviparity, as in most animals, ovoviviparity, as found in some fishes, reptiles and amphibians.

In flowering plants, sexual reproduction involves the fusion of male and female gametes to produce seeds. This process typically includes pollination, fertilisation and development. Before pollination can occur, reproductive structures must be fully matured. This reproductive structure is the flower.

Structure of a flower

A typical flower has four main parts called the floral parts. These are the sepals (or calyx), petals (or corolla), stamens (or androecium), and carpels (or gynoecium). Stamens are the male reproductive organs and are made up of the anthers (which produce pollen) and filaments (which hold up the anthers). Carpels or pistils are the female reproductive organs and are made up of the stigma (receives pollen), style (holds up the stigma), and ovary (contains ovules).

Table 4.11: Floral Parts and Their Function

Floral part	Function
Sepal	Protects the flower at the bud stage before it opens
Petal	Attracts pollinators with its bright colours
Anther	Produces pollen, which contains the male sex cell
Filament	Holds the anther in place
Stigma	Receives the pollen during pollination
Style	Holds up the stigma
Ovary	Contains the ovule, which contains the female sex cell
Receptacle	Holds all the floral parts in place

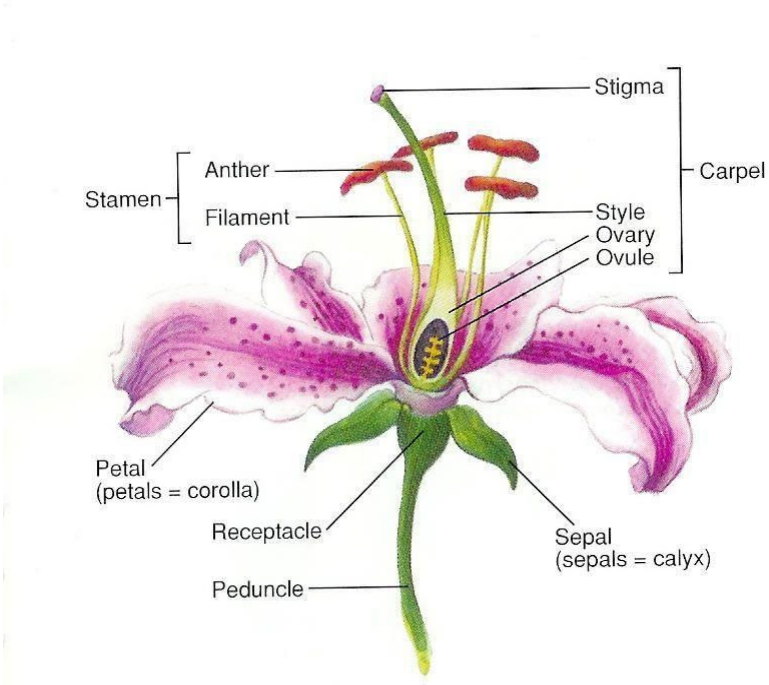


Figure 4.28: Parts of a Flower

Floral Formula

The floral parts can be represented with a floral formula. The floral formula is the symbolic representation of the various structures and parts of a flower using numbers, symbols and letters to give information about the morphology of the flower. Features captured in the floral formula include:

a. floral symmetry: actinomorphic (radial) or zygomorphic (bilateral)
b. sexuality (bisexual or unisexual)
c. number and arrangement of floral parts (e.g. sepals, petals, stamens and carpels)
d. fusion or separation of floral parts.

The floral formula of a flower can be determined by following the steps below.

1. A freshly cut flower (e.g. hibiscus or okra) is carefully dissected and separated into its parts: sepals (calyx), petals (corolla), stamens (androecium), carpels (gynoecium)
2. The number of each floral part is counted, and their arrangement is noted.
3. The position of the ovary is either on top of the receptacle of the flower(superior) or within the receptacle of the flower (inferior).
4. The symmetry of the flower (actinomorphic or zygomorphic) is also observed.
5. The floral formula is written using the letters:

   K = Calyx (sepals), C = Corolla (petals), A = Androecium (stamens), G = Gynoecium (carpels)

   Other symbols used are given below.

   a. ⚥ = bisexual flower
   b. ↑ = zygomorphic (bilateral symmetry)
   c. ⊕ = actinomorphic (radial symmetry)
   d. A line under G = superior ovary
   e. A line over G = inferior ovary
   f. ( ) = fused structure

Example
⊕ K5 C5 A(∞) G1: This shows a bisexual, actinomorphic flower with 5 sepals, 5 petals, many stamens that are fused, and one carpel with a superior ovary.

Male and Female Reproductive Parts of a Flower

The male reproductive parts (stamens or androecium) of the flower are the anther, which produces the pollen grains that contain the male gametes, and the filaments, which hold the anther.

The female reproductive parts (gynoecium/pistil/carpel) are the stigma (sticky surface) that receives pollen, the style /stalk that holds the stigma and connects it to the ovary and the ovary that contains ovules, which develop into seeds after fertilisation.

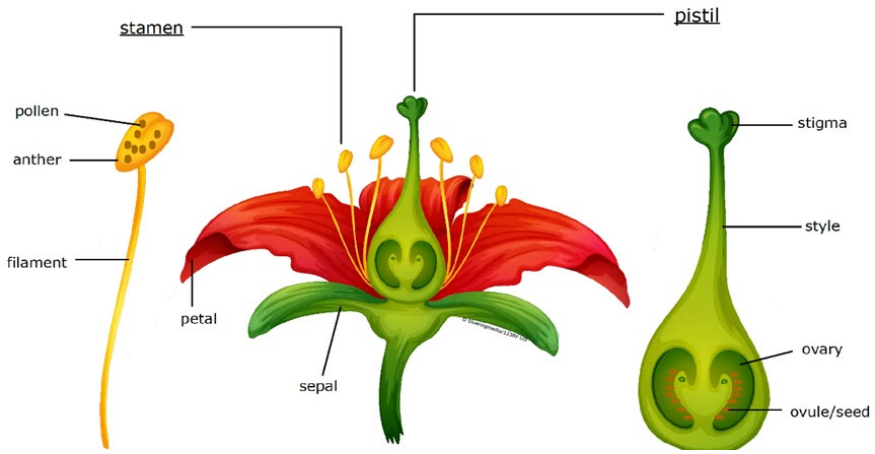


Figure 4.29: Male and female reproductive parts of a flower

When the pollen grains from the anther reach the stigma of the flower, pollination is said to have occurred. This can happen within the same flower or between flowers of the same species.

Activity 4.7 Flower Dissection and Function Exploration

Objective: Dissect a flower to observe its parts and discuss their functions in a group setting.

Materials

- Real flowers (e.g., lilies, daisies or hibiscus)
- Dissecting tools (scissors, tweezers: improvised with a pair of dividers in a maths set)
- Hand lenses (improvised with a smooth clear bottle filled with water and covered tightly)
- Notebooks
- Observation sheets

Instructions

1. Find a partner in the class and gather all the materials and the flower needed.
2. Carefully remove the petals, sepals, stamens, and carpels.
3. Use hand lenses to examine the structures closely.
4. Record all observation, note the identified parts and hypothesise the functions based on observations made.
5. Confirm the functions of each part and write out the floral formula
6. Share your findings with the class

Self-Pollination and its Adaptations

Self-Pollination refers to the transfer of pollen grains from the anther to the stigma of the same flower or another flower on the same plant. Examples of plants that go through self-pollination are cassava, potatoes, tomatoes, pea plants, rice and wheat. Self-pollinated flowers have evolutionarily developed several mechanisms to enable them to survive successfully within the environment. Some of these adaptive strategies are:

1. Anthers are close to stigma.
2. Flowers may remain closed (cleistogamy).
3. Flowers are often small and less bright (dull).
4. They produce less pollen.

Cross Pollination and its Adaptations

Cross-pollination is the transfer of pollen grains from the anther of one flower to the stigma of another flower on a different plant of the same species. Examples of plants that go through cross-pollination are cocoa, cashew, palm plants, sunflower and apples. Examples of adaptations for cross-pollination include the following:

1. Stamens and carpels mature at different times (dichogamy).
2. Structural barriers prevent self-pollination.
3. Brightly coloured petals and scents to attract pollinators.
4. Production of nectar.
5. Long stamens or styles encourage contact with pollinators.

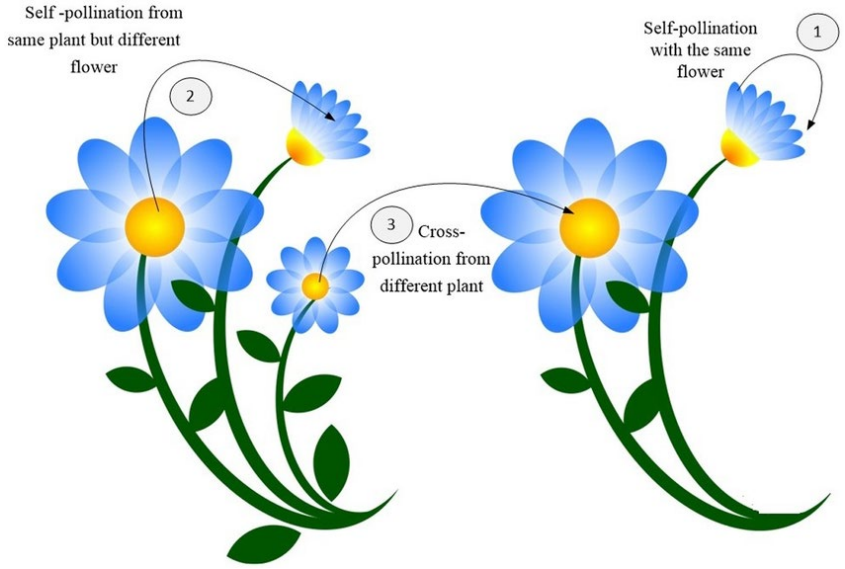


Figure 4.30: Self-pollination and Cross-pollination

Agents of pollination

These are the organisms or natural factors that cause or facilitate pollination in flowering plants. Living or biotic factors that cause pollination include animals such as insects, birds, and bats. Non-living or abiotic agents include wind, rivers or rain.

Activity 4.7 Me! Pollinate, You! Pollinate or We! Pollinate Debate

Objective: Engage in a debate to explore the advantages and disadvantages of self-pollination versus cross-pollination.

Materials

- Research materials (books, articles, internet access)
- Debate guidelines
- Notepads for notes

Instructions

1. Join one team in the class: one representing self-pollination and the other representing cross-pollination.
2. Research on the assigned pollination method, focus on:
   a. Key adaptations and benefits.
   b. Potential drawbacks and limitations.
3. Prepare arguments to support your position, anticipating counterarguments from the opposing team.
4. Participate in a structured debate where you present your arguments, followed by rebuttals.
5. After the debate, discuss what you learned about the adaptations associated with each pollination method.

Double Fertilisation in Flowering Plants

Double fertilisation refers the event of two fertilisations in which there is the fusion of a female embryonic sac with two male sperm cells (gametes), resulting in the formation of a diploid zygote and a triploid endosperm. This is a unique feature in angiosperms (flowering plants). The major processes involved in double fertilisation are;

1. Pollen grains lands on the stigma, absorbs water and nutrients to swell and germinate.
2. Pollen tube grows down the style and into the ovary to reach the embryo sac.
3. Pollen tube penetrates the embryo sac at the micropyle and releases two sperm cells.
4. One sperm cell fuse with the egg cell to form a diploid zygote, while the other sperm cell fuses with the two polar nuclei to form a triploid endosperm for nourishment.

The endosperm is a nutrient-rich tissue essential for seed development and nourishment of the growing embryo. The main importance of double fertilisation is seed development and nutrient supply.

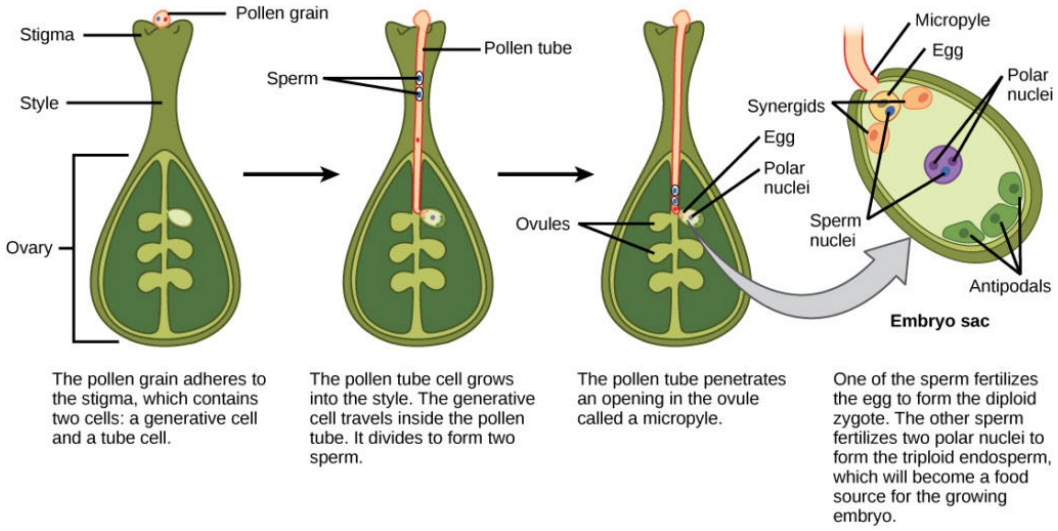


Figure 4.31: The Process of Double Fertilisation

Activity 4.8 Flower Structure Role-Playing Game

Objective: Engage in a role-playing game to explore the roles of different floral parts in reproduction.

Materials

- Role cards for different flower/plant parts

Sample role cards

Role Card 1: Flower Structure Role: Overall, Flower Structure Function: Support the entire reproductive process.	**Role Card 2: Nectar** Role: Nectar Glands Function: Produce nectar to attract pollinators.
Role Card 3: Sepals Role: Sepals Function: Protect flower bud before blooming.	**Role Card 4: Petals** Role: Petals Function: Attract pollinators with colour and scent.
Role Card 5: Carpels Role: Carpels Function: House the ovules and facilitate fertilisation.	**Role Card 6: Stamens** Role: Stamens Function: Produce pollen for reproduction.
Role Card 7: Roots Role: Roots Function: Anchor the plant and absorb water and nutrients.	**Role Card 8: Seeds** Role: Seeds Function: Ensure the next generation of the plant.

- Scenario cards outlining specific reproductive challenges

Sample scenario cards

Scenario Card 1: Invasive Species **Challenge:** An invasive plant species is outcompeting you for space and resources. How can you modify your flowering time or structural features to enhance your chances of reproduction against this competitor?	**Scenario Card 2: Lack of Pollinators** **Challenge:** A sudden decline in local bee populations has affected pollination rates for many flowers in your area. As a flower, how can you attract alternative pollinators or adapt to survive this change?
Scenario Card 3: Seed Dispersal Challenges **Challenge:** Heavy rains have caused flooding, potentially washing away seeds before they can germinate. How does your flower adapt its seed structure or dispersal method to ensure survival and successful reproduction?	**Scenario card 4: Limited Light Availability** **Challenge:** A new building has been constructed nearby, blocking sunlight from reaching your flower. What adaptations can you make to your structure or reproductive strategy to ensure you still attract pollinators and produce seeds?

Scenario Card 5: Environmental Changes **Challenge:** Due to climate change, the temperature in your habitat has increased considerably. As a flower, how do you adapt your blooming time or structure to ensure successful reproduction in the new climate?	**Scenario Card 6: Competition for Resources** **Challenge:** A neighbouring flower species with brighter colours and more nectar has moved into your area, attracting more pollinators. What structural adaptations can you make to compete for pollinators and resources?
Scenario Card 7: Soil Degradation **Challenge:** The soil in your area has become depleted of nutrients due to over-farming. As a flower, how do you adjust your root structure or reproductive strategy to thrive in less favourable conditions?	**Scenario Card 8: Seed Predation** **Challenge:** Small animals have started eating your seeds before they can germinate. What changes can you make to your seed structure or reproductive strategy to protect your seeds and ensure future generations?

Instructions

1. Select a role card representing a flower/plant part (e.g., petals, stamens, carpels)
2. Select a scenario card that presents a challenge related to reproduction (e.g., a lack of pollinators, environmental changes).
3. Individually or in a small group, discuss how your flower part can adapt or respond to the selected challenge. emphasise how structural differences affect reproductive strategies.
4. Present your scenario and solution to the class.

Activity 4.9 Double Fertilisation Concept Map

Objective: Create a concept map to visually represent the process of double fertilisation and its outcomes.

Materials

- Large paper or poster boards
- Markers, coloured pencils, or digital tools for concept mapping
- Research materials on double fertilisation

Instructions

1. Review your knowledge on double fertilisation.
2. Create a concept map detailing the process. Include the following in the process:
   a. Key stages of double fertilisation
   b. Outcomes
   c. Significance for seed development and plant reproduction.

3. Present your concept map to the class and explain the connections and processes illustrated.
4. Discuss how the concept maps help clarify the understanding of double fertilisation and its outcomes.

Fruits

After double fertilisation has occurred the ovule matures to become a seed. The ovary wall starts to grow into the fruit. The fruit continues to grow while containing the seeds. When the fruit matures, it often changes colour, texture, and size. These changes attract animals for seed dispersal.

Types of Fruits

Fruits can be classified based on many factors such as the development of floral parts, structure and origin, and the type of dispersal.

1. Fruits classification by the Structure and Origin

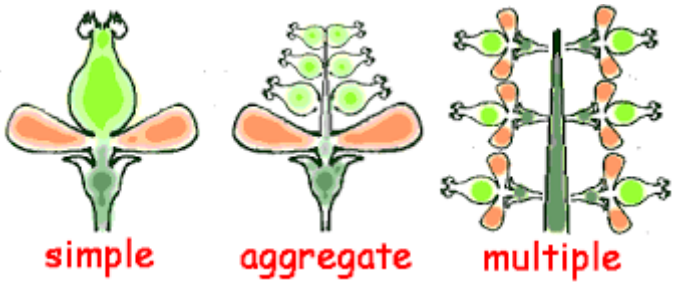


Figure 4.32 Fruit Classification by Structure

Simple fruits

They are fruits that develop from a single ovary in a flower. The various forms of simple fruits are:

a. Fleshy fruits – These are simple fruits with soft fleshy pericarp or fruit wall. The types are berries, drupes, pomes, etc. Examples are tomatoes, bananas, mangoes, oranges, pawpaw, lime, lemon and peach fruits

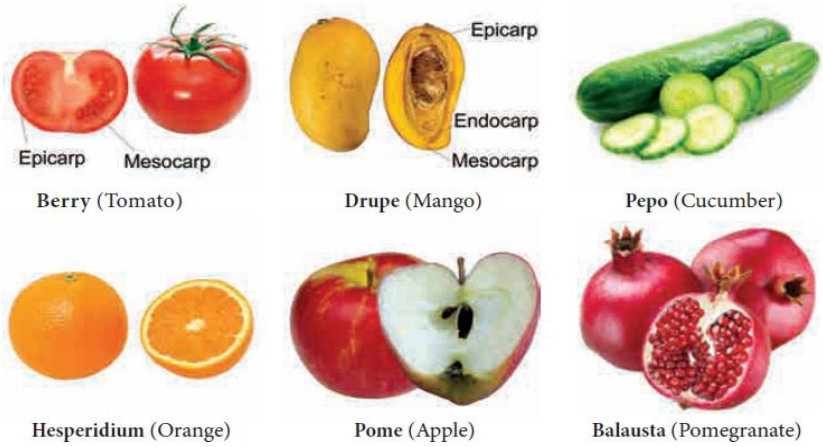


Figure 4.33: Simple Fleshy Fruit

b. Dry fruits – These are simple fruits characterised by a dry, non-fleshy pericarp. The two main types:

i. dry dehiscent fruits open to release seeds. Examples are peas and beans
ii. dry indehiscent fruits do not open to release seeds. Examples are nuts, achenes and grains.



Figure 4.41: Dry dehiscent fruit Figure 4.42: Dry indehiscent fruit

Figure 4.34: Dry Dehiscent Fruits **Figure 4.35:** Dry Indehiscent Fruits

Aggregate fruits

These are fruits that develop from multiple ovaries of a single flower; examples are strawberries and raspberries.



Figure 4.36: Calatropis, Strawberry, Raspberry and Custard apple

Composite or multiple fruits

Composite fruits are fruits which develop from ovaries of multiple flowers that fuse; examples are pineapples, jackfruit, noni fruit and fig fruits (less known in Ghana).



Figure 4.37: Figs, Pineapple and Jackfruit

Fruit classification by the development of Floral Parts

1. True fruits: These are fruits that develop from the ovary of a flower. Examples are tomatoes and peaches.
2. False fruits/Accessory or Pseudocarps: These are fruits that develop from parts of the flower, such as the receptacle and floral parts, instead of the ovary. Examples are apples, pears and strawberries.

Classification of fruits based on Mode of Dispersal

1. Wind Dispersed: Fruits that are lightweight and can be carried by the wind. Examples are dandelion seeds and maple seeds.
2. Animal Dispersed: Fruits that attract animals, which eat them and disperse the seeds. Examples are berries and cherries.
3. Water Dispersed: Fruits that can float and are dispersed by water. Examples are coconuts and some types of mangroves.

Seeds and Their Classification

A seed is the reproductive unit of a plant that develops from the ovules in the ovary of a flower after fertilisation. The seed contains the embryo and is surrounded by the seed coat. Most seeds have food storage tissue (endosperm and cotyledon) and an embryo for germination.

Two main ways of classifying seeds are the number of cotyledons (seed leaves) they contain and whether they have endosperm or not.

1. Based on the number of cotyledons, seeds are considered as:
   a. Monocotyledonous seeds (Monocot seeds): These are seeds that contain only one cotyledon (seed leaf). Examples are palm seeds, pawpaw, grains and cereals.

b. Dicotyledonous seeds/Dicot seeds: These are seeds with two cotyledons (seed leaves). Examples are bean seeds, peas, mangoes, oranges and sunflower seeds.

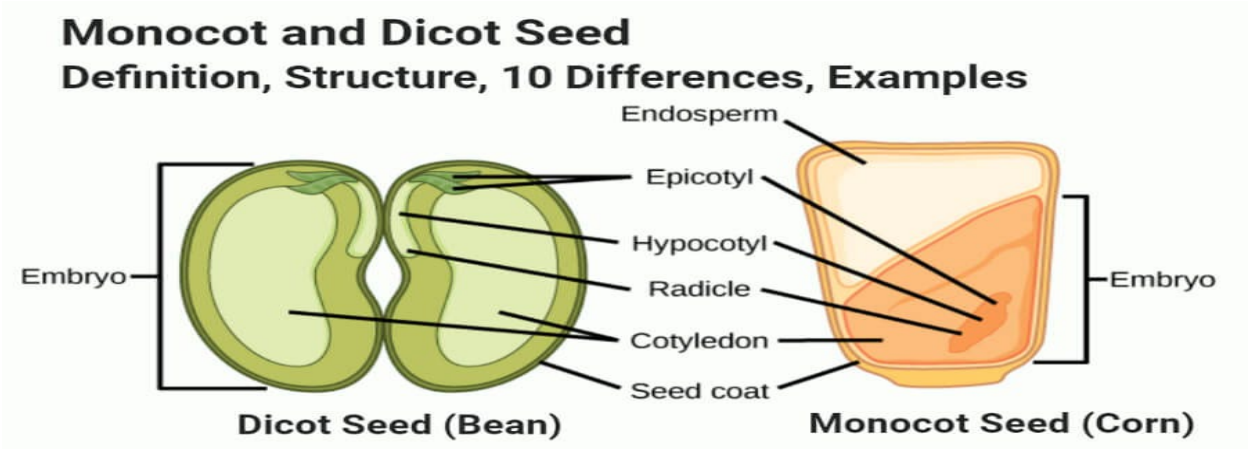


Figure 4.38: Dicot seed (bean) and Monocot seed (corn)

2. Based on the presence of endosperm, seeds are considered as:
   a. Endospermic seeds when they possess endosperm. Typical examples are rice, maize, wheat and castor seeds.
   b. Non-endospermic seeds, when they do not have endosperm. Typical examples are peas, beans, soya bean, cowpea and barley.

Fruit and Seed Dispersal

This is the process by which plants spread their seeds to new locations, allowing them to colonise new habitats and spread in different locations. There are several mechanisms or methods by which this is achieved. These include:

1. Wind: Seeds light-winged or with hairs (e.g. dandelion, maple).
2. Water: Seeds have air spaces or fibrous husks for floating (e.g. coconut).
3. Animals: Fleshy fruits eaten and seeds dispersed in droppings (e.g. mango), or seeds attach to fur (e.g. burdock).
4. Explosive Mechanism: Fruit bursts open to scatter seeds (e.g. balsam).

   Fruit and seed dispersal are important among plants because the process

   a. reduces competition with the parent plant
   b. allows colonisation of new areas
   c. increases the chances of survival among plant species.

Seed Germination and Its Requirements

Seed germination is the stage in seeds when the seed begins to grow and develop into a seedling. The requirements or conditions necessary for germination are:

1. Water to soften the seed coat and activate enzymes.
2. Oxygen for aerobic respiration to produce energy for the developing seed.
3. Warmth for enzyme activity (most seeds germinate within the temperature range of 150C to 300C).
4. Light or Darkness. Some seeds such as lettuce and tobacco require light for germination, while others, including onion and cucumber germinate best under darkness.
5. Viability of the seeds. Viable seeds are capable of germinating and growing into healthy plants under the right conditions.

Types of Germination

There are two main types of germination. These are

1. Epigeal germination: This is the type of germination where the cotyledons are pushed above the soil level when the seed germinates. The stem below the cotyledon is called the hypocotyl. This elongates to push the cotyledon above the soil. Examples of this epigeal germination is found in plants such as cocoa, beans, peas, tomatoes and sunflower.
2. Hypogeal germination: It is the type of germination where the cotyledons stay below the soil level when the seed geminates. The stem that grows above the cotyledon is called the epicotyl. The epicotyl elongates and pushes out of the ground, while the cotyledon remains in the soil. Examples of this type of germination is found in maize, sorghum, millet, rice, coconut, grasses

Note: Although monocot seeds are mainly hypogeal, dicot seeds show both epigeal and hypogeal germinations

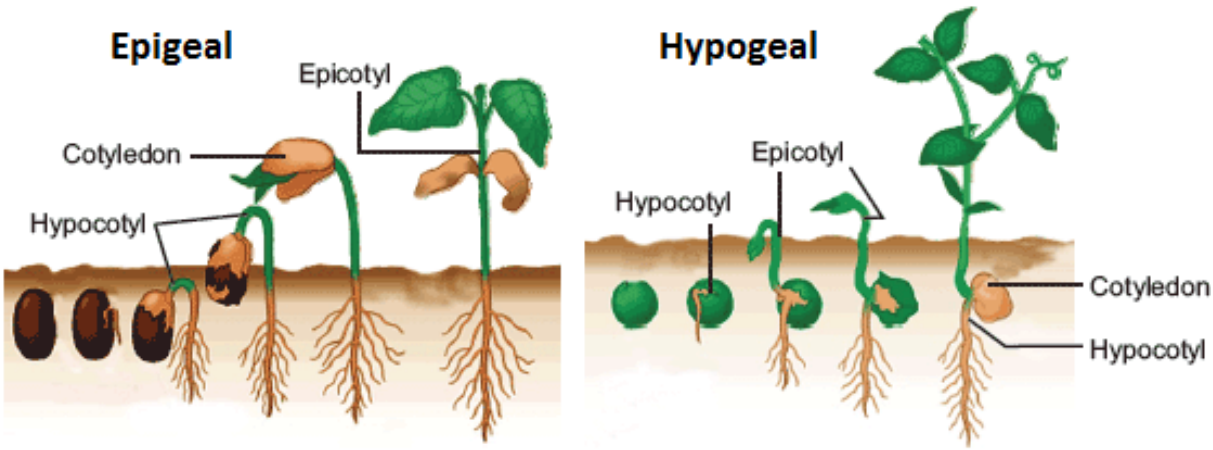


Figure 4.39: Types of Germination

Activity 4.10 Exploring Fruits and Their Seed Germination

Objective: To study the role of fruits in seed protection and dispersal, and observe the germination process of seeds.

Materials

- Various types of fruits (e.g., apples, oranges, tomatoes, beans)
- Plastic bags or containers for seeds
- Paper towels or cotton balls
- Soil or seed-starting mix
- Plant pots or biodegradable cups
- Watering cans or spray bottles
- Rulers
- Observation journals
- Markers or labels

Instructions

1. Analysis of the role of fruits in flowering plants, emphasising their function in seed protection and dispersal.
2. Select and dissect the fruits to observe the seeds inside, noting the number, size, and type of seeds.
3. Identify the type of fruit and find out how it aids in seed dispersal (e.g., fleshy fruits attract animals, while others may be carried by wind).
4. Collect seeds from the dissected fruits and place them in labelled plastic bags or containers for later use.
5. Select some of the seeds collected and prepare them for germination.
6. Moisten the paper towels or cotton balls.
7. Place the moistened paper towels or cotton balls in a small container and add the seeds on top. OR Plant seeds in soil-filled pots or biodegradable cups, ensuring proper depth and spacing.
8. create labels for your pots or containers, include the type of seed and the date of planting on the label.
9. Assess the conditions needed for germination (moisture, warmth, light) and find out how to provide them.
10. Over the next week or two, observe your seeds daily and record any changes in your observation journals (e.g. sprouting time, growth progress), take measurements (e.g., height of sprouts) and sketch your observed changes.
11. After the germination period, discuss your results with your peers in class.
12. Ask your classmates questions like:
    a. Which seeds germinated successfully?
    b. How did the different fruits' structures affect seed viability?
    c. What conditions were most beneficial for germination?
13. Write a reflection on what you have learned about the relationship between fruits and seeds and the germination process. Include any surprises or challenges you encountered.
14. Present your findings to the class.

IMPORTANCE OF REPRODUCTION IN FLOWERING PLANTS FOR THE SUSTENANCE OF LIFE

Importance of Reproduction in Flowering Plants

Reproduction in flowering plants is essential for the continuation of plant species and the balance of ecosystems. The main importance is that:

1. Reproduction ensures that plant species do not die out, allowing them to produce new generations.
2. Sexual reproduction introduces genetic diversity, enabling plants to adapt to changes in the environment.
3. Flowering plants provide fruits, seeds, and other plant parts that serve as food for humans and other living things.
4. Many flowering plants are cultivated for commercial purposes through export and import marketing to boost the economy of entrepreneurs and states.
5. There is the formation of fruits and seeds that are dispersed and colonised in new locations to spread and ensure survival.

Activity 4.11 Ecological Impact Assessment

Objective: Conduct an ecological impact assessment of a degraded area and propose a restoration strategy using flowering plants.

Materials

- Assessment templates
- Field notebooks
- Measuring tools e.g. rulers
- Research materials on local ecosystems and flowering plants

Instructions

1. Visit a local degraded area and assess:
   a. soil quality.
   b. existing vegetation and signs of erosion.
   c. local wildlife activity.
2. Record your observations and data and note factors that contribute to the degradation of the area.
3. Based on your findings, develop a restoration strategy that includes:
   a. selected flowering plants that are native and beneficial for the ecosystem.

b. methods for planting and maintaining these plants.
c. expected outcomes for the local environment and wildlife.

4. Present your assessment and restoration proposal to the class or local community and emphasise the importance of the chosen plants and strategies.

EXCRETION IN FLOWERING PLANTS

Excretory Structures in Flowering Plants

Excretion is a natural process where living organisms remove waste products produced by their bodies during metabolism to the outside of the body. Some of the waste products in plants are oxygen, excess carbon dioxide, excess water, resins, latex, gum, tannins, saponins, terpenes, alkaloids, phytoliths and glycosides.

Plants do not have any special excretory organs like those found in animals. Instead, plants use ordinary structures to remove their waste products. These structures are:

1. ***Stomata:*** These are small pores mainly found on the leaves of plants. The stomata allow gases to flow in and out of the tissues of leaves. Waste products such as oxygen (from photosynthesis) and carbon dioxide (from respiration) leave the plant through the stomata. Water vapour is also lost through stomata during transpiration.
2. ***Lenticels:*** These are small openings in the bark of stems and branches. They facilitate the exchange of gases like carbon dioxide, oxygen and water vapour from the inner tissues of the plants to the environment.



Figure 4.40: Lenticels on the Bark of a Tree

3. Leaf fall (abscission): Some plants store waste products in the leaves; when these leaves fall off the plant, the wastes are removed along with them.
4. Old bark: plants that accumulate waste in old bark excrete the waste when the bark peels off.
5. Storage in harmless forms: Some wastes are stored in tissues or structures such as vacuoles until the plant can safely remove or reuse them.

Activity 4.12 Scavenger Hunt and Footnote on Plant Waste Products

Objective: Observe and document three different types of plants, noting their characteristics and visible waste products, and creating visual representations of these plants.

Materials

- Observation journal
- pens, pencils
- plant identification guide (optional)
- coloured pencils or markers

Instructions

1. Go around the school compound search and identify at least three different plants.
2. For each plant, describe its characteristics and any visible waste products in your observation journal.
3. Create detailed sketches of the plants (you can photograph, or draw)
4. Note each sketch with observations about how the plants excrete waste.
5. Present your visual representation to your peers in class.

Importance of Some Plant Wastes and their Modes of Excretion

Plants produce various waste products that may have important uses within the environment. These include

1. **Oxygen (O_2):** It is produced during photosynthesis. It is excreted through stomata and lenticels. This oxygen is vital for respiration in living organisms including plants.
2. **Carbon dioxide (CO_2):** This is produced during respiration. It is excreted through stomata and lenticels. Carbon dioxide is used by the plant for photosynthesis.
3. **Water vapour:** This is lost mainly through transpiration via stomata. Transpiration helps in cooling the plant and transporting minerals from the roots to various parts.
4. **Resins, gums, tannins, and latex:** These are stored in some parts of the plant such as bark, stems, or branches and may be excreted through cracks or injuries. These substances can protect the plant from pests and diseases. For example,
    a. **Gum** (e.g. acacia gum) seals the wound and prevents infection.
    b. **Latex** (e.g. from rubber tree) helps seal damaged areas.
    c. **Resins** deter herbivores and pests.

Table 4.12: Different Types of Plants and How They Excrete Waste Materials

Type of plant	Waste materials	Structures for/ process of waste removal
Herbaceous plants (soft-stemmed plants)	Carbon dioxide, oxygen, water vapour	Diffusion through the stomata
Woody plants (trees and shrubs)	Carbon dioxide, oxygen, water vapour	Diffusion through the stomata and lenticels
	Other wastes	Shedding of leaves and old bark
Aquatic plants (water plants)	Oxygen and carbon dioxide	Diffusion into the surrounding water.
Succulent plants (e.g. cactus)	Crystals, gum	Stores in their tissues
	Water vapour, carbon dioxide and oxygen	Diffusion through the stomata



Figure 4.41: Resin excreted by the bark of a tree



Figure 4.42: Tree gum on a branch

Activity 4.13 Research Report and Infographic Creation

Objective: Investigate a specific plant waste product and explain its significance, excretion method, and ecological role through a visual representation.

Materials

- Access to online resources or library books
- writing materials
- graphic design software or paper
- coloured markers.

Instructions

1. Choose a specific plant waste product (e.g., latex, resin, gum).
2. Research its significance, how the plant excretes it, and its ecological role.
3. Write a report summarising your findings.

4. Create an infographic that visually represents the key points from your research, including the origin, significance, and ecological role of the waste product.
5. Present your report and infographic to the class, highlighting the main insights.

Activity 4.14 Excretion Venn Diagram

Objective: Compare plant and animal excretion methods, highlighting similarities and differences.

Materials

- Paper
- writing tools
- reference materials on excretion methods.

Instructions

1. Research on plants' and animals' excretion methods.
2. Outline the similarities and differences in the excretion methods.
3. Create a Venn diagram that illustrates the differences and similarities between plant and animal excretion.
4. Present your diagram to the class and explain your findings

Activity 4.15 Systems in Sync – Exploring Plant and Animal Life

Objective: To explore and compare plant and animal systems.

Instructions

Note: Your teacher would set up three observation stations for this activity.

Start with the Review Stations

Move around the classroom to visit three stations. Each station focuses on a different system.

1. Station 1 (Year 1): Transport systems in plants and animals
2. Station 2 (Year 2): Respiratory and excretory systems
3. Station 3 (Year 3): Coordination systems (nervous and hormonal)

At each station

a. Read the summary notes and look at the diagrams or models.
b. Write down key points in your notebook, especially differences and similarities between plant and animal systems.

Choose Your Creative Task

Pick one of the following tasks. Choose the one that matches how you learn best.

1. Poster or Infographic: Draw and label a visual comparison of plant and animal systems.
2. Podcast or Skit: Record or perform a short explanation of the systems.
3. 3D Model or Diagram: Build a model using paper, clay, or recycled materials.
4. Comparative Report: Write a short report comparing the systems across the three years.

   Your task must include:

   a. One system from each year (transport, respiration/excretion, coordination)
   b. At least three similarities and three differences.
   c. One real-life example for each system.

Gallery Walk & Peer Feedback

1. Display or present your work.
2. Walk around and look at your classmates' projects.
3. Leave a comment or question on each one using sticky notes or a feedback sheet.

Final Reflection

- In your notebook, write on how plant and animal systems work together to support life.
- Be ready to share your answer in a short class discussion.

EXTENDED READING

- www.webmd.com

- www.my.clevelandclinic.org

- www.byjus.com



- www.healthdor.com



REVIEW QUESTIONS

1. How do flowering plants manage byproducts from metabolic processes?
2. How do habitat destruction and pollution impact the reproductive success of flowering plants?
3. Evaluate common reproductive health issues, such as infertility or sexually transmitted infections (STIs).
4. Discuss the adaptation strategies of flowering plants in arid environments regarding waste management.
5. What are the primary functions of the musculoskeletal system in mammals?
6. Explain how flowering plants support biodiversity in various habitats.
7. Construct a detailed diagram that illustrates the interactions between the respiratory and muscular systems during physical activity. Explain the significance of these interactions.
8. How does the brain control the rate of breathing?
9. Describe the role of hormones in the reproductive process.
10. What role do stomata play in the excretion process of plants?
11. Analyse how the reproductive system interacts with the endocrine system to regulate reproductive functions.
12. Evaluate how sexual reproduction contributes to genetic diversity in flowering plants.
13. How do flowering plants contribute to the food chain?
14. Analyse the relationship between flowering plants and their pollinators. How does this relationship benefit both parties?
15. Develop a comprehensive report on the impact of climate change on respiratory health across populations. Include potential solutions to mitigate these effects.
16. Describe the role of flowering plants in ecosystems.
17. Identify the main structures involved in the reproductive process of flowering plants.
18. Analyse how the musculoskeletal system interacts with the nervous system to coordinate movement.
19. Explain how environmental conditions can affect the success of sexual reproduction in flowering plants.
20. Report on the impact of lifestyle choices (e.g., diet, exercise) on reproductive health. Include evidence-based recommendations for maintaining reproductive health.
21. How is the reproduction of flowering plants interconnected with other life

forms, including animals and microorganisms? What conclusions can you draw from this interconnectedness?

22. Explain the process of fertilisation in flowering plants.
23. How do flowering plants contribute to the food chain?
24. Assess the importance of excretion in maintaining plant health and resilience against stressors.
25. Assess the impact of climate change on flowering plant reproduction.
26. Analyse the economic significance of flowering plants in agriculture and horticulture.
27. Evaluate how the reproduction of flowering plants contributes to soil health and nutrient cycling.
28. Identify the primary waste products that flowering plants need to excrete.
29. Propose a conservation plan aimed at protecting flowering plants and their habitats. What measures would you include to ensure their reproductive success?
30. Discuss the role of haemoglobin in the transport of oxygen and carbon dioxide
31. Evaluate two common musculoskeletal disorders.
32. Outline how muscles and bones work together to produce movement.
33. What is the role of hormones in communicating signals throughout the body?

ANNEXES

ANNEX 1

Mendel's Second Law explained

Genes are found on chromosomes.

During meiosis, chromosomes pair up with their homologous partner and line up along the equator of the cell. They are then pulled apart and migrate to the poles of the cell. The important point here is that each chromosome pair separates independently of the others. Hence ' independent assortment'. This means that if two genes for two different characteristics are found on two different chromosomes, they segregate/separate independently of one another. Mendel was very lucky, because all seven traits he studied had genes which were on the seven different chromosomes which pea plants happen to have. If any two traits had been on the same chromosome, then they would not have segregated independently of one another, and he would have been in deep trouble.

Many genes are on the same chromosomes, of course, and we say they are linked. The only way they might be separated is by a process called crossing over at chiasmata, which occurs during meiosis and produces an almost infinite degree of variation.

Humans have 23 pairs of chromosomes, which means there are over 8 million ways in which they can segregate during meiosis (2 to the power of 23). In pea plants, there are only 128 different ways in which their chromosomes can segregate (2 to the power of 7)

You do not mention linkage or crossing over in your text at all, which is a major omission, and makes the understanding of the Second Law difficult if not impossible, and also omits description of the most important source of genetic variation on the planet.

ANNEX 2

This note below describes the ABO system clearly with reference to why it is and the new concepts of co-dominance and incomplete dominance, which apply.

Sometimes recessive alleles are not totally hidden by dominant alleles and the alleles are then referred to as **incompletely dominant**. In other cases, both alleles have an equal effect on the phenotype of an individual and are described as **co-dominant**. However, the distinction between incompletely dominant alleles and co-dominant alleles is not easy to quantify. Some examples are given below:

Sickle-cell anaemia is a recessive condition in which blood haemoglobin is malformed. Anyone with two 'sickle-cell' alleles suffers from severe sickle-cell anaemia. But anyone with only one 'sickle-cell' allele and one 'normal' allele suffers from a mild form of the disease. This is because only some of the haemoglobin is affected. Interestingly, those with mild sickle-cell anaemia are more resistant to malaria. The disorder is much more common in areas of the world where malaria is endemic (always present) because someone with one 'sickle-cell' allele is more likely to survive a malarial attack than someone without the allele.

Red blood cells have a number of antigenic 'self' protein markers on their surfaces which are important in situations where blood has to be transfused from one person to another. If the protein markers of a donor's blood don't match those of the recipient, the recipient will recognise the donated blood as foreign and attack it with antibodies. Coagulation can then occur and the recipient can die. One such blood group system is the ABO system. The genetics of this system are slightly more complicated because three alleles are involved. They are described as **multiple alleles**. An individual can, of course, have only two of these alleles, one from each parent. Alleles A and B are co-dominant to allele O, which is recessive. The table summarises possible genotypes and phenotypes.

BLOOD GROUPS (PHENOTYPES)	ALLELES (GENOTYPES)
A	AO or AA
B	BO or BB
AB	AB only
O	OO only
(The alleles are sometimes written I^A, I^B, I^0)	

People with blood group A have anti-B antibodies in their **plasma** (blood fluid), so they cannot receive blood from those of blood group B or AB. Likewise, people of blood group B cannot receive blood from those with blood group A or AB. People with blood group O are universal donors because they have no antigenic markers on their red blood cells; those of blood group AB are universal recipients (receivers of blood) because they have no antibodies against red blood cells in their plasma.

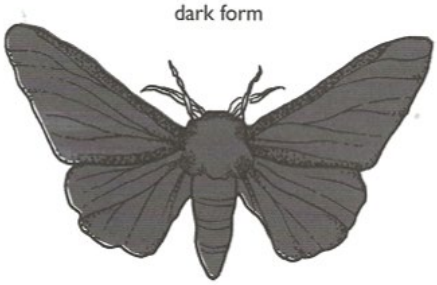
Another blood group system is the **Rhesus system**. Individuals who are Rhesus-positive have an antigenic marker on their cells; those who are Rhesus-negative do not. The allele for the antigenic marker is dominant (see *page 30*).

The peppered moth

light form



dark form



Insects

Many insects are now resistant to insecticides such as DDT, and many house plant pests, such as greenfly, are resistant to house plant insecticides. The peppered moth (*Biston betularia*) is a well-known example of adaptation by an insect to a change in the environment brought about by human activity. The moth is normally a speckled grey in colour. Occasionally a mutation occurs which makes the moth black. Normally, in the countryside, these 'melanic' moths are easily spotted by birds and eaten. As a result, there are never many black moths to be seen. However, with the arrival of the Industrial Revolution two hundred years ago, the environment near the cities was blackened with the soot from millions of chimneys. As a result, the mutant black moths became invisible to the predators and the speckled grey ones were spotted and eaten. Before long, the woodlands near the cities became populated by black moths, rather than grey ones. This is an example of one small step in the evolutionary process which has been witnessed within a short period of time.

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GLOSSARY

Auxins	Plant hormones promoting cell elongation; key in tissue culture.
Bacteriophage	Virus that infects bacteria; used as vectors in genetic engineering.
Biomimetic	Technology/design imitating nature.
Bipedal movement	Walking on two legs.
Bronchitis	Inflammation of bronchi causing coughing and mucus.
Buoyant	Able to float in air or water.
Callus	Undifferentiated plant cells formed in tissue culture.
Cartilage	Flexible connective tissue without blood vessels.
Cleistogamy	Self-fertilisation in unopened flowers.
Coitus	Sexual intercourse.
Congenital	Present from birth.
Costal cartilage	Connects ribs to sternum; allows chest expansion.
Crop	Bird organ for food storage.
Crossing over	Exchange of genetic material during meiosis.
Cytochrome C	Protein used in cellular respiration and evolutionary studies.
Cytokinins	Plant hormones promoting cell division.
Cytosol	Fluid portion of cytoplasm.
Denaturation	PCR step where DNA strands separate.
Dendrites	Neuron extensions receiving signals.
Diaphragm	Main breathing muscle separating chest and abdomen.
Dichogamy	Male and female organs mature at different times.
Dissociate	To separate molecules.
DNA profile	Unique genetic pattern used in forensics.
Drip irrigation	Slow water release near plant roots.
Efficacy	Ability of a substance to produce desired effect.
Emphysema	Lung disease damaging alveoli.
Endemic	Restricted to a specific region or population.
Endocarp	Innermost fruit layer around seeds.
Endonucleases	Enzymes cutting DNA at specific sites.
Epicarp	Outermost fruit layer (skin).

Epigeal germination	Cotyledons emerge above soil.
Epistasis	One gene masks another.
Explant	Plant tissue used in culture.
Expression	Using gene information to make proteins.
Fermentation	Microbial conversion of sugars.
Flocs	Microbial clusters with fungal elements.
Foetus	Human offspring from week 8 to birth.
Galapagos finches	Birds central to Darwin's evolution theory.
Gel electrophoresis	Separates DNA/RNA/proteins by size.
Genetic markers	DNA sequences identifying traits/diseases.
Genetic polymorphism	Multiple forms of a gene in a population.
Genitalia	Reproductive organs.
Gestation	Development period in womb.
Glycolysis	First stage of respiration breaking glucose into pyruvate.
Grafting	Joining plant parts to grow together.
Homoiothermic	Maintaining constant body temperature.
Homologous	Similar in structure/origin.
Hydrocarbons	Molecules of hydrogen and carbon.
Hypogeal germination	Cotyledons stay below soil.
Implantation	Embryo embeds in uterus lining.
Incubation	Controlled environment for growth.
Intercostal muscles	Muscles between ribs aiding breathing.
Invertebrates	Animals without backbones.
Isomers	Same formula, different structures.
Karyokinesis	Nuclear division in cell division.
Lactose	Milk sugar.
Layering	Plant propagation by rooting attached stems.
Ligation	Joining DNA fragments.
Locus	Gene's position on a chromosome.
Low grade ore	Ore with little metal content.
Lymph	Fluid aiding immunity.
Manubrium	Upper sternum section.
Menopause	End of menstruation.
Meristem	Plant tissue with dividing cells.
Mesocarp	Middle fruit layer.
Metabolise	Break down substances for energy.
Metabolism	All chemical reactions in an organism.
Microbiota	Microorganism community in an environment.
Motility	Ability to move.

Mucous	Protective slimy secretion.
Neurotransmitters	Chemicals transmitting nerve signals.
Ore	Mineral-rich rock for extraction.
Oviparity	Laying eggs externally.
Ovoviviparity	Eggs develop inside mother; live birth.
Parthenogenesis	Asexual reproduction from unfertilised egg.
Parturition	Giving birth.
Patent	Legal right to an invention.
Pelvic bones	Bones forming pelvis.
Photoperiod	Duration of daily light exposure.
Pitching	Fish head moves up/down.
Placenta	Organ connecting foetus to mother.
Plankton	Microscopic drifting organisms.
Plantlets	Young plants from tissue culture.
Plaque	Bacterial buildup or historical marker.
Plasmid	Circular bacterial DNA used as vector.
PCR	Technique to amplify DNA.
Potency	Strength of a substance's effect.
Primers	Short DNA sequences starting PCR synthesis.
Probiotics	Beneficial live microorganisms.
Pyrolysis	Heating organic matter without oxygen.
Quarantine	Isolation to prevent disease spread.
Relic	Historic object or remains.
Respirator	Device aiding breathing.
Rolling	Fish rotates around its axis.
Rotifers	Microscopic aquatic animals.
Saturation	Degree of oxygen bound to haemoglobin.
Secrete	Release substances from cells.
Segregation	Separation of alleles during gamete formation.
Sinuses	Air-filled skull cavities.
Sister chromatids	Identical DNA copies formed in division.
Sludge	Thick waste material.
Solarisation	Using sunlight for soil pest control.
Somatic	Relating to body cells.
Speciation	Formation of new species.
Sputum	Mucus coughed from lungs.
Starter culture	Microorganisms used to begin fermentation.
Sternum	Breastbone.
Surveillance	Close monitoring or observation.
Symbiotic	Long-term interaction between species.
Synergids	Cells guiding pollen tube to egg.

Transesterification	Producing biodiesel from fats.
Transfection	Introducing foreign DNA into cells.
Transformation	Bacterial uptake of foreign DNA.
Vector	Vehicle carrying DNA into cells.
Vertebrae	Bones of the spine.
Viviparity	Live birth after internal development.
Xiphoid process	Lower part of sternum.
Yawing	Turning left or right in horizontal plane.
Zygomorphic	Bilaterally symmetrical flowers.

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This book is intended to be used for the Year Three 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' self-study 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.

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