KURIKULUM STANDARD SEKOLAH MENENGAH

BIOLOGY FORM 4

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Preface

This textbook has been written based on the *Dokumen Standard Kurikulum dan Pentaksiran* (DSKP) for Biology Form 4, published by the Ministry of Education, Malaysia. It is guided by the concepts of Scientific Skills, Science Process Skills, Higher Order Thinking Skills, 21st Century Skills and the STEM teaching and learning approach. The objective of this textbook is to develop well-rounded pupils and to equip them with the skills needed for the 21st century.

Special features of this book:

Biological Lense
Additional information related to theories and concepts

Our World of Biology
Illustrates the application of theories and concepts learnt in everyday life

Brainstorm!
Challenges pupils to think critically and creatively

Malaysian Innovation
The successes of Malaysian scientists and the related scientific and technological developments in Malaysia

Millennial Career
Describes careers related to a concept or topic

STEM Bulletin
Highlights current developments in the related fields of science and technology

Across the Fields
Shows the connection between biology and other fields

Activity Zone
Suggested activities for pupils to carry out

Higher-order thinking questions which cover applying, analysing, evaluating and creating questions

Take Note!
Reminders for students when carrying out activities or experiments

Formative Practice
Questions to test pupils' understanding at the end of every subtopic

Summative Practice
Questions to test pupils' understanding at the end of every chapter

Summary
A summary of the main concepts

Self Reflection
A checklist on the mastery of concepts for pupils' reference

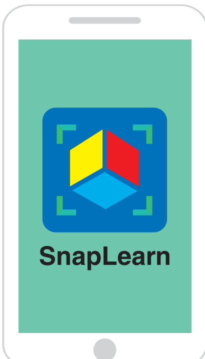
4.2.3
Learning Standard based on the Form 4 Biology *Dokumen Standard Kurikulum dan Pentaksiran* (DSKP)

A Fun Learning Experience

This book consists of digital resources in the form of Augmented Reality (AR) and QR codes. These resources can be accessed by scanning the AR or QR codes which can be found in selected pages, using a smartphone or electronic tablet.

Steps in accessing the AR resources

1



App Store Google Play

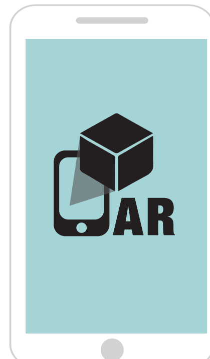
iOS 7.0 or Android 4.0 and above

Download the ***SnapLearn*** app onto your electronic device.

2

Click on the button and scan the above code.

3



Scan the pages with the above icon to access the AR resources.

Accessing the QR resources

A variety of complementary content such as videos, additional activities, quizzes and additional information can be accessed by scanning the QR codes found in selected pages using any QR code scanner.

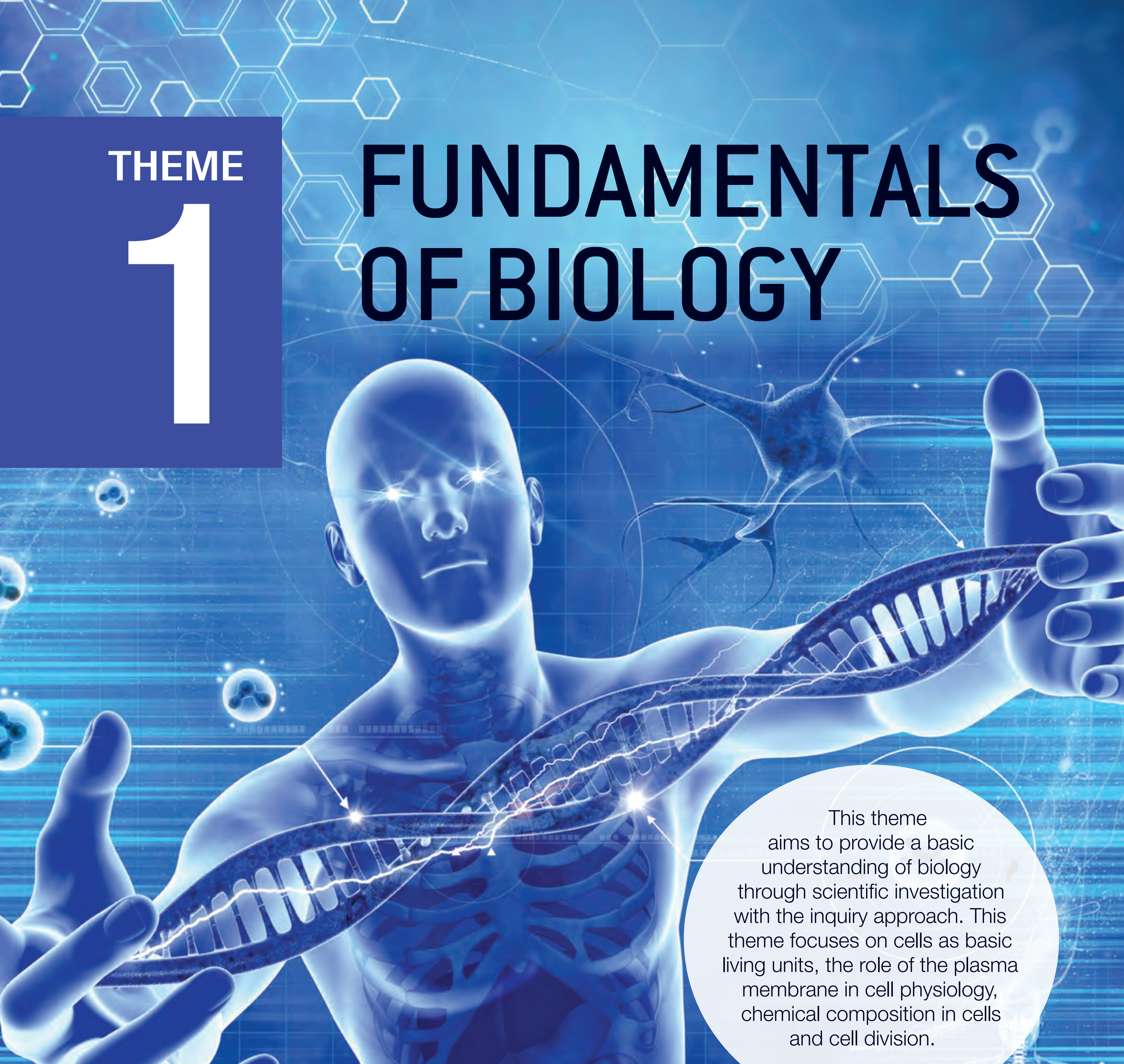
ICT 4.4
Quiz: Test your understanding of lipids

ICT 7.1
Video: Aerobic respiration

ICT 10.1
Activity: Studying the effects of changes in total surface area to volume ratio (TSA/V) on diffusion rate.

THEME 1

FUNDAMENTALS OF BIOLOGY



This theme aims to provide a basic understanding of biology through scientific investigation with the inquiry approach. This theme focuses on cells as basic living units, the role of the plasma membrane in cell physiology, chemical composition in cells and cell division.

CHAPTER

1 Introduction to Biology and Laboratory Rules

What are the effects of the Industrial Revolution 4.0 on the fields of biology?

Do You KNOW...

- What does biology mean?
- What are the fields of study in biology?
- What type of careers can you pursue in the fields of biology?
- What are the safety equipment and rules in a biology laboratory?
- How do you communicate in the fields of biology?
- How is knowledge gained through scientific investigation?

1.1 Fields and Careers in Biology

- **1.1.1** State the meaning of biology.
- **1.1.2** List the fields of study in biology, careers and development in related fields.
- **1.1.3** Generate ideas about development in biology fields and contribution of technology in biology to humans.
- **1.1.4** Give examples of careers related to the fields of biology.

1.2 Safety and Rules in Biology Laboratory

- **1.2.1** Explain self protective equipment and their functions.
- **1.2.2** Identify and justify substances that can be disposed into the sink.
- **1.2.3** Identify and justify substances that cannot be disposed into the sink.
- **1.2.4** Describe methods in managing biological wastes.
- **1.2.5** Communicate about steps to manage accidents in a laboratory.
- **1.2.6** Conclude safety practices in a biology laboratory.

1.3 Communicating in Biology

- **1.3.1** Communicate by constructing tables based on experimental data.
- **1.3.2** Plot a suitable graph based on the data from an experiment.
- **1.3.3** Sketch biological drawings based on observations.
- **1.3.4** Identify body planes, sections and directional terms in organisms.

1.4 Scientific Investigation in Biology

- **1.4.1** Design an experiment to solve a problem using scientific investigation methods.

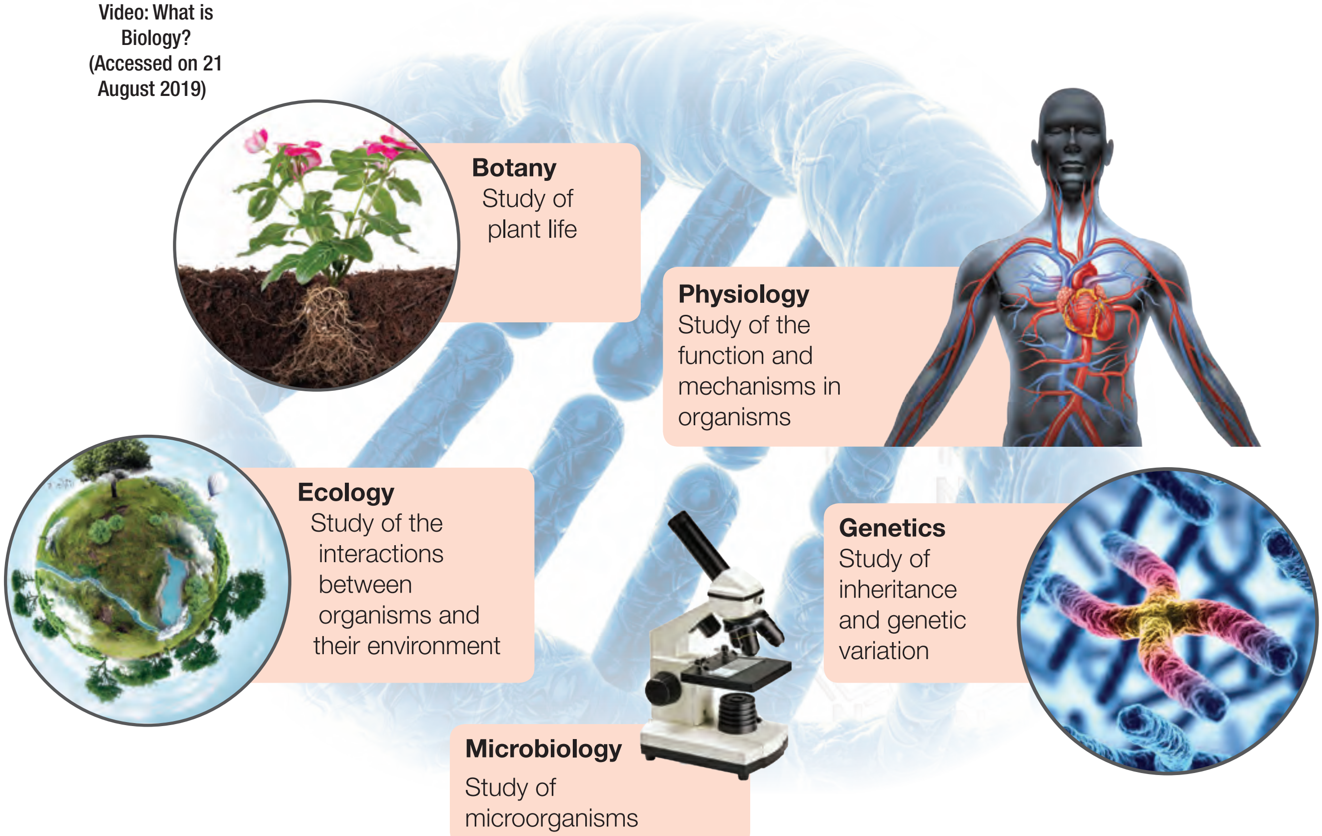
1.1 Fields and Careers in Biology

What is Biology?

The word 'Biology' comes from the Greek word, 'bios' meaning life, and 'logos' meaning study. **Biology** is a detailed study of living things in the natural environment. Biology allows us to understand the structure and function of organisms, as well as the relationships and interactions between organisms with their environment. Some examples of biological study areas are shown below in Photograph 1.1.

ICT 1.1

Video: What is Biology? (Accessed on 21 August 2019)



PHOTOGRAPH 1.1 Examples of biological research areas

Biological Lens

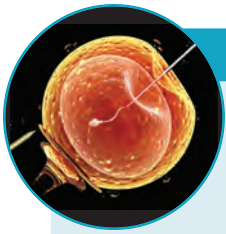
The three-dimensional (3D) bioprinting technique is used to print and form artificial tissues and assist in the field of modern medical engineering.

Malaysian Innovation

One of Malaysia's success in technological innovation is the production of biological scaffold derived from shellfish for use in dental treatment. Technological innovation in Malaysia is spearheaded by researchers from public and private universities and research institutions.

The contribution of biology in everyday life

Biological knowledge has contributed a lot to mankind. Here are some examples of how biology has contributed to everyday life (Photograph 1.2).



MEDICAL

In vitro fertilisation, family planning, plastic surgery and gene therapy.

PHARMACEUTICAL

Production of synthetic vitamins, vaccines, insulin and synthetic enzymes.

FOOD PRODUCTION

Use of microorganisms in the production of cheese, soy sauce, tapai and tempe.

AGRICULTURE

Transgenic crops and animals, hydroponic and aeroponic technology.

PHOTOGRAPH 1.2 Contribution of biology in everyday life

Careers in Biology

PHOTOGRAPH 1.3 Careers in biology

Formative Practice 1.1

1. What does biology mean?
2. List three fields of biology and the development in those fields.
3. Choose one development in the field of biology and discuss its contributions to humans.
4. Name five careers that are related to the fields of biology.

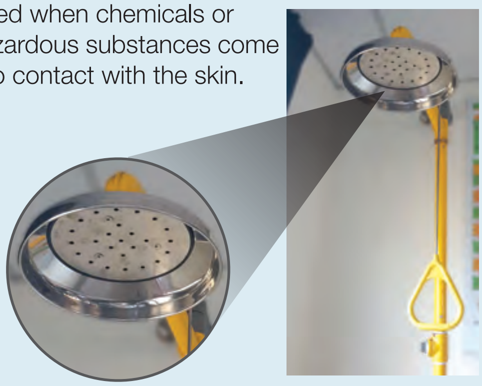
1.1.3 1.1.4

1.2 Safety and Rules in Biology Laboratory

A biology laboratory is essential for conducting scientific investigations. To avoid unwanted incidences, we must always adhere to the safety rules and measures in a biology laboratory. We must also know the personal protective equipment and understand their functions.

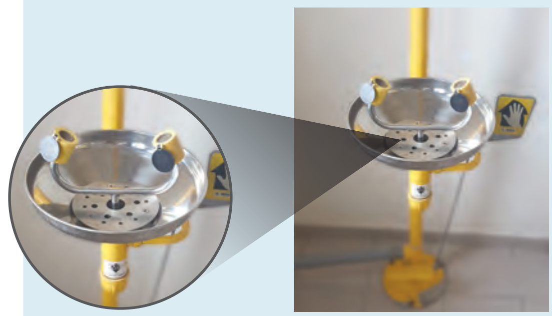
EMERGENCY SHOWER STATION

Used when chemicals or hazardous substances come into contact with the skin.



EYE WASH STATION

Used to wash the eyes when exposed to chemicals or hazardous substances.



FUME HOOD

To avoid breathing in hazardous gases like chlorine, bromine and nitrogen dioxide.

LAMINAR FLOW CABINET

Provides a flow of filtered air for a clean work area in the laminar flow cabinet.

BIOLOGICAL SAFETY CABINET

Provides an enclosed work space to study materials that have been (or are likely to have been) contaminated by pathogens.

PHOTOGRAPH 1.4 Equipment and their functions in a biology laboratory

1.2.1

Brainstorm!

Why can certain substances be disposed into the sink?

Substances that can be disposed into the sink

- Chemicals with pH values 5–9
- Low concentration liquids and solutions that are harmless to users (sucrose solution, dye solution, distilled water)

Substances that cannot be disposed into the sink

- Organic solvents (acetone, alcohol, benzene)
- Substances that have a pH value of less than 5 or more than 9
- Chemicals (acids, greases, oils)
- Solid waste (chemicals, glass, rubber)
- Heavy metals (mercury)
- Volatile substances
- Toxic substances
- Organic waste (microorganisms, carcases)
- Reactive substances
- Radioactive substances

Brainstorm!

Why can't certain substances be disposed into the sink?

PHOTOGRAPH 1.5 Personal protective equipment and their functions in the biology laboratory

1.2.1 1.2.2 1.2.3

Methods for managing biological waste

After carrying out an experiment, there are wastes that need to be managed with care before disposal. Methods for managing different biological wastes according to Standard Operating Procedures are listed in Table 1.1.

TABLE 1.1 Methods for managing biological waste (Photograph 1.6)

Biological waste categories	Example	Management method
Category A (sharp wastes)	Sharp instruments such as syringes, needles, glass, scalpel and other sharp instruments that can cause injuries	Placed into a special bin for sharp material disposal. This bin does not need to be sterilised.
Category B (non-sharp wastes)	Biological solid waste such as gloves, tissue papers, petri dishes, plastic culture containers and hardened agar	Packed first in autoclave resistant **biohazard plastic bags**, sterilised in an autoclave for decontamination, and then placed into a **biohazard bin** (Photograph 1.6). Biohazard plastic bags cannot be thrown into regular waste baskets.
Category C (animal carcases)	Animal carcases, organs and tissues	Wrapped carefully in absorbent material (such as tissue papers), packed carefully into a biohazard plastic bag and **frozen**.
Category D (liquids)	Broth culture and liquid medium such as blood	All biological liquid waste must be decontaminated by autoclaving before disposal. Sterilised biological liquid wastes must be disposed immediately.

Take Note!

- Decontamination by autoclaving is done at a temperature of 121°C and pressurised at 15 psi for 20 minutes.
- Biohazard plastic bags that have been sterilised in an autoclave and sharp waste bin must be stored temporarily in a controlled storage place until the scheduled time for disposal.

PHOTOGRAPH 1.6 Equipment to manage biological wastes

1.2.4

Accidents in the laboratory

Accidents in laboratories can be caused by carelessness, negligence or lack of skill in carrying out experiments. Here are the steps in managing accidents in laboratories.

STEPS TO HANDLE GENERAL CHEMICAL SPILLS

1. Inform your teacher.
2. Declare the spill area as a restricted zone.
3. Prevent the chemical spill from spreading using sand.
4. Scoop up the chemical spill using appropriate equipment.
5. Dispose it safely.

PHOTOGRAPH 1.7 Chemical spills are stopped from spreading by using sand

STEPS TO HANDLE MERCURY SPILLS

1. Inform your teacher.
2. Declare the spill area as a restricted zone.
3. Sprinkle sulphur to cover the mercury spills.
4. Call the fire and rescue department.

Practices in a biology laboratory

The biology laboratory is a place for learning and research. However, there are some general safety rules that must always be practised by pupils.

Activity Zone

Find information on handling accidents in laboratories set by the following agencies:
(i) *Malaysian Biosafety and Biosecurity Association* (MBBA).
(ii) *National Institute of Occupational Safety and Health* (NIOSH).

CLOTHING ETHICS

Use a lab coat, gloves, safety shoes and goggles when appropriate.

LABORATORY SAFETY RULES

- Do not work alone in the laboratory without supervision.
- Wash your hands after conducting an experiment.
- Do not bring in irrelevant items into the laboratory.
- Clean your workstation using disinfectant.
- Dispose wastes according to the set procedures.
- Do not eat and drink in the laboratory.
- Identify all safety symbols on substances and equipment before use.

SAFETY MEASURES FOR FIRES

- Stop work immediately and switch off all nearby power sources. Unplug appliances.
- Exit the laboratory according to the emergency exit plan.
- Call the fire and rescue department.
- Do not panic and stay calm.
- Do not turn back to collect your belongings.
- Assemble at the assembly point.

1.2.5 1.2.6

HANDLING GLASS AND CHEMICALS

- Be cautious when handling hot glassware.
- Report any damaged equipment or glassware to teachers immediately.
- Keep flammable chemicals away from fire sources.
- Do not touch, taste and smell chemicals directly.

HANDLING LIVE SPECIMENS

- Use appropriate gloves when handling biological specimens.
- Specimens that are not harmful and have been dissected should be buried or frozen.
- Wash hands with antiseptic detergents before and after experiments.
- All surfaces and workstations should be cleaned with disinfectant before leaving the lab.

EMERGENCY HELP

The following procedures should be followed in the event of an accident:

- Inform your teacher.
- Call the fire and rescue emergency number.
- Remove the victim from the scene.
- Give emergency treatment.
- Make the place of accident as a restricted area.

Scientific Attitudes and Noble Values

Scientific attitudes and noble value practices when carrying out a scientific investigation:

- **Having interest** and **curiosity** towards the environment.
- **Being honest** and **accurate** in recording and validating data.
- **Being diligent** and **persevering** in carrying out a study.
- **Being responsible** about the safety of oneself, others and the environment.
- **Appreciating** and **practising** clean and healthy living.
- **Appreciate** the contributions of science and technology.
- Think **critically** and **analytically**.

Formative Practice 1.2

1. State three examples of personal protective equipment in the lab and their functions.
2. After conducting an experiment, you are given a task to manage the disposal of Category B biological waste (non-sharp wastes). Think of the best way so that the biological waste does not affect the environment.
3. An accident has occurred in the laboratory involving mercury spills. Explain the steps in handling the mercury spills.
4. Chemicals must be handled with care to avoid unwanted accidents. List steps for proper handling of chemicals.

1.3 Communicating in Biology

Biologists who conduct research need to communicate their research findings. Communication in biology involves tables, graphs and biological drawings.

Tables

ICT 1.2

Video: How to draw a graph (Accessed on 21 August 2019)

Tables are used to record and present data. When you conduct an investigation, the experimental data needs to be recorded in a suitable table. A table allows you to organise data systematically for easy comparison.

The headings in the table consist of the manipulated variable and the responding variable with the respective unit.

a. The manipulated variable is placed in the column on the left side.

b. The responding variable is placed in the column on the right side.

Table 1.2 shows an example of a table in an experiment on the effects of different temperatures (manipulated variable) on the volume of oxygen (O_2) released by aquatic plants (responding variable).

TABLE 1.2 Volume of oxygen released by aquatic plants at different temperatures

Temperature (°C)	Volume of oxygen released (cm^3)
30	2.0
40	14.0
50	12.0
60	6.0
70	3.0

Graph

The relationship between the manipulated variable and responding variable can be illustrated in the form of a graph. There are several types of graphs such as line graphs, bar charts and histograms. The line graph shown in Figure 1.1 is based on the data in Table 1.2.

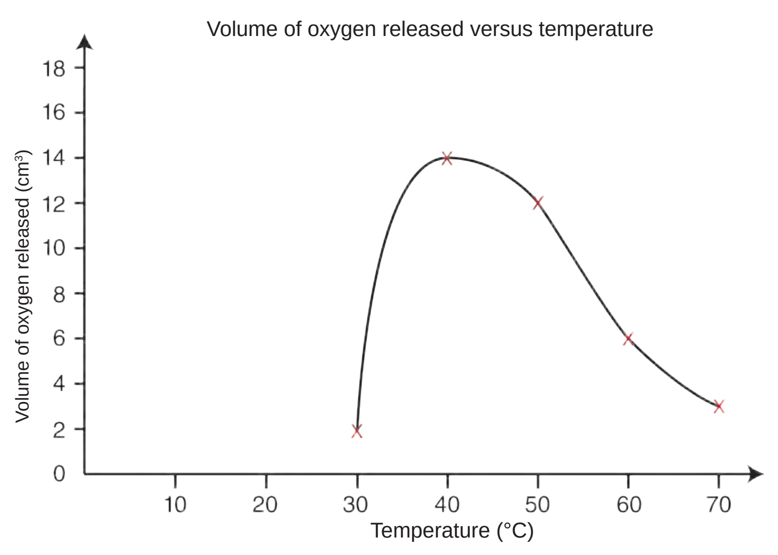


FIGURE 1.1 Example of a line graph

GENERAL METHOD OF DRAWING A GRAPH

- The responding variable is represented by the vertical axis (y-axis) and the manipulated variable is represented by the horizontal axis (x-axis).
- The scaling on the axis must be uniform.
- Mark the points with an appropriate symbol such as 'x'.
- Title the graph: "Graph (responding variable) versus (manipulated variable)".

1.3.1 1.3.2

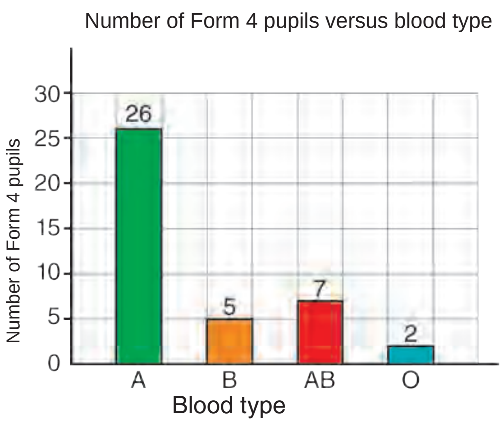


FIGURE 1.2 Example of a bar chart

Take Note!

The graph title must be written as "<Y-axis label> versus <X-axis label>".

A histogram shows the visual distribution of data and the frequency of a value in a data set.

METHOD OF DRAWING A HISTOGRAM

- Draw two axes where the horizontal axis/X represents the data that has been divided into groups according to the appropriate range while the vertical axis/Y shows the frequency.
- Insert labels and units on the axes.
- The size or width of the bars must be the same for all class gap with no spacing between the bars.

A bar chart presents data using vertical bars that are not attached to each other.

METHOD OF DRAWING A BAR CHART

- Draw two axes, the horizontal axis/X to represent the manipulated variable and the vertical axis/Y to represent the responding variable.
- Each width of the bar needs to be uniform.
- The bar height depends on the frequency of the data.
- Bar charts are used to make comparisons between two or more items at a time.

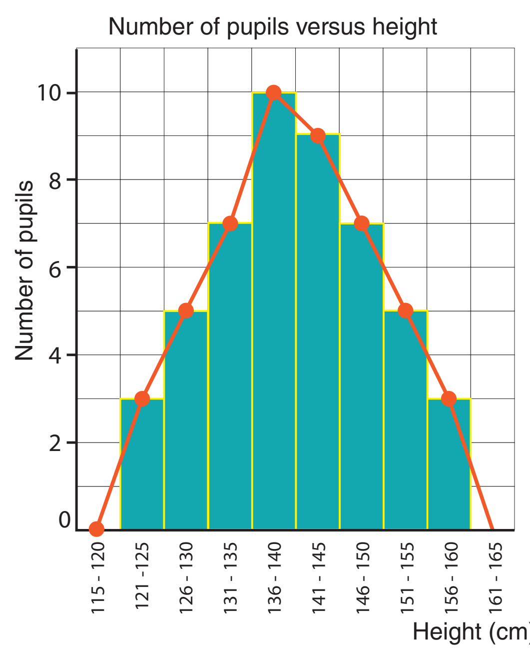


FIGURE 1.3 Example of a histogram

Biological drawings

Biological drawings must be exact to give an accurate representation of an observed specimen.

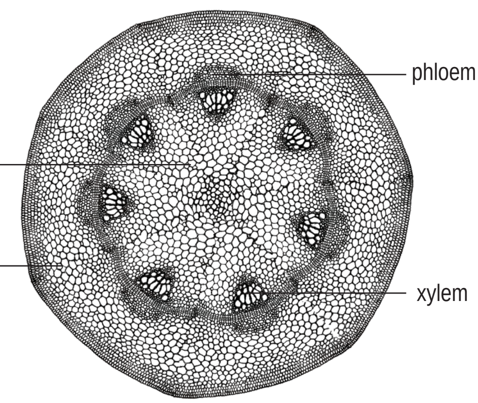
Characteristics of biological drawings

- Large and accurate; use a sharp pencil and not a colour pencil or pen.
- Not shaded artistically.
- Lines drawn must be clear, clean and continuous. Do not use a ruler to draw the outline of a specimen.

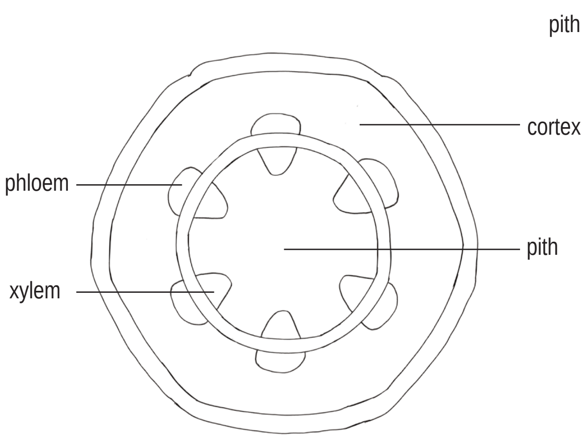
- Drawings must be labelled. Label lines must point to the correct structure, no arrowheads, must be straight and not cross each other.
- Drawings must have titles.
- Each structure in the drawing must be placed in the correct position, and its size should be proportionate to the rest of the structures.
- **A plan drawing** is a line drawing that shows the outline of a structure.
- **A detailed drawing** shows the cells in a structure.
- **The magnification factor** of a drawing must be stated, for example:

$$\frac{\text{Length of drawing in cm}}{\text{Length of specimen in cm}} = \frac{2.4}{1.2} = 2x$$

Therefore, the magnification factor is 2x.



(b) Detailed drawing



(a) Plan drawing

FIGURE 1.4 Example of (a) plan drawing and (b) detailed drawing of cross section of dicotyledon stem

Plane, section and direction

In biology, research and observation of an organism's structure are done based on the **plane**, **section** and **direction**. The **plane** refers to a flat surface of shadow passing through the body. There are three main planes used (Figure 1.5):

- **sagittal plane** (divides the body into right and left parts)
- **frontal plane** (divides the body into frontal and rear parts)
- **horizontal plane** (divides the body into upper and lower parts)

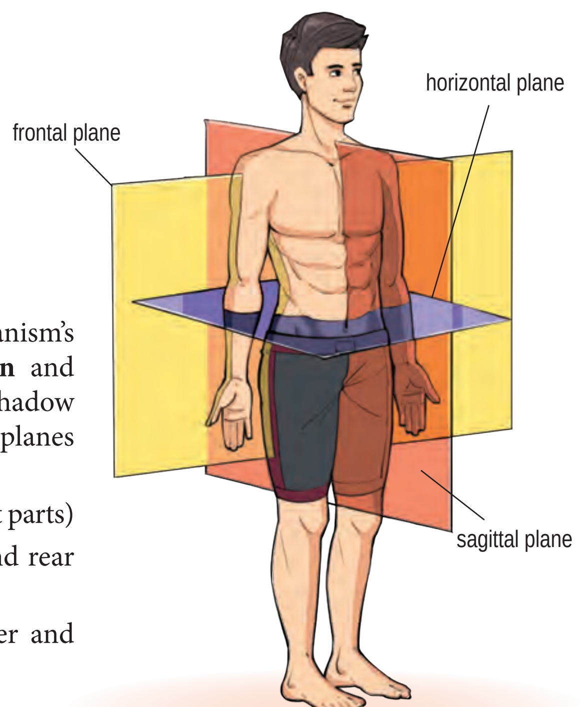
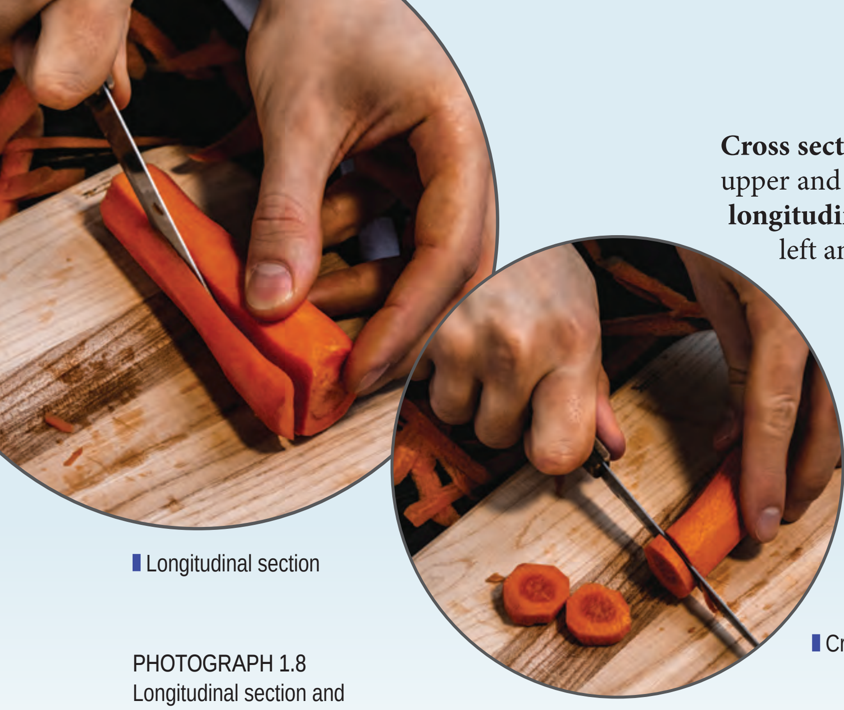


FIGURE 1.5 Sagittal, frontal and horizontal planes

Cross section divides the structure into upper and lower portions horizontally while **longitudinal section** divides the structure into left and right portions (Photograph 1.8).



PHOTOGRAPH 1.8 Longitudinal section and cross section of a red carrot

Many anatomical drawings of animals and plants need to be labelled with direction. All vertebrates have the same fundamental body plan that is symmetrical. Direction consists of **anterior**, **ventral**, **posterior**, **dorsal**, **superior**, **inferior** and **lateral**. By studying anatomical directions in biology, you can identify the orientation of the vertebrate that is stated.

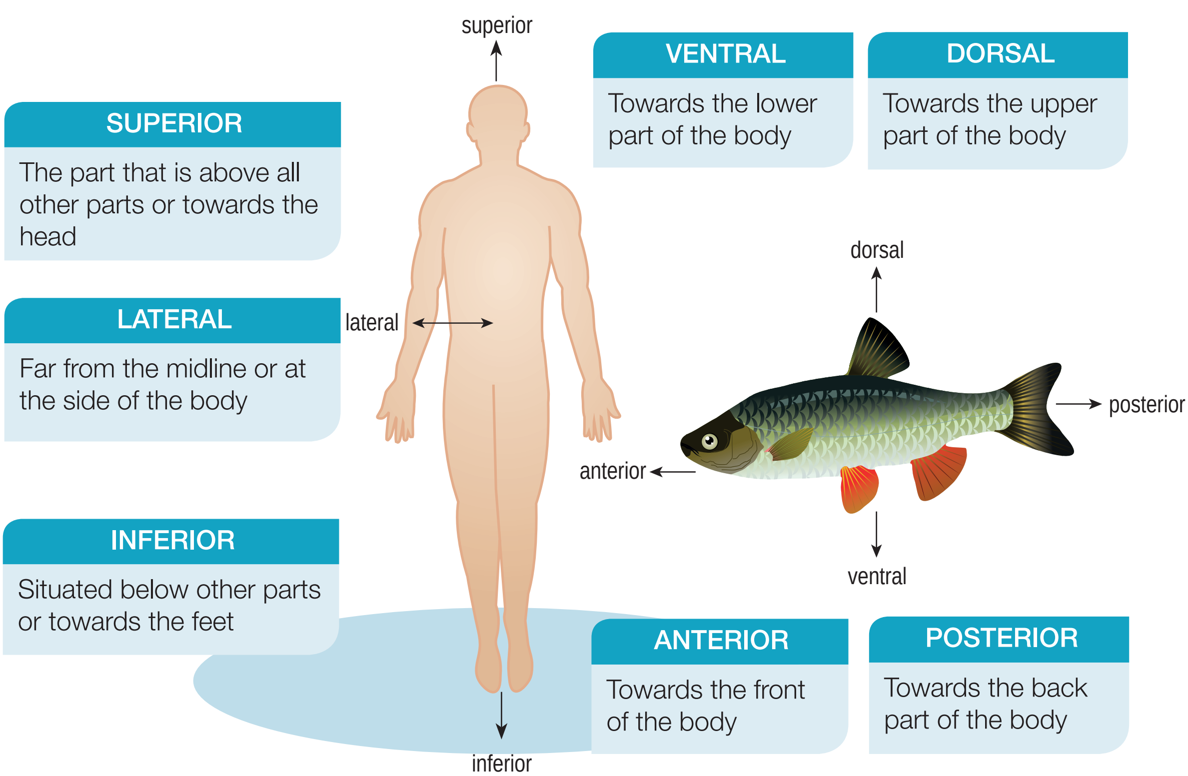


FIGURE 1.6 Directional terms in biology

1.4 Scientific Investigation in Biology

Scientific investigations prove the validity of a hypothesis that has been made. The following are the steps in carrying out a scientific investigation.

1. Identifying problems that can be tested using a scientific investigation
2. Forming a hypothesis
3. Identifying and controlling variables and data collection method
4. Planning and carrying out a scientific investigation
5. Collecting data
6. Interpreting data and results through scientific reasoning
7. Forming a conclusion
8. Writing a report

After you have completed the experiment, you need to write a report to prove that you have conducted the experiment. If a report is not written, your experiment will be invalid. Here is an example of an experimental report framework.

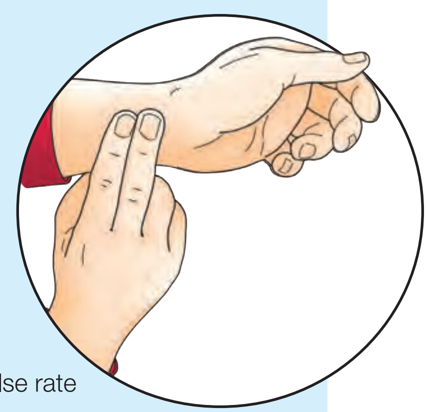
Activity 1.1 Studying the effects of an activity on a pupil's pulse rate

Experiment

Problem statement
What is the effect of a vigorous activity on the pupil's pulse rate?

Hypothesis
The pupil's pulse rate increases after a vigorous activity.

Variables
Manipulated: Vigorous activity
Responding: Pupil's pulse rate
Fixed: Pupil



Measuring pulse rate

Materials and apparatus
Stopwatch

Specimen
Pupil

Procedure
1. Count the pupil's pulse for one minute before carrying out the activity.
2. The pulse is counted by placing two fingers on the wrist.
3. The pupil is asked to carry out a vigorous activity for three minutes.
4. After the vigorous activity is carried out, count the pupil's pulse again for one minute.
5. Record the results in the following table.

Results

Pupil	Pulse rate (number of pulse beats per minute)	
	Before the vigorous activity	After the vigorous activity
A		
B		

Take Note!

Make sure the pupil is seated quietly when the pulse rate is taken.

Take Note!

Make sure pupils with health issues such as breathing and cardiovascular problems do not take part in this activity.

Discussion

1 State the relationship between the pupil's pulse rate with vigorous activity.
2 Explain why the pulse rate increases after doing a vigorous activity.

Conclusion

Based on the results, state if the hypothesis can be accepted or rejected.

Report

Prepare a complete report based on the experiment that was carried out.

Formative Practice 1.3

1 The table below shows the results of an experiment to study the effects of substrate concentration on biochemical reactions.

Test tube	Starch concentration (%)	Time to complete starch hydrolysis (minute)	Rate of hydrolysis of starch (% minute^{-1})
A	1.0	2.5	0.4
B	2.0	3.0	0.7
C	3.0	3.5	0.9
D	4.0	4.0	1.0

(a) Based on the table above, identify the manipulated variable and responding variable.
(b) Draw a graph of rate of starch hydrolysis versus starch concentration using the correct scale and units.

2 State five characteristics that a biological drawing must have.
3 State the three main planes that are used for observation of the structure of an organism.
4 List the steps in a scientific investigation.

Summary

INTRODUCTION TO BIOLOGY AND LABORATORY RULES

Fields and Careers in Biology

- Meaning of biology
- Developments in biology
- Contribution of biology in life
- Careers in biology

Safety and Rules in the Biology Laboratory

- Personal protective equipment and their functions
- Methods of managing biological wastes
- Safety practices in the biology laboratory

Communicating in Biology

- Tables
- Graphs
- Bar charts
- Histograms
- Biological drawings
- Planes, sections and directions

Scientific Investigation in Biology

Steps in a scientific investigation

Self Reflection

Have you mastered the following concepts?

- Meaning of biology
- Areas of study in biology, careers and progress in the related fields
- Development in the fields of biology and contribution of biological technology to humans
- Careers related to biology
- Personal protective equipment and their functions
- Substances that can be disposed into the sink
- Substances that cannot be disposed into the sink
- Methods of managing biological waste
- Steps to manage accidents in the laboratory
- Practices in a biology laboratory
- Tables based on data from experiments conducted
- Appropriate graphs based on data from experiments conducted
- Biological drawings based on observations made
- Body planes, sections and directional terminology in organisms
- Experiment to solve problems using the scientific investigation method

Summative Practice 1

1 Why are you not allowed to wear slippers while in the laboratory?

2 Give the meaning of
   (a) cross section
   (b) longitudinal section

3 Discuss methods of biological waste management.

4 Describe the stages involved in a scientific investigation.

5 (a) An experiment was conducted to demonstrate the hydrolysis of starch by the amylase enzyme. Experiment apparatus provided are as in Figure 1. After an hour, samples from each test tube were tested using iodine test.

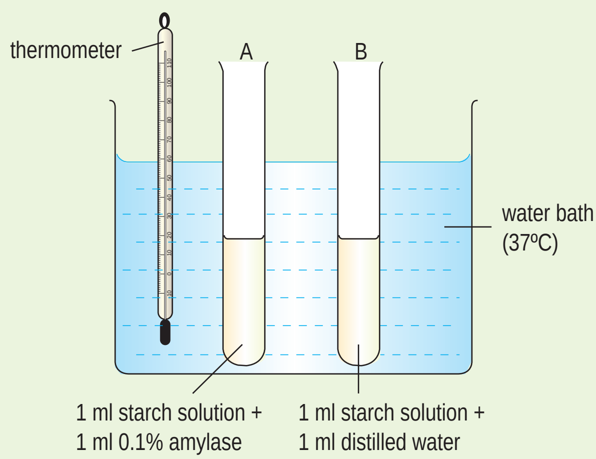


FIGURE 1

   (i) Identify the problem statement for this experiment.
   (ii) State the appropriate hypothesis for this experiment.
   (iii) Identify the manipulated variable, responding variable and constant variable.

   (b) A pupil spilled hydrochloric acid while conducting an experiment. What action should be taken by the pupil?

Essay Questions

6

FIGURE 2

(a) Figure 2 shows an accident in a biology laboratory due to two pupils playing with fire while conducting an experiment. The accident caused one of the boys' shirt to catch fire. Explain what the victim's friend should do.

(b) Azlin is conducting an experiment involving the use of a thermometer. Accidentally, she drops the thermometer on the floor and the thermometer breaks. What steps does Azlin need to take in handling the spilled mercury waste? Explain your answer.

(c) Plan an experiment to study the effect of sugar on the growth of yeast.

Enrichment

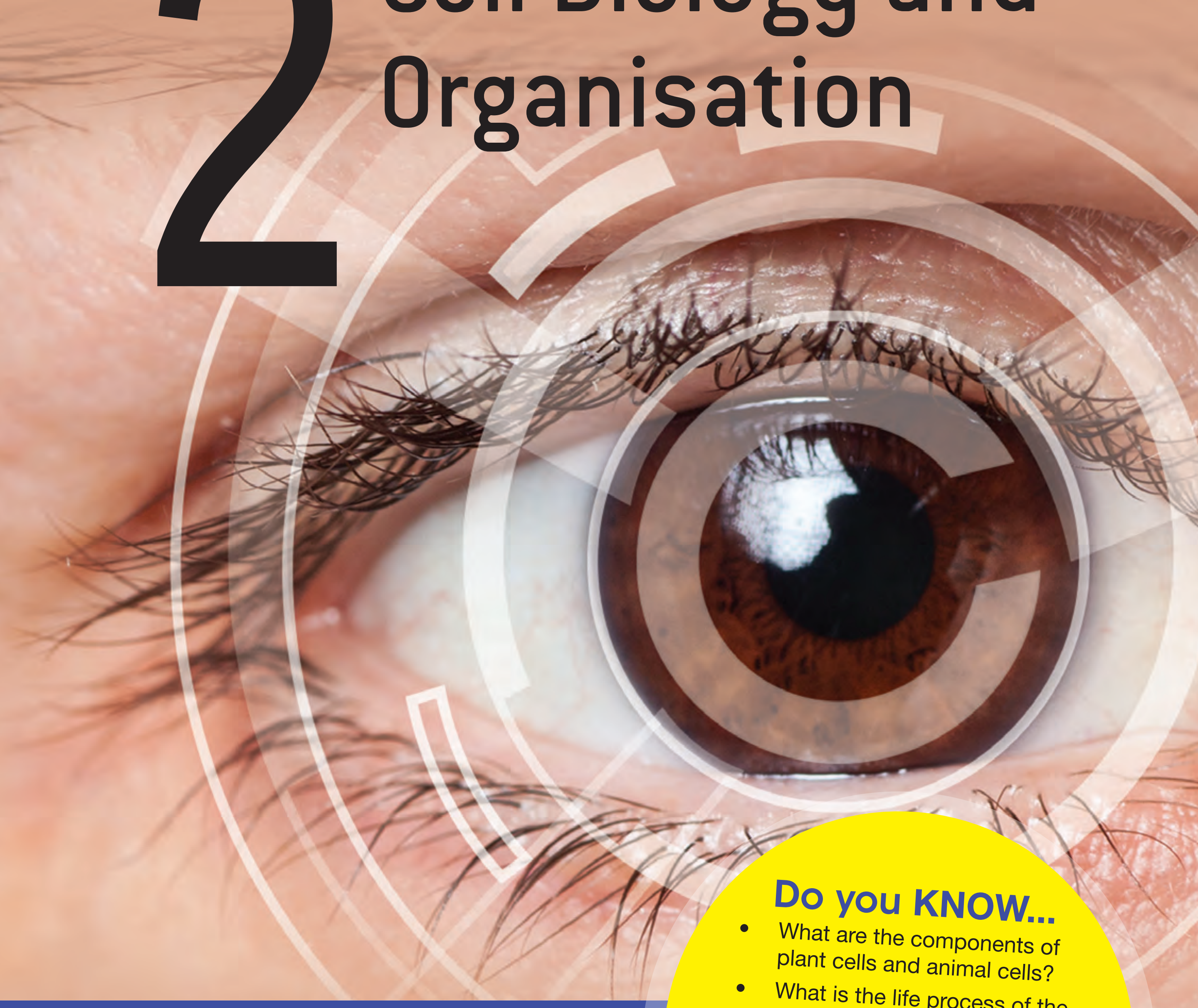
7 The emergence of Industrial Revolution 4.0 has begun to change the way we work and the way we live. Various industries are experiencing drastic changes and at the same time transforming jobs related to those industries. In your opinion, what is the effect of the Industrial Revolution 4.0 to everyday life? Justify your opinion.

8 If you are given an assignment by your teacher to collect information on the development of tissue culture technique in Malaysia, suggest the steps that need to be taken to complete your assignment.

Complete answers are available by scanning the QR code provided

CHAPTER

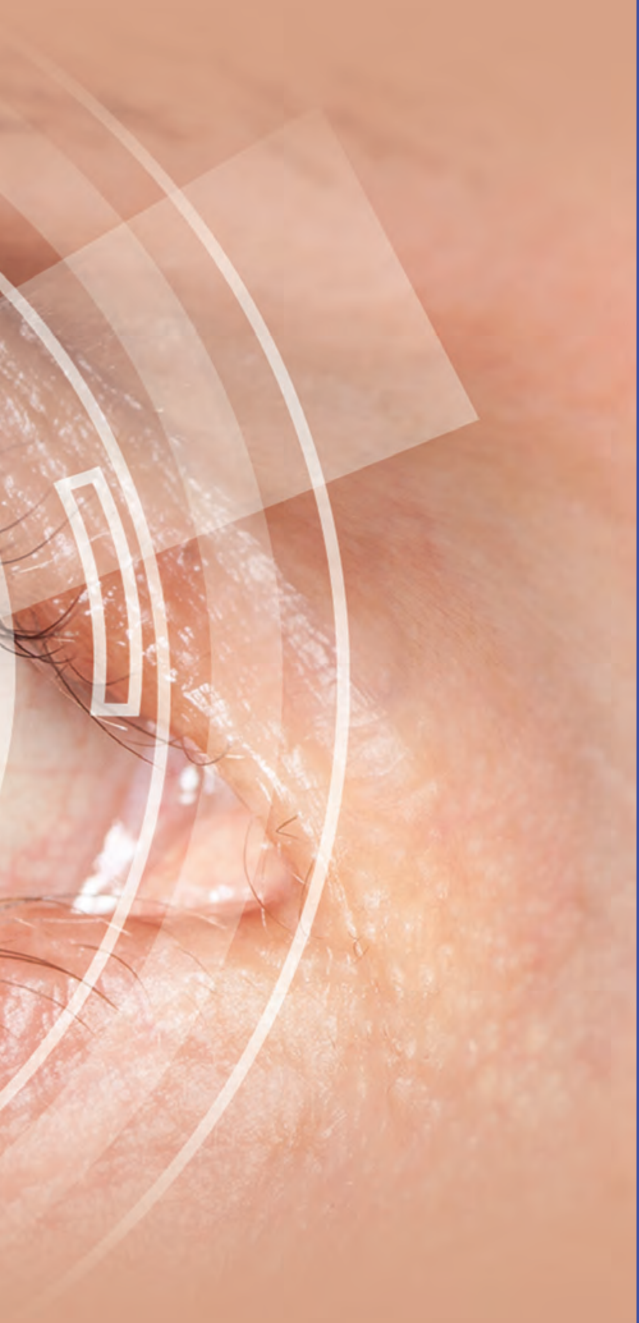
2 Cell Biology and Organisation



Do you KNOW...

- What are the components of plant cells and animal cells?
- What is the life process of the unicellular organism?
- What is the relationship between specialised cell structures and their functions?
- What are the levels of organisation in multicellular organisms?

Which cell has the longest life span?



2.1 Cell Structure and Function

- **2.1.1** Prepare microscope slides of animal and plant cells.
- **2.1.2** Identify the structures of animal and plant cells based on observations through a light microscope.
- **2.1.3** Analyse the components of animal and plant cells as seen on micrographs.
- **2.1.4** State the main functions of components of animal and plant cells as seen on micrographs.
- **2.1.5** Compare and contrast components of animal and plant cells.

2.2 Living Processes in Unicellular Organisms

- **2.2.1** Conceptualise living processes in unicellular organisms such as *Amoeba* sp. and *Paramecium* sp.
- **2.2.2** Deduce living processes in unicellular organisms as seen through a light microscope.

2.3 Living Processes in Multicellular Organisms

- **2.3.1** Correlate the uniqueness of specialised cell structures with their functions in multicellular organisms.
- **2.3.2** Identify specialised cells in multicellular organisms.
- **2.3.3** Analyse the density of certain organelles with the functions of specialised cells in multicellular organisms.
- **2.3.4** Describe the effects of deficiency, absence or failure in the function of an organelle of certain cells in multicellular organisms.

2.4 Levels of Organisation in Multicellular Organisms

- **2.4.1** Make a sequence of levels of organisation in multicellular organisms.
- **2.4.2** Identify cells, tissues or organs in an organ system.
- **2.4.3** Communicate about organ systems in multicellular organisms with their main functions.

2.1 Cell Structure and Function

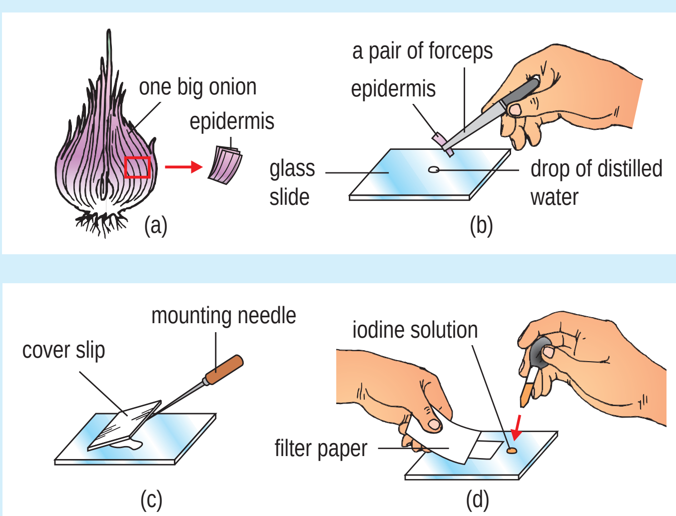
You may still recall the shape of cells you learned in Form 1. Much like the bee hive which is made up of hexagonal-shaped units, all living things are also made up of cells that are combined together. **Cells** are the basic units of all living things. Let us examine the structure of animal cells and plant cells through a light microscope.

Activity 2.1 Preparing and examining slides of plant cells — Observation

Materials
One big onion, iodine solution, distilled water and filter paper

Apparatus
Glass slides, cover slips, light microscope, scalpel, a pair of forceps, dropper and mounting needle

Procedure
1. Cut a piece of scale leaf from a big onion **(a)**.
2. Remove the translucent epidermis from the inside of the scale leaf using a scalpel.
3. Add a drop of distilled water at the centre of the slide and lay the onion epidermis on the water **(b)**.
4. Using a mounting needle, cover the onion epidermis with a cover slip by placing it at a 45° angle to the slide and slowly press it down. The temporary slide of this specimen is named as **wet mount**. Make sure there are no air bubbles trapped in the wet mount slide **(c)** and the onion epidermis is not folded.
5. Add a drop of iodine solution on one side of the cover slip. Place the filter paper at the opposite end of the cover slip to draw the iodine solution to absorb and stain the entire onion epidermis. This technique is known as the **irrigation technique (d)**.



Preparation of plant cell slide

Take Note!

Air bubbles that are trapped under the cover slip can be removed by gently tapping the cover slip with the tip of a sharp pencil.

6 Use a piece of filter paper to absorb excess iodine and distilled water.
7 Observe the slide through a light microscope with a low-power objective lens and then with a high-power objective lens.
8 Draw the epidermal cells structure that can be observed and label it completely. Record the magnification power.

Discussion
1 What are the components of the cell that can be observed through the light microscope?
2 Does a plant cell have a fixed shape?
3 Name another type of plant that can be used in this activity to replace the onion.

Conclusion
Suggest a suitable conclusion for this observation.

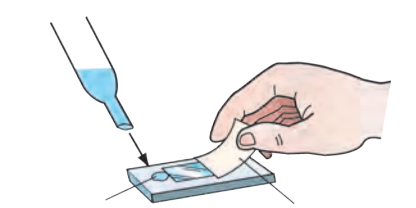
Using the same slide preparation method, prepare a slide of cheek cells (slide of animal cells) using a methylene blue solution.

Activity 2.2 Preparing and examining slides of animal cells
Observation

Materials
Animal cell (cheek cell), methylene blue solution, distilled water, filter paper and toothpick

Apparatus
Glass slides, cover slips, light microscope, dropper and mounting needle

Procedure
1 Gently scrape the inside of the cheek with a blunt tooth pick.
2 Transfer the scrapping into a drop of water on a clean glass slide and cover with the cover slip.
3 Stain the cheek cells with methylene blue solution using the irrigation technique.
4 Examine the cheek cells through a light microscope. Draw the cheek cells that can be observed. Record the magnification power.



Preparation of animal cell slide

Discussion
1 What are the components of the cell that can be observed through the light microscope?
2 Does the human cheek cell have a permanent shape?
3 Can you see dark blue spots on the prepared cheek cell?
4 What are the similarities between animal cells and plant cells? Which component is present in the onion cell but is not present in the cheek cell?

Conclusion
Suggest a suitable conclusion for this observation.

Components of animal and plant cells and their functions

MITOCHONDRION (PLURAL: MITOCHONDRIA)

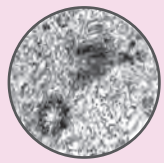
- It is rod-shaped or spherical
- It consists of two layers of membranes, which are the smooth outer membrane and folded inner membrane
- Contains enzymes that play a role in cellular respiration

Function:

- A site that generates energy through the glucose oxidation process during cellular respiration
- Energy released in the form of ATP molecules (adenosine triphosphate) to be used by the cells

CENTRIOLE

- Small cylindrical components that exist in pairs in animal cells
- Made up of complex arrangement of microtubules
- Does not exist in plant cells



Function:

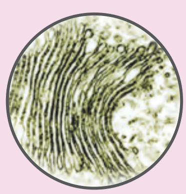
Forms spindle fibre during cell division in animal cells

GOLGI APPARATUS

- Consists of a stack of parallel flattened sacs that are coated by a single cell membrane
- New membrane is added at one end of the Golgi apparatus and vesicles bud off from the other end.

Function:

Processes, modifies, packs and transports chemicals such as protein, carbohydrate and glycoprotein (combination of carbohydrate and protein)



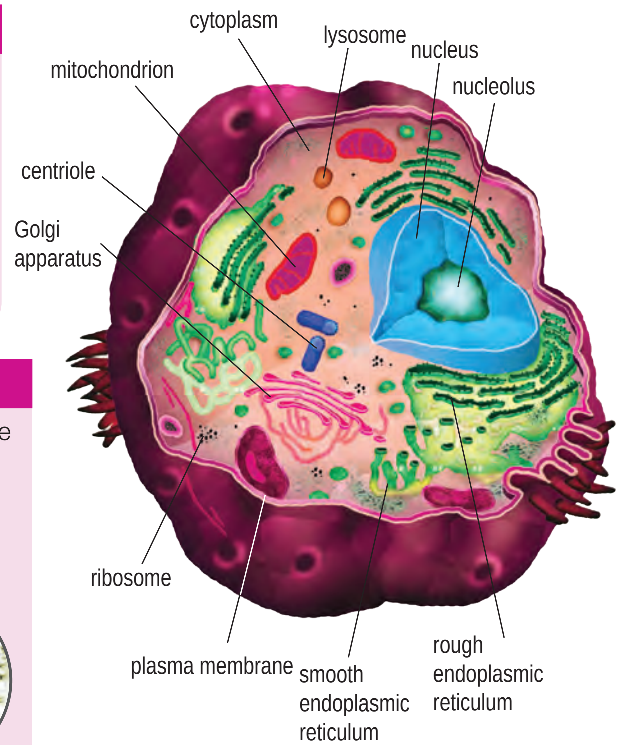
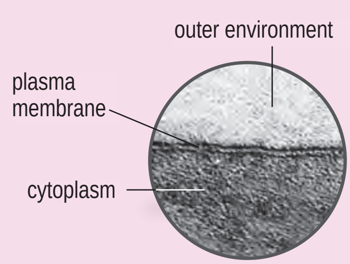


FIGURE 2.1 Animal cells

PLASMA MEMBRANE

- Outer membrane that surrounds the entire content of cell
- Made of proteins and phospholipids
- Thin and elastic film
- Partially permeable



Function:

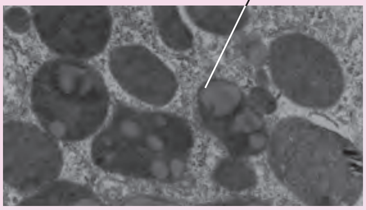
- Separates content of cell from the external environment
- Controls movement of substances into and out of the cell
- Allows exchange of nutrients, respiratory gases and waste materials between cells and their surroundings

LYSOSOME

- Small spherical sac enclosed in a single membrane
- Contains hydrolytic enzymes

Function:

- Hydrolyses complex organic molecules such as protein, nucleic acid and lipid
- Breaks down bacteria and components of damaged cells

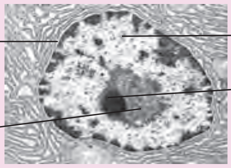


NUCLEUS (PLURAL: NUCLEI)

- Largest component in the cell
- Spherical, compressed and enclosed in a nuclear membrane with many pores
- The nucleus contains chromosomes, nucleolus and nucleoplasm.

Function:

- Controls all cell activities
- Has chromosomes that contain deoxyribonucleic acid (DNA). DNA determines the cell characteristics and metabolic function.

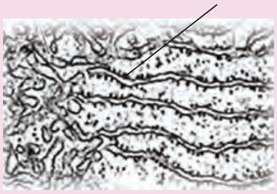


RIBOSOME

- Small, compact and spherical granules
- Consists of protein and ribonucleic acid (RNA)
- Ribosomes are present on the surface of the rough endoplasmic reticulum or exist freely in the cytoplasm.

Function:

- Site for protein synthesis

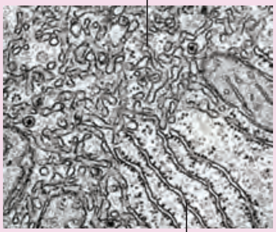


ENDOPLASMIC RETICULUM

- Consists of a system of interconnected folded flattened sacs
- Endoplasmic reticulum membrane is continuous with the nuclear membrane.
- There are two types of endoplasmic reticulum:
  - Rough endoplasmic reticulum has ribosomes attached to the surface
  - Smooth endoplasmic reticulum does not have ribosomes

Function:

- The transport system within the cell
- Provides a wide surface for enzyme attachment and biochemical reactions
- The rough endoplasmic reticulum transports proteins synthesised by ribosomes.
- The smooth endoplasmic reticulum synthesises and transports glycerol and lipids, and carries out the detoxification of drugs and metabolic by-products.



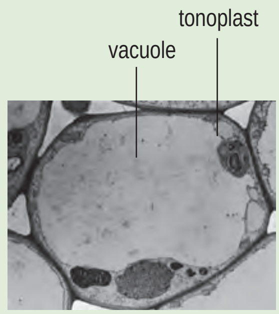
2.1.3 2.1.4

VACUOLE

- Liquid-filled sac, which is the cell sap.
- A vacuole is surrounded by the tonoplast membrane.
- Young plant cells have many small vacuoles while mature plant cells have a large vacuole.
- The vacuole in animal cells is small.
- Cell sap contains water, organic acids, sugars, amino acids, enzymes, mineral salts, oxygen, carbon dioxide and metabolic by-products.

Function:

- Water is absorbed into the vacuole plant cell and the cell becomes turgid.
- In unicellular animals, the vacuole contracts during osmoregulation, osmosis and excretion.

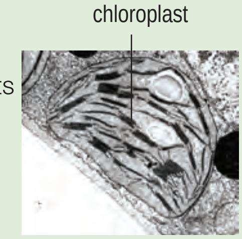


CHLOROPLAST

- Oval shaped
- Consists of two layers of membrane
- Contains chlorophyll pigments in the grana that give plants a green colour

Function:

Chlorophyll absorbs sunlight and converts it to chemical energy during photosynthesis.



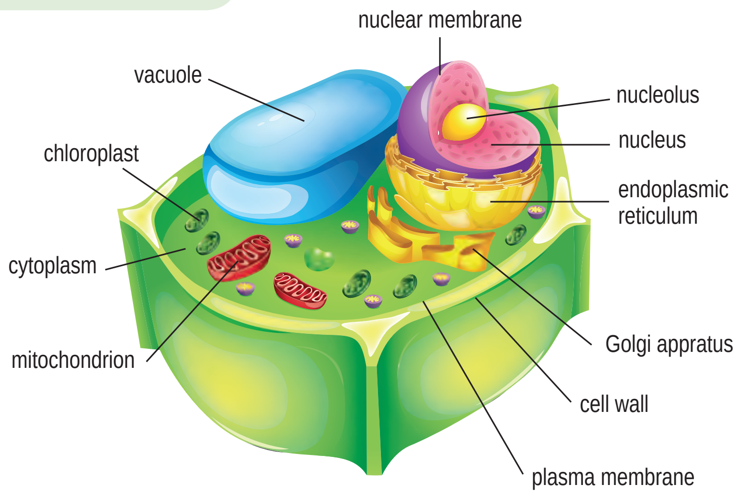


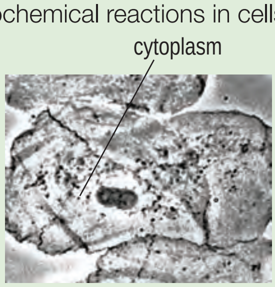
FIGURE 2.2 Plant cell

CYTOPLASM

- Consists of a jelly-like medium that contains components of the suspended cells
- Contains organic compounds (such as protein, lipid and carbohydrate) and inorganic compounds (such as potassium ions)

Function:

Acts as a medium for biochemical reactions in cells

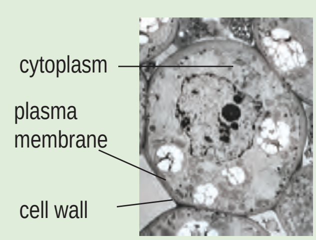


CELL WALL

- A strong and rigid outer layer
- Made from cellulose fibre
- Fully permeable

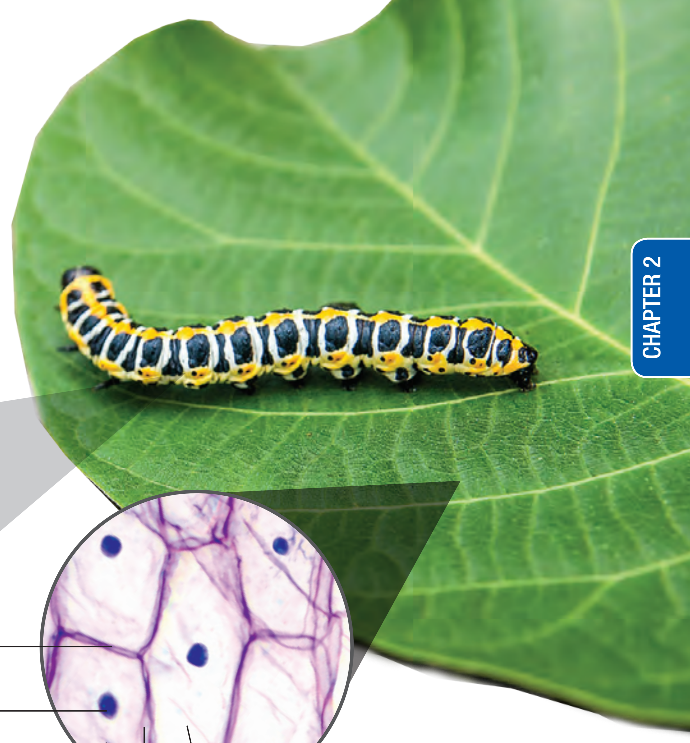
Function:

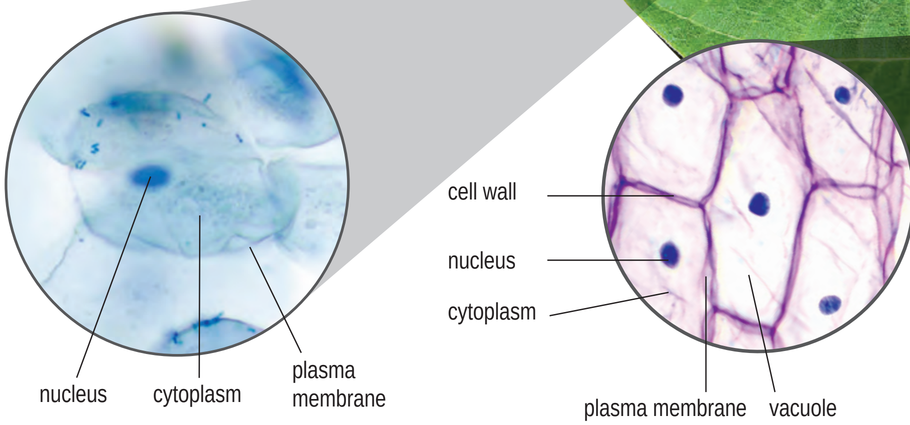
- Maintains the shape of plant cells
- Provides mechanical support to plant cells



Compare and contrast the components of animal cells and plant cells

You have learned about the components in animal and plant cells. What are the similarities and differences between the components in animal and plant cells?





PHOTOGRAPH 2.1 Structure of plant and animal cells through a light microscope

SIMILARITIES

Both cells are made of nucleus, cytoplasm, plasma membrane, Golgi apparatus, mitochondrion, endoplasmic reticulum and ribosomes.

DIFFERENCES

PLANT CELLS	ANIMAL CELLS
• Has a fixed shape	• Does not have a fixed shape
• Has a cell wall	• Does not have a cell wall
• Has chloroplasts	• Does not have chloroplasts
• Has a large vacuole	• No vacuole/if present, it is small
• Stores carbohydrate in the form of starch	• Stores carbohydrate in the form of glycogen
• Does not have a centriole	• Has centrioles

Formative Practice 2.1

1 State one structural difference between the rough endoplasmic reticulum and the smooth endoplasmic reticulum.

2 Why is the use of an electron microscope important in studying cells?

3 Chloroplast is found in some plant cells only. Give one example of a plant cell that does not have chloroplast and give your reasons.

4 Compare and contrast animal cells and plant cells.

2.1.5

2.2 Living Processes in Unicellular Organisms

ICT 2.1

Activity: Studying the life processes of unicellular organisms

Unicellular organisms are made up of only one cell. However, this cell is a complete unit of life like multicellular organisms. Unicellular organisms carry out all life processes: respiration, movement, nutrition, responding to stimulus, reproduction, growth and excretion. Protozoans are the simplest form of unicellular organisms. Examples of protozoa are *Amoeba* sp. and *Paramecium* sp. Let us look at the life processes of *Amoeba* sp. and *Paramecium* sp.

MOVEMENT

- *Amoeba* sp. constantly changes its shape when it encounters obstacles. *Amoeba* sp. moves by extending out its **pseudopodium** (false feet). This is followed by the flow of cytoplasm into the extended pseudopodium.
- *Paramecium* sp. moves using rhythmic cilia beats.

RESPONDING TO STIMULI

Amoeba sp. and *Paramecium* sp. respond to stimuli such as chemicals, touch or bright light by moving away from the stimuli.

RESPIRATION

Exchange of oxygen and carbon dioxide gases occur through the plasma membrane by **simple diffusion** on the surface of the cell.

NUTRITION

1. *Amoeba* sp. moves towards food by extending its pseudopodium to trap food particles by phagocytosis (Figure 2.3). For *Paramecium* sp. the presence of cilium beat helps transfer food particles into the oral groove.
2. The food vacuole is combined with lysosome. The food particles are hydrolysed by the enzyme lysozyme in the lysosomes.
3. The nutrients are absorbed into the cytoplasm.
4. Undigested food is discharged when the *Amoeba* sp. moves. Undigested food in the *Paramecium* sp. is discharged through the anus.

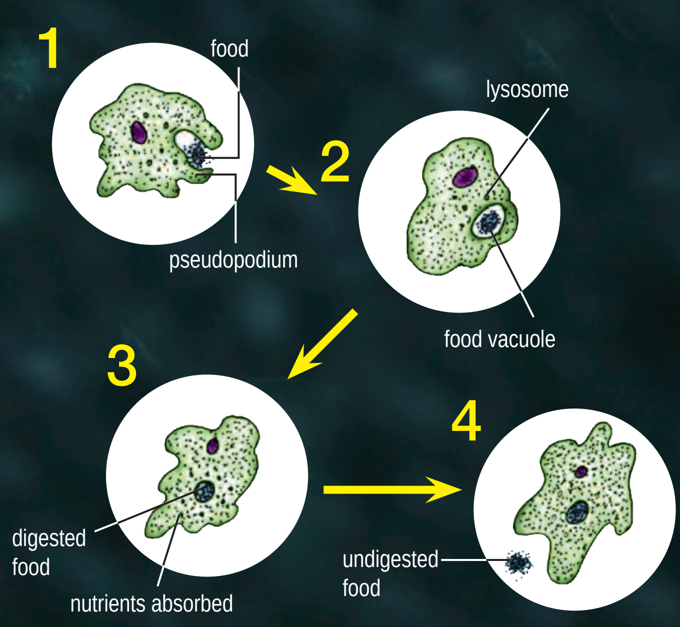


FIGURE 2.3 Nutrition in *Amoeba* sp.

GROWTH

Ameoba sp. and *Paramecium* sp. grow by synthesising new cytoplasm.

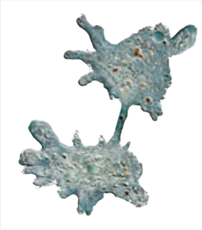
2.2.1 2.2.2

EXCRETION

- Waste such as carbon dioxide and ammonia are removed by diffusion.
- As *Amoeba* sp. and *Paramecium* sp. live in freshwater environments, water will diffuse by osmosis and fill the contractile vacuole.
- When the vacuole expands to the maximum size, contraction occurs and water is excreted from time to time.
- This process is called **osmoregulation**.

REPRODUCTION

- When the conditions are suitable and there is plenty of food, *Amoeba* sp. and *Paramecium* sp. will reproduce via **asexual reproduction** that is **binary fission** through mitosis.

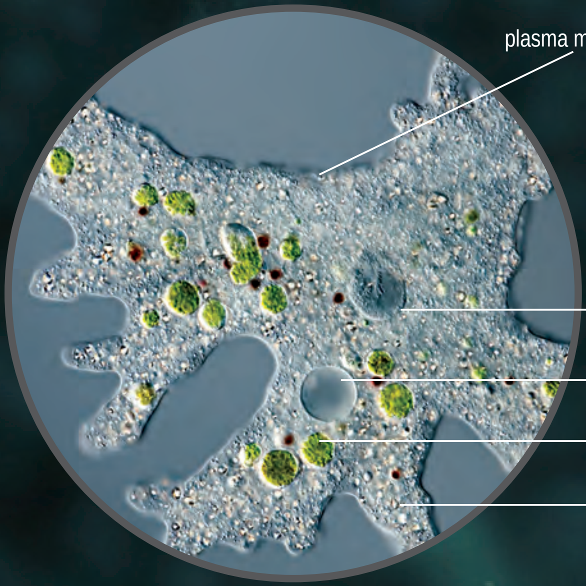


Binary fission

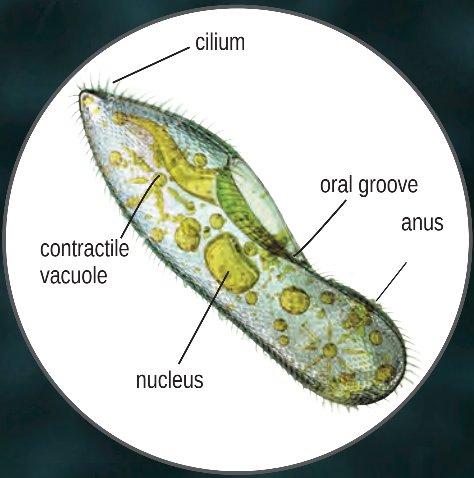
- However, when the environmental conditions are not suitable, such as dry conditions, low temperature and food shortage, the *Amoeba* sp. forms **spores** that will only germinate when the environment improves.

Conjugation

- For *Paramecium* sp., sexual reproduction, that is **conjugation** occurs when environmental conditions are not suitable.



PHOTOGRAPH 2.2 *Amoeba* sp.



PHOTOGRAPH 2.3 *Paramecium* sp.

Formative Practice 2.2

1. What is the function of the contractile vacuole in a *Paramecium* sp.?
2. How does the *Amoeba* sp. move?
3. How does the *Amoeba* sp. reproduce when the environment is unfavourable?
4. Predict what will happen to the contractile vacuole if the *Paramecium* sp. is placed in a concentrated salt solution.

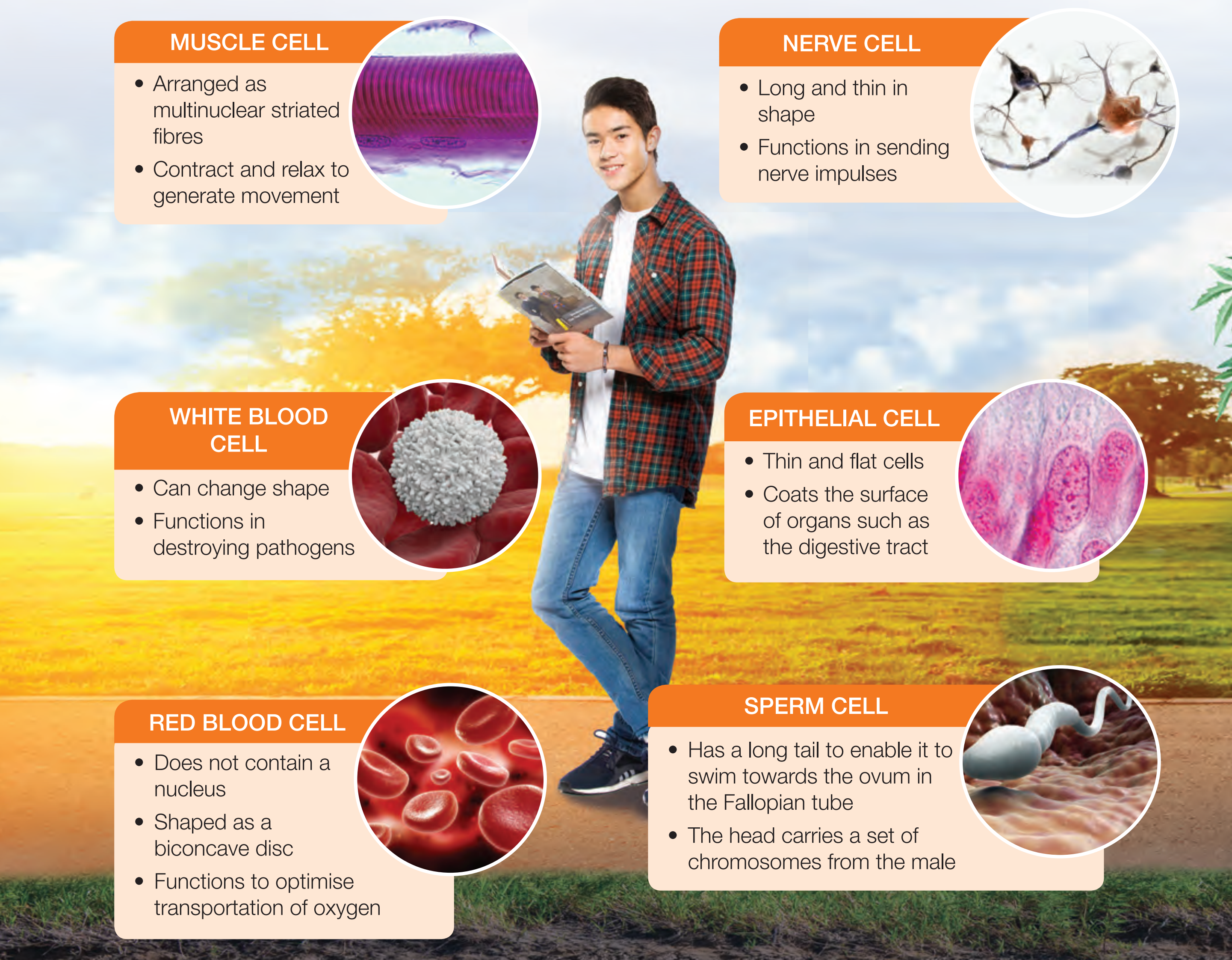
Activity Zone

Conduct an experiment using a light microscope to examine the living processes of unicellular organisms.

2.2.1 2.2.2

2.3 Living Processes in Multicellular Organisms

There are various types of cells in multicellular organisms which are different in size, shape and arrangement. The cell structure correlates to its function, and each type of cell is specialised to carry out a specific function. Photographs 2.4 and 2.5 show several types of specialised cells found in humans and plants as well as how these cells are adapted to carry out their respective functions.



PHOTOGRAPH 2.4 Several types of human cells that undergo specialisation to carry out different functions

ICT 2.2
Activity: Observe plant tissue and animal tissue slides through a light microscope

SIEVE TUBE ELEMENT

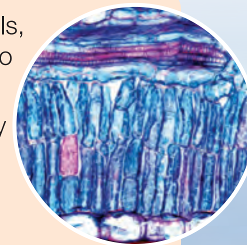
- Long cylindrical tubes arranged from end to end
- Transports organic materials from leaves to storage organs such as fruits

XYLEM VESSEL

- Long, continuous hollow tube
- Functions in transporting water and mineral salts from the roots to the other parts of the plant

PALISADE MESOPHYLL CELL

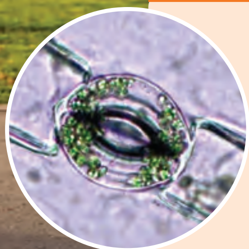
- Consists of long cylindrical cells, arranged vertically and close to each other
- Contains high chlorophyll density
- This arrangement allows maximum absorption of sunlight for photosynthesis



SPONGY MESOPHYLL CELL

- Cells are loosely arranged with lots of air space in between
- Large air space allows exchange of gas from the inside of the leaves to the palisade mesophyll cells

GUARD CELL



- Modified lower epidermal cells with the thicker cell wall on the inner side
- Controls the opening and closing of the stoma. Stoma is the opening that allows the exchange of oxygen and carbon dioxide

ROOT HAIR CELL

- Has a long projection which adds surface area for the absorption of water and mineral salts

PHOTOGRAPH 2.5 Certain types of plant cells undergo specialisation to carry out different functions

2.3.1

Cell organisation in humans

You have learned that multicellular organisms (such as humans) consist of different types of cells with specific functions. How are these cells arranged to form a complex organism?

Tissues are a group of cells that have the same structure and function and are arranged together to carry out a specific function. In organisms, tissues can be classified into four different types which are **epithelial tissue, muscle tissue, nerve tissue** and **connective tissue.**

Epithelial tissue

Epithelial tissue covers the outer surface (skin) and hollow surfaces in the body (digestive tract and respiratory tract) (Figure 2.4). The epithelial tissue structure is adapted based on its function. For example, the epithelial tissue on the skin protects against infections, injuries, chemicals and dehydration. Epithelial tissues that coat the trachea have projections like hair, known as **cilia** (singular: cilium).

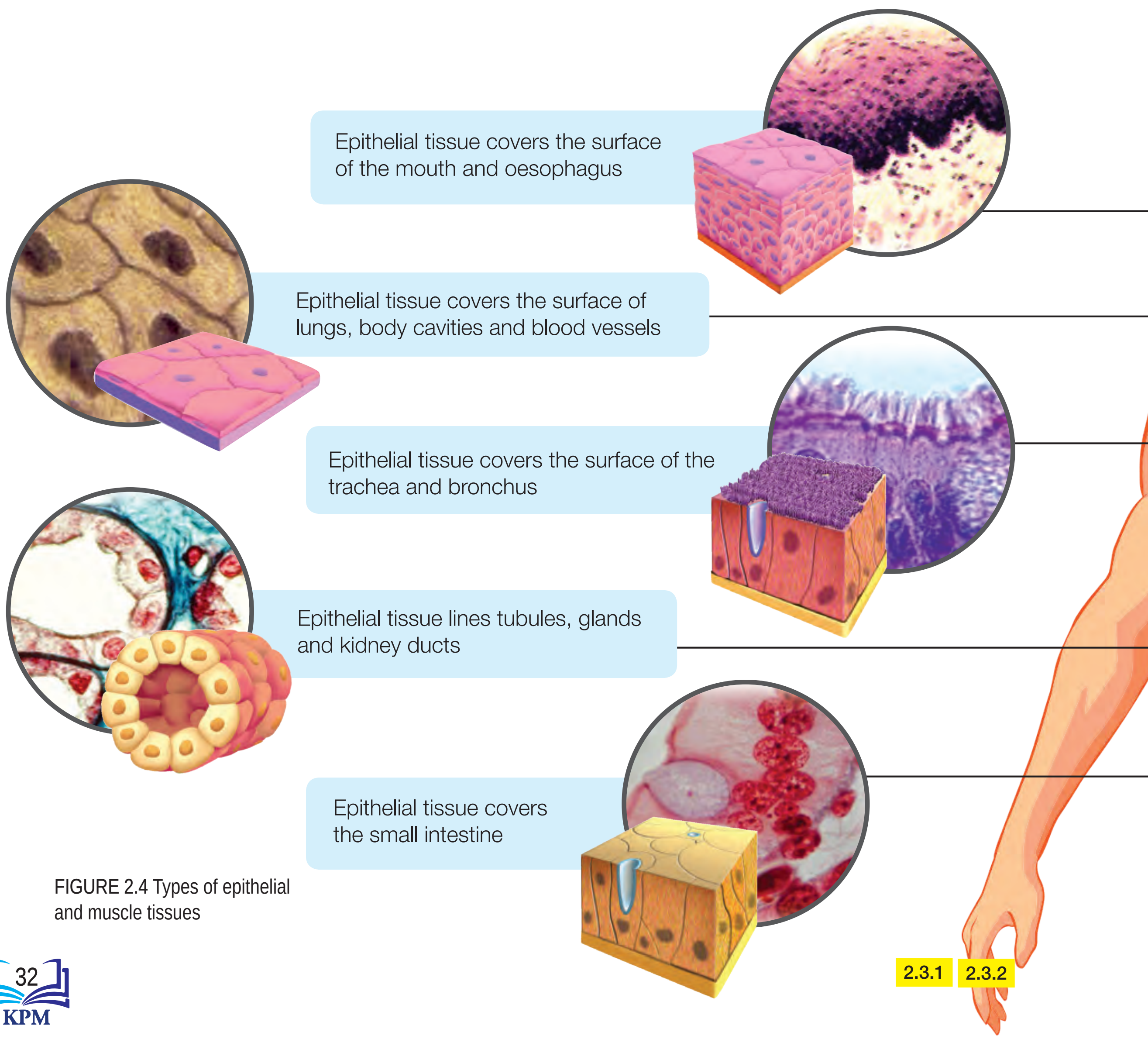
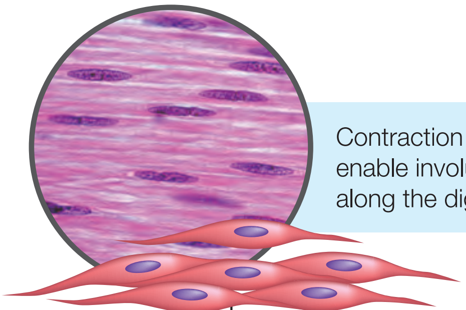


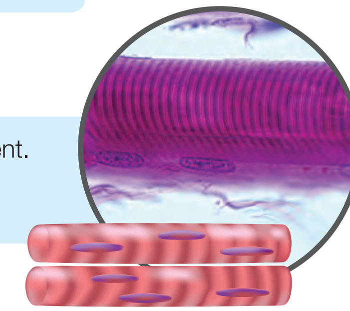
FIGURE 2.4 Types of epithelial and muscle tissues

Muscle tissue

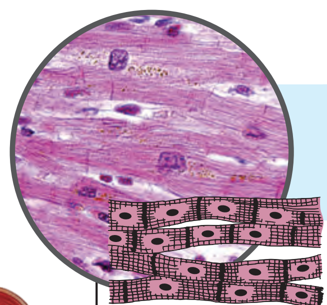
There are three types of muscle tissue: **smooth muscle** (found in the digestive tract, blood vessel, urinary tract and reproductive tract), **skeletal muscle** (found in legs and hands) and **cardiac muscle** (found in the heart wall) (Figure 2.4).



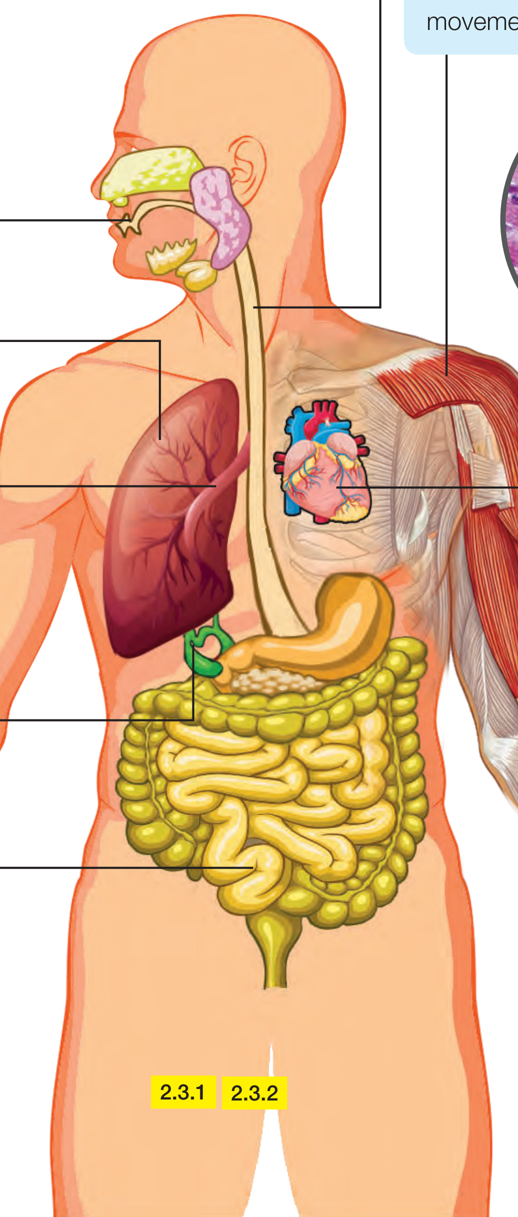
Contraction and relaxation of **smooth muscle** enable involuntary activities such as peristalsis along the digestive tract.



Skeletal muscle is involved in controlled movement. Skeletal muscles contract and relax to generate movement in bones and limbs.

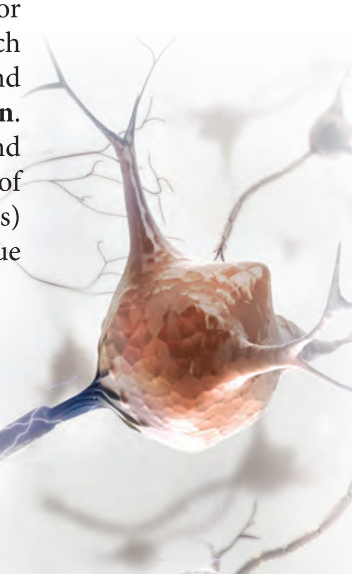


Cardiac muscle builds walls of the heart that contract to pump blood to the whole body. Cardiac muscle contraction is involuntary.



Nerve tissue

Nerve tissue is made of **neuron** or **nerve cells** (Photograph 2.6). Each neuron consists of a cell body and nerve fibre called **dendrite** and **axon**. Nerve tissues can detect stimuli and then send information in the form of an electrical signal (nerve impulses) to the muscles or glands. Nerve tissue regulates and controls body activity.



PHOTOGRAPH 2.6 Nerve tissue

2.3.1 2.3.2

ICT 2.3

Activity: Discuss the importance of cell specialisation in multicellular animals and plants

Connective tissue

The connective tissue consists of various types of tissues and fibres (Figure 2.5). This tissue is distributed all over the body and has many functions. One of its functions is to link the organs.

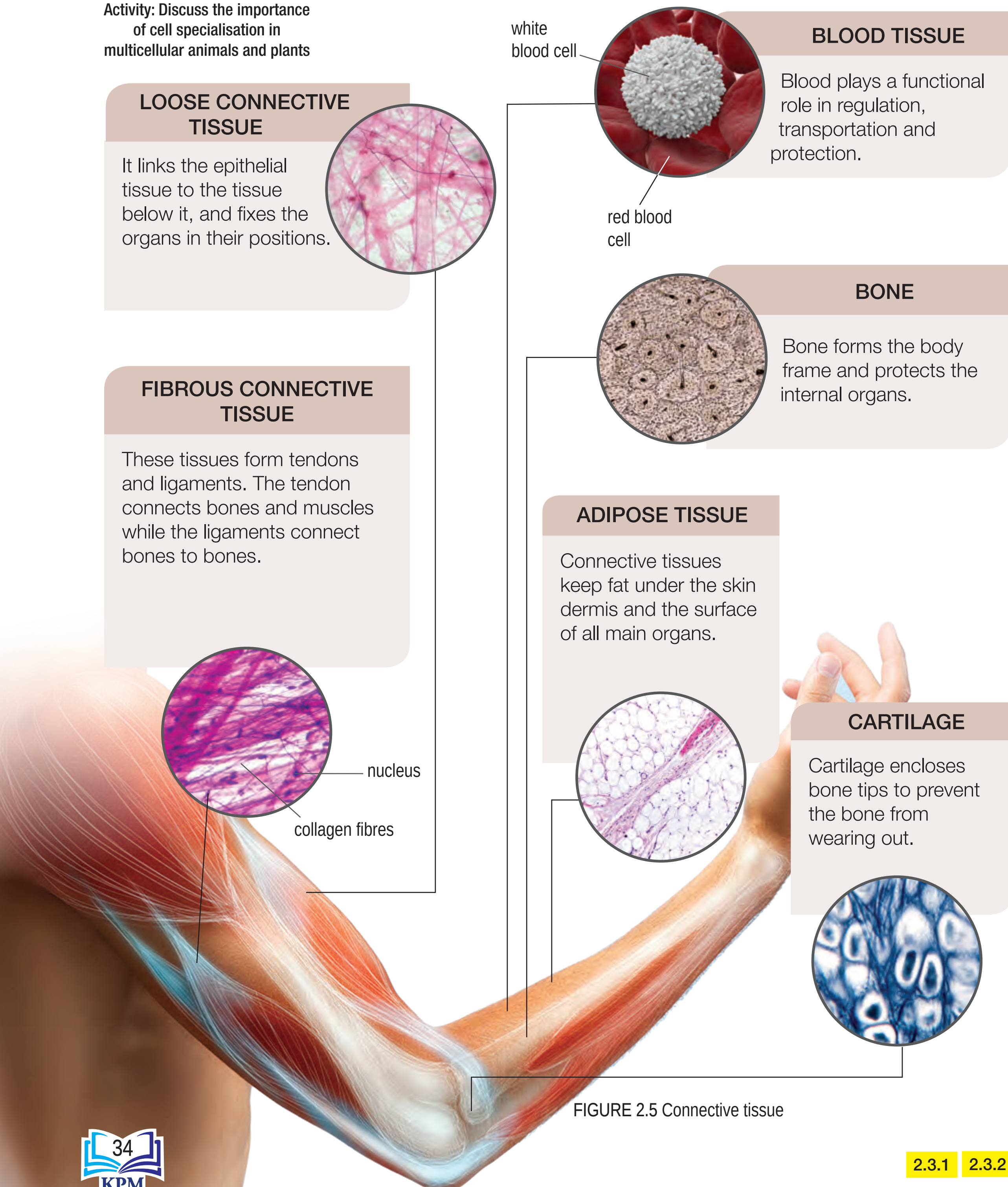


FIGURE 2.5 Connective tissue

Tissue organisation in plants

Tissue organisation in plants is summarised in Figure 2.6.

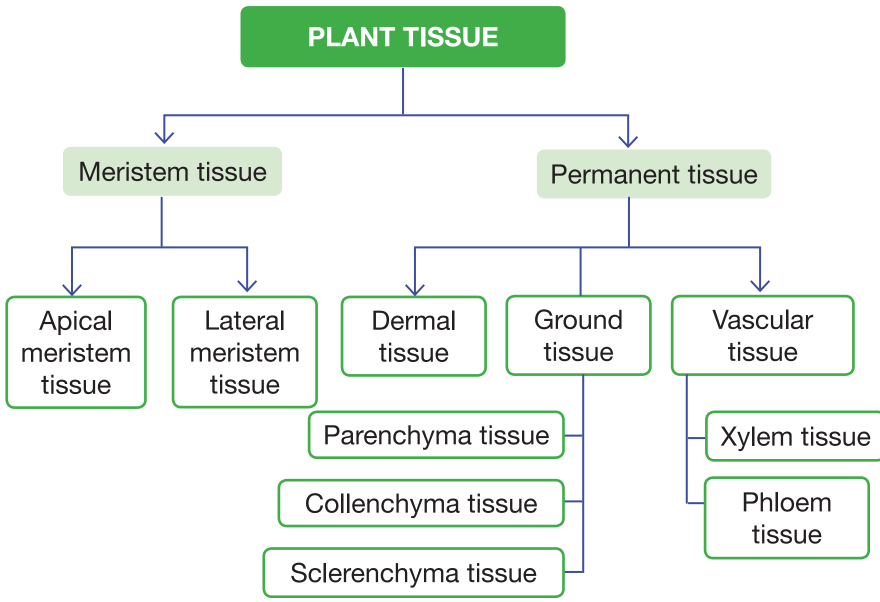
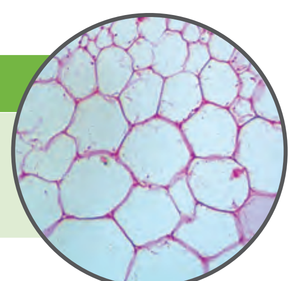


FIGURE 2.6 Tissue organisation in plants

PHOTOGRAPH 2.7
Meristem tissue at the tip of the root

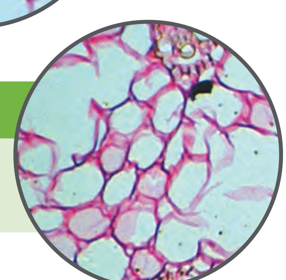
PARENCHYMA TISSUE

Functions to store starch, protein and water. This tissue can also carry out photosynthesis.



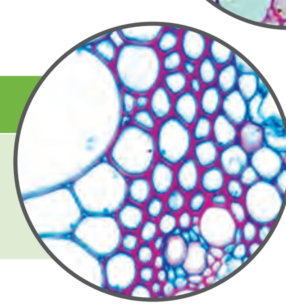
COLLENCHYMA TISSUE

Functions in giving support to young, non-woody stems (herbaceous plants).

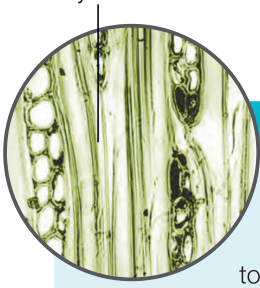


SCLERENCHYMA TISSUE

Functions in providing support and mechanical strength to all mature parts of the plant.



PHOTOGRAPH 2.8
Different types of ground tissues



VASCULAR TISSUE

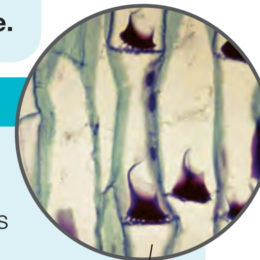
Vascular tissues are made up of **xylem tissue** and **phloem tissue.**

XYLEM TISSUE

The xylem functions in transporting water and mineral salts from the roots to other parts of the plant. Ligneous xylem tissue wall provides support and mechanical strength to the plants.

PHLOEM TISSUE

The phloem functions in transporting organic matters such as sucrose from the leaves to all parts of the plant.



Density of certain cell components and specialised cell functions

Since the functions performed by cells are different, some cells have a higher density of certain cell components. The density of a cell component in a particular cell is related to the specific function of the cell. Table 2.1 provides examples of cells that have a higher density of certain cell components.

TABLE 2.1 Relationship between cell component density with specialised cell functions

Types of cell	Cell component found in abundance	Function
Sperm cell	**Mitochondrion**	Requires a lot of energy to swim towards the uterus and Fallopian tube to fertilise the secondary oocytes
Muscle cell such as flight muscle cells in insects and birds		Requires a lot of energy to contract and relax to enable movement and flight
Plant meristem cell		Requires a lot of energy to carry out active cell division process to produce new cells
Palisade mesophyll cell	**Chloroplast**	Absorbs more sunlight to carry out the process of photosynthesis
Spongy mesophyll cell		
Pancreatic cell	**Rough endoplasmic reticulum** **Golgi apparatus**	Increases synthesis and secretion of digestive enzymes
Goblet cell in intestinal epithelium and respiratory tract		Produces mucus
Liver cell		• Metabolises carbohydrates • Detoxification of drugs and poisons

2.3.3

All cell components perform their respective functions to ensure that the cells function at the optimum level. The collaboration of all the components of the cells is similar to a factory with different parts and each with its specific function. What happens to the cell if there is a deficiency, absence or failure in any of the cell components such as lysosomes, mitochondrion, chloroplasts or ribosomes?

Failure of the mitochondrion function or a mitochondrion disjunction can cause stunted growth, weak muscles, hearing and vision problems. Tay-Sachs is a hereditary disease caused by the failure of enzymes to produce in the lysosomes. Tay-Sachs patients will experience stunted growth and mental retardation.

Formative Practice 2.3

1 State the components of cells found in high density in cells that secrete protein products.

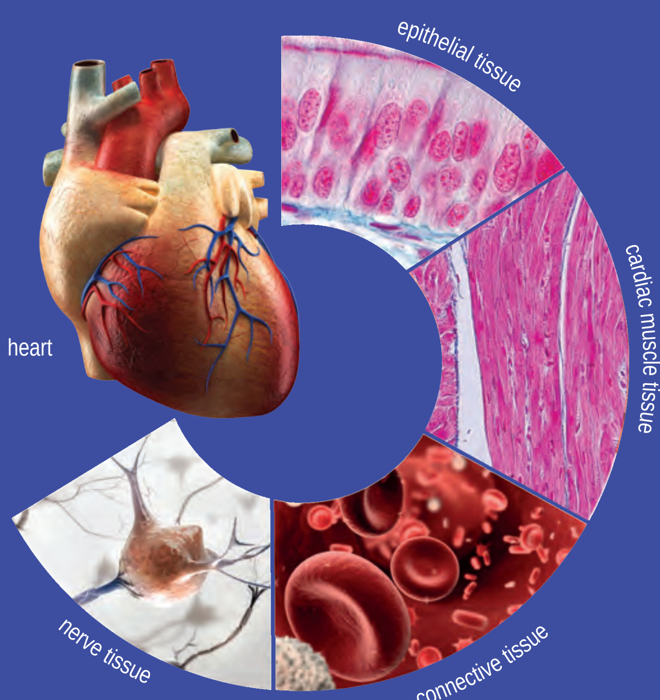
2 Briefly describe the structure and function of the nerve tissue.

3 Explain why the palisade mesophyll cell contains a lot of chloroplast.

4 Fat cells have three adaptive characteristics to allow the storage of fat. Describe the three characteristics.

2.4 Levels of Organisation in Multicellular Organisms

A group of different tissues combine to form **organs**. Organs perform special functions as a result of the combination of tissues that form the organ. For example, the heart organ is composed of epithelial tissue, cardiac muscle tissue, connective tissue and nerve tissue. The epithelial tissue fills up space in the heart. Cardiac muscle tissue functions in pumping blood to the rest of the body. Connective tissues such as the blood, connect the systems in the organ. Nerve tissue regulates the rhythm of the heartbeat.



PHOTOGRAPH 2.9 Tissues that form the heart organ

2.3.4 2.4.1

Each multicellular organism is made up of many organs. Different organs work together to carry out a specific function to form an organ system.

There are 11 main organ systems in the human body (Figure 2.7), which are the respiratory system, digestive system, blood circulatory system, lymphatic system, nervous system, integumentary system, endocrine system, skeletal system, muscular system, urinary system and reproductive system.

ENDOCRINE SYSTEM

- The endocrine gland that secretes hormones

Main function

- Coordinates body activities with the nervous system

RESPIRATORY SYSTEM

- Trachea, nose, lungs and diaphragm

Main function

- Exchange of oxygen and carbon dioxide gases between the body and external environment

MUSCULAR SYSTEM

- Skeletal muscles, smooth muscles and cardiac muscles

Main function

- Contracts and relaxes to produce movements in different parts of the body

MALE REPRODUCTIVE SYSTEM

- Testes, prostate gland and penis

Main function

- Produces sperm and male sex hormone

FEMALE REPRODUCTIVE SYSTEM

- Ovary, uterus, Fallopian tube, vagina and cervix

Main function

- Produces ovum and female sex hormones

LYMPHATIC SYSTEM

- Spleen, lymph nodes and lymph vessels

Main function

- Maintains balance of bodily fluids and prevents infectious diseases

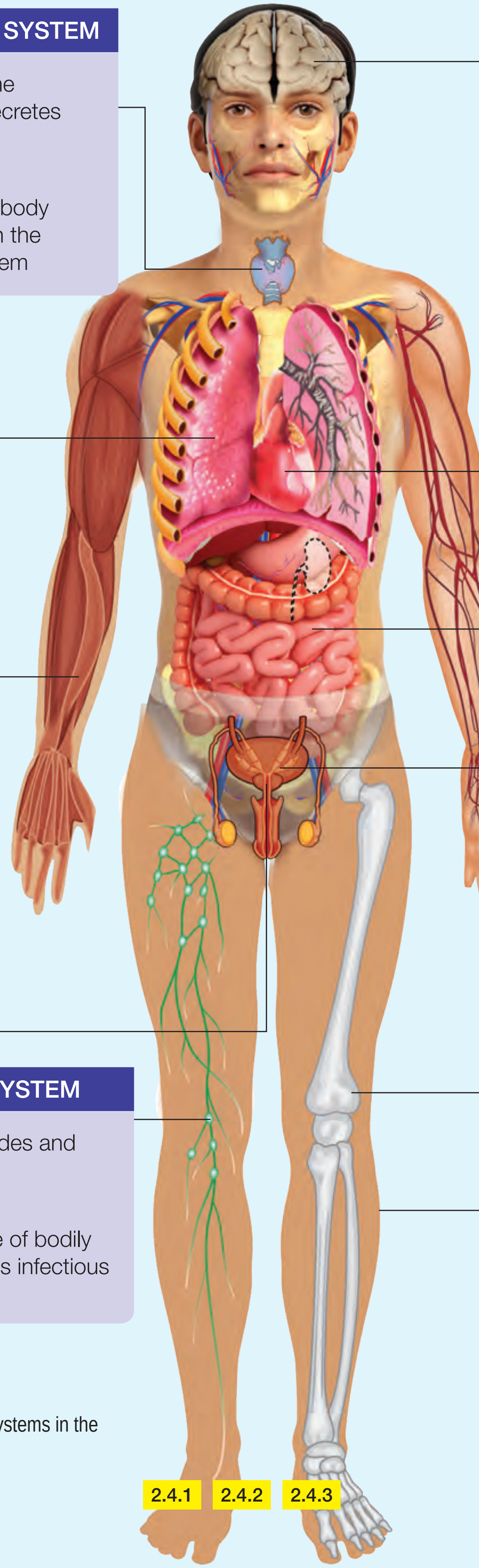


FIGURE 2.7 Main organ systems in the human body

2.4.1 2.4.2 2.4.3

NERVOUS SYSTEM

- Brain, spinal cord and peripheral nerves

Main function

- Detects and sends information in the body, as well as coordinates body activities

BLOOD CIRCULATORY SYSTEM

- Heart, artery, vein and blood capillary

Main function

- Transports nutrients, respiratory gases and waste products

DIGESTIVE SYSTEM

- Mouth, oesophagus, stomach, liver, pancreas, small intestine and large intestine

Main function

- Digests food into a simpler form for easy absorption

URINARY SYSTEM

- Kidney, ureter, urethra and bladder

Main function

- Eliminates waste products such as urea and uric acid from the body

SKELETAL SYSTEM

- Bone, cartilage, ligament and tendon

Main function

- Supports the body, protects the internal organs and provides a base for muscle adhesion

INTEGUMENTARY SYSTEM

- Skin

Main function

- Protects the body from physical injury, infection and dehydration

2.4.1 2.4.2 2.4.3

Cell
↓
Tissue
↓
Organ
↓
System
↓
Multicellular organism

All the organ systems are coordinated and collaborated as one complete organism. The sequence of the organisation of cells in a multicellular organism is shown in Figure 2.8.

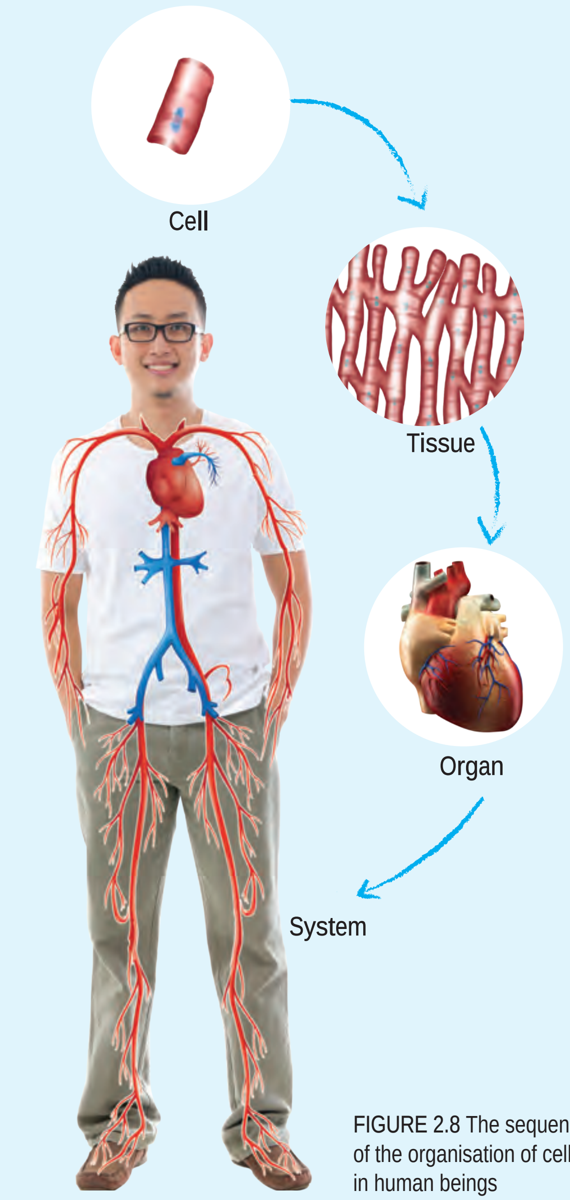


FIGURE 2.8 The sequence of the organisation of cells in human beings

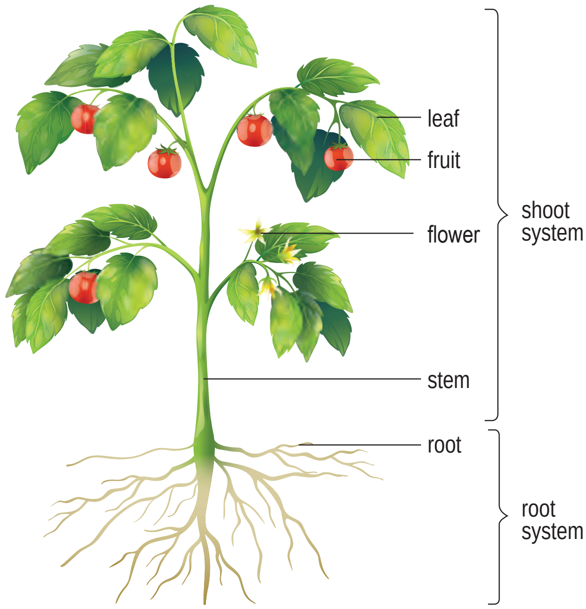


FIGURE 2.9 Two main systems in plants

The plant system is divided into the **shoot system** and the **root system** (Figure 2.9).

- The **shoot system** consists of stems, leaves, shoots, flowers and fruits.
- Stems and twigs are support systems that support the leaves at a vertical position to allow maximum absorption of sunlight during photosynthesis.
- Flowers are involved in the pollination process.
- The **root system** consists of all roots in a plant that function in absorbing water and mineral salts as well as providing support for plants.

Formative Practice 2.4

1. State arrangement of sequence in the organisation of cells in a multicellular organism.
2. The skin is the largest organ in the body. Why is skin classified as an organ?
3. Stems, twigs and flowers are organs in a plant. Describe how stems, twigs and flowers function in the shoot system.
4. Predict what will happen if the organisation level of cells does not exist in an organism.

Summary

CELL BIOLOGY AND ORGANISATION

Cell Structure and Function

Cell components
- Nucleus
- Mitochondrion
- Ribosome
- Centriole
- Golgi apparatus
- Chloroplast
- Cell membrane
- Cell wall
- Vacuole
- Cytoplasm
- Lysosome
- Rough endoplasmic reticulum
- Smooth endoplasmic reticulum

Living Processes in Unicellular Organisms

Amoeba sp. and *Paramecium* sp.
- Movement
- Response to stimuli
- Nutrition
- Respiration
- Growth
- Excretion
- Reproduction

Living Processes in Multicellular Organisms

- Relationship between specific cell structure and cell function
- Relationship between cell component density and cell function
- Effect of the absence of cell components to the cell

Levels of Organisation

Cell → Tissue → Organ → System → Organism

2.4.2 2.4.3

Self Reflection

Have you mastered the following important concepts?

- Structure and function of animal cells and plant cells
- Similarities and differences between animal cells and plant cells
- Living process of unicellular organism
- Living process of multicellular organism
- Relationship between cell component density in a cell and its specific function
- Effect of the absence or failure of the cell component function in multicellular organisms
- Sequence of levels of organisation in multicellular organisms
- Organ systems with its main functions in multicellular organisms

Summative Practice 2

1 Why is chloroplast only found in plant cells and not in animal cells?

2 Explain the asexual reproduction of *Amoeba* sp.

3 An aphid is a small insect which sucks sap in plants. An aphid puts its mouth in the stem of a plant and sucks its nutrients. Name the liquid obtained from the plant and explain why aphids are mostly found in the daytime.

4 Figure 1 shows a plant cell.

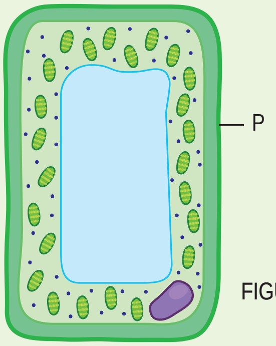


FIGURE 1

State the characteristics of P and its function.

5 **X** is a digestive organ consisting of cells with a high concentration of rough endoplasmic reticulum for protein digestion. What is **X**? Explain your answer.

6 Plant cells undergo process X to form xylem vessels. Name process X. Explain how xylem vessels are specialised in transporting water and mineral salts.

7 Arif is a farmer. He uses a weed killer to control the weed population growth on his farm. Weed killers can stop the transportion of certain minerals in plants through the hair root tissue. Explain why.

8 Explain how an *Amoeba* sp. can survive in fresh water that is hypotonic to the cytoplasm of the organism.

9 Figure 2 shows one cell that can be seen through an electron microscope.

(a) (i) Name structure K.
(ii) State the function of structures K and N.

(b) Explain how L mantains the turgidity of the cell.

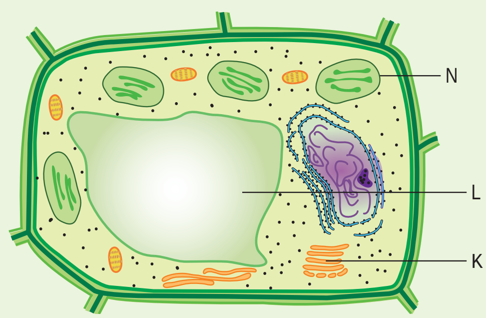


FIGURE 2

10 State the differences between the following:
(a) meristematic tissue with plant epidermal tissue,
(b) cell and tissue,
(c) epithelial tissue and muscle tissue.

11 Figure 3 shows the structure of a leaf.

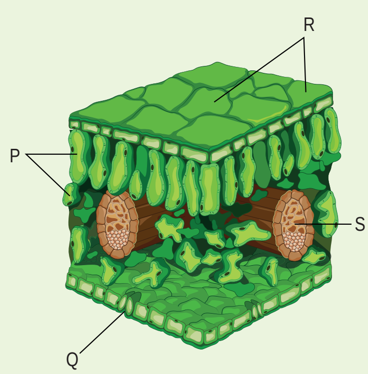


FIGURE 3

(a) Name the cells labelled P and R.
(b) State the functions of cells P and R.
(c) Explain the role of cell Q in increasing the rate of photosynthesis.
(d) S contains two types of tissue.
(i) Name the two tissues.

(ii) Explain the adaptive features of tissues in S that help in the transportation of materials in plants.

Essay Questions

12 Using an example of a unicellular organism, explain the five living processes of this organism.

13 Figure 4 shows a unicellular organism that lives in a fresh water pond.

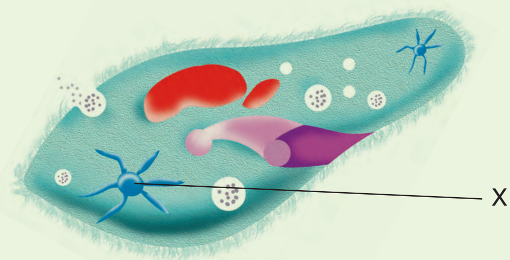
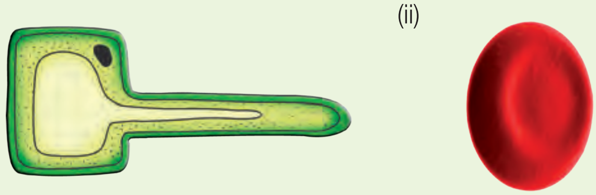


FIGURE 4

(a) Explain the function of **X** in osmoregulation.
(b) Predict what will happen if a cell does not have a Golgi apparatus. Explain your answer.
(c) For each of the following cell, explain the relationship between structure and function.

(i) (ii)



cell P cell Q

FIGURE 5

Enrichment

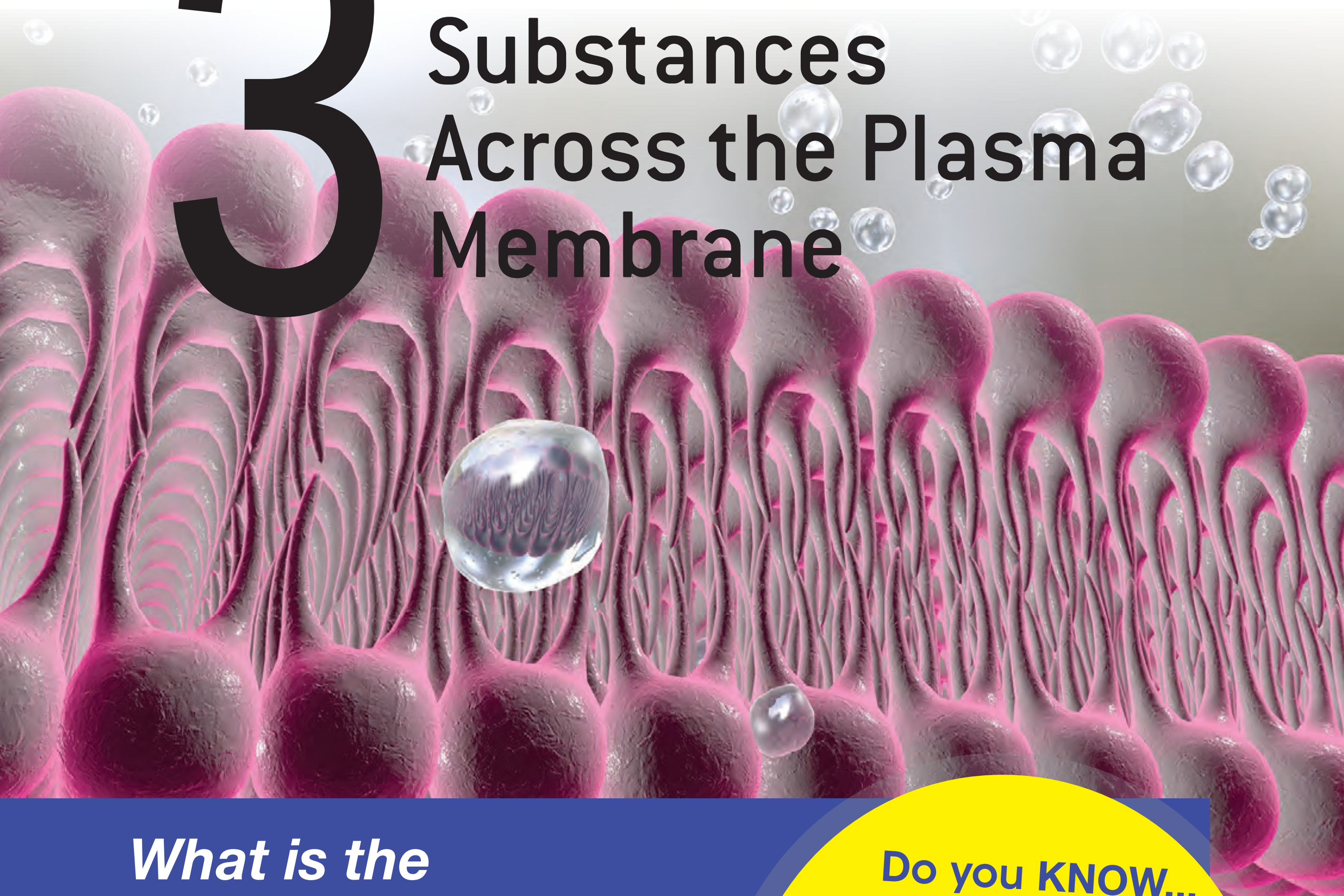
14 Many cancers start with the epithelial tissue. This includes lung cancer, colon cancer and skin cancer. What are the two characteristics of this tissue that can cause cancer?

15 The damage to the cartilage disc between the vertebrae of the spine is difficult to repair by their own cells. What is the latest technology that can be used to develop new cartilage tissues?

Complete answers are available by scanning the QR code provided

CHAPTER

3 Movement of Substances Across the Plasma Membrane



What is the association of carrier protein on plasma membrane with genetic diseases such as* hyperkalemic periodic paralysis *(HYPP) in horses?

Do you KNOW...

- What is the fluid mosaic model?
- What are the characteristics of substances that are able to move across the plasma membrane?
- What are the examples of passive and active transport?
- How do you apply the concept of movement of substances in everyday life?

3.1 Structure of Plasma Membrane

3.1.1 Justify the necessity of movement of substances across a plasma membrane.
3.1.2 Describe the components of a plasma membrane and its function based on the fluid mosaic model.
3.1.3 Draw and label the components of a plasma membrane based on the fluid mosaic model.
3.1.4 Describe the permeability of a plasma membrane.

3.2 Concept of Movement of Substances Across a Plasma Membrane

3.2.1 State the characteristics of substances that are able to move across a plasma membrane in these aspects:
- size of molecules
- polarity of molecules
- ionic charge

3.2.2 Conduct experiments to study the movement of substances across a selectively permeable membrane by using:
- Visking tubing
- simple osmometer

3.2.3 Describe by using examples movement of substances across a plasma membrane:
- passive transport
- active transport

3.2.4 Compare and contrast passive transport and active transport.

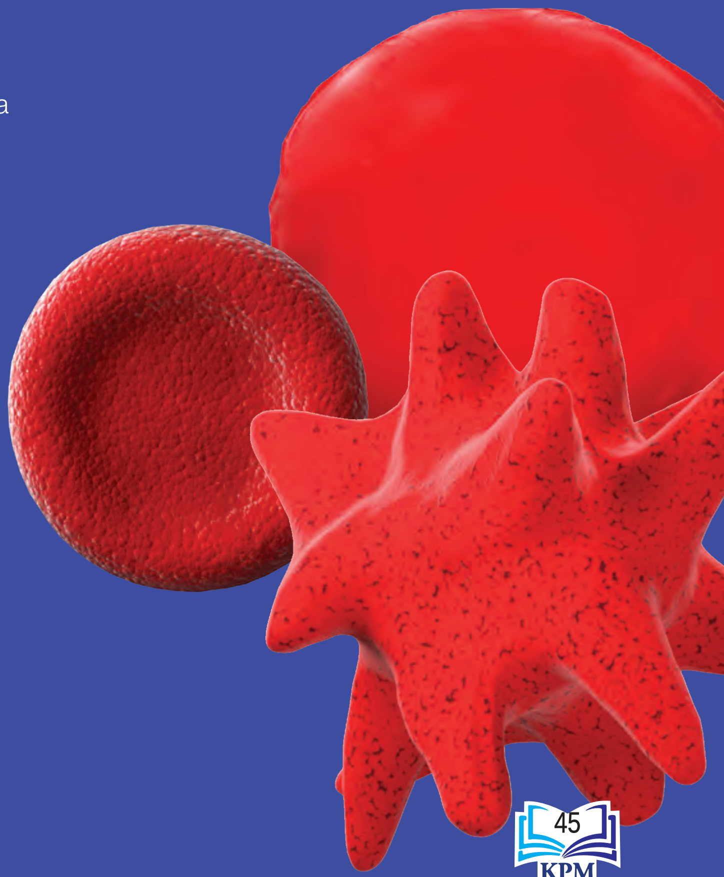
3.3 Movement of Substances Across a Plasma Membrane in Living Organisms

3.3.1 Explain by using examples the process of passive transport in organisms.
3.3.2 Explain by using examples the process of active transport in organisms.
3.3.3 Define solution:
- hypotonic solution
- hypertonic solution
- isotonic solution

3.3.4 Design an experiment to study the effects of different concentrations of solution on animal and plant cells.
3.3.5 Communicate about the effects of hypotonic, hypertonic and isotonic solutions on cell based on movement of water molecules:
- animal cell
- plant cell

3.4 Movement of Substances Across a Plasma Membrane and its Application in Daily Life

3.4.1 Conduct an experiment to determine the concentration of cell sap of a plant tissue.
3.4.2 Correlate the concentration of cell sap in a plant tissue with the phenomenon of plant wilting.
3.4.3 Explain by using examples the application of the concept of movement of substances across a plasma membrane in daily life.
3.4.4 Communicate about reverse osmosis in water purification



3.1 Structure of Plasma Membrane

The necessity of movement of substances across a plasma membrane

Living cells require substances from the external environment to carry out living processes. At the same time, the metabolic processes in cells produce waste that need to be disposed of from the cells. What are the substances required by cells and the waste products of cells? How do these substances move in and out of cells?

Cells must allow some substances to move into and out of the cells to maintain the living processes. The movement of substances into and out of the cell is regulated by the plasma membrane. Before you learn about how substances move across the plasma membrane, let us look at its structure.

ICT 3.1

Activity:
To discuss the need for movement of substances across the plasma membrane

Activity Zone

Draw a model of the plasma membrane and its related components.

Structure of the plasma membrane

In Chapter 2, you have learned that each cell is enclosed in a thin plasma membrane which separates the living cell from its environment.

According to the fluid mosaic model, protein molecules float within the phospholipid bilayer, forming a mosaic pattern that changes frequently. Figure 3.1 shows the plasma membrane.

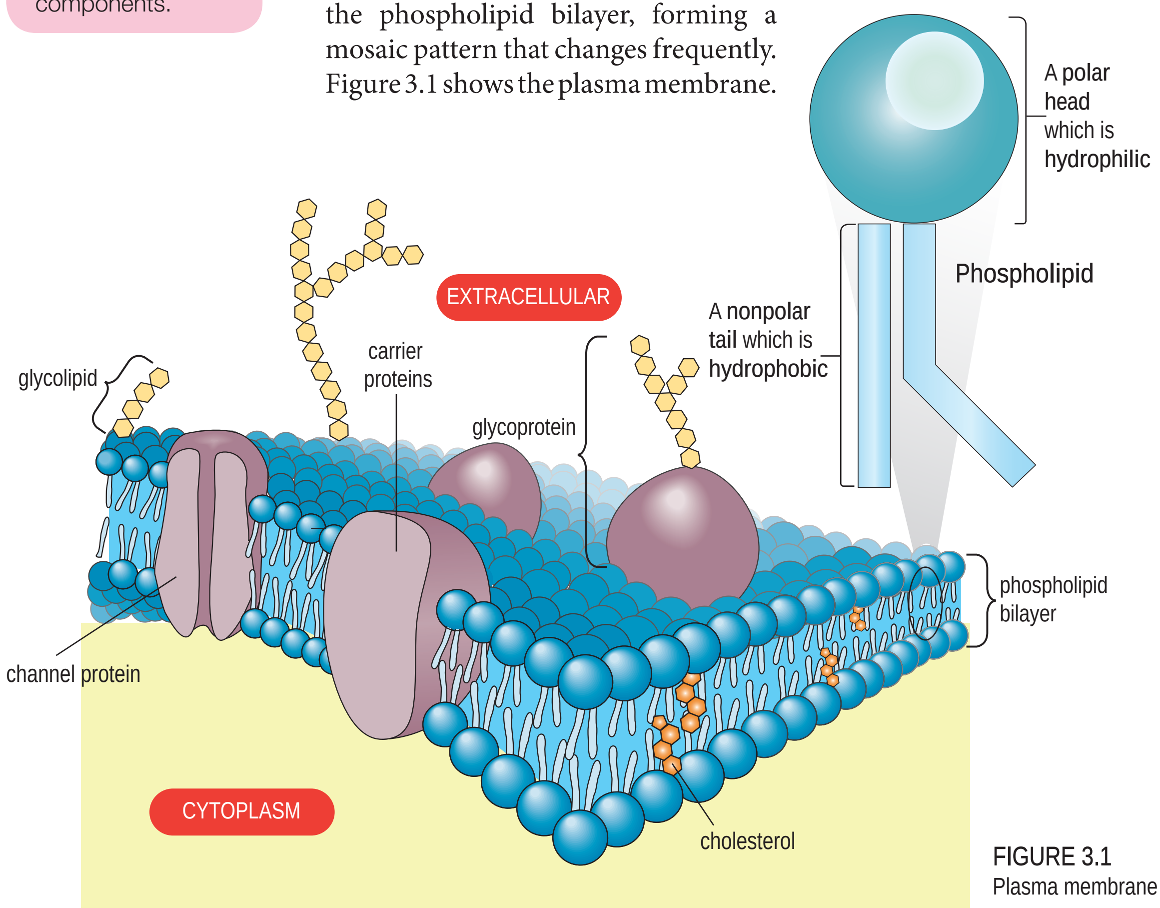


FIGURE 3.1 Plasma membrane

3.1.1 3.1.2 3.1.3

Each phospholipid molecule consists of:

- **A polar head** which is **hydrophilic** (attracted to water)
- **A nonpolar tail** which is **hydrophobic** (repels water)

The heads of the phospholipid molecule in the outer layer face the extracellular fluid, whereas the phospholipid heads in the inner layer face the cytoplasm. The tails of the phospholipid molecule of the two layers face each other.

There are various types of protein molecules embedded partially or fully within the membrane. The protein molecules are widely dispersed between the phospholipid bilayer. The protein molecules with channels or canals are known as **channel proteins**, whereas the protein molecules that function as carriers are called **carrier proteins** (Figure 3.2).

Biological Lens

There were many plasma membrane models proposed by scientists. However, the fluid mosaic model proposed by S. J. Singer and G. L. Nicholson in 1972 is the accepted model by scientists today.

CHAPTER 3

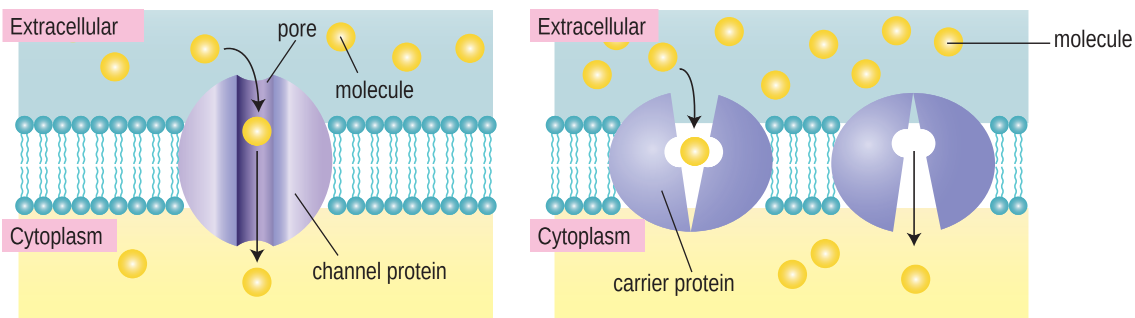


FIGURE 3.2 Models of channel and carrier proteins

Some proteins and lipids have carbohydrate chains attached to them, known as glycoprotein and glycolipid respectively (Figure 3.1). **Glycoprotein** and **glycolipid** act as receptors to hormones such as insulin, stabilise the membrane by forming hydrogen bonds with water and act as antigens for cell identification.

There are also cholesterol molecules found between the phospholipid molecules (Figure 3.1). **Cholesterols** make the phospholipid bilayer stronger, more flexible and less permeable to water-soluble substances such as ions. The phospholipid bilayer, proteins and cholesterols are not static but form a dynamic and flexible structure. This contributes to the 'fluid' characteristic of the plasma membrane and makes the plasma membrane more flexible.

Millennial Career

Biochemists who specialise in cell and molecular biology can work in the pharmaceutical industry, biotechnology and forensics.

Permeability of a plasma membrane

A membrane is said to be **permeable** to a substance if the membrane allows the substance to pass through it freely. On the contrary, a membrane is **impermeable** if a substance is unable to move across it. The plasma membrane is a selectively permeable membrane. What does **selectively permeable membrane** mean? Selectively permeable membrane only allows free movement of certain molecules across it, and prevent or limit the movement of other substances.

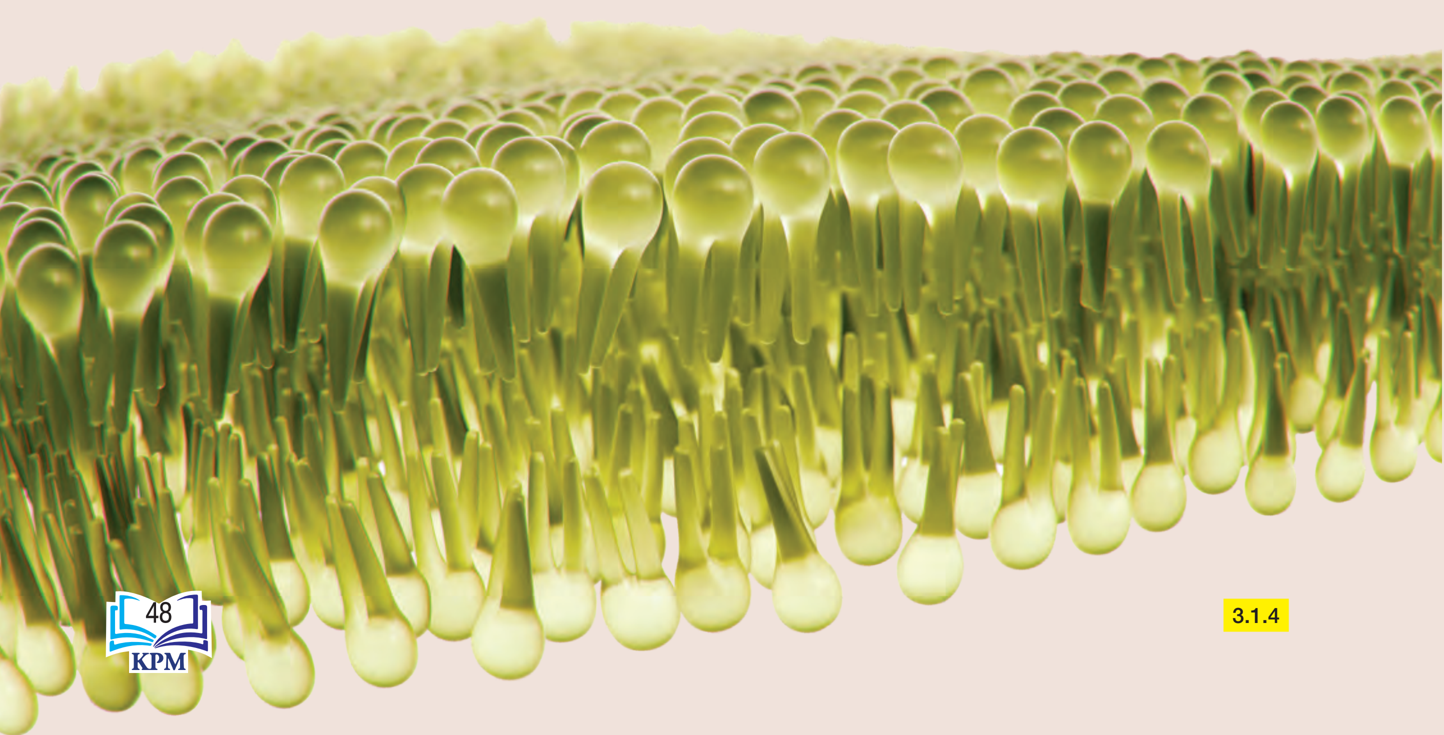
The plasma membrane has a selectively permeable property due to its **building structure.** The phospholipid bilayer and protein determine the membrane permeability towards specific substances. We will learn about the characteristics of substances that are able to move across the plasma membrane in the next unit.

ICT 3.2

Video: Fluid mosaic model of a plasma membrane
(Accessed on 21 August 2019)

Formative Practice 3.1

1. What are the two main components of the plasma membrane?
2. Explain the meaning of fluid mosaic model.
3. Predict what will happen to the plasma membrane if there is no cholesterol.
4. Explain the role of phospholipid and protein in ensuring the permeability of the plasma membrane.



3.2 Concept of Movement of Substances Across a Plasma Membrane

ICT 3.3

Video: Movement of molecules and ions across the plasma membrane
(Accessed on 21 August 2019)

The characteristics of substances that are able to move across a plasma membrane

There are three common factors that determine whether a molecule can pass through a plasma membrane, which are **molecule size** , **polar molecule** and **ionic charge**.

CHARACTERISTICS OF MOVEMENT OF SUBSTANCES ACROSS A PLASMA MEMBRANE

LIPID-SOLUBLE SUBSTANCES

Nonpolar molecules

Examples:

- Fatty acid
- Glycerol
- Fat soluble vitamins (A, D, E, K)
- Steroid compounds

LIPID INSOLUBLE SUBSTANCES

SMALL MOLECULE AND ION

- Polar molecules (Example: water)
- Nonpolar molecules (Examples: oxygen, carbon dioxide)
- Ion (Examples: K^+, Na^+, Ca^{2+}, Mg^{2+})

LARGE MOLECULE

Examples:

- Glucose
- Amino acid

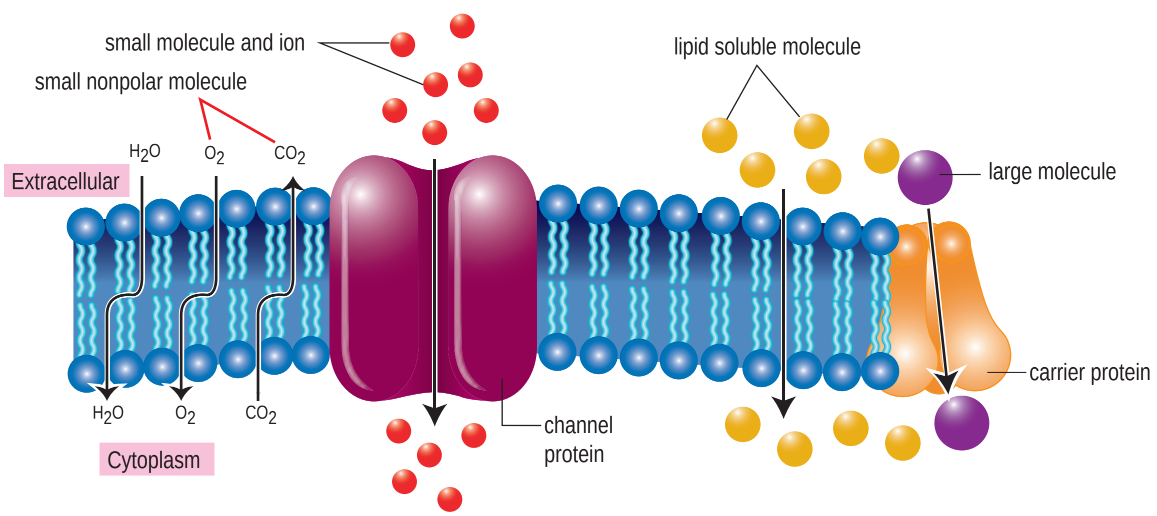


FIGURE 3.3 Movement of substances across a plasma membrane

Conduct the following experiment to show that the movement of substances across a selectively permeable membrane depends on the size of the molecule.

Activity 3.1 Studying the movement of substances across a selectively permeable membrane

Experiment

Problem statement
Does the size of dissolved particles affect the movement of substances across a selectively permeable membrane?

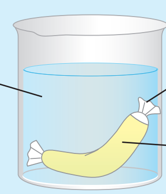
Hypothesis
Only small molecules are able to diffuse through a selectively permeable membrane while a large molecule cannot diffuse through a selectively permeable membrane.

Variables
Manipulated: Molecule size
Responding: Presence of molecules in the Visking tubing and beaker
Fixed: Surrounding temperature and soaking time

Materials
Benedict's solution, 1% starch suspension, iodine solution, 30% glucose solution, distilled water, Visking tubing (12 cm) and thread

Apparatus
Beaker, test tube, Bunsen burner, dropper and measuring cylinder

Procedure
1 Soak the Visking tubing in water for 5 minutes to soften it. Make a knot and tie one end of the Visking tubing with thread to prevent leaking.
2 Fill the Visking tubing with the 10 ml glucose solution and 10 ml starch suspension. Tie one end of the Visking tubing tightly with a thread. The solution colour is recorded.
3 Rinse the outside of the Visking tubing with distilled water.
4 Add 400 ml of distilled water in a beaker.
5 Place the Visking tubing in the beaker and leave it for 30 minutes.
6 After 30 minutes, remove and transfer the Visking tubing into a dry beaker.



7 (a) Conduct the iodine test for the solutions in the Visking tubing and in the beaker. Put 2 ml of each solution in separate test tubes and add 1 ml of the iodine solution. Observe the colour produced.
(b) Conduct the Benedict's test on the solutions in the Visking tubing and in the beaker. Put 2 ml of each solution into separate test tubes and add 1 ml of Benedict's solution. Heat the solutions in a water bath for 5 minutes and record any changes in colour.

Results

	Contents	Iodine test	Benedict's test
Visking tubing	10 ml glucose solution + 10 ml starch suspension		
Beaker	400 ml distilled water		

Discussion

1 What molecule is found in (a) Visking tubing (b) beaker?

2 What are the inferences that can be made based on the (a) size of the starch molecule (b) size of the glucose molecule compared to the pore size in the Visking tubing?

3 What are the similarities between a Visking tubing and a plasma membrane?

Conclusion

Is the hypothesis accepted? Suggest a suitable conclusion.

Activity 3.2 Studying the movement of substances across a Visking tubing using a simple osmometer

Experiment

Problem statement

How do the water molecules permeate across selectively permeable membranes?

Hypothesis

Water molecules permeate from an area of high water potential to an area of low water potential.

Variables

Manipulated: Time
Responding: Increase in the level of sucrose solution in a capillary tube
Fixed: Concentration of sucrose solution

Materials

30% sucrose solution, Visking tubing (12 cm), thread and distilled water

Apparatus

Retort stand with a clamp, 25 cm capillary tube, syringe, ruler, 50 ml beaker, marker pen, scissors and stopwatch

Procedure

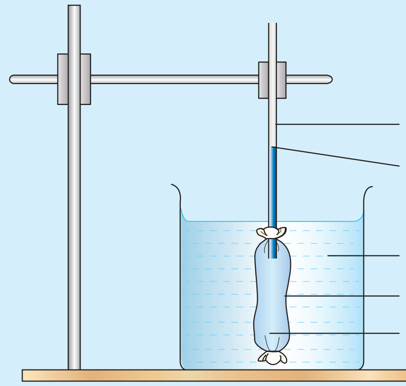
1 Cut a Visking tubing (12 cm).

2 Soak the Visking tubing in water for 5 minutes to soften it.

3 Tie one end of the Visking tubing tightly using thread to form a bag.

4 Fill the Visking tubing with the 30% sucrose solution using the syringe.

5 Tightly tie the other end of the Visking tubing to a capillary tube.
6 Rinse the outer part of the Visking tubing with distilled water.
7 Clamp the capillary tube vertically to the retort stand.
8 Immerse the Visking tubing in a beaker containing distilled water.
9 With a marker pen, mark the level of sucrose solution in the capillary tube at the beginning of the experiment.
10 Measure and record the level of sucrose solution in the capillary tube for every 2 minutes from the previous level for 12 minutes.
11 Plot a graph of the level of sucrose solution (mm) against time (minutes).



Results

Time (minutes)	0	2	4	6	8	10	12
Level of sucrose solution (mm)							

Discussion

1 Based on the graph, explain the relationship between the levels of sucrose solution and time.
2 What caused the change in the levels of sucrose solution?
3 What inferences can be made regarding the size of the sucrose molecules and water, and the pore size of the Visking tubing?
4 Predict the results if the experiment is repeated using a Visking tubing filled with distilled water, and a beaker filled with a 30% sucrose solution.

Conclusion

Is the hypothesis accepted? Suggest a suitable conclusion.

Our World of Biology

Do you know that an egg membrane can be used to replace the Visking tubing? Can you make an egg osmometer?

The movement of substances across a plasma membrane occurs through **passive** and **active transport**.

Passive transport

An analogy of passive transport is like riding a bicycle downhill. The process does not involve the use of energy. **Simple diffusion**, **osmosis** and **facilitated diffusion** are examples of passive transport.

Simple diffusion

Simple diffusion is the movement of molecules or ions from an area of high concentration to an area of low concentration. The moving molecules are said to move down the concentration gradient until a dynamic equilibrium is achieved. This may occur with or without the presence of a plasma membrane. Lipid soluble molecules (fatty acids and glycerol), oxygen and carbon dioxide diffuse through the phospholipid bilayer as simple diffusion (Figure 3.4).

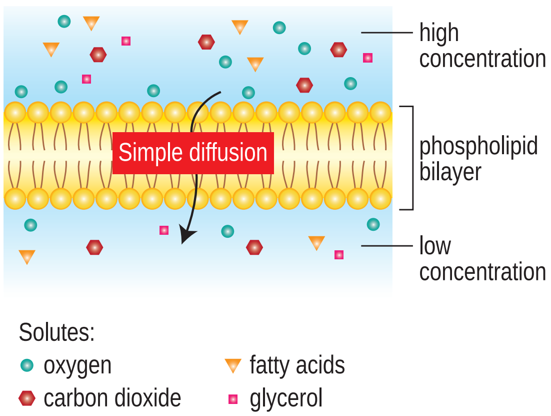


FIGURE 3.4 Simple diffusion through the phospholipid bilayer

Osmosis

Osmosis is a passive transport process that is similar to diffusion but it involves only water molecules. Osmosis refers to the net movement of water molecules from an area of **high water potential** (low solutes concentration) to an area of low water potential (high solutes concentration) randomly through a selectively **permeable membrane.** The selectively permeable membrane is permeable to water but impermeable to some solutes such as sucrose molecules (Figure 3.5). The same situation occurs in cells through the phospholipid bilayer (Figure 3.6).

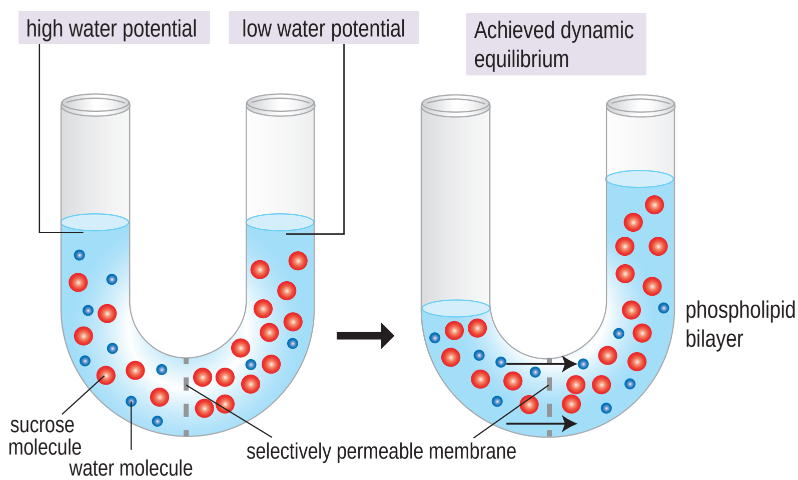


FIGURE 3.5 Osmosis

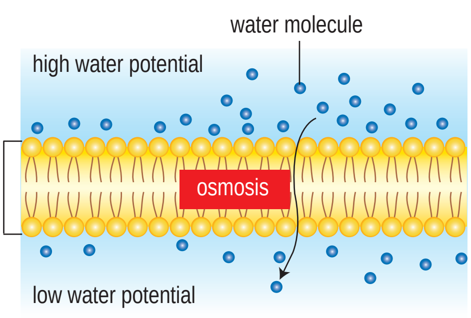


FIGURE 3.6 Osmosis through the phospholipid bilayer

Facilitated diffusion

Lipid-insoluble molecules such as ions, large molecules such as amino acids and glucose are unable to pass through the phospholipid bilayer. These substances move across the membrane with the aid of **transport proteins** (**carrier** or **channel proteins**). This process is known as **facilitated diffusion**. Facilitated diffusion **does not require energy** because the transport proteins transport molecules **down a concentration gradient**. The process continues until a **dynamic equilibrium** is achieved when the concentration of molecules is the same at both sides of membranes.

CHANNEL PROTEINS form channels or canals to allow small-sized solutes and ions to diffuse across the plasma membrane. Channels have specific internal characteristics that only allow specific ions to pass through it.

CARRIER PROTEINS have **specific** sites and can only bind to a specific molecule. For example, glucose molecules can only bind to the specific site of a glucose carrier protein.

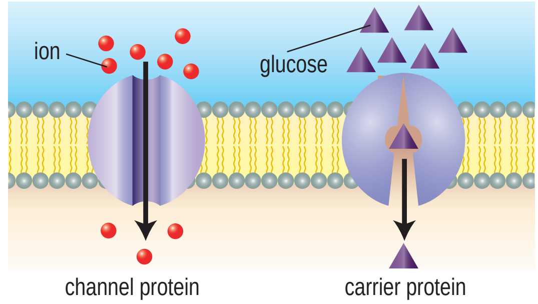


FIGURE 3.7 Facilitated diffusion through channel and carrier proteins

The process of the movement of glucose molecules across a plasma membrane occurs through a facilitated diffusion (Figure 3.8).

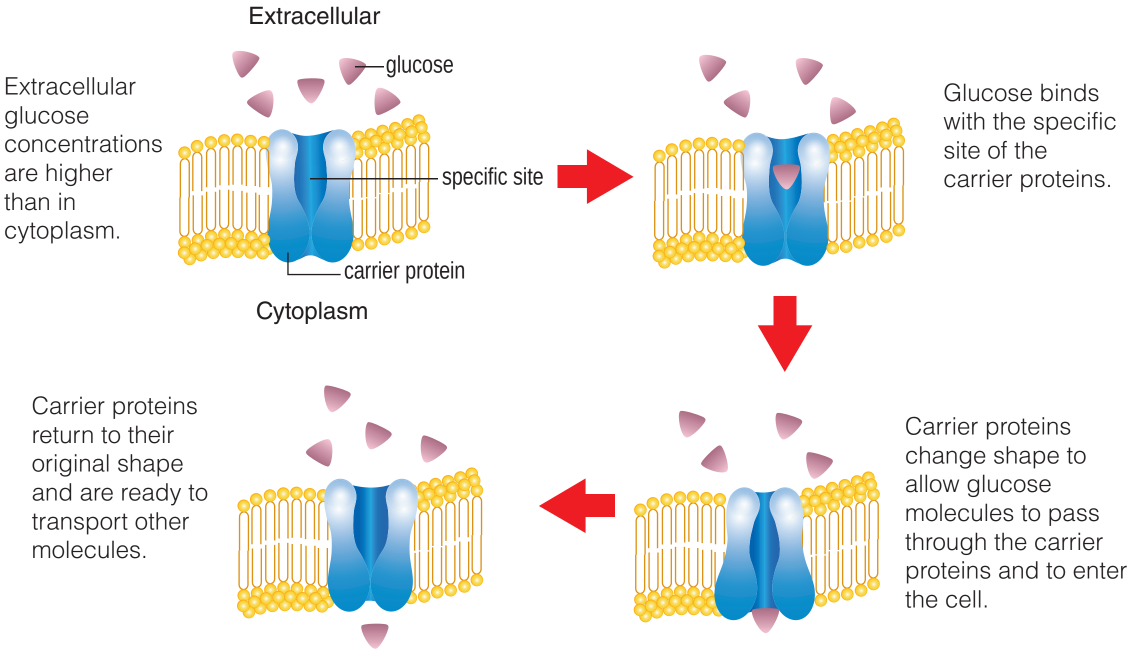


FIGURE 3.8 Facilitated diffusion through carrier proteins

Active transport

Movement of substances across a plasma membrane may occur by **active transport**. The characteristics of an active transport are as follows:

- The movement of molecule or ion substances across a plasma membrane occurs **against a concentration gradient**.
- It requires energy from **ATP** (adenosine triphosphate) molecules generated during cellular respiration.
- It requires **specific carrier protein** with **specific sites** to bind with certain molecules or ions.
- Carrier proteins also possess receptors to bind with **ATP molecules**. Carrier proteins **change shape** when a phosphate group attaches to it. As a result, molecules or ions move across a membrane (Figure 3.9).

Active transport results in the **accumulation** or **excretion** of molecules or ions in the cell. Carrier proteins involved in active transport are known as **pumps**.

For example, in animal cells, the carrier proteins that transport sodium ions to extracelullar, and potassium ions into the cell are called **sodium-potassium pump**. The mechanism of the sodium-potassium pump is described in Figure 3.9.

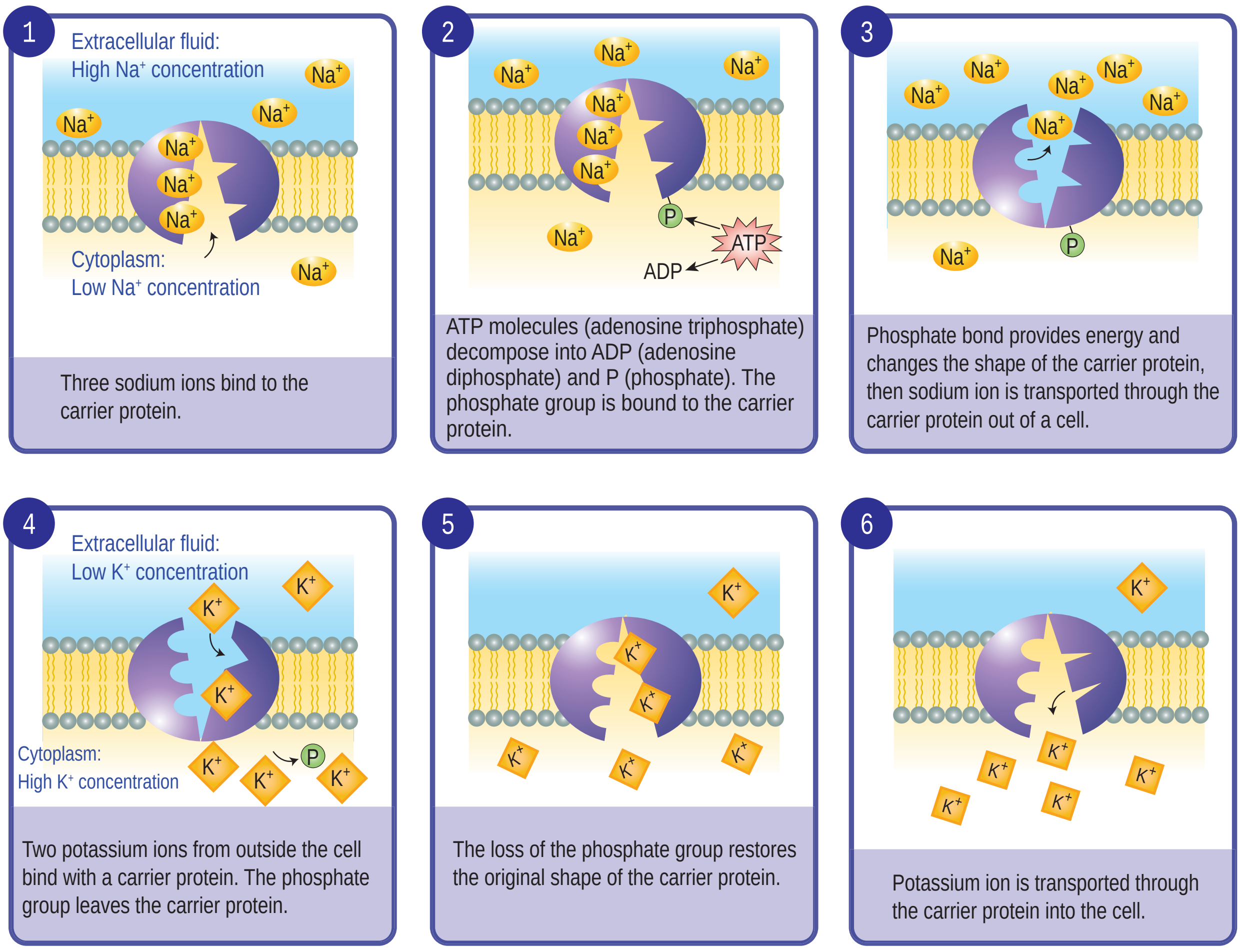


FIGURE 3.9 Sodium-potassium pump

There is another type of pump known as the **proton pump**. For example, the proton pumps that are found on the epithelial cells lining the stomach cavity. Proton pump causes the acidity of the stomach contents. Energy from the ATP enables the hydrogen ion to be transported by the carrier proteins (proton pump) towards the extracellular fluid. This causes an accumulation of the hydrogen ion and acid production in the stomach cavity. The proton pump mechanism is described in Figure 3.10.

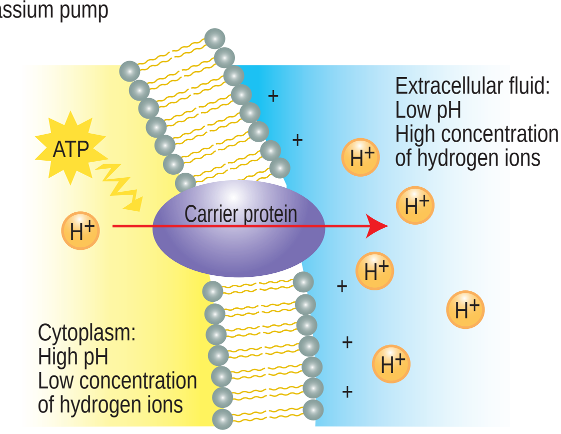


FIGURE 3.10 Proton pump

3.2.3

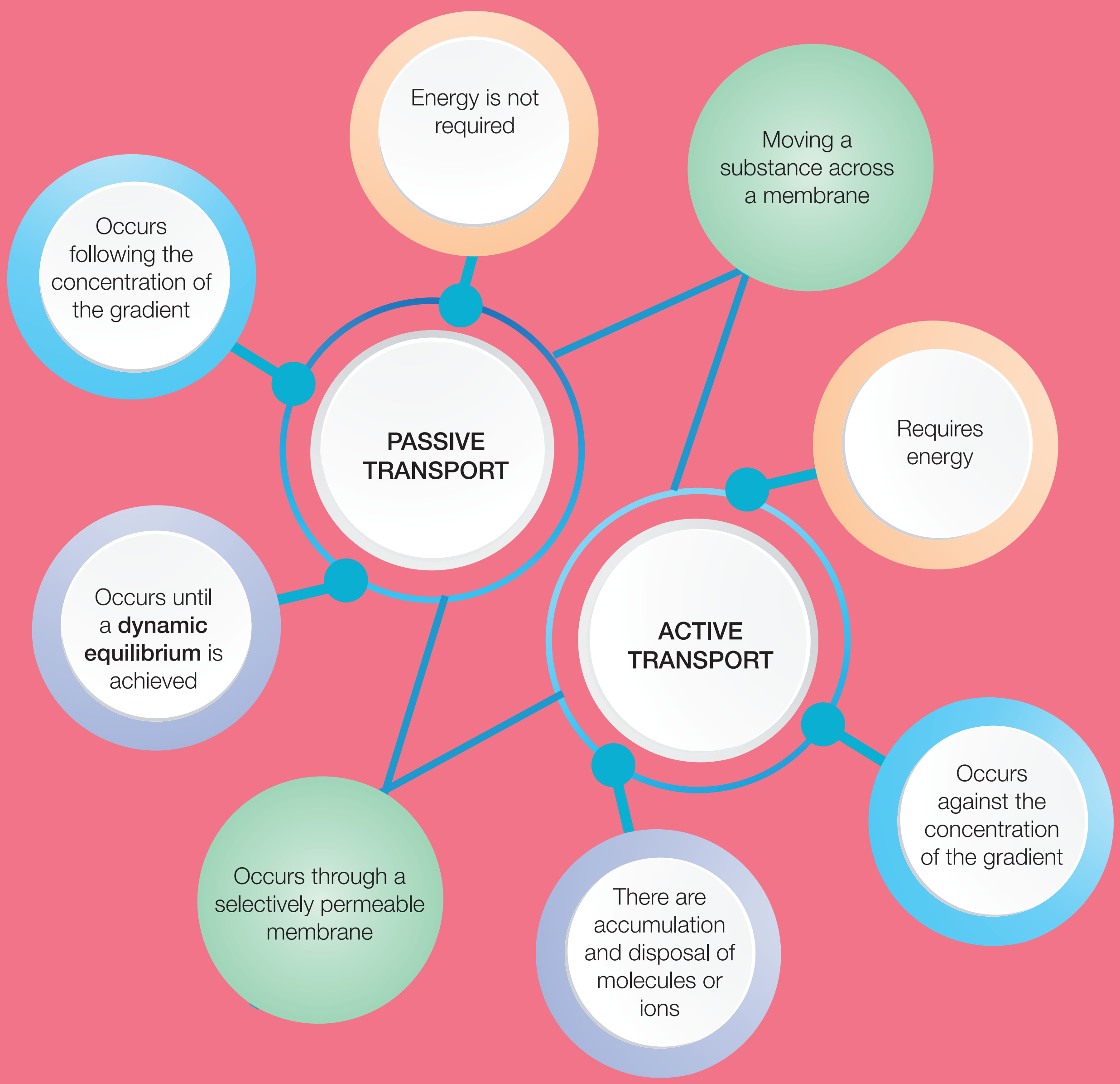


FIGURE 3.11 Similarities and differences between passive and active transports

Formative Practice 3.2

1 Give some examples of substances that are able to pass through the phospholipid bilayer.

2 Describe how sodium ions are transported out of the cell.

3 A scientist conducts an experiment by soaking the roots of a plant in a solution which contains mineral salts at different levels of oxygen concentrations. Explain why the mineral salts concentration in the roots increased when the oxygen concentration in the solution increases by 10%.

3.3 Movement of Substances Across a Plasma Membrane in Living Organisms

Active and passive transport in living organisms

Where do passive and active transport occur in living organisms?

Passive transport in organisms occurs during:	**Active transport** in organisms occurs during:
• gaseous exchange between an alveolus and a blood capillary through simple diffusion (Figure 3.12) • reabsorption of water occurs by osmosis through the renal tubule in the kidney • absorption of water by a plant root hair cell by osmosis (Figure 3.13) • absorption of fructose molecule in the villus by facilitated diffusion	• absorption of glucose and amino acids in the villus • reabsorption of glucose through the renal tubule in the kidney • transport of sucrose from a leaf to a phloem tissue • absorption of mineral ions by a plant root hair cell (Figure 3.13)

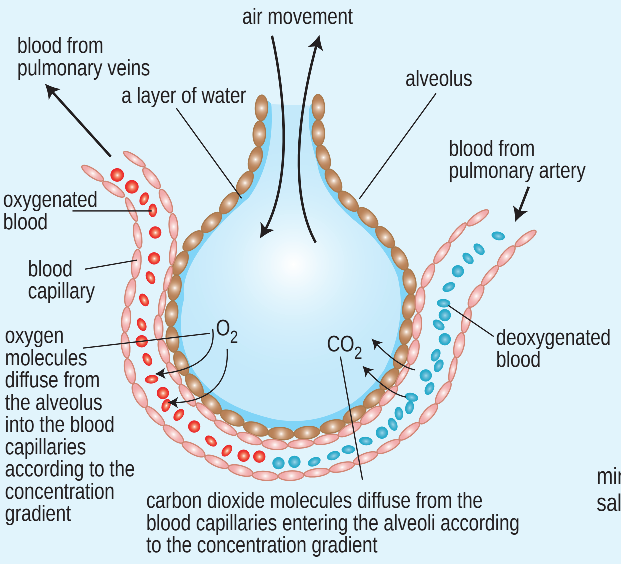


FIGURE 3.12 Gaseous exchange at the alveoli occurs by simple diffusion

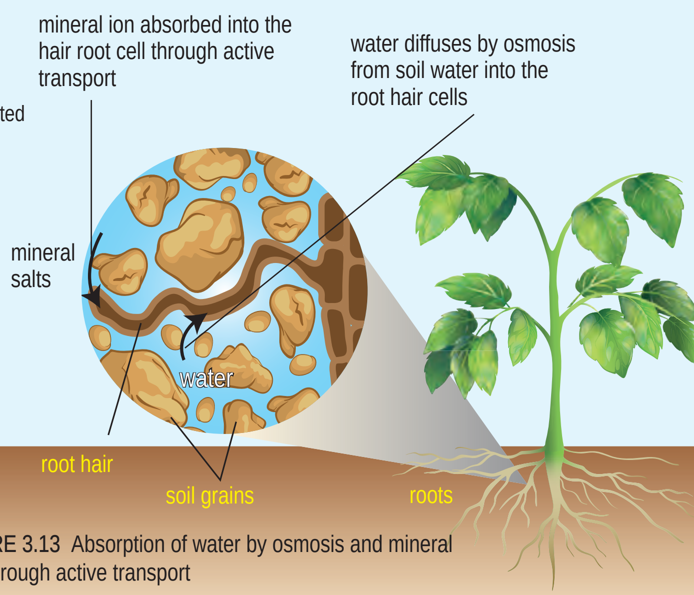


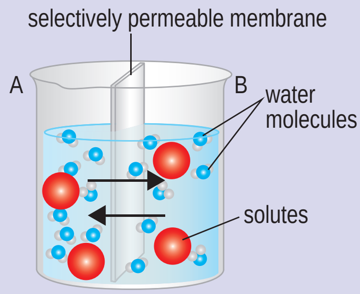
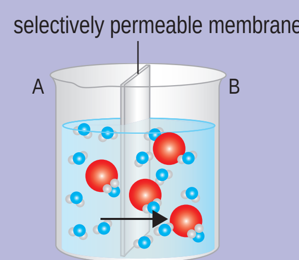
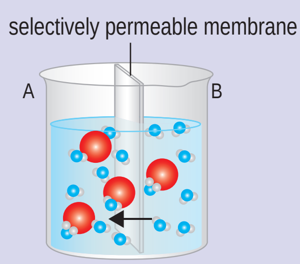
FIGURE 3.13 Absorption of water by osmosis and mineral ions through active transport

3.3.1 3.3.2

Isotonic, hypotonic and hypertonic solutions

Generally, there are three types of solutions: **isotonic**, **hypotonic** and **hypertonic**. As you have learned, diffusion of water occurs by osmosis from an area of high water potential to an area of low water potential across a plasma membrane. The explanation on each solution is summarised in Table 3.1.

TABLE 3.1 Isotonic, hypotonic and hypertonic solutions

Concept	Definition		Explanation
Isotonic solution	Solution A and B have the same concentrations of solutions.		Solutions A and B are isotonic toward each other. No net movement of water.
Hypotonic solution	Solution A has a low solutes concentration and high water potential.		Solution A is hypotonic to solution B. Water diffuses from solution A to B by osmosis.
Hypertonic solution	Solution A has a high solutes concentration and low water potential.		Solution A is hypertonic to B. Water diffuses from solution B to A by osmosis.

Activity Zone

Conduct an experiment to observe the effect of osmosis on an egg plasma membrane.

The effects of hypotonic, hypertonic and isotonic solutions on animal cells and plant cells

The cell cytoplasm contains solutes such as glucose and mineral salts. The fluid found in the cell is known as **intracellular fluid**. Each cell is surrounded by **extracellular fluid**.

Therefore, the cell will always go through the osmosis process and movement of water across the plasma membrane, depending on the water potential of the extracellular fluid and intracellular fluid.

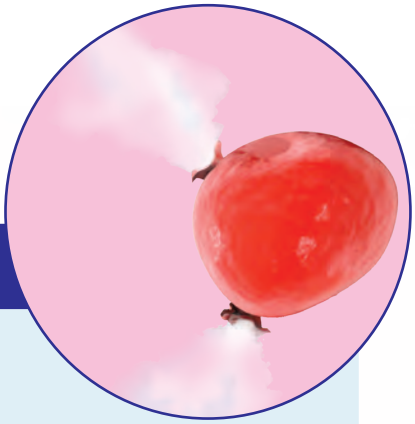
Biological Lens

The term haemolysis is only used for the burst of red blood cells.

AR

THE EFFECTS OF HYPOTONIC, ISOTONIC AND HYPERTONIC SOLUTIONS ON ANIMAL CELLS

EFFECT OF HYPOTONIC SOLUTION



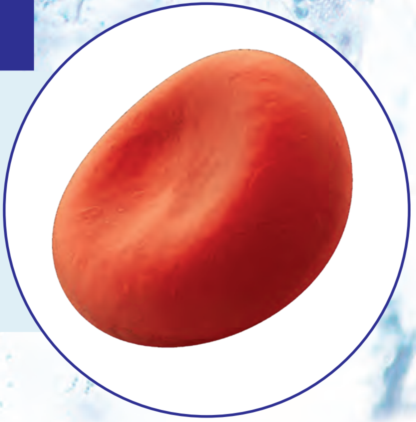
- When red blood cells are placed in a hypotonic solution, water will diffuse into the cells by osmosis, causing the cells to swell and finally burst.
- This is because the plasma membrane is too thin to withstand the osmotic pressure built up in the cells.
- The burst of red blood cells is known as **haemolysis**.

EFFECT OF HYPERTONIC SOLUTION

- When red blood cells are placed in a hypertonic solution, water will move out of the cells by osmosis.
- This will cause the cells to shrink.
- The red blood cells are said to undergo **crenation**.

EFFECT OF ISOTONIC SOLUTION

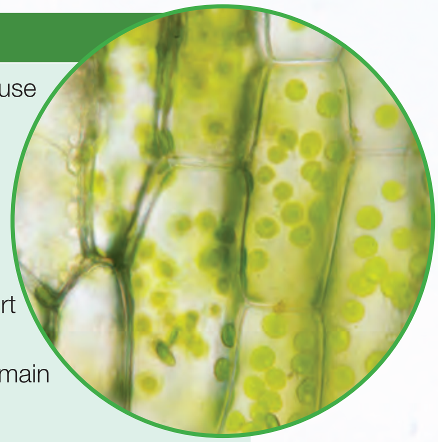
- Water diffuses into and out of the cell by osmosis at the same rate.
- No net movement of water across the plasma membrane.
- The cells maintain their normal shape.



3.3.4 3.3.5

EFFECT OF HYPOTONIC SOLUTION

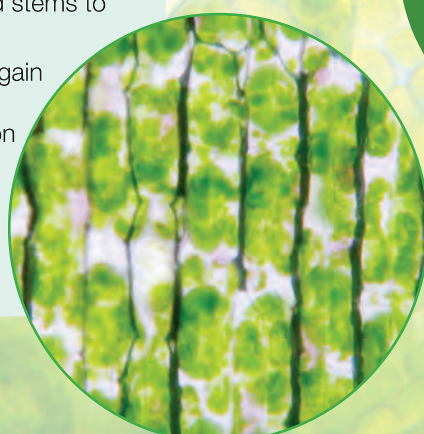
- When plant cells are placed in a hypotonic solution, water will diffuse into the vacuoles by osmosis.
- This will cause the vacuoles to expand and push the cytoplasm and plasma membrane against the cell wall.
- In this condition, the cells are said to be **turgid**.
- Plant cells do not burst because the cell wall is rigid and strong.
- Turgor pressure is important to plant cells because it gives support and maintains the shape of cell.
- Cell turgidity causes guard cell to swell to allow the stomata to remain open for photosynthesis.

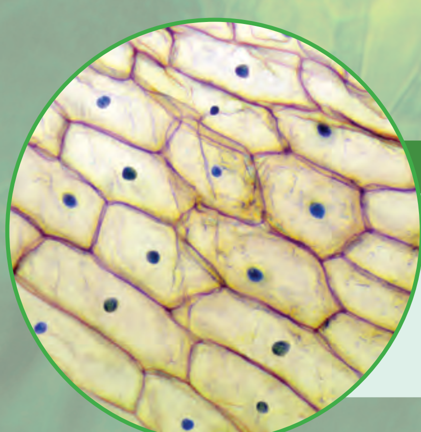


THE EFFECTS OF HYPOTONIC, ISOTONIC AND HYPERTONIC SOLUTIONS ON PLANT CELLS

EFFECT OF HYPERTONIC SOLUTION

- When plant cells are placed in a hypertonic solution, water will diffuse out of the vacuoles by osmosis.
- Vacuoles and the cytoplasm will shrink, causing the plasma membrane to be pulled away from the cell wall.
- This process is known as **plasmolysis.** Plasmolysis causes leaves and stems to bend downwards and wilt.
- Plasmolysed plant cells can regain their turgidity if the cells are returned to a hypotonic solution immediately.
- The cells are said to undergo **deplasmolysis**.





EFFECT OF ISOTONIC SOLUTION

- When the sap of the plant cell and extracellular solution are isotonic, water potential is the same.
- The movement of water diffusion in and out of cells is the same.
- Cells become **flaccid**.

Activity 3.3 Studying the effects of hypotonic, hypertonic and isotonic solutions on animal cells

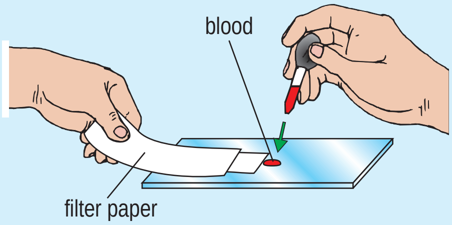
Experiment

Problem statement

What is the effect of hypotonic, hypertonic and isotonic solutions on animal cells?

Hypothesis

- Hypotonic solution causes the cell to explode.
- Hypertonic solution causes the cell to shrink.
- Isotonic solution causes the cell to remain normal.



Variables

Manipulated: Concentration of surrounding solution
Responding: Chicken blood cells condition
Fixed: Surrounding temperature and types of cell

Materials

Fresh chicken blood, 0.15 M and 0.50 M sodium chloride solutions, filter paper and distilled water

Apparatus

Light microscope, glass slide, dropper, mounting needle and cover slip

Take Note!

Red blood cells from the chicken are kept in sodium chloride solution to prevent blood clot.

Procedure

1. Prepare four slides and label as A, B, C and D.
2. Place a drop of fresh chicken blood on slide A and put a cover slip onto it.
3. Observe the shape of the red blood cells under a light microscope.
4. Put a drop of distilled water on slide B and cover with a cover slip.
5. Add a drop of blood on the edge of one side of the cover slip. At the same time, place a filter paper at the opposite side of the cover slip to spread the blood beneath the cover slip.
6. Examine the slide under a light microscope and draw the shape of the red blood cells in the table below.
7. Repeat steps 4 to 6. Replace the distilled water with 0.15 M sodium chloride solution (slide C) and 0.50 M sodium chloride solution (slide D).

Results

Slide	Observation	Labelled drawing of cell shape
A (red blood cells)		
B (red blood cells in distilled water)		
C (red blood cells in 0.15 M sodium chloride solution)		
D (red blood cells in 0.50 M sodium chloride solution)		

Discussion

1. Discuss and explain the results obtained for each slide.
2. Which solution is hypotonic, hypertonic and isotonic to the red blood cells?
3. What happened to the red blood cells in slides B and D?

Conclusion

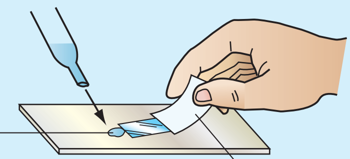
Is the hypothesis accepted? Suggest a suitable conclusion.

Activity 3.4 Studying the effects of hypotonic, hypertonic and isotonic solutions on plant cells

Experiment

Problem statement
What is the effect of different solution concentrations on plant cells?

Hypothesis
- Hypotonic solution causes the plant cells to become turgid.
- Hypertonic solution causes the plant cells to undergo plasmolysis.
- Isotonic solution causes the plant cells to become flaccid.



Variables
Manipulated: Concentration of surrounding solution
Responding: Plant cells condition
Fixed: Types of plant cells

Materials
0.50 M and 1.0 M sucrose solutions, distilled water, filter paper and an onion bulb

Apparatus
Light microscope, glass slide, cover slip, small knife, mounting needle, dropper and a pair of forceps

Procedure
1. Prepare three slides and label as A, B and C.
2. Peel off the epidermal layer (skin) from the inner surface of an onion scale leaf and place it in a drop of distilled water on slide A. Use a cover slip to cover the glass slide.
3. Observe the epidermal cells of the onion scale leaf under the microscope. Draw and label your observation.
4. Peel off another epidermal layer (skin) of the onion scale leaf and put it on slide B. Cover with a cover slip. Add a drop of 0.50 M sucrose solution on the edge of one side of the cover slip. Spread the solution under the cover slip by placing a filter paper at the opposite side of the cover slip. Examine the epidermal cell under the microscope. Draw and label your observation.
5. Repeat step 4 by replacing 0.50 M sucrose solution with 1.0 M sucrose solution (slide C).
6. Flow excess distilled water through the onion scale leaf on slide C. Observe the cells under the microscope. Draw and label your observation.

Results

Slide	Observation	Labelled drawing of cell shape
A (distilled water)		
B (0.5 M sucrose solution)		
C (1.0 M sucrose solution)		
Slide C after being flowed with excess distilled water		

Discussion

1. Discuss and explain the results obtained for each slide.
2. Which solution is hypotonic, hypertonic and isotonic to plant cells?
3. What happened to the plant cells in slide C?

Conclusion

Is the hypothesis accepted? Suggest a suitable conclusion.

Activity 3.5 Studying and determining the concentration of extracellular solution which is isotonic to the cell sap of a plant

Experiment

Problem statement

What is the concentration of the extracellular solution which is isotonic to the cell sap of potatoes?

Hypothesis

Concentration of the extracellular solution which is isotonic to the potato cell sap does not change the mass of the potato cell sap.

Variables

Manipulated: Concentration of sucrose solution
Responding: Percentage of difference in the mass of potato strips
Fixed: Soaking period, surrounding temperature and type of potato

Materials

Potato, distilled water, 0.1 M, 0.2 M, 0.3 M, 0.4 M, 0.5 M, 0.6 M sucrose solutions and filter paper

Apparatus

Test tube, cork borer, knife, forceps, ruler, 50 ml beaker, measuring cylinder, test tube rack and electronic weighing scale

Procedure

1. Seven petri dishes are prepared and labelled as A, B, C, D, E, F and G.
2. Fill each beaker with the following solutions:
   Beaker A: distilled water
   Beaker B: 0.1 M sucrose solution
   Beaker C: 0.2 M sucrose solution
   Beaker D: 0.3 M sucrose solution
   Beaker E: 0.4 M sucrose solution
   Beaker F: 0.5 M sucrose solution
   Beaker G: 0.6 M sucrose solution
3. A medium-sized cork borer is pressed into a potato.
4. The potato strip is then removed from the cork borer.
5. Next, the potato strip is cut to 50 mm in length.
6. Steps 3 to 5 are repeated to obtain 6 more cylinder of potato strips of the same length.
7. Wipe the potato strips using filter paper and each is weighed to get the initial mass.
8. Pour the solutions in beaker A to G into the test tube A to G, respectively. Each potato strip is soaked completely in each test tube.

Take Note!
Do not hold the potato with your hands while cutting. You should use a cutting board as a base.

3.4.1

9 After soaking for 30 minutes, remove each potato strip from the respective test tube and wipe dry with a filter paper. Weigh each strip to get the final mass.

10 The results are recorded. Plot a graph of the percentage of difference in mass against the concentration of sucrose solution.

Results

Test tube	Beaker	Mass of potato strips (g)		Difference in mass (g)	Percentage of difference in mass (%)
		Initial mass	Final mass		
A	Distilled water				
B	0.1 M sucrose solution				

Discussion

1 What is the texture and condition of each potato strip after being soaked in different concentrations of sucrose solutions?

2 How do you determine the concentration of sucrose solution which is isotonic to the potato sap cell from your graph?

3 Based on the experiment, discuss the process of osmosis in different concentrations of sucrose solutions.

Conclusion

Is the hypothesis accepted? Suggest a suitable conclusion.

Formative Practice 3.3

1 Explain what will happen to the following cells when they are soaked in a solution with a higher concentration of solutes compared to the intracellular fluid:

(a) red blood cells

(b) plant cells

2 Explain the effect of the hypotonic solution on red blood cells.

3 Explain the effect of the isotonic solution on plant cells.

4 Explain the following situations based on the osmosis concept:

(a) Why do hawkers spray water on their fruits and vegetables?

(b) Explain what happens when sugar is sprinkled on strawberries.

3.4 Movement of Substances Across a Plasma Membrane and Its Application in Daily Life

You have definitely eaten canned pickles, salted fish and fruits before. How are the concepts of osmosis and diffusion applied in food preservation?

You can also apply the concept of movement of substances across a plasma membrane by conducting Activity 3.6.

Activity 3.6 Applying the concept of movement of substances across a plasma membrane

Project

Materials

Egg, banana, cabbage, a variety of fruits, gelama fish, sugar, salt, vinegar and boiled water

Apparatus

Knife, bottle and oven

Procedure

1 Conduct the activity in a group.

2 Apply the concept of movement of substances across a plasma membrane in food production.

3 Use local raw materials and market the products at schools.

4 Among the food products that you can prepare are colourful preserved eggs, different flavours of smoked banana, salted fish, pickles and coloured cabbage.

Malaysian Innovation

A group of researchers in Malaysia were successful in developing *Sil-RH Membrane Distillation.* This membrane is made from paddy chaff and can be used for the desalination process.

Phenomenon of plant wilting

Fresh plants

Excessive use of fertilisers may cause wilting in plants. Dissolved fertilisers will cause soil water to be hypertonic to the sap cell of roots. Consequently, water will diffuse by osmosis from the roots' cell sap to the soil, and cells will become plasmolysed. Cells in plants will recover once they are watered. However, if the period of plasmolysis is prolonged, wilted plants will eventually die.

Wilted plants

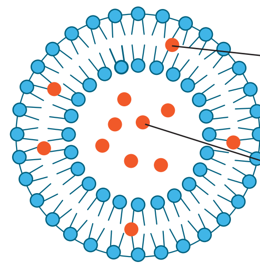
3.4.2

The concept of movement of substances across a plasma membrane has many applications in our daily lives, for example:

Rehydration drinks such as oral rehydration salts help to recover loss of water and electrolytes in individuals with diarrhoea.

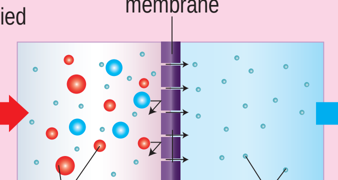
Isotonic drinks help athletes to recover loss of water and electrolytes such as potassium and sodium through perspiration.

Saline solutions, normally used in medicine, are isotonic solution to the blood plasma. It contains 0.85–0.90 g sodium chloride per 100 ml.



Liposomes are vesicles that contain aqueous solution surrounded by a phospholipid bilayer membrane. Liposomes are used to protect drugs or active substances taken orally from being destroyed by gastric juices. This way, drugs can reach the target cells.

Reverse osmosis is a technology commonly used to extract fresh water from seawater using the desalination process. In a reverse osmosis equipment, pressure is applied to push the seawater through a semi-permeable membrane. The membrane allows water molecules to pass through it but not foreign particles, salt and microorganisms. As a result, only pure fresh water is released.



Activity Zone

Study the reverse osmosis process in water purification.

ICT 3.4

Video: Liposome application
(Accessed on 21 August 2019)

Formative Practice 3.4

1 Explain why green chillies are preserved using vinegar and sugar.

2 Pickled pineapples are prepared by soaking the pineapple pieces in a thick sugar solution. State two advantages and disadvantages of this method as compared with keeping fresh pineapples.

3 Ariana had diarrhoea after eating stale food. Suggest something that can help her to recover.

4 A liposome is a vesicle that contains an aqueous solution that is surrounded by a phospholipid bilayer membrane. Explain the use of liposomes in everyday life.

3.4.3 3.4.4

Summary

MOVEMENT OF SUBSTANCES ACROSS A PLASMA MEMBRANE

Structure of Plasma Membrane

- Fluid mosaic model
- Plasma membrane consists of carrier proteins, channel proteins, phospholipid bilayer, glycoprotein, glycolipid and cholesterol

Concept of Movement of Substances Across a Plasma Membrane

- Passive transport
  - Simple diffusion
  - Osmosis
  - Facilitated diffusion
- Active transport

Movement of Substances Across a Plasma Membrane in Living Organisms

- Passive and active transport in living organisms
- Isotonic, hypotonic and hypertonic solutions
- Effect of isotonic, hypotonic and hypertonic solutions on animal cells and plant cells

Movement of Substances Across a Plasma Membrane and its Application in Daily Life

- Phenomenon of plant wilting
- Application of movement of substances across a plasma membrane in daily life
- Reverse osmosis process in water purification

Self Reflection

Have you mastered the following important concepts?

- The necessity of movement of substances across a plasma membrane
- Components of a plasma membrane and its function based on the fluid mosaic model
- Permeability of a plasma membrane
- The characteristics of substances that are able to move across a plasma membrane
- Passive and active transport
- Hypotonic, hypertonic and isotonic solutions
- Effect of different solution concentrations on plant cells and animal cells
- Application of the concept of movement of substances across a plasma membrane in daily life

Summative Practice 3

1 State the meaning of passive transport.

2 The characteristic of a membrane decides if the molecule can move across the membrane. Explain why the plasma membrane is impermeable to many types of molecules.

3 Explain why food is preserved using a thick sugar solution.

4 (a) Explain the role of contractile vacuole in controlling the water equilibrum in an *Amoeba* sp.
(b) Predict what will happen when the *Amoeba* sp. is transferred to the sea. Explain your answer.

5 (a) Figure 1 shows one component cell that is found in the cell.
(i) Name the component of the cell in Figure 1.
(ii) Label X and Y.
(b) In an experiment, the palisade mesophyll is soaked in filtered water for a period of time. Explain what will happen to the cell.

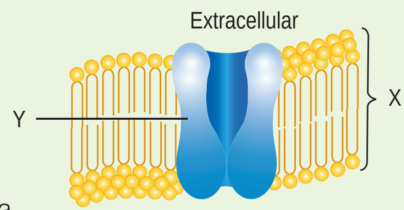


FIGURE 1

6 Figure 2 shows a type of substance movement across a plasma membrane. Explain why calcium ion in Figure 2 is taken to extracellular.

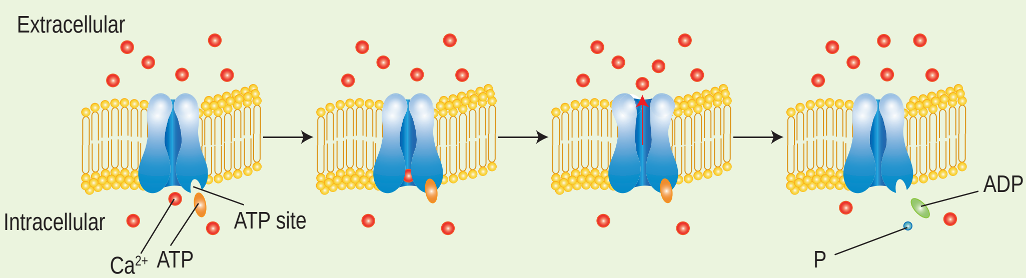


FIGURE 2

7 A research on the effect of the concentration of different salt solutions on human red blood cells was conducted. A droplet of blood was dropped into three test tubes A, B and C containing different solution contents. Test tube A contained 4.5% sodium chloride, test tube B contained filtered water and test tube C contained 0.85% sodium chloride. All three test tubes were set aside for 30 minutes.
(a) Explain the observed solution of each test tube for 30 minutes.
(b) Describe your observation on test tubes A and B.
(c) Draw the shape of the red blood cell for each test tube when viewed through the microscope.
(d) Suggest a suitable concentrated solution to keep red blood cells. Give justifications for your answer.

Essay Questions

8 State the similarities and differences between simple diffusion and osmosis.

9 (a) Some housewives soak their vegetables in salt solution before cooking to get rid of pesticides and worms.

(i) Explain why vegetables that are soaked too long in salt solution wither.

(ii) Suggest a way to revive the turgidity of the vegetables.

(b) Explain in detail how the molecules of amino acid are moved across a plasma membrane.

(c) Cosmetic cream containing lyposome is said to be more effective in skin care. Give your assessment on this statement.

Enrichment

10 You work in a company that produces drinks for different groups of athletes. The suggested carbohydrate concentration for the drinks are as follows: A gymnast:1–3%; middle distance runner: 6–8%; and footballer:10–12%.
Give justifications for the concentration of drinks that you produce.

11 The rate of movement of material P and material S across a plasma membrane is shown in Figure 3 and 4.

(a) Give an example of material P and explain how material P can move across a membrane plasma.

(b) Compare the movements of material P and material S across the membrane plasma.

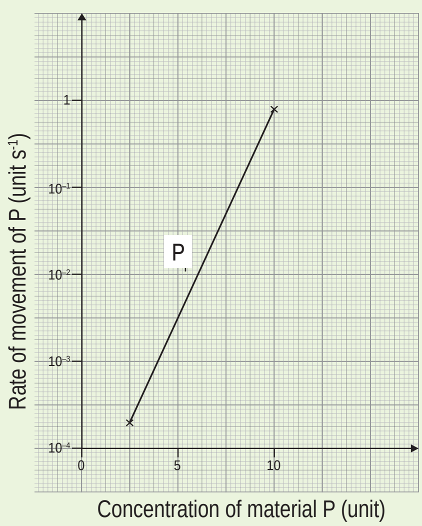


FIGURE 3

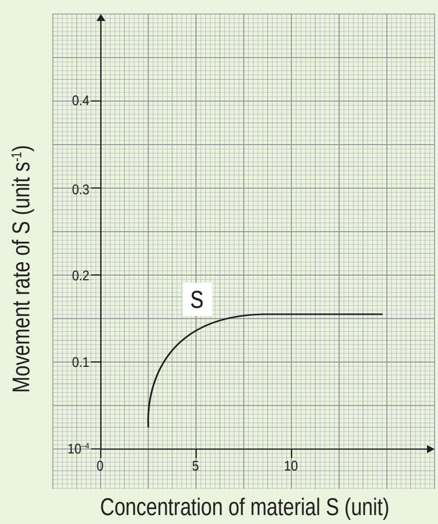


FIGURE 4

Complete answers are available by scanning the QR code provided

CHAPTER

4 Chemical Composition in a Cell

How can the knowledge of biological elements and molecules be used for biological control of fresh water snails?

Do You KNOW...

- What is the chemical composition in a cell?
- What are the properties of water and its importance in a cell?
- What are the elements found in carbohydrates, proteins, lipids and nucleic acids?
- How are polymers produced from monomers?
- What is the importance of carbohydrates, proteins, lipids and nucleic acids in a cell?

4.1 Water

- **4.1.1** Describe the properties of water molecule.
- **4.1.2** Correlate the properties of water with its importance in the cell.

4.2 Carbohydrates

- **4.2.1** List the elements of carbohydrate.
- **4.2.2** Explain the types of carbohydrates:
  - monosaccharides.
  - disaccharides.
  - polysaccharides.
- **4.2.3** Conceptualise the formation and breakdown of:
  - disaccharides.
  - polysaccharides.
- **4.2.4** Write and explain the word equation for the formation and the breakdown of disaccharides.
- **4.2.5** Justify the importance of carbohydrates in cell.

4.3 Proteins

- **4.3.1** List the elements of proteins.
- **4.3.2** Conceptualise the formation and breakdown of dipeptides and polypeptides.
- **4.3.3** Write and explain the word equation for the formation and the breakdown of dipeptides.
- **4.3.4** Justify the importance of proteins in a cell.

4.4 Lipids

- **4.4.1** List the elements in lipids.
- **4.4.2** Explain the main types of lipids.
- **4.4.3** Describe the formation and the breakdown of a triglyceride.
- **4.4.4** Write and explain the word equation for the formation and the breakdown of a triglyceride.
- **4.4.5** Justify the importance of lipids in cell and multicellular organisms.

4.5 Nucleic acids

- **4.5.1** List the elements in nucleic acids.
- **4.5.2** Explain the structure of nucleotides:
  - nitrogenous base
  - ribose or deoxyribose sugars
  - phosphate
- **4.5.3** Describe the structure of the nucleic acids:
  - deoxyribonucleic acid (DNA)
  - ribonucleic acid (RNA)
- **4.5.4** Justify the importance of nucleic acids in cells:
  - carrier of hereditary information.
  - production of proteins.
- **4.5.5** Describe the formation of chromosomes from DNA and proteins.

4.1 Water

In Form Two, you have learned briefly about water and organic compounds. Examples of organic compounds are carbohydrates, proteins, lipids and nucleic acids. What is the function of organic compounds and water in the cells of an organism?

Properties of water and its importance in a cell

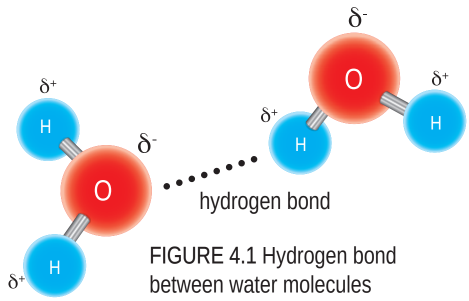


FIGURE 4.1 Hydrogen bond between water molecules

POLARITY OF WATER

- Water is an inorganic compound consisting of the hydrogen (H) and oxygen (O) elements.
- Water molecules are **polar molecules** because shared electrons between oxygen and hydrogen will be attracted towards oxygen which is more electronegative (δ⁻).
- This polarity produces hydrogen bonds and allows water to act as a **universal solvent** (Figure 4.1).
- The universal solvent properties of water allow solutes such as glucose and electrolytes to be transported through the plasma membranes into cells for biochemical reactions.

COHESIVE FORCE AND ADHESIVE FORCE OF WATER

- Water molecules are attached to each other through a **cohesive force**.
- At the same time, water molecules are also attached to other surfaces through **adhesive force**.
- Both forces produce the capillary action which allows water to enter and move along narrow spaces, such as in the xylem tube.

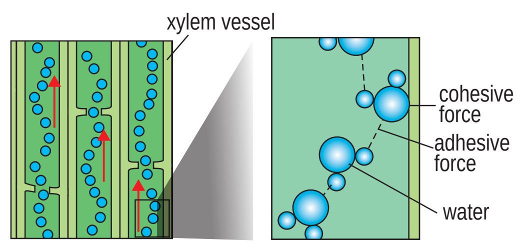


FIGURE 4.2 Cohesive force and adhesive force inside the xylem tube

Brainstorm!

How do aquatic animals live in frozen sea water?

PHOTOGRAPH 4.1 A polar bear in the sea covered with ice

SPECIFIC HEAT CAPACITY OF WATER

- Water has a high specific heat capacity of 4.2 kJ kg^{-1} °C^{-1}.
- This means that 4.2 kJ of heat energy is required to raise the temperature of one kilogram of water by 1°C.
- Water absorbs a lot of heat energy with a small rise in temperature. This characteristic is very important to maintain the body temperature of organisms.

ICT 4.1

Quiz: Test your understanding of water

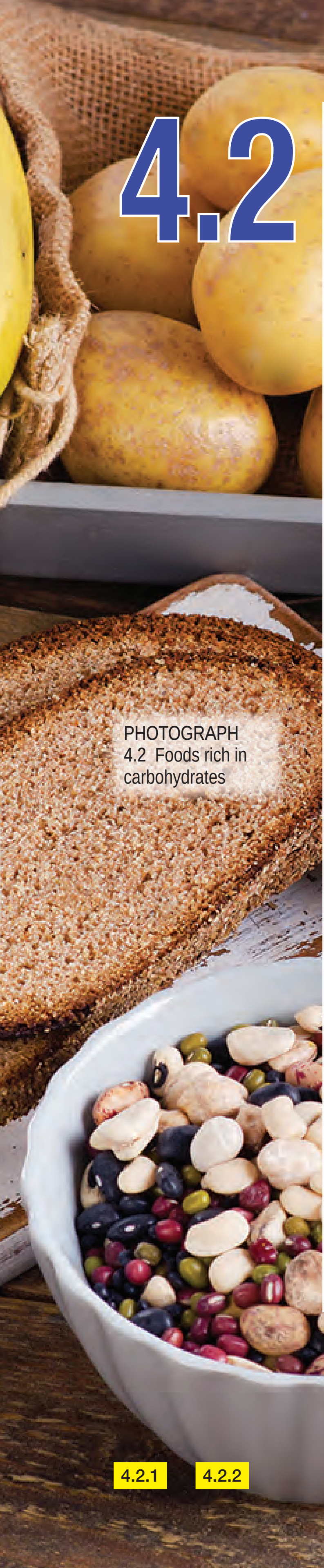
Formative Practice 4.1

1 What chemical bonds are broken when water changes from liquid to water vapour?
2 Why is water known as polar molecule?
3 State the meaning of adhesive force and cohesive force.
4 Explain how perspiration helps to lower the body temperature.

4.2 Carbohydrates

Organic compounds are chemical compounds that contain carbon elements. Large and complex compounds form macromolecules. Most macromolecules are **polymers** comprising small molecules known as **monomers** (building blocks). Carbohydrates, proteins and nucleic acids are polymer molecules of organic compounds.

Carbohydrates are important as a source of energy and the basic structure of some organisms. **Carbohydrates** are organic compounds consisting of the elements carbon (C), hydrogen (H) and oxygen (O) in the ratio 1:2:1 and with the chemical formula $(CH_2O)_n$.



PHOTOGRAPH 4.2 Foods rich in carbohydrates

Types of carbohydrates

There are three main types of carbohydrates, which are:

- monosaccharides (simple sugars)
- disaccharides
- polysaccharides (complex sugars)

Monosaccharides

Monosaccharides are carbohydrate monomers, which are the simplest carbohydrate units. Monosaccharides can combine to form polymers through a condensation reaction. Most monosaccharides taste sweet, can form crystals and dissolve in water.

Examples of monosaccharides:

- **Glucose** is a sugar found in plants such as rice and wheat as well as fruits such as grapes. Glucose is the most commonly found monosaccharide and most polysaccharides are formed from this sugar.
- **Fructose** is the sugar found in honey and sweet fruits.
- **Galactose** is found in milk.

Monosaccharide has the reducing power, which is the ability to transfer hydrogen (or electron) to other compounds. This is called the reducing process. When the monosaccharide is heated in Benedict's solution, the monosaccharide will reduce the blue copper (II) sulphate to a brick red precipitate of copper (I) oxide which is not soluble in water. All monosaccharides give this reaction and it is known as **reducing sugars**.

4.2.1 4.2.2

Activity Zone

Design an experiment to ascertain the presence of reducing sugar and non-reducing sugar (sucrose).

Disaccharides

Disaccharide molecules are formed when two simple sugar molecules (monosaccharides) combine through **condensation** to form a **disaccharide** unit. This process involves the removal of a water molecule.

$$\text{Glucose} + \text{glucose} \xrightarrow{\text{condensation}} \text{Maltose} + \text{water}$$
$$\text{Glucose} + \text{fructose} \xrightarrow{\text{condensation}} \text{Sucrose} + \text{water}$$
$$\text{Glucose} + \text{galactose} \xrightarrow{\text{condensation}} \text{Lactose} + \text{water}$$

Disaccharides can also be broken down to their monosaccharide units through **hydrolysis** and the addition of one water molecule.

$$\text{Maltose} + \text{water} \xrightarrow{\text{hydrolysis}} \text{Glucose} + \text{glucose}$$
$$\text{Sucrose} + \text{water} \xrightarrow{\text{hydrolysis}} \text{Glucose} + \text{fructose}$$
$$\text{Lactose} + \text{water} \xrightarrow{\text{hydrolysis}} \text{Glucose} + \text{galactose}$$

Examples of disaccharides include sucrose, maltose and lactose (Photograph 4.3). Lactose and maltose are reducing sugars while sucrose is a non-reducing sugar.

PHOTOGRAPH 4.3 Examples of disaccharides and its sources

Biological Lens

Sucrose is a non-reducing sugar because it does not reduce copper (II) sulphate solution. If sucrose is hydrolysed (disintegrated) into units of monosaccharides (glucose and fructose) earlier, the Benedict's test will show a positive result.

4.2.2 4.2.3 4.2.4

Polysaccharides

Polysaccharides are sugar polymers consisting of monosaccharide monomers. Similar to disaccharides, polysaccharides are formed through the condensation process and involves hundreds of monosaccharides to form long molecular chains. Polysaccharides are not soluble in water due to their large molecular size. Polysaccharides neither taste sweet nor crystallise.

Polysaccharides can also disintegrate through hydrolysis with the help of dilute acids, boiling and enzyme action. Polysaccharides play various roles in organisms.

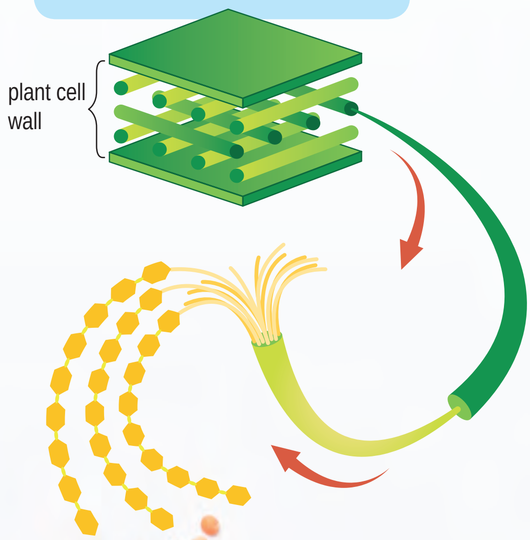
ICT 4.2

Quiz: Test your understanding of carbohydrates

Importance of carbohydrates in cells

- As a source of energy, for example glucose
- As a food reserve, for example glycogen in animal cells and starch in plant cells
- As a support structure, for example cellulose in the plant cell wall

Cellulose forms the main structure of the plant cell wall.



Starch is the main storage of polysaccharide in plants. Starch is also found in chloroplasts. Source: grains, potatoes and legumes.

Glycogen is the main storage of polysaccharide found in muscle cells and animal liver cells.

PHOTOGRAPH 4.4 Examples of polysaccharides

Our World of Biology

Chitin, a type of polysaccharide, is used as a surgical thread. The advantage is that chitin will decompose after the sewn wound heals.

Formative Practice 4.2

1 Name the elements in carbohydrates.
2 List the main types of carbohydrates.
3 Give examples of reducing sugars and non-reducing sugars.
4 Explain why sucrose is a non-reducing sugar.

4.2.3 4.2.5

4.3 Protein

PHOTOGRAPH 4.5
Foods rich in proteins

Protein is a complex compound composed of **carbon**, **hydrogen**, **oxygen** and **nitrogen** elements. Most proteins also contain **sulphur** and **phosphorus**. Foods rich in proteins include fish, meat, milk, beans and eggs. All proteins are composed of one or more polymers known as **polypeptides**. Each polypeptide is made up of **monomers** or small units known as **amino acids**. A polypeptide can consist of fifty to thousands of amino acid molecules. Amino acids are linked together through the **condensation** process.

Dipeptides are composed of two amino acid molecules which are linked together by a **peptide bond** through the condensation process. In this process, one water molecule is removed. Further **condensation** can link more amino acids to form a **polypeptide** chain.

$$\text{Amino acid + amino acid} \xrightarrow{\text{condensation}} \text{Dipeptide + water}$$

$$\text{Dipeptide + water} \xrightarrow{\text{hydrolysis}} \text{Amino acid + amino acid}$$

Each dipeptide can be broken down into an amino acid through hydrolysis.

There are about 20 types of amino acids present naturally. Various types of polypeptide molecules can be formed from the 20 types of amino acids. This is because each type of protein differs in terms of the amino acid sequence in its polypeptide chain.

Importance of proteins in a cell

Proteins are used to build new cells, repair damaged tissues and for the synthesis of enzymes, hormones, antibodies and haemoglobin. Proteins also form building blocks such as keratin in the skin, collagen in bones and myosin in muscle tissues.

The breakdown of proteins or polypeptides by digestive enzymes gives us the energy to carry out our daily activities. Polypeptides can disintegrate into amino acids. This amino acid is then used again to build the protein molecules needed by the body. You will learn in detail about the process of protein digestion in Chapter 9.

ICT 4.3

Quiz: Test your understanding of proteins

Formative Practice 4.3

1 State the monomers of proteins.
2 Name the reaction that forms dipeptide.
3 State two importance of proteins.
4 Explain the effect of protein deficiency in a diet on the hair and nails of an individual.

4.3.1 4.3.2 4.3.3 4.3.4

4.4 Lipids

Lipids are naturally occurring hydrophobic compounds found in plant and animal tissues. Like carbohydrates, lipid is made up of carbon, hydrogen and oxygen elements but with a much higher ratio of hydrogen atoms to oxygen atoms.

Lipids are insoluble in water but soluble in other organic solvents, for example, alcohol, ether and chloroform.

Biological Lens

The presence of fats can be tested with the ethanol emulsion test. The formation of a white emulsion shows a positive result of the presence of lipids.

ICT 4.4

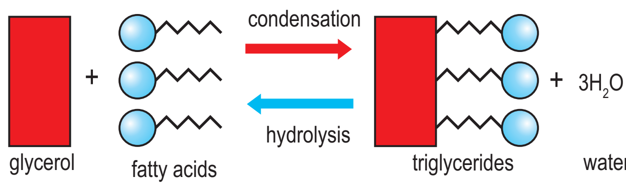
Quiz: Test your understanding of lipids

Types of lipids

Types of lipids include **fats**, **waxes**, **phospholipids** and **steroids**.

Fats

Fats and **oils** are **triglycerides**. **Triglycerides** are a type of ester formed from the **condensation** of one **glycerol** molecule with **three molecules of fatty acids**. Triglycerides can be **hydrolysed** again into fatty acids and glycerol through the reaction of hydrolysis. **Glycerols** are a type of three carbon alcohol that contain three **hydroxyl** groups (–OH).



There are two types of fatty acids, namely **saturated fatty acids** and **unsaturated fatty acids**. The similarities and differences between saturated fats and unsaturated fats are shown in Tables 4.1 and 4.2.

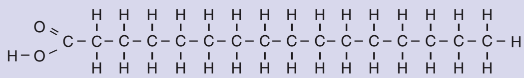
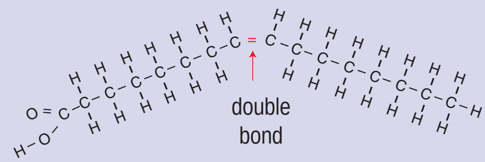
TABLE 4.1 Similarities between saturated fats and unsaturated fats

Similarities
Both consist of carbon, hydrogen and oxygen elements.
Both contain glycerol and fatty acids.
Both contain nonpolar molecules.

PHOTOGRAPH 4.6 Foods rich in lipids

4.4.1 4.4.2 4.4.3

TABLE 4.2 Comparison between saturated fats and unsaturated fats

Saturated fats	Unsaturated fats
Fatty acids only have single bonds between carbon. 	Fatty acids have at least one double bond between carbon. 
Do not form chemical bonds with additional hydrogen atoms because all bonds between carbon atoms are saturated.	Double bonds can still receive one or more additional hydrogen atoms because carbon atoms are unsaturated.
Exist in solid form at room temperature.	Exist in liquid form at room temperature.
Source: butter and animal fat	Source: olive and fish oil

Our World of Biology

Saturated fats are not good for health because it raises the cholesterol level in the blood in the form of low-density lipoprotein (LDL). This increases the risk of a heart attack. Saturated fats can also increase the risk of diabetes.

Wax

Wax contains one molecule of alcohol that combines with another molecule of fatty acid and is waterproof.

Phospholipid

Phospholipids are a major component of plasma membranes and are made up of one molecule of glycerol that combines with two molecules of fatty acid and one group of phosphate.

Steroids

Steroids are lipids that do not contain fatty acids. Examples of steroids are cholesterol, testosterone, estrogen and progesterone.

Importance of lipids in cells

Fats function as reserved energy for animals. In addition, fats also function as a liner to protect internal organs and act as a heat insulator for animals.

Waxes are an important component in cuticles that cover the epidermis of leaves and sebum secreted by our skin. The function of glycolipid is to ensure the stability of the plasma membrane and to help in the cell identification process. Cholesterol is important in steroid hormone synthesis.

Formative Practice 4.4

1 State the elements in lipids.
2 List the types of lipids.

3 Give your opinion on the intake of synthetic steroids to build body muscles.

4.4.4 4.4.5

4.5 Nucleic Acids

ICT 4.5

Activity: Making a DNA model

Nucleic acids are one or two polymer chains comprising of nucleotide monomers. Nucleic acids are formed from the elements of carbon, hydrogen, oxygen, nitrogen and phosphorus. Each nucleotide consists of a **pentose sugar** (5-carbon sugar), a **nitrogenous base** and a **phosphate group** that are combined together through the condensation process (Figure 4.3). There are two types of pentose sugars, that are, **ribose** and **deoxyribose**. The nitrogenous base consists of **adenine** (A) **guanine** (G), **cytosine** (C), **thymine** (T) and **uracil** (U).

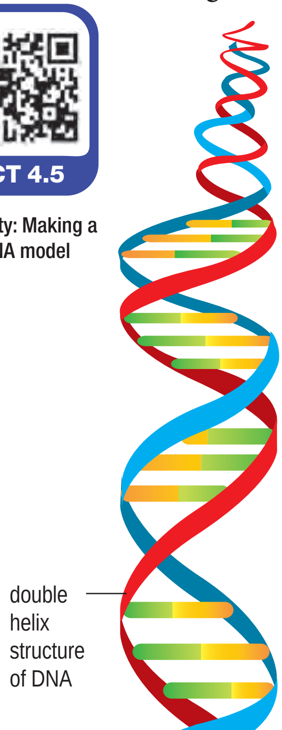
There are two types of nucleic acids:

- **deoxyribonucleic acid (DNA)**
- **ribonucleic acid (RNA)**

Ribonucleic acid (RNA) contains **ribose sugar** while deoxyribonucleic acid (DNA) contains **deoxyribose sugar**.

Deoxyribonucleic acid (DNA)

DNA consists of two polynucleotide chains that are intertwined in opposite directions and form the **double helix** (Figure 4.3). The nitrogenous base groups on both polynucleotide chains are matched and bound together by hydrogen bonds. The nitrogenous bases for DNA are adenine (A), guanine (G), thymine (T) and cytosine (C). Adenine will pair with thymine while guanine will pair with cytosine.



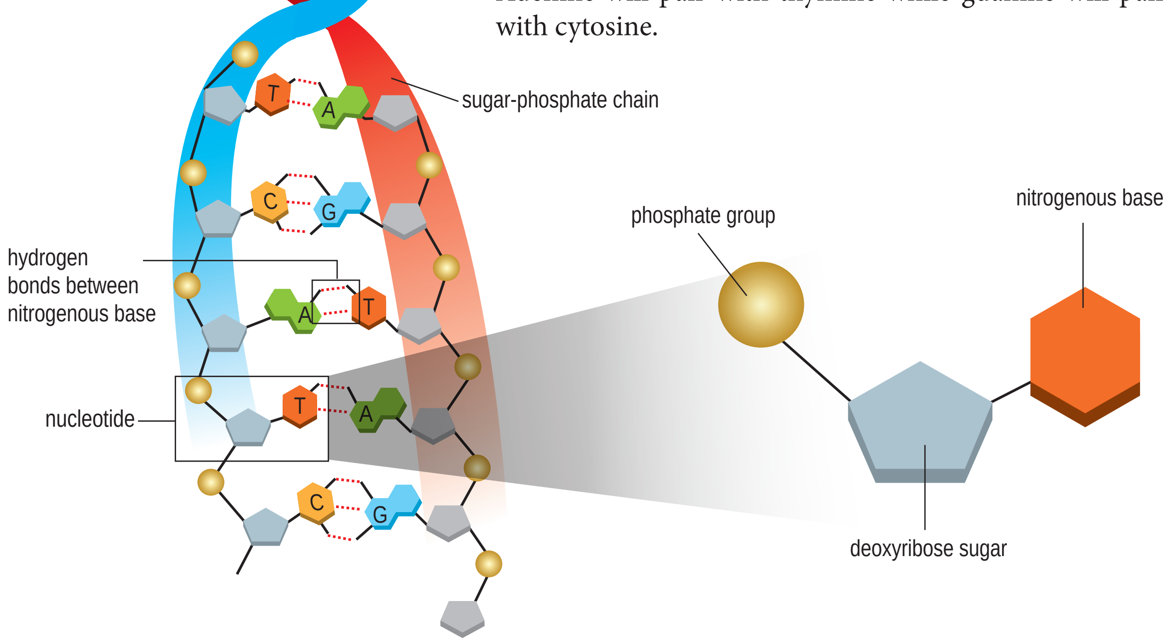


FIGURE 4.3 Double helix structure of DNA

4.5.1 4.5.2 4.5.3

Ribonucleic acid (RNA)

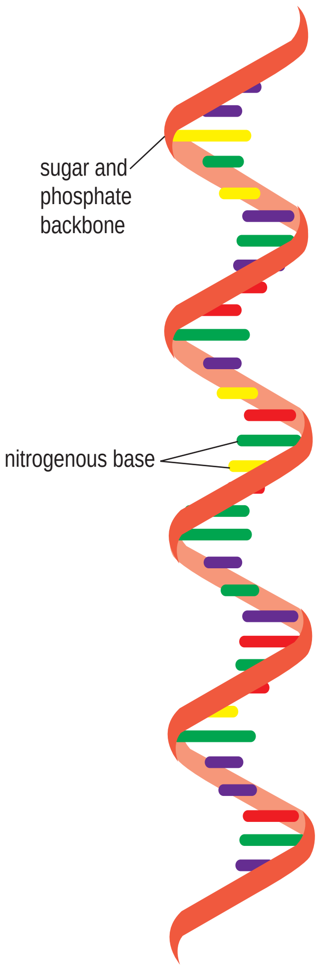


FIGURE 4.4 Structure of RNA

The RNA structure is a single polynucleotide chain which is shorter compared to DNA (Figure 4.4).

The nitrogenous bases for RNA are adenine, guanine, cytosine and uracil. Thymine in DNA is replaced by uracil in RNA.

The three main types of RNA, are **messenger RNA (mRNA)**, **ribosomal RNA (rRNA)** and **transfer RNA (tRNA)**. These three RNAs are involved in the protein synthesis process.

Importance of nucleic acids in a cell

Do you know what determines the characteristics of an organism such as eye colour or height? DNA is important as a **carrier of hereditary information** and a determinant of characteristics in living organisms. DNA contains genetic codes carried by nitrogenous bases (A, G, C and T) for the synthesis of polypeptides which form proteins.

The **genetic code** is written as a series of three bases that determine the sequence of amino acids in proteins to be synthesised. For example, the AUG codon (base sequence: adenine, uracil and guanine) on mRNA is the code for methionine amino acid (Figure 4.5). The three-base sequence in DNA is transcribed into mRNA codons which are then translated into the amino acid sequence to form a single polypeptide chain. This means that the sequence of nucleotides in DNA determines the amino acid sequence in the polypeptide chain that builds the corresponding protein.

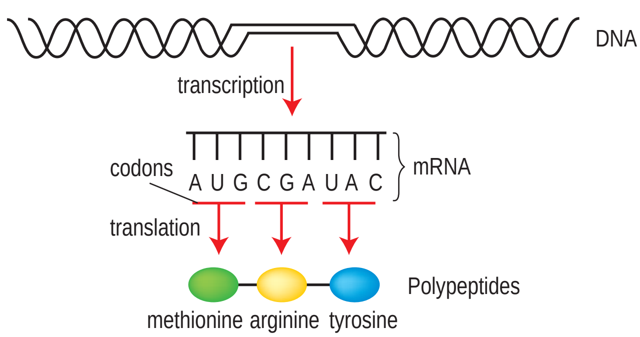


FIGURE 4.5 Genetic code on mRNA is translated into protein

ICT 4.6

Quiz: Test your understanding of nucleic acids

Formation of chromosomes from DNA and proteins

Chromosomes are formed from DNA polynucleotide chains that are wound around a protein called **histone**. Histones do not carry genetic information. DNA molecules combine with histone proteins to form **nucleosomes**. Nucleosomes are intertwined to form the chromosome structure.

4.5.3 4.5.4 4.5.5

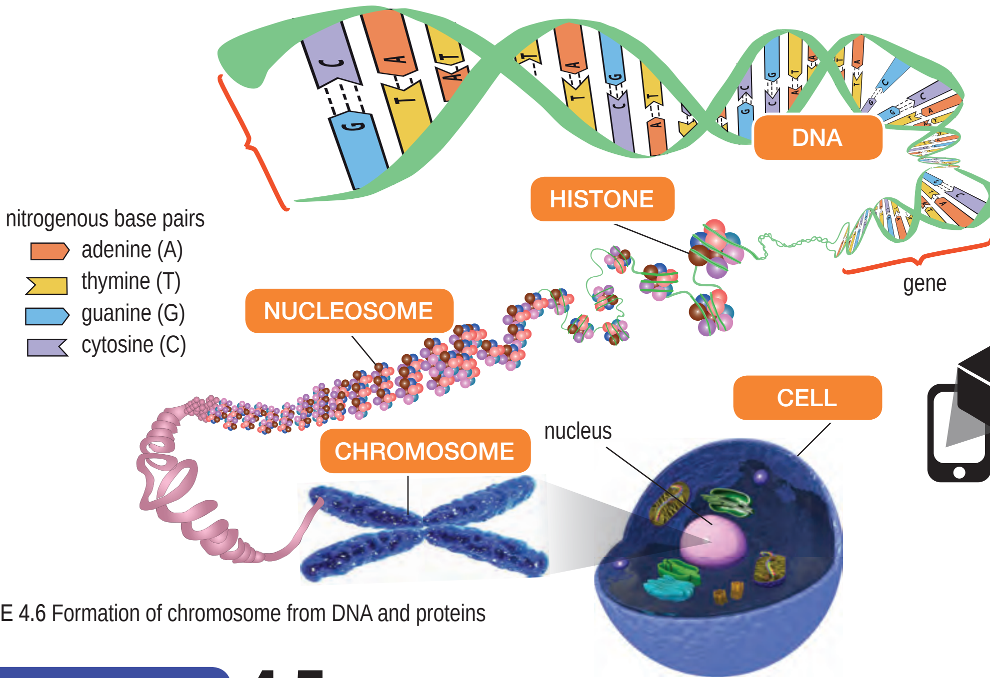


FIGURE 4.6 Formation of chromosome from DNA and proteins

Formative Practice 4.5

1 State two types of nucleic acids.
2 State the components in a nucleotide.
3 Explain why the RNA structure is shorter than the DNA structure.
4 Explain the possibility that may occur if a cell does not have a nucleic acid.

Summary

CHEMICAL COMPOSTION IN A CELL

Water
Characteristics: water polarity, specific heat capacity of water, adhesive force and cohesive force of water

Carbohydrates
Type:
- monosaccharide: glucose, fructose and galactose
- disaccharide: maltose, sucrose and lactose
- polysaccharide: starch, glycogen and cellulose

Proteins
Amino acid → Dipeptides → Polypeptides

Lipids
- Type: fats, wax, phospholipids and steroids
- Comparison between saturated fats and unsaturated fats

Nucleic Acids
- Each nucleotide consists of pentose sugar, nitrogeneous base and phosphat group
- Type:
  - DNA
  - RNA

Self Reflection

Have you mastered the following important concepts?

- Properties of water and its importance in cells
- Types of carbohydrates and its importance in cells
- Elements of proteins and its importance in cells
- Types of lipids and its importance in cells
- Structure of nucleic acids and its importance in cells
- Formation of chromosomes

Summative Practice 4

1 Wax is a type of lipid. Wax can be found in the leaf cuticle, fruits and seeds. Explain the function of wax on a fruit skin.

2 Figure 1 shows a nucleotide.

(a) Name the components P, Q and R.

(b) Complete Figure 2 to show a complete DNA molecule.

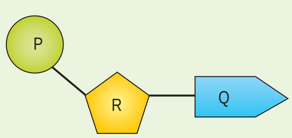


FIGURE 1

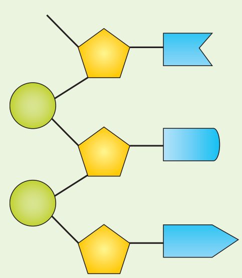


FIGURE 2

3 State the differences between

(a) the structure of a DNA molecule and a polypeptide molecule

(b) the structure of DNA and RNA

4 (a) How does water help in the respiration and digestion process?

(b) What are the characteristics of aquatic life that allows them to live throughout winter?

5 Figure 3 shows the reaction between the formation and the decomposition of lipids.

(a) (i) Name the parts labelled K, L and M.

(ii) State processes P and Q.

(b) Fatty acids are divided into saturated fatty acids and unsaturated fatty acids. State the four differences between saturated fats and unsaturated fats.

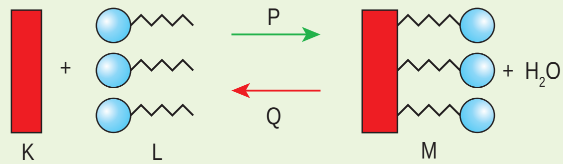


FIGURE 3

Essay Questions

6 Figure 4 shows the production of carbohydrates through the process of photosynthesis. Carbohydrate is a type of macromolecule.

(a) Explain the meaning of organic compound macromolecules.

(b) Explain the formation of polysaccharide.

(c) Discuss the importance of organic compounds in cells.

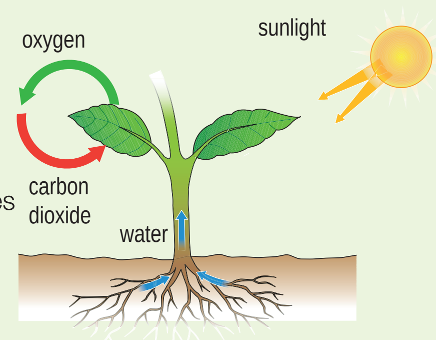


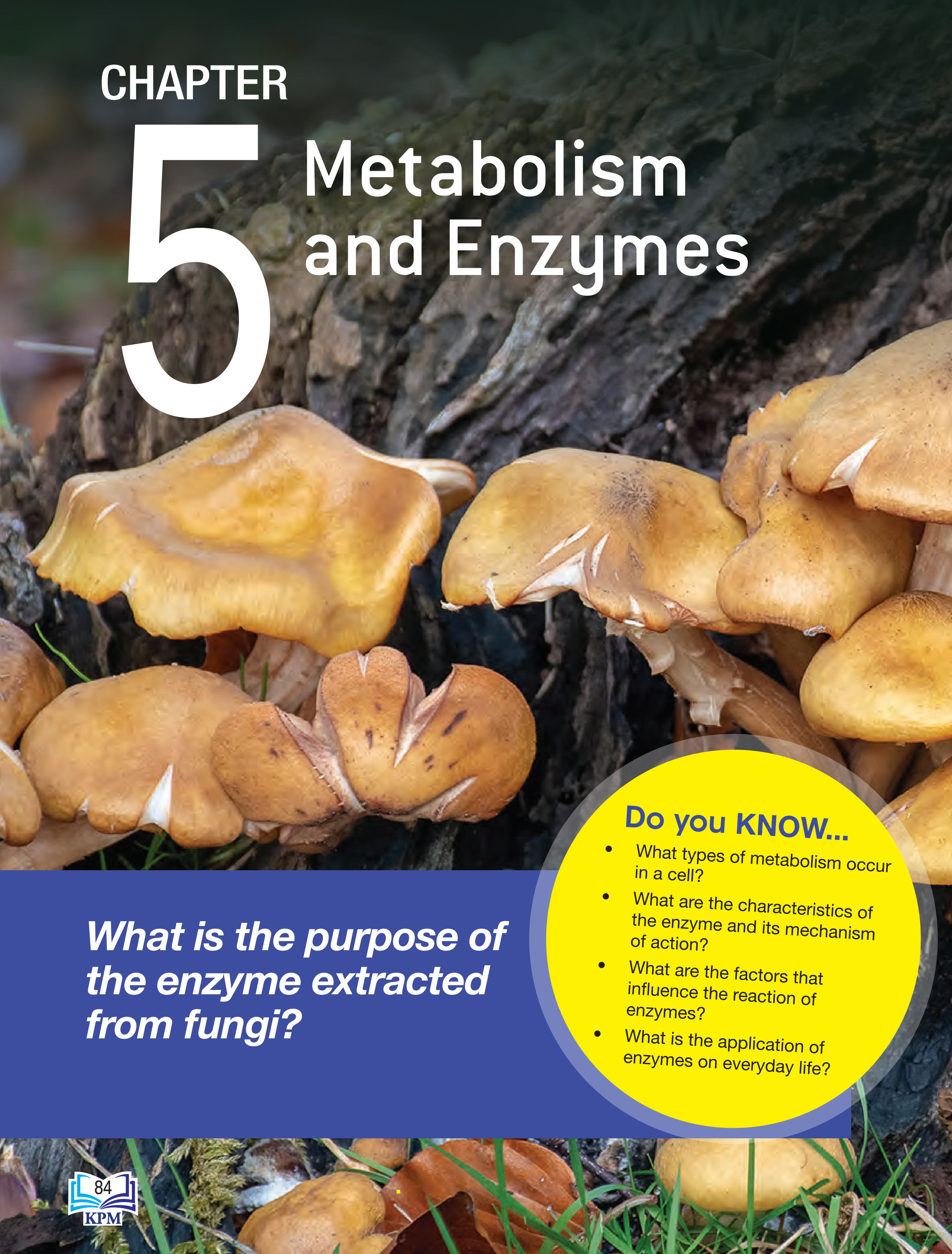
FIGURE 4

Enrichment

7 Ariff practises a diet low in carbohydrates. Suggest what needs to be done to reduce the starch in potatoes during food preparation.

8 The results of biological studies have been widely applied in various industries to enhance quality and productivity and to overcome problems. Among the studies being used by environmentalists are biodegradable plastics and environmentally friendly batteries. A group of scientists in Malaysia have succeeded in inventing environmentally friendly batteries using seaweed pulp. In your opinion, how did research on chemical elements in seaweed help scientists to invent environmentally friendly products?

Complete answers are available by scanning the QR code provided



CHAPTER 5 Metabolism and Enzymes

What is the purpose of the enzyme extracted from fungi?

Do you KNOW...

- What types of metabolism occur in a cell?
- What are the characteristics of the enzyme and its mechanism of action?
- What are the factors that influence the reaction of enzymes?
- What is the application of enzymes on everyday life?

5.1 Metabolism

5.1.1 Define metabolism.
5.1.2 State the types of metabolism in a cell:
- anabolism
- catabolism

5.2 Enzymes

5.2.1 Define enzymes.
5.2.2 Reason out the necessity of enzymes in metabolism.
5.2.3 Describe the naming of enzymes with the addition of *–ase* to their substrates.
5.2.4 Characterise the general properties of enzymes.
5.2.5 Communicate about the involvement of specific organelles in the production of:
- intracellular enzymes
- extracellular enzymes

5.2.6 Explain the mechanism of enzyme action using the ‘lock and key’ hypothesis.
5.2.7 Interpret energy diagrams to explain the mechanism of enzyme action.
5.2.8 Correlate the mechanism of enzyme action with the change in the following factors:
- temperature
- pH
- substrate concentration
- enzyme concentration

5.2.9 Design and conduct experiments to study the effects of temperature and pH on the activities of amylase and pepsin.

5.3 Application of Enzymes in Daily Life

5.3.1 Explain by using examples the application of enzymes in daily life.

5.1 Metabolism

Metabolism refers to all chemical reactions that occur in a living organism. The processes in metabolism involve the conversion of food into energy in the form of ATP, and the formation of carbohydrate, protein, lipid and nucleic acid.

Types of metabolism in a cell

There are two types of metabolism, which are **catabolism** and **anabolism**. **Catabolism** is the process of breaking down complex substances into simple substances. This reaction releases energy. For example, the breakdown of glucose during cellular respiration to generate energy.

Generally, catabolic reactions are as follows:

$$\underset{\text{(substrate)}}{A} \longrightarrow \underset{\text{(products)}}{B + C}$$

Anabolism is the process of synthesising complex molecules from simple molecules. This reaction uses or absorbs energy. For example, the formation of glucose during photosynthesis.

Generally, anabolic reactions are as follows:

$$\underset{\text{(substrate)}}{A + B} \longrightarrow \underset{\text{(product)}}{C}$$

5.2 Enzyme

In a cell, biochemical reactions occur at a high rate to protect the living processes. Biochemical reactions can occur quickly in cells due to the presence of enzymes that help speed up reactions.

An **enzyme** is an organic catalyst that is mostly made up of proteins and is produced by living cell organisms. However, not all enzymes are synthesised from proteins. The substances needed for an enzyme reaction are called **substrates**. Substrates will bind with enzymes at a specific site known as the **active site** and form an **enzyme-substrate complex** (Figure 5.1).

Biological Lens

The *Alcanivorax borkumensis* bacteria produces hydroxylase enzymes to break down an oil spill in the sea and change it to a non-toxic substance.

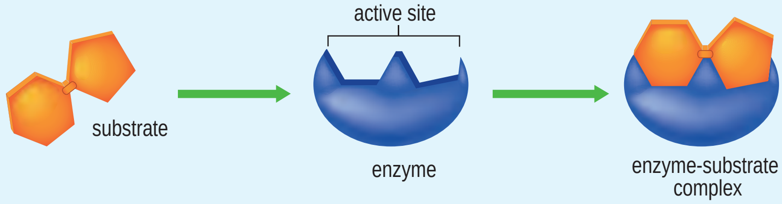


FIGURE 5.1 Formation of an enzyme-substrate complex

5.1.1 5.1.2 5.2.1 5.2.2

Enzyme nomenclature

In the 1960s, *The International Union of Biochemistry and Molecular Biology* (IUBMB) introduced the enzyme nomenclature based on the substrate or reaction it catalyses. The name of the enzyme is derived by adding '-*ase*' to the name of the substrate it catalyses.

An example of the '-*ase*' added to substrate is the lactase enzyme, which catalyses the hydrolysis of lactose.

$$\text{Lactose + water} \xrightarrow{\text{Lactase}} \text{Glucose + galactose}$$

However, there are also a few enzymes that do not follow this naming system, especially enzymes that were discovered before the systematic naming system was introduced. Some examples are: trypsin, pepsin, and renin.

Activity Zone

Collect information on the enzyme nomenclature conventionally and based on *The International Union of Biochemistry and Molecular Biology* (IUBMB). Present it in class.

General characteristics of enzymes

GENERAL CHARACTERISTICS OF ENZYMES

- Enzymes act **rapidly**.
- Enzymes are only required in **small quantities** and are **reusable**.
- The **structure** of enzymes remain **unchanged** and are not destroyed after a reaction.
- Enzymes are biological catalysts that **speed up biochemical reactions.**
- The reaction of enzymes are **specific**. Only substrate that fit the form completely with an enzyme in an active site can combine.
- Some enzymes need **cofactors** to work more efficiently. An example of a cofactor is vitamin B, and magnesium ion.
- Enzyme activity can be slowed down or stopped by enzyme **inhibitors**. An example of an inhibitor is heavy metal such as lead or mercury.
- Most of the reactions catalysed by enzymes are **reversible**.

Biological Lens

'Glycolysis' originates from the words 'glucose' and 'lysis' (break down) and is the breakdown of glucose by the hexokinase enzyme to produce energy and pyruvate.

Intracellular and extracellular enzymes

Enzymes that are synthesised in a cell for its own use are called **intracellular enzymes**. For example, the hexokinase enzyme that is used in the glycolysis process during cellular respiration.

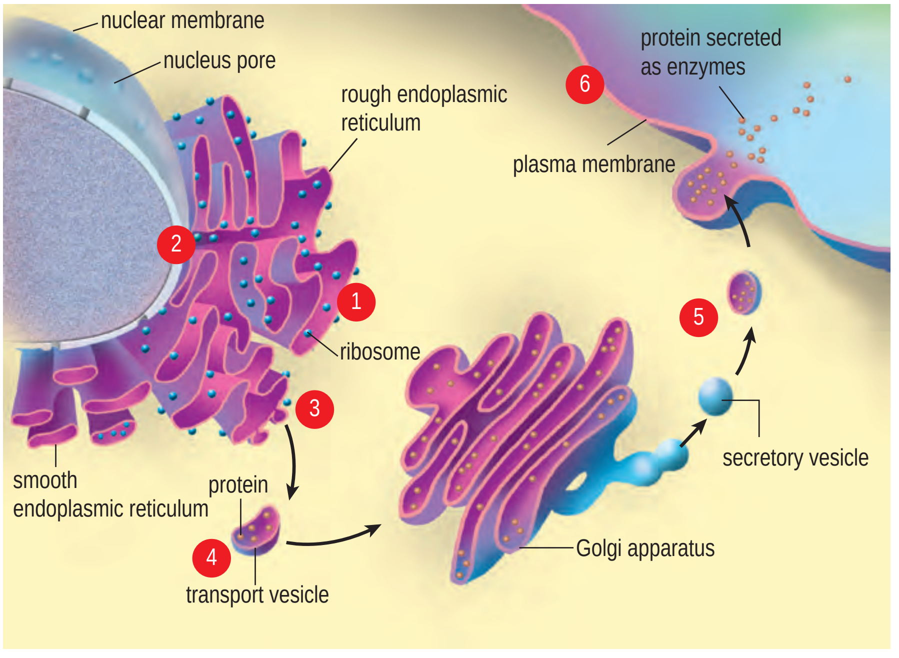
On the other hand, enzymes that are secreted outside the cell are known as **extracellular enzymes**. For example, the trypsin enzyme is produced by the pancreatic cells and secreted into the duodenum to break down polypeptides.

How are extracellular enzymes produced? The production of enzymes involves a few specific components of cells (Figure 5.2).

1 Ribosome is the site of protein synthesis.

2 Proteins synthesised by ribosome enter the lumen of the rough endoplasmic reticulum and are transported through it.

3 Once it reaches the end of the rough endoplasmic reticulum, the membrane buds off to form transport vesicles.



4 The transport vesicle that contains proteins moves towards the Golgi apparatus and then fuses with it.

5 In the Golgi apparatus, the proteins are modified into enzymes and secreted in secretory vesicles that are formed from the tip of the Golgi apparatus.

6 Secretory vesicles will move towards the plasma membrane and fuse with it to secrete extracellular enzymes.

FIGURE 5.2 Production of extracellular enzymes

Mechanism of enzyme action

The 'lock and key' hypothesis

Most enzymes are complex proteins made up of polypeptide chains that are folded into three-dimensional structures. This three-dimensional structure has an active site with a specific configuration that complements a specific substrate molecule. The binding of a molecule substrate on an active site of enzymes is specific like a 'lock and key' combination (Figure 5.3). The enzyme is represented by a 'lock' and the substrate is represented by a 'key'.

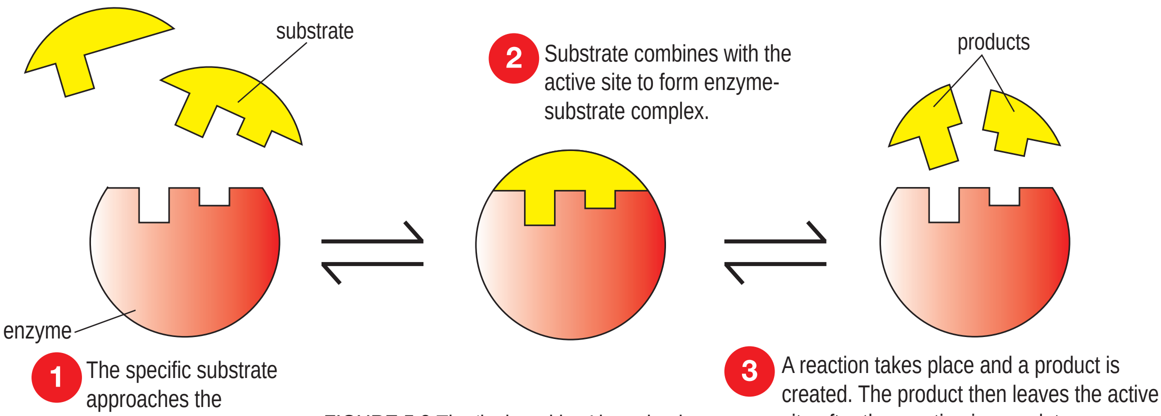


FIGURE 5.3 The 'lock and key' hypothesis

Most reactions inside the cell require high activation energy. **Activation energy** is the energy needed to break the bond in the substrate molecule before reaction can occur. Enzymes function by lowering the activation energy (Figure 5.4). By doing so, the rate of biochemical reactions in the cell is accelerated.

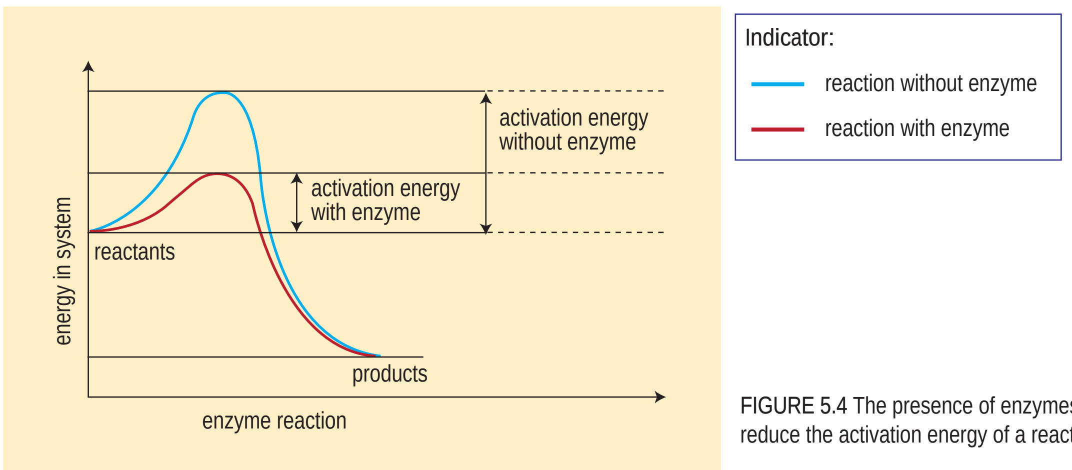


FIGURE 5.4 The presence of enzymes will reduce the activation energy of a reaction

The mechanism of enzyme action and factor changes

There are many factors that affect the mechanism of enzyme action. The chemical bond in enzymes can be easily transformed as a result of chemical changes and physical conditions. Among these factors are temperature, pH, enzyme concentration and substrate concentration.

Effects of temperature

Figure 5.5 shows the effects of temperature on the rate of biochemical reaction controlled by enzymes.

1
- At a low temperature, the rate of reaction catalysed by enzymes is low.
- When the temperature rises, the kinetic energy of the substrate molecules and enzymes also increases. This increases the **frequency of effective collision** between the substrate molecules and enzyme molecules.
- The rate of reaction between enzymes and substrate molecules increases.
- With every rise in temperature of 10°C, the rate of reaction controlled by the enzymes will double until it reaches the optimal temperature.

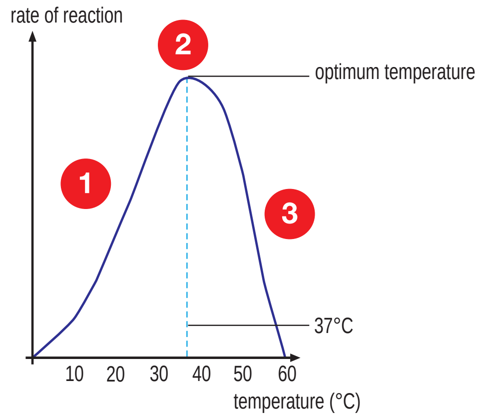


FIGURE 5.5 The effects of temperature on the reaction rate of an enzyme

2
At optimal temperature, the enzyme reaction is at its maximum. The **optimal temperature** for enzyme reactions in the human body is around 37°C.

3
- After reaching the optimal temperature, any further increase in temperature will reduce the enzyme activity rapidly until it stops at 60°C.
- At this temperature, the enzymes become denatured as the chemical bonds in the enzyme molecules break at extreme temperatures.
- The enzymes are unable to retain the three-dimensional form. The active site of enzymes changes. The substrate does not complement the active site of enzymes.

Effects of pH

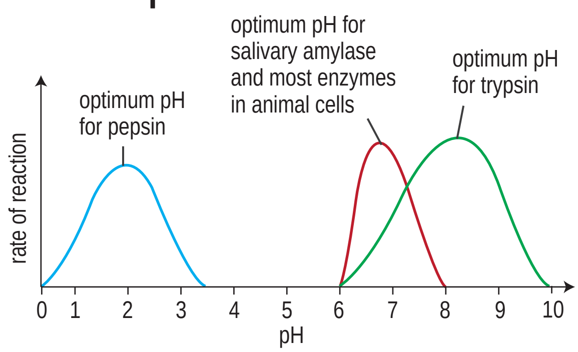


FIGURE 5.6 The effect of pH on the enzyme activities of pepsin, salivary amylase and trypsin

- The enzyme activity is influenced by the pH of the surrounding solution. Generally, all enzymes react most effectively at their optimal pH.
- Most enzymes are most active in the range of between pH 6 and 8. For example, the salivary amylase works at pH 6.8.
- However, there are some exceptions. For example, the pepsin enzymes in the stomach act at the optimal pH range of between 1.5 and 2.5. The trypsin enzyme in the duodenum, on the other hand, only works well in an alkaline medium, at a pH of around 8.5 (Figure 5.6).

- The change in pH value changes the charge (ion H^+) of the active site of enzymes and the substrate surface. As a result, the enzyme-substrate complex cannot be formed.
- When the pH of the environment returns to the optimum level, the charge on the active site will be restored. The enzyme will return to function as normal.
- The extreme change in the pH value will break the structural chemistry bond and change the active site of enzymes. Denatured enzyme (Figure 5.7).

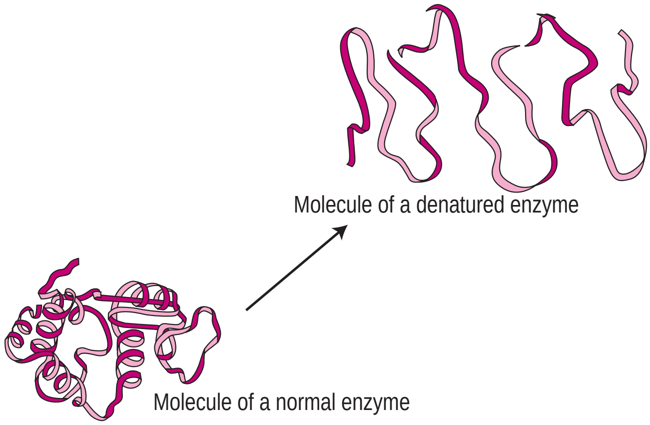


FIGURE 5.7 Molecule of a denatured enzyme

The effect of substrate concentration

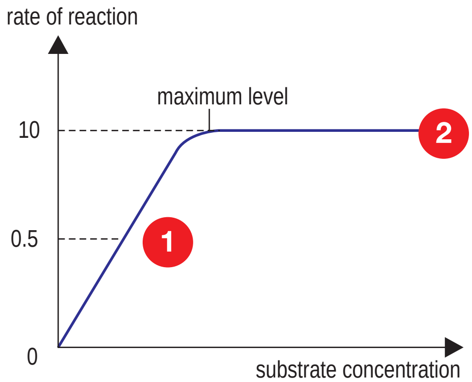


FIGURE 5.8 The effect of substrate concentration on the rate of enzyme reaction

If the concentration of enzymes is fixed while the concentration of substrate is increased, the reaction rate controlled by enzymes will also increase, leading to an increase in products created (Figure 5.8).

1
- When substrate concentration increases, the opportunity for an effective collision between the substrate and enzyme molecules also increases.
- The reaction rate continues to increase until it reaches the **maximum level.** The rate of reaction is constant.

2
- At the maximum level, the concentration of enzymes becomes a **limiting factor**. The reaction rate can only increase when the concentration in enzymes increases.
- After reaching the maximum level, all active sites of enzymes are saturated with substrate and are involved in the catalytic reaction.

The effect of enzyme concentration

1 When the concentration of enzyme increases, the rate of enzyme reaction will increase because of the presence of more active sites that are ready for catalytic action.

2 If the concentration of an enzyme in one reaction is doubled, the amount of substrate converted to products per unit of time is also doubled with the condition that there is an excess supply of substrate.

3 At the maximum rate, the concentration of the substrate becomes the **limiting factor**. The rate of reaction can only be increased by adding more substrate.

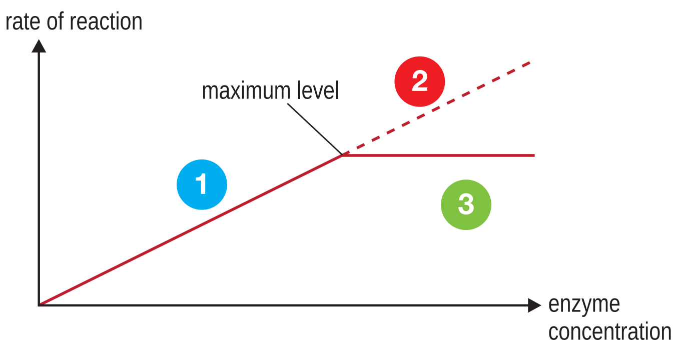


FIGURE 5.9 Effects of enzyme concentration on the enzyme reaction rate

5.2.8

Activity 5.1 Studying the effect of temperature on the amylase enzyme activity

Experiment

Problem statement
What is the effect of temperature on the reaction rate of an amylase enzyme?

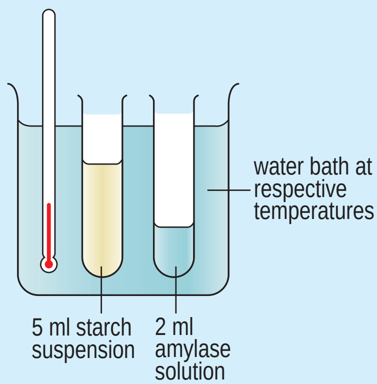
Hypothesis
An increase in temperature increases the reaction rate of an amylase enzyme up to an optimum temperature. The reaction rate of an enzyme decreases after the optimum temperature.

Variables
Manipulated: Temperature
Responding: Reaction rate of an amylase enzyme
Fixed: The concentration of amylase and starch suspension (substrate) and the pH of the reaction medium

Materials
1% starch suspension, 0.5% amylase enzyme solution, iodine solution, ice and filtered water

Apparatus
Beaker, test tube, syringe, dropper, glass rod, white grooved tile, thermometer, Bunsen burner, tripod stand, wire gauze, test tube rack, measuring cylinder and stopwatch

Procedure
1. Using a syringe, put 5 ml of 1% starch suspension into each test tube labelled A1, B1, C1, D1 and E1.
2. Using another syringe, put 2 ml amylase enzyme solution in each test tube labelled A2, B2, C2, D2 and E2.
3. Test tubes A1 and A2, B1 and B2, C1 and C2, D1 and D2, E1 and E2, are placed respectively in 5 separate water baths at fixed temperatures of 20°C, 30°C, 40°C, 50°C and 60°C.
4. Incubate all test tubes for 5 minutes.
5. Meanwhile, prepare a dry, white grooved tile and put a drop of iodine solution into the tile.
6. After incubating for 5 minutes, pour the starch suspension in test tube A1 into test tube A2. Stir the mixture with a glass rod. Start the stopwatch immediately.
7. Use the dropper to extract a drop of the mixture from test tube A2 and drop it immediately into the first groove on the tile containing the iodine solution (The first groove is considered as zero minute).
8. Repeat the iodine test every 30 minutes. Rinse the dropper with the water from the beaker after each sampling. Record the time taken to complete the starch hydrolysis, that is, the time when the mixture remains brownish yellow in colour when tested with the iodine solution.
9. Keep all test tubes immersed in the respective water baths throughout the experiment. Repeat steps 5 to 8 for each pair of test tubes B1/B2, C1/C2, D1/D2 and E1/E2.



10 Record your results in an appropriate table. Plot your graph to show the reaction rate of the enzyme ($minute^{-1}$) against temperature (°C).

Results

Temperature (°C)	Time for starch hydrolysis to complete (minute)	Rate of reaction ($minute^{-1}$)
20		
30		
40		
50		
60		

Discussion

1 Why do you need to incubate the test tubes in the respective water baths for 5 minutes at the beginning of the experiment?

2 What is the result of amylase action on starch?

3 What is the function of the iodine solution?

4 Based on the drawn graph, explain the effect of temperature on the enzyme activity.

Conclusion

Is the hypothesis accepted? Suggest a suitable conclusion for this experiment.

Activity 5.2 Studying the effect of pH on the pepsin enzyme activity

Experiment

Problem statement

What is the optimum pH of a pepsin enzyme reaction?

Hypothesis

pH 2 is the most optimum for the pepsin enzyme reaction.

Variables

Manipulated: pH medium reaction
Responding: The clarity or turbidity of the mixture reaction
Fixed: Albumen concentration, pepsin solution concentration and temperature of reaction medium

Materials

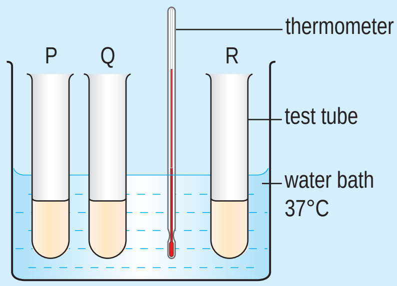
Albumen suspension (egg white), 1% pepsin solution, 0.1 M hydrochloric acid, 0.1 M sodium hydroxide solution, water bath at the temperature of 37°C, pH paper and distilled water

Apparatus

Beaker, dropper, thermometer, test tube, 5 ml syringe (without needle), stopwatch, Bunsen burner, tripod stand, wire gauze, thermometer and test tube rack

Procedure

1. Prepare three test tubes and label as P, Q and R.
2. Put 5 ml albumen suspension in each test tube using a syringe.
3. Add the following solution into each test tube:
   - P: 1 ml 0.1 M hydrochloric acid + 1 ml 1% pepsin solution
   - Q: 1 ml distilled water + 1 ml 1% pepsin solution
   - R: 1 ml 0.1 M sodium hydroxide solution + 1 ml 1% pepsin solution
4. Dip a piece of pH paper into each test tube and record the pH of the mixture.
5. Put all the test tubes in a water bath with a fixed temperature of 37°C for 20 minutes.
6. Observe the state of the mixture at the beginning of the experiment and after 20 minutes.
7. Record the results in a table.



Results

Test tube	pH	Clarity or turbidity	
		0 minute	After 20 minutes
P			
Q			
R			

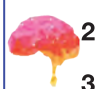
Discussion

1. Why is it necessary to incubate the test tube in a water bath with a fixed temperature of 37°C?
2. What is the effect of pH on pepsin action on albumen?
3. Discuss the result obtained for test tubes P, Q and R.

Conclusion

Is the hypothesis accepted? Suggest a suitable conclusion for this experiment.

Formative Practice 5.1



1. What will happen if ribosomes in a pancreas cell do not function?
2. Why must our body temperature be maintained at 37°C?
3. What is the optimum pH for a pepsin enzyme action?
4. Y is the enzyme that catalyses the hydrolysis of sucrose into glucose and fructose. What is enzyme Y?

5.3 Application of Enzymes in Daily Life

Enzymes have long been widely used in the commercial sector and for everyday use. The enzymes used are extracted from natural resources such as bacteria or are produced synthetically.

Immobilized enzymes are enzymes that combine with inert and insoluble substances to increase the resistance of enzymes towards change in factors such as pH and temperature. With this method, the enzyme molecules will remain in the same position throughout the catalytic reaction and then be separated easily from its product. This technology is known as **immobilized enzyme technology**. This technology is used in various industrial applications (Photograph 5.1).

CHAPTER 5

Formative Practice 5.2

1 How are enzymes produced?
2 How does immobilized enzyme technology help to accelerate the enzyme reaction?
3 Give examples of industries that use enzymes in the manufacturing of products.

Digestive enzymes are used in the medical sector

Pectinase and cellulase enzymes are used in juice production

Amylase, lipase, protease and cellulase enzymes in bio detergent

Lactose enzymes are used in lactose-free milk

Trypsin enzyme extracts fur from animal hide to make leather products

Protease enzyme separates the fish skin

PHOTOGRAPH 5.1 Enzyme immobilization technology is used in various industrial application

5.3.1

Summary

METABOLISM AND ENZYMES

Metabolism

- Anabolism
- Catabolism

Enzyme

- Enzyme nomenclature: adding -*ase* to the substrate
- General characteristics of enzymes
- Intracellular and extracellular enzymes
- Enzyme action mechanism—'lock and key' hypothesis
- Factors that influence the enzyme action
  - Temperature
  - pH
  - Substrate concentration
  - Enzyme concentration

Application of Enzymes in Daily Life

- Digestive enzymes
- Lactose-free milk and fruit juice
- Bio detergent
- Leather product (separate fur from animal hide)

Self Reflection

Have you mastered the following important concepts?

- Types of metabolism
- General characteristics of enzymes
- Mechanism of enzyme action
- Factors that influence the mechanism of enzyme action
- Application of enzymes in daily life

Summative Practice 5

1 Some chefs sometimes wrap meat in papaya leaves and the meat is marinated for 5 hours before it is cooked. What is the purpose of wrapping with papaya leaves?

2 Why are apples that have been boiled after they are peeled, do not change colour to brown?

3 (a) Enzymes are used in industries and everyday life. Explain the use of enzymes to extract agar-agar from seaweed.
(b) State one function of lipase in the food industry.

4 (a) State two characteristics of enzymes.
(b) Explain why only certain substrate can combine with enzymes.
(c) (i) What is the hypothesis that is used to explain the mechanism of enzyme action? In this hypothesis, what represents the structure of enzymes and the structure of the substrate?
(ii) Which characteristics of enzymes can explain this hypothesis?

Essay Questions

5 (a) If you are a food entrepreneur, suggest an enzyme that you can use to process meat and fish. State the function of this enzyme.
(b) Discuss how the characteristics of the enzymes can influence its action.

Enrichment

6 The enzymes that exist in the bacteria strain which live in hot spring areas can be extracted and added to laundry detergent. Suggest why enzymes from these bacteria are suitable to be used as laundry detergent.

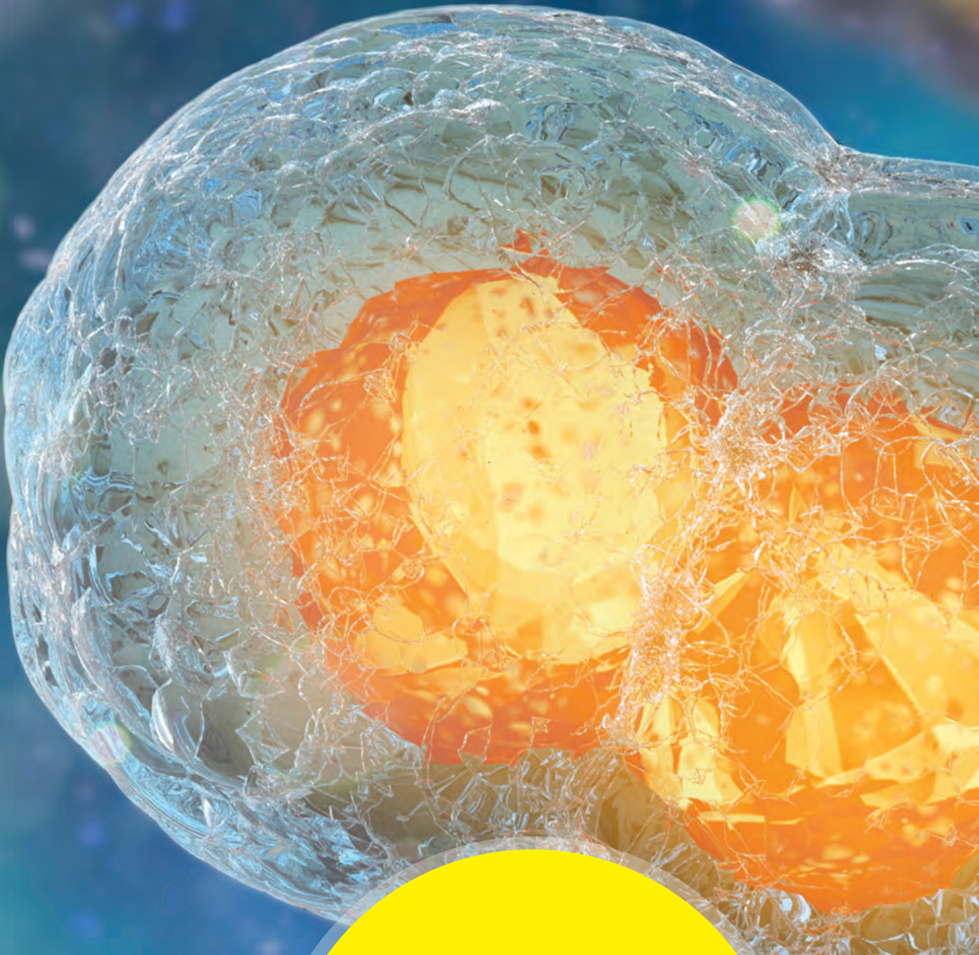
7 Why does cyanide poisoning cause immediate death?

8 Fresh fruits can be processed to produce juice. Fruits are crushed and squeezed before the juice is extracted. Plant cells contain strong cellulose walls. However, if enzymes that contain pectinase enzymes are used, more juice can be extracted. Based on this information, suggest one laboratory experiment that can extract more fruit juice than the pressing method.

Complete answers are available by scanning the QR code provided

CHAPTER

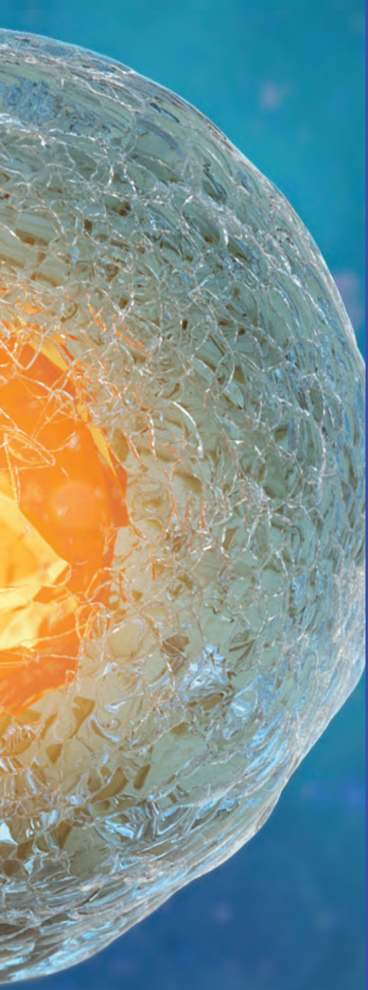
6 Cell Division



Do You KNOW...

- How does growth happen?
- How does an organism produce new cells?
- How is genetic variation created?

Can identical organisms be produced?



6.1 Cell Division

6.1.1 Describe:
- karyokinesis (nuclear division)
- cytokinesis (cytoplasmic division)

6.1.2 Describe the terms haploid, diploid, chromatin, homologous chromosomes, paternal chromosome and maternal chromosome.

6.2 Cell Cycle and Mitosis

6.2.1 Describe the phases in a cell cycle:
- interphase
- G_1 phase
- S phase
- G_2 phase
- M phase
- mitosis
- cytokinesis

6.2.2 Arrange the stages of mitosis in the correct order.

6.2.3 Communicate about the cell structure of each stage of mitosis and cytokinesis by using labelled diagrams.

6.2.4 Compare and contrast mitosis and cytokinesis in animal and plant cells

6.2.5 Discuss the necessity of mitosis in:
- development of embryo
- growth of organisms
- healing of wounds on the skin
- regeneration
- asexual reproduction

6.3 Meiosis

6.3.1 State the meaning of meiosis.

6.3.2 Identify types of cells that undergo meiosis.

6.3.3 State the necessity of meiosis in:
- the formation of gametes (gametogenesis).
- producing genetic variation
- maintaining diploid chromosomal numbers from one generation to another.

6.3.4 Explain the stages of meiosis in the correct order:
- meiosis I
- meiosis II

6.3.5 Draw and label the cell structure in each stage of meiosis I, meiosis II and cytokinesis.

6.3.6 Compare and contrast meiosis and mitosis.

6.4 Issues of Cell Division on Human Health

6.4.1 Explain the effects of abnormal mitosis on human health:
- tumour
- cancer

6.4.2 Evaluate the effects of abnormal meiosis on Down syndrome individuals.

6.1 Cell Division

Cells in our body always grow, divide and die. As such, the dead cells must be replaced with new cells. Cells in the body produce new cells through the cell division process. Cell division involves two stages, that is karyokinesis and cytokinesis.

- **Karyokinesis** involves the division of the nucleus.
- **Cytokinesis** involves the division of the cytoplasm.

The organism's body cells are divided into **somatic cells** and **reproductive cells** or **gametes**.

Brainstorm!

What happens when cells cannot undergo cell division?

ORGANISM CELL

SOMATIC CELL	GAMETE
• Body cells apart from gametes. • Somatic cells are produced through the mitosis process. • It contains a **diploid** number of chromosomes, that is, each cell contains two sets of chromosomes or 2n. In human somatic cells, 2n = 46.	• Gametes are reproductive cells. • Gametes are produced through the meiosis process. • It contains a **haploid** number of chromosomes, that is, each cell contains one set of chromosomes or n. In human gametes, n = 23.

In diploid cells, one set of chromosomes originate from the male parent or **paternal chromosomes** and another set is from the female parent or **maternal chromosomes**. Both paternal and maternal chromosomes have the same structural characteristics. This pair of chromosomes are called **homologous chromosomes** (Figure 6.1). **Chromatin** is a chromosome that looks like a long thread.

ICT 6.1
Importance of cell division (Accessed on 21 August 2019)

FIGURE 6.1 Haploid and diploid chromosomes

Formative Practice 6.1

1 Give the definition of the following terms:
(a) karyokinesis (c) chromatin
(b) cytokinesis (d) homologous chromosomes

2 Predict what will happen if the cells in the reproductive organs of humans are unable to produce haploid cells.

6.1.1 6.1.2

6.2 Cell Cycle and Mitosis

What is a cell cycle?

The **cell cycle** refers to the sequence of events that involves DNA multiplication and cell division to produce two daughter cells. The cell cycle consists of **interphase** and **M phase**. **Interphase** is the longest phase in the cell cycle. This phase is made up of the **G_1**, **S** and **G_2** phase.

G_1 PHASE

1 Cells grow. Cell components such as mitochondrion and endoplasmic reticulum are produced at this stage. Proteins used in the cell cycle are also synthesised during this time. At this stage, the nucleus looks big and the chromosome is in the form of chromatin.

S PHASE

2 DNA synthesis occurs in the S phase. The DNA in the nucleus is replicated. Each chromosome multiplies into two identical chromosomes known as sister chromatids. Both chromatids contain the same copy of the DNA molecule. Both chromatids are joined at the centromeres.

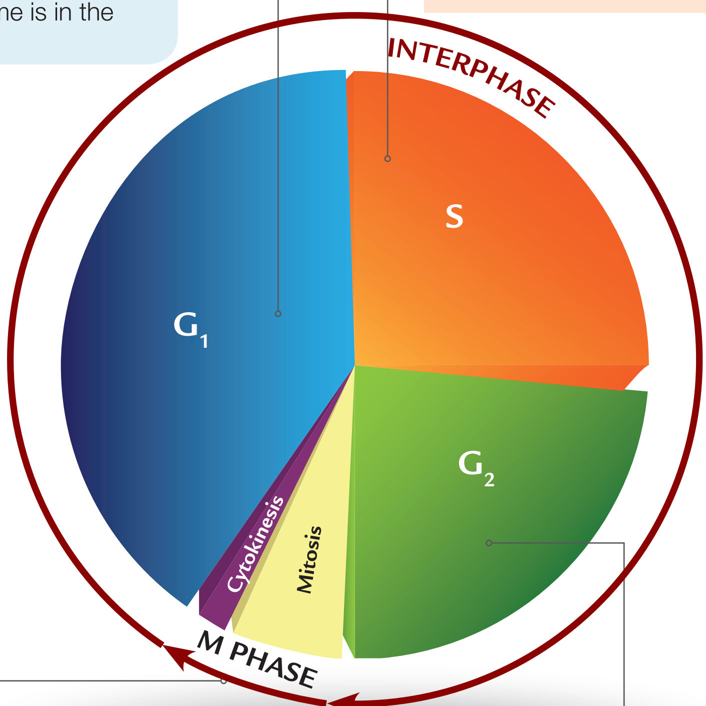


FIGURE 6.2 Cell cycle

M PHASE

4 M phase is made up of **mitosis** and **cytokinesis**. Mitosis involves prophase, metaphase, anaphase and telophase.

G_2 PHASE

3 The cells will continue to grow and remain active metabolically during the G_2 phase. Cells gather energy and make final arrangements to enter the next stage of cell division. After the interphase stage, the cell will enter the M phase.

Our World of Biology

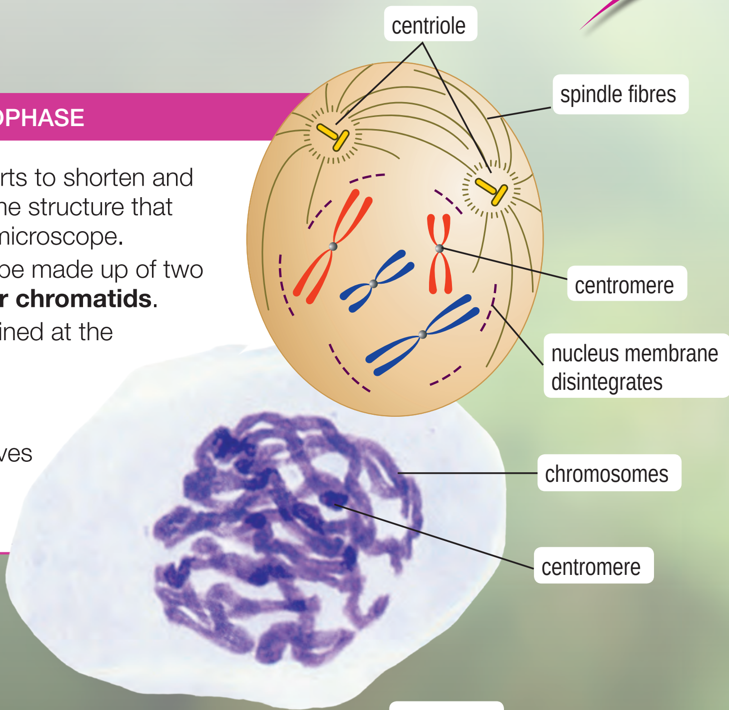
The failure of mitotic division in somatic cells will not be inherited by the next generation.

Mitosis

Mitosis is defined as the division of the nucleus of parent cell into two nuclei (Photograph 6.1). Each nucleus contains the same number of chromosomes and genetic content with the nucleus of parent cell.

PROPHASE

- In the nucleus, chromatin starts to shorten and thicken to form a chromosome structure that can be seen through a light microscope.
- The chromosome is seen to be made up of two identical threads called **sister chromatids**.
- Both sister chromatids are joined at the **centromere**.
- The nucleus membrane disintegrates, the nucleolus disappears, the centriole moves to the opposite poles and spindle fibres start to form.



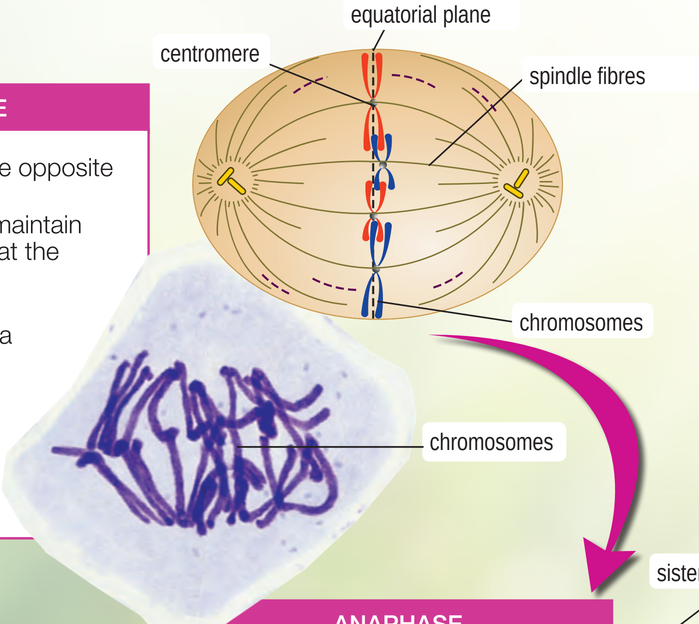
ICT 6.2

Activity: Design three dimensional models of the mitotic stages

PHOTOGRAPH 6.1 Mitosis at the tip of the plant root

METAPHASE

- Centrioles are at the opposite poles of the cell.
- The spindle fibres maintain the chromosomes at the equatorial plane.
- The chromosomes become aligned in a single row on the equatorial plane.
- Metaphase ends when the centromere begins to divide.



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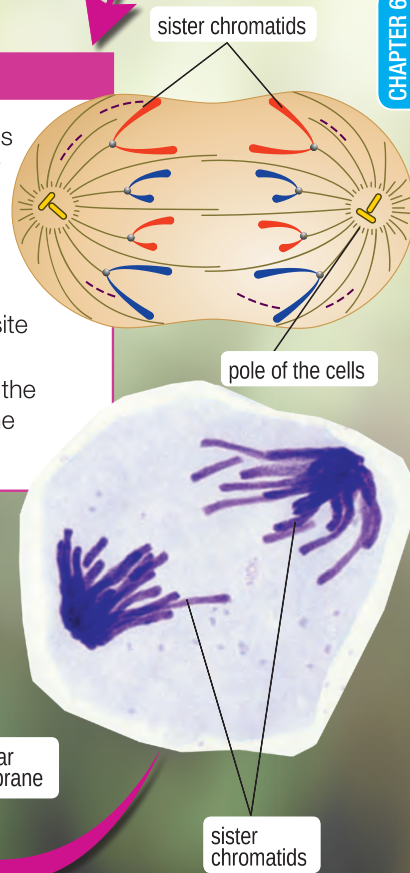
ANAPHASE

- The centromere divides into two and the sister chromatids separate.
- Spindle fibres shorten, contract and the sister chromatids are attracted to the opposite pole cells.
- Anaphase ends when the chromatid arrives at the pole of the cell.



TELOPHASE

- When the chromatids are at the opposite poles, they are now called the daughter chromosome.
- Each pole contains one set of complete and identical chromosomes.
- Chromosomes are shaped again as fine chromatin threads.
- Nucleoli are formed again.
- Spindle fibres disappear.
- A new nucleus membrane is formed.
- The telophase stage is followed by cytokinesis.

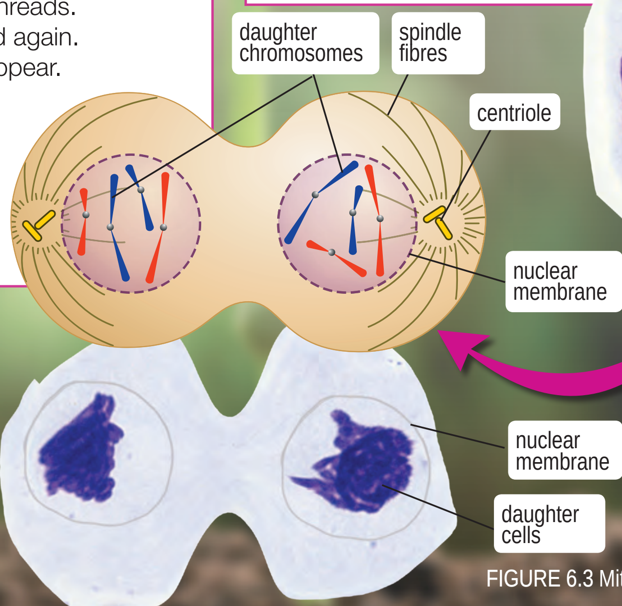


FIGURE 6.3 Mitosis

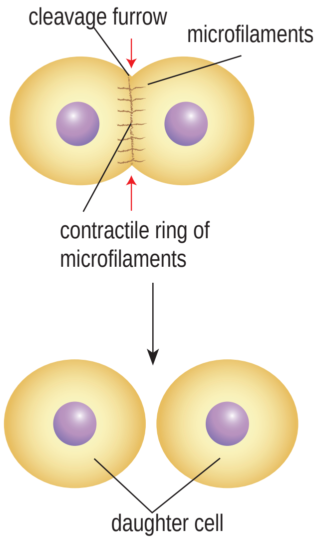


FIGURE 6.4 Cytokinesis in animal cells

The differences between mitosis and cytokinesis in animal cells and plant cells

Plant cells do not contain centrioles. However, plant cells can still form spindle fibres during mitosis.

Cytokinesis is different between animal cells and plant cells. Cytokinesis is the division of cytoplasm that happens immediately after the nucleus is formed, that is, at the end of telophase. Cytokinesis occurs in animal cells when the plasma membrane constricts in the middle of the cell between the two nuclei (Figure 6.4). Microfilaments at the point of constriction will contract, causing the cell to constrict until it splits to form two daughter cells.

Cytokinesis in plant cells also begins when the formed vesicles combine to form cell plates at the centre of the cell (Figure 6.5). The cell plates are surrounded by a new plasma membrane and a new cell wall substance is formed among the spaces of the cell plates. The cell plates expand outwards until they combine with the plasma membranes. At the end of cytokinesis, cellulose fibres are produced by the cells to strengthen the new cell walls. Two daughter cells are formed. Each cell has a diploid condition.

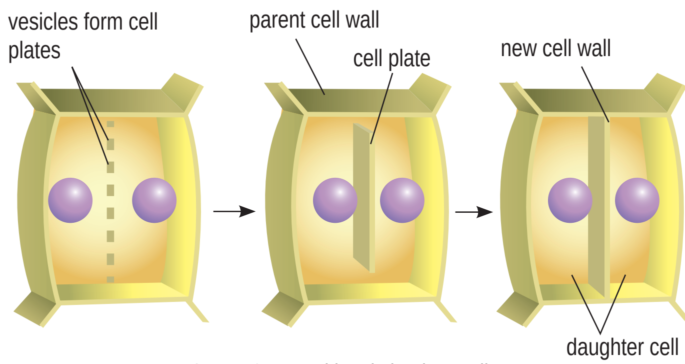


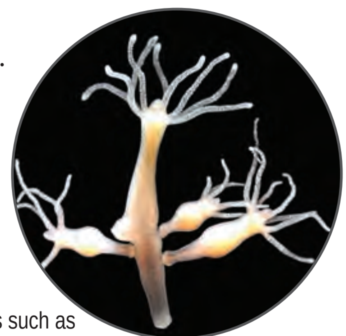
FIGURE 6.5 Cytokinesis in plant cells

The necessity of mitosis

Mitosis is important for the following life processes.

For embryo development and organism growth, mitosis ensures that rapid cell growth occurs.

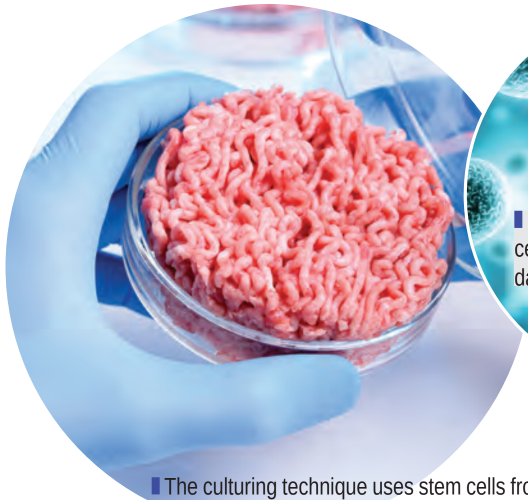
Through the mitosis process, the lizard is able to grow a new tail (regeneration) if the tail breaks.



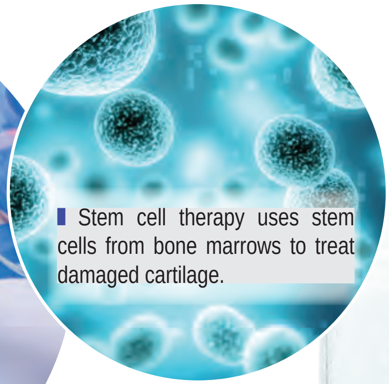
Mitosis aids organisms such as hydra to produce new individuals through the formation of new buds.

When the body is injured, mitosis will produce new cells to replace cells that are dead or damaged.

PHOTOGRAPH 6.2 The necessity of mitosis for living organisms



The culturing technique uses stem cells from animals which are then cultured in laboratories to produce meat.



Stem cell therapy uses stem cells from bone marrows to treat damaged cartilage.

In agriculture, the technique of culturing plant tissues is used to produce young plants through the culturing of parent cells without going through the fertilisation process.

PHOTOGRAPH 6.3 The application of mitosis in the fields of medicine and agriculture

Formative Practice 6.2

1 State the application of mitosis in the field of agriculture.
2 Explain the process that occurs during the S phase.
3 Predict what will happen if the spindle fibres fail to develop.
4 Explain the necessity of mitosis for life processes.

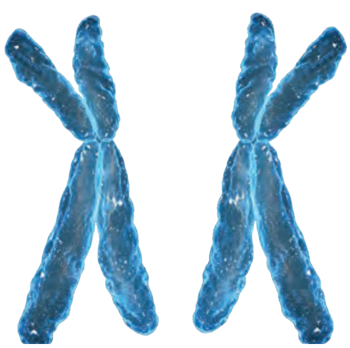
6.3 Meiosis

Meiosis is the process of cell division that occurs in reproductive organs to produce gametes that contain half the number of chromosomes (haploid) of the parent cells (diploid). Meiosis occurs in the testis (male) and ovary (female) for animals and humans.

The need for meiosis

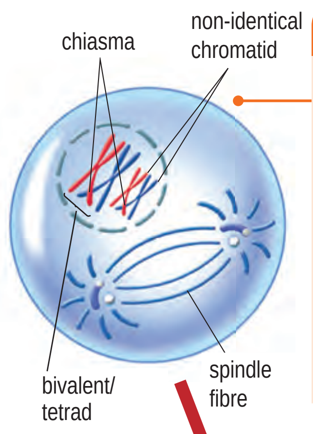
Meiosis forms gametes through the process of **gametogenesis** and ensures that **the diploid chromosome number** of organisms that carry out sex reproduction is always maintained from one generation to the next. Meiosis also produces **genetic variation** in the same species. Meiosis is divided into two stages of cell division, that is **meiosis I** and **meiosis II** (Figure 6.6).

a. Meiosis I comprises of **prophase I**, **metaphase I**, **anaphase I** and **telophase I**.
b. Meiosis II comprises of **prophase II**, **metaphase II**, **anaphase II** and **telophase II**.



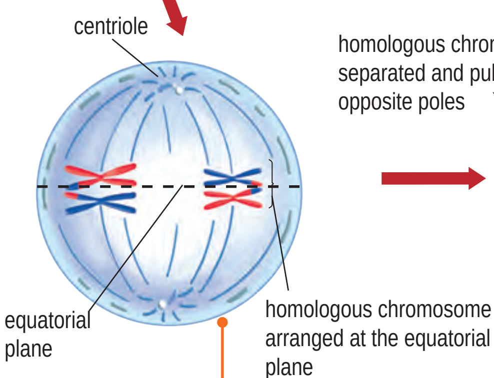
PHOTOGRAPH 6.4 Homologous chromosome

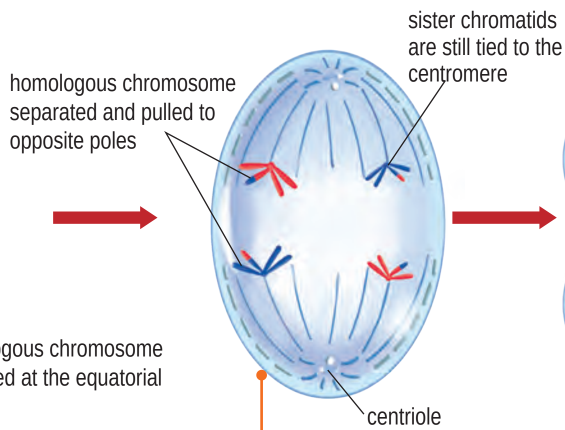
6.3.1 6.3.2 6.3.3



PROPHASE I

- Chromatin **shortens**, **thickens** and forms visible chromosomes. The pairing of homologous chromosomes (**synapsis**) forms **bivalent** (or known as a **tetrad,** that is four chromatids for each homologous chromosome).
- The **crossing over** process that is an exchange of genetic material between non-identical chromatids takes place. Crossing over produces a **combination of genes** that are **new** in chromosomes. The point where the chromatids cross over is called **chiasma**. At the end of prophase I, the nucleus membrane and nucleoli will start to disappear. Both centrioles will move towards the opposite pole cells. Spindle fibres are formed among the centrioles.





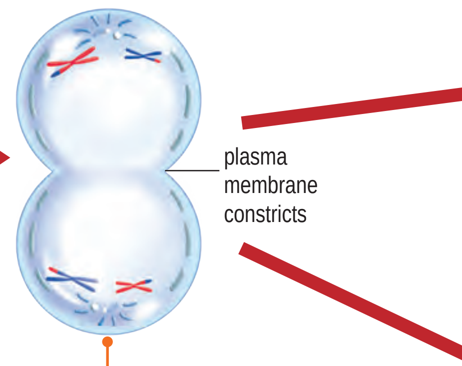


FIGURE 6.6 Meiosis

METAPHASE I

- The homologous chromosomes are arranged at the **equatorial plane**.
- One chromosome from each pair of the homologous chromosome is tied to the spindle fibres from one pole cell and its homologous is tied to the spindle fibres from the opposite pole cell.
- The sister chromatids are still tied together because the centromere has not separated.

ANAPHASE I

- The spindle fibres contract and cause each homologous chromosome to separate from its homologous pair and be pulled to the opposite poles.
- Each chromosome is still made up of a pair of sister chromatids tied to a centromere and move as one unit.

TELOPHASE I

- The chromosomes arrive at the opposite pole cells.
- Each polar cell contains a number of haploid chromosomes that are made up of one set of chromosomes only.
- The spindle fibres will then disappear.
- Nucleoli will reappear and the nuclear membrane is formed.

- Telophase I is succeeded by the cytokinesis process that produces two daughter cells.
- Both daughter cells produced are in the **haploid** condition.
- The interphase for meiosis I is usually short and the DNA does not replicate.

AR

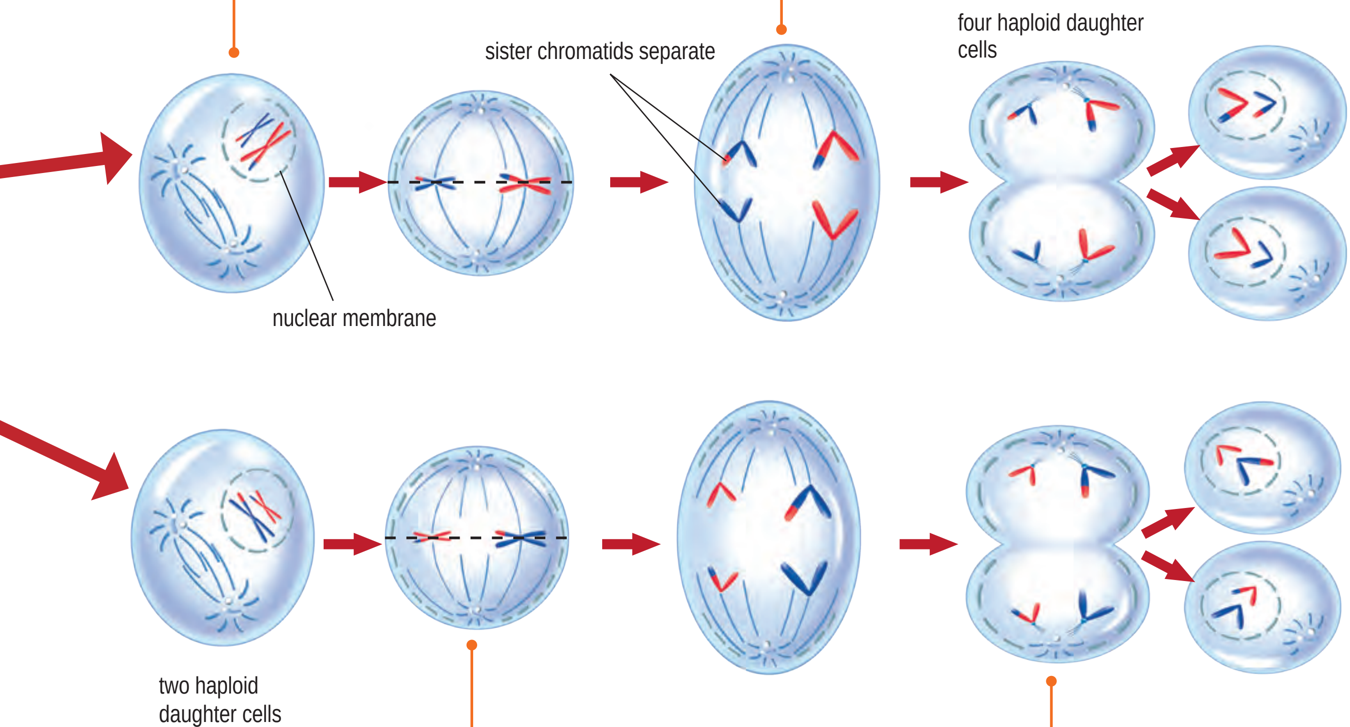
6.3.4 6.3.5

PROPHASE II

- The nucleoli and the nuclear membrane disappear.
- Each chromosome is made up of sister chromatids that are joined at the centromere.
- The spindle fibres start to form in both daughter cells.

ANAPHASE II

- The sister chromatid centromere starts to separate.
- The **sister chromatid** pair separates and moves towards the opposite poles led by the centromere.
- Each chromatid at this stage is known as a **chromosome**.



METAPHASE II

- **Chromosomes** are arranged at random on the equatorial plane for each daughter cell.
- Each chromatid is tied to the spindle fibres at the **centromere**.
- Metaphase II ends when the centromere separates.

TELOPHASE II

- Chromosomes arrive at the pole of the cell.
- Spindle fibres disappear. The nuclear membrane and the nucleoli are reconstructed.
- The number of chromosome for each daughter cell is half the number of parent chromosomes.
- Telophase II ends with the process of **cytokinesis** that produces **four daughter cells** that are **haploid**.
- Each haploid cell contains **half the number of parent cell** chromosomes. The genetic content is also different from the diploid parent cell. The haploid cells develop into gametes.

Activity Zone

Build a thinking tool to compare and contrast:
(a) meiosis I and meiosis II
(b) meiosis and mitosis

Comparison and contrast between meiosis and mitosis

You have learned about two types of cell divisions, that is the mitosis and meiosis. What is the main event that differentiates mitosis and meiosis and between meiosis I and meiosis II? Compare and contrast the two types of cell division.

Formative Practice 6.3

1. State the most obvious difference between meiosis I and meiosis II.
2. Explain how meiosis I can reduce the number of chromosomes in the daughter cell.

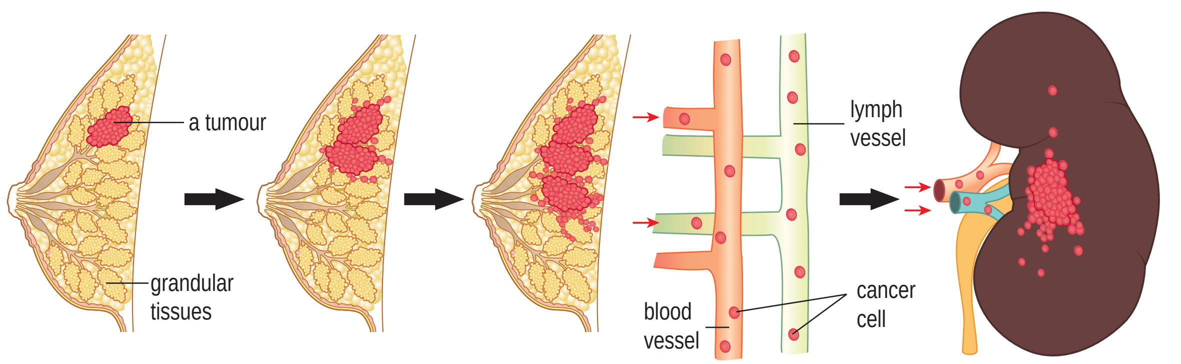
6.4 Issues of Cell Division on Human Health

The cell cycle is controlled by a special control system at each G_1, S, G_2 and M phase to ensure proper division of the cells. However, uncontrolled cell division sometimes can lead to the formation of tumours.

Tumour is divided into two types which are **benign tumour** and **malignant tumour**. A benign tumour is not dangerous and can be removed surgically. A malignant tumour is also called **cancer**. Cancer is caused by several factors such as radiation (x-ray, gamma rays and ultraviolet rays), chemical substances (such as tar in tobacco), carcinogens (such as formaldehyde and benzene), genetic factors, and also bacteria and viruses. This will cause the cells to divide continuously and develop into a tumour. The cancer cells will spread and destroy normal cells around them. This condition will affect the functions of the tissues around them. Cancer that is not identified at the early stage can cause damage to the organs and finally death (Figure 6.7).

ICT 6.3

Video: Cancer
(Accessed on 21 August 2019)



The tumour grows from a single cell.

Cancer cells compete to get nutrients from other tissues around them.

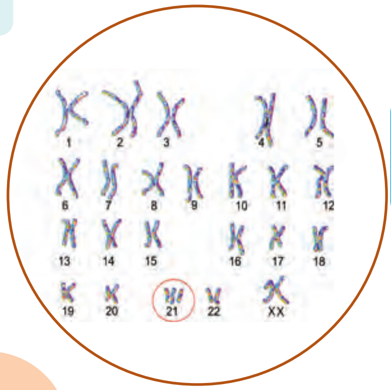
The cancer cells spread through the lymph vessels and blood vessels to other parts of the body.

A new tumour develops on other organs.

FIGURE 6.7 The development of breast cancer

Any abnormality during the division of meiosis can also cause genetic diseases such as Down syndrome. This happens because the spindle fibres fail to function during anaphase I or anaphase II. As a result, the chromosome fails to separate (nondisjunction). Gametes will have an abnormal number of chromosomes (22 or 24 chromosomes). If fertilisation between a normal gamete (23 chromosomes) and an abnormal chromosome (24 chromosomes) occurs, the zygote will carry 47 chromosomes which is an abnormal condition (Figure 6.8).

PHOTOGRAPH 6.5
A child with Down syndrome displays certain characteristics such as stunted body growth and mental retardation



PHOTOGRAPH 6.6
The complete chromosome set of an individual with Down syndrome

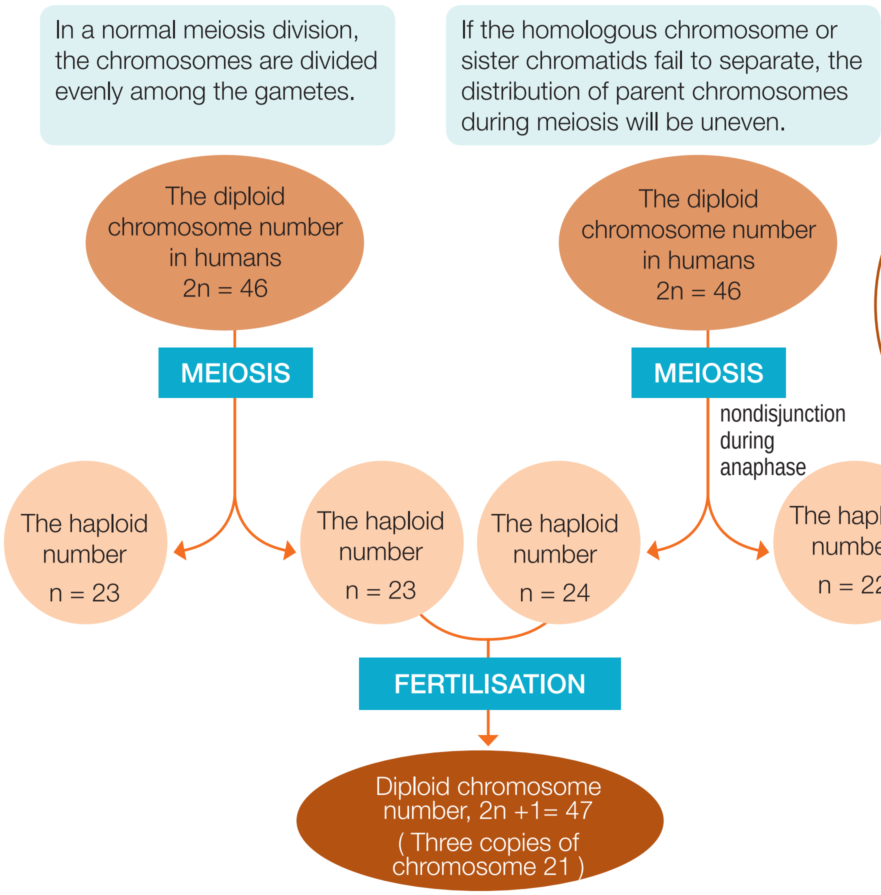


FIGURE 6.8 Formation of trisomy 21

An individual with Down syndrome has 47 chromosomes, which is an extra chromosome at the 21st set. This condition is known as **trisomy 21**. This syndrome can cause mental retardation, slanted eyes and a slightly protruding tongue.

Formative Practice 6.4

1 Explain why radiotherapy is used to control or stop the growth of cancer cells.

2 Nondisjunction conditions in humans can cause genetic diseases such as Down syndrome. State the number of chromosomes and the characteristics that are found in an individual with Down syndrome.

6.4.2

Summary

CELL DIVISION

- Cell Division
  - Karyokinesis (nuclear division)
  - Cytokinesis (cytoplasmic division)
- Cell Cycle and Mitosis
  - M phase (mitosis and cytokinesis)
  - Interphase (G_1, S and G_2 phase)
- Meiosis
  - Meiosis I and meiosis II
  - The similarities and differences between meiosis and mitosis
- Issues of Cell Division on Human Health
  - The effects of mitosis abnormality: tumour, cancer
  - The effects of meiosis abnormality: Down syndrome

Self Reflection

Have you mastered the following important concepts?

- Definitions of karyokinesis, cytokinesis, haploid, diploid, chromatin, homologous chromosomes, paternal and maternal chromosomes
- Cell cycle
- Stages of mitosis
- The differences between mitosis and cytokinesis between animal cells and plant cells
- Stages of meiosis
- Differences and similarities between meiosis and mitosis
- The need for mitosis and meiosis
- The effects of mitosis and meiosis abnormality towards human health

Summative Practice 6

1 Name the sequences in the mitosis process.

2 What is the function of the centriole in the division of animal cells?

3 State one difference between mitosis metaphase and meiosis metaphase I.

4 (a) Explain the importance of cell division that happens at the tip of a plant root.

(b) A farmer wants to plant a large number of quality breed mango trees in a short time for commercial purposes. State and explain the techniques that can be used by the farmer.

5 Figure 1 shows a cell at stage M in a cell cycle. Draw both cells that will be formed if the P chromosome does not separate.

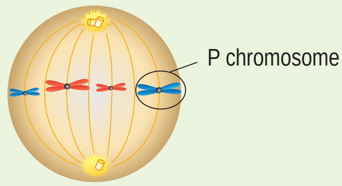


FIGURE 1

Essay Questions

6 Figure 2 shows the complete set of chromosomes of an individual.

(a) State the genetic disorder this individual has.

(b) Explain how this individual is born with this genetic disorder.

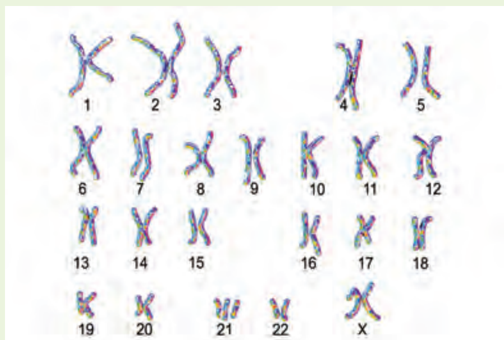


FIGURE 2

7 Cancer cells are formed after normal cells are exposed to factor Y.

(a) Explain the formation of cancer cells.

(b) State two examples of factor Y that causes the formation of cancer cells.

(c) State two ways to avoid the development of cancer cells.

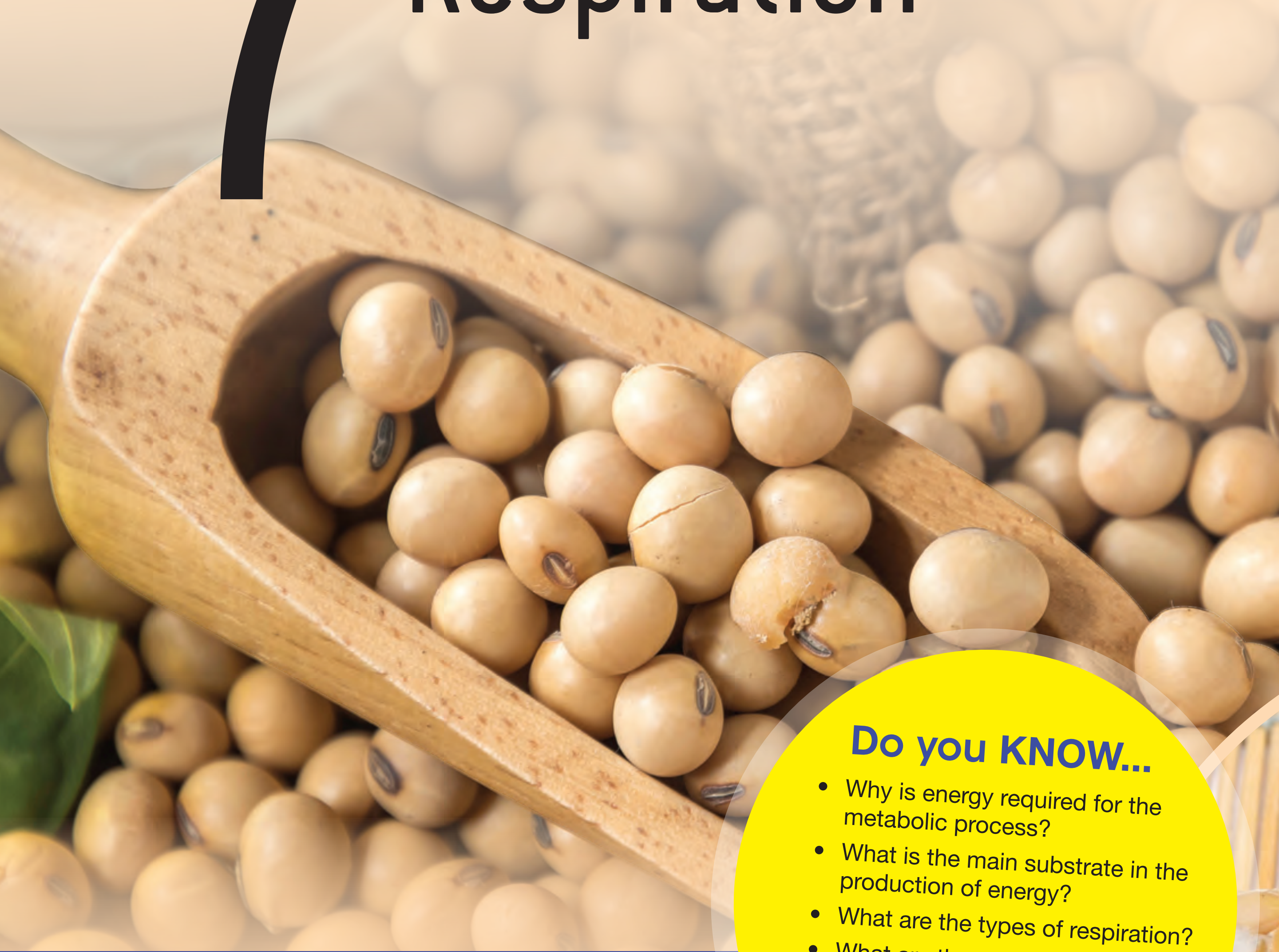
Enrichment

8 The development of plant tissue culture has allowed scientists to improve the quality and quantity of a crop. Scientists in Malaysia have succeeded in patenting a product that can be sprayed on orchid plants to overcome infections caused by a virus. This branch of biotechnology is called *RNA interference* technology. In your opinion, can the spray technology be used for all organisms as protection against infections?

Complete answers are available by scanning the QR code provided

CHAPTER

7 Cellular Respiration



How is tempe processed?

Do you KNOW...

- Why is energy required for the metabolic process?
- What is the main substrate in the production of energy?
- What are the types of respiration?
- What are the processes that occur in aerobic respiration and fermentation?

7.1 Production of energy through cellular respiration

- 7.1.1 Justify the necessity of energy in metabolic processes.
- 7.1.2 Identify the main substrate used in energy production.
- 7.1.3 List the types of cellular respiration:
  - aerobic respiration
  - anaerobic respiration
  - fermentation

7.2 Aerobic respiration

- 7.2.1 Conceptualise energy production from glucose during aerobic respiration in cells.
- 7.2.2 Write a word equation for aerobic respiration in cells.
- 7.2.3 Conduct an experiment to study aerobic respiration.

7.3 Fermentation

- 7.3.1 State the factors that cause fermentation to occur in cells.
- 7.3.2 Explain by using examples of energy production from glucose during fermentation in:
  - human muscle cells
  - *Lactobacillus*
  - yeast
  - plants such as paddy
- 7.3.3 Write and explain word equations for:
  - lactic acid fermentation
  - alcohol fermentation
- 7.3.4 Conduct an experiment to study fermentation in yeast.
- 7.3.5 Compare and contrast aerobic respiration and fermentation.

7.1 Production of energy through cellular respiration

In Chapter 5, you have learned about two types of metabolic reaction, which are **anabolism** and **catabolism**. Both of these reactions involve energy.

- The catabolism process releases energy.
- The anabolism process uses energy.

Without energy, the anabolic processes such as protein formation which is the basic muscle substance will not occur.

Activity Zone

Conduct a group discussion about the energy requirements in the metabolic process.

The main substrate in energy production

Cellular respiration is carried out to generate the energy needed by all living cells. **Cellular respiration** is the oxidation process of organic molecules through several stages to release energy. The main substrate for cellular respiration is **glucose**. Chemical energy found in glucose is released to produce energy required by cells. In humans and animals, glucose is obtained through the digestion of carbohydrates from the food eaten.

In green plants, light energy can be trapped by chlorophyll for the photosynthesis process to produce glucose.

Types of cellular respiration

There are two types of cellular respiration, which are aerobic and anaerobic respiration. **Aerobic respiration** occurs in the presence of oxygen. **Anaerobic respiration** occurs in the absence of oxygen. **Fermentation** is an alternative pathway of obtaining energy besides cellular respiration. In fermentation, the breakdown of glucose is incomplete in conditions of limited oxygen or without oxygen. This chapter focuses only on aerobic respiration and fermentation.

Formative Practice 7.1

1 Give five examples of the necessity of energy in a metabolic process.

2 State the main substrate in the production of energy.

3 State the meaning of cellular respiration and the types of cellular respiration.

4 Explain how humans, animals and plants acquire glucose to produce energy.

7.1.1 7.1.2 7.1.3

7.2 Aerobic Respiration

Aerobic respiration is the breakdown of glucose involving oxygen to produce chemical energy. Oxygen is used to oxidise glucose to produce carbon dioxide, water and energy.

The aerobic respiration process begins with the glycolysis process. **Glycolysis** means the breakdown of glucose by enzymes. This process occurs in the cytoplasm. One glucose molecule is broken down into two pyruvate molecules.

The following process occurs in the mitochondrion. Pyruvate produced from glycolysis is then oxidised through a series of reactions to produce **carbon dioxide**, **water** and **energy**. A large amount of this energy is used to produce **adenosine triphosphate (ATP)** molecules.

ICT 7.1

Video: Aerobic respiration
(Accessed on 21 August 2019)

Brainstorm!

The number of mitochondrion in the muscle cells of an athlete increases after intensive training. Explain how this contributes to the achievement of the athlete as compared with those who do not undergo intensive training.

Glycolysis	**Oxidation of Pyruvate**
Glucose → Pyruvate →	Carbon dioxide + water + energy
(Occurs in the cytoplasm)	(Occurs in the mitochondrion)

The aerobic respiration is simplified as follows.

- ATP molecules are produced when a group of non-organic phosphate is added to adenosine diphosphate (ADP).

$$\text{ADP + phosphate} \xrightarrow{\text{energy}} \text{ATP}$$

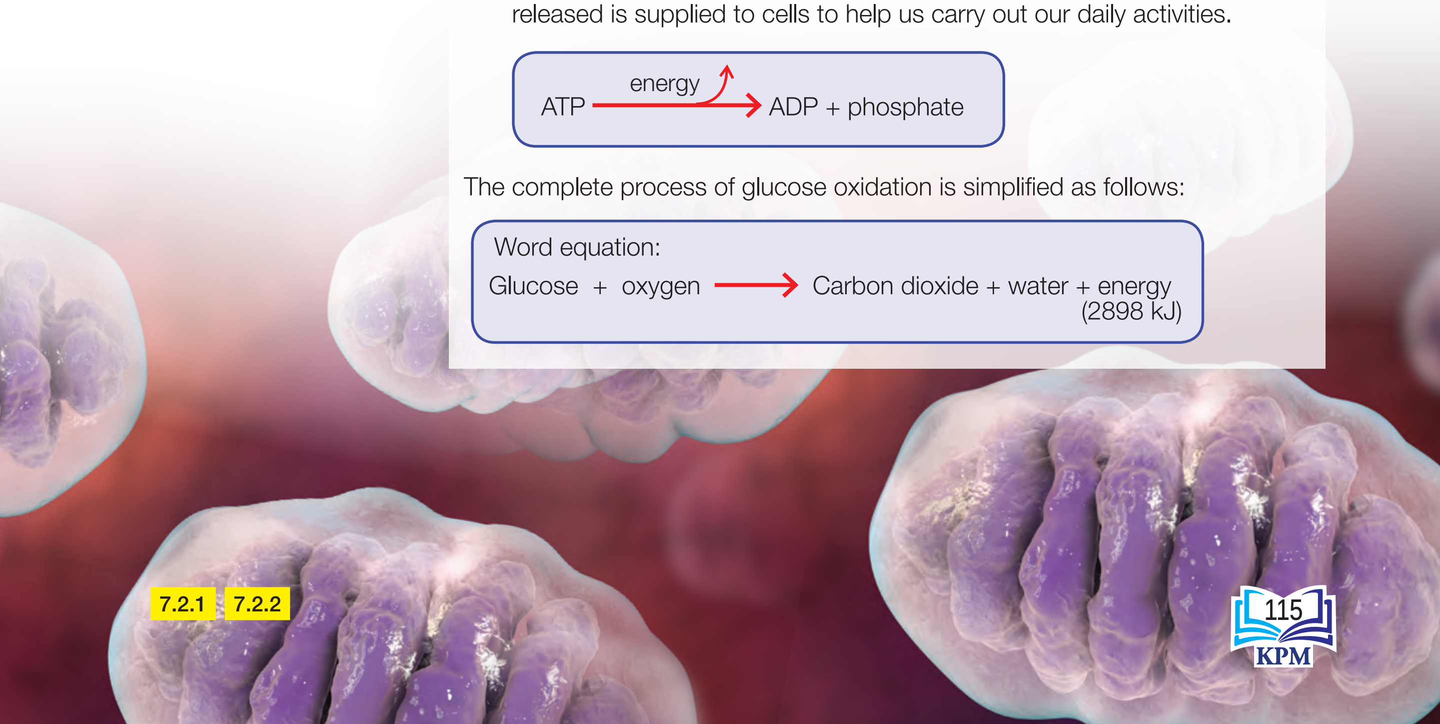
- ATP molecules have weak phosphate links.
- When the phosphate links on ATP molecules are broken, the energy released is supplied to cells to help us carry out our daily activities.

$$\text{ATP} \xrightarrow{\text{energy}} \text{ADP + phosphate}$$

The complete process of glucose oxidation is simplified as follows:

Word equation:

Glucose + oxygen → Carbon dioxide + water + energy (2898 kJ)



7.2.1 7.2.2

CHAPTER 7

Activity 7.1 To study aerobic respiration

Experiment

Problem statement
Do living organisms carry out aerobic respiration?

Hypothesis
Living organisms use oxygen and release carbon dioxide during aerobic respiration.

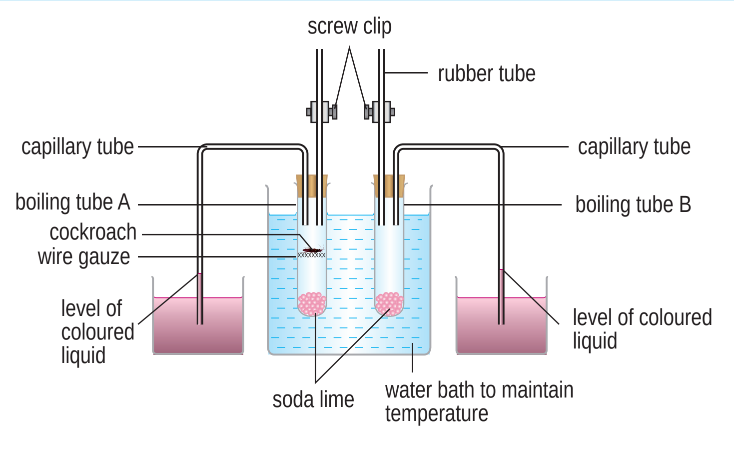
Variable
Manipulated: Presence of living organisms
Responding: Increase in the level of coloured liquid
Fixed: Initial level of coloured liquid

Take Note!

Wipe all connectors with petroleum jelly to ensure that the apparatus prepared is airtight.

Materials
Water, coloured liquid, soda lime, living organism (cockroach) and petroleum jelly

Apparatus
Boiling tubes, screw clip, wire gauze, 250 ml beaker, capillary tube, ruler, rubber tube and water bath



Apparatus set-up to study aerobic respiration process

Biological Lens

The apparatus set-up is called a respirometer. It is used to measure the rate of respiration of an organism by estimating the rate of oxygen used.

Procedure
1 Prepare the apparatus as shown in the figure above.
2 Prepare two boiling tubes labelled A and B.
3 Fill both boiling tubes with 10 g soda lime.
4 Put the wire gauze in the middle of boiling tube A.
5 Put a cockroach on the wire gauze in boiling tube A while the boiling tube B is left empty.
6 Wipe all connections of the apparatus with petroleum jelly.
7 Close the screw clip and mark the height of the initial level of the coloured liquid in the capillary tube for both boiling tubes.
8 Leave the apparatus for an hour.
9 Measure and record the final height of the coloured liquid in both capillary tubes after an hour with a ruler.
10 Record your observations in the following table.

Results

Boiling tube	Initial level (cm)	Final level (cm)	Difference in levels (cm)
A			
B			

Discussion

1 What is the purpose of preparing boiling tube B?
2 What is the function of soda lime in the boiling tube?
3 Is there a change in the level of coloured liquid in capillary tube A? Explain your answer.

Conclusion

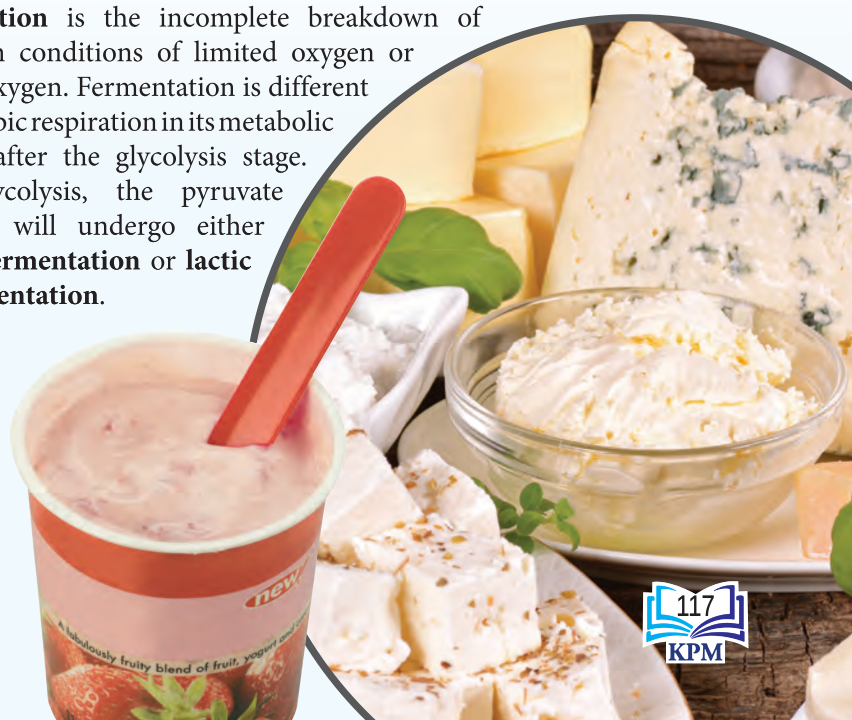
Is the hypothesis accepted? Suggest a suitable conclusion.

Formative Practice 7.2

1 State the meaning of aerobic respiration.
2 Suggest another substrate apart from glucose that can be used by cells for cellular respiration.
3 State the word equation for aerobic respiration.
4 Describe the processes involved in aerobic respiration to produce energy.

7.3 Fermentation

Fermentation is the incomplete breakdown of glucose in conditions of limited oxygen or without oxygen. Fermentation is different from aerobic respiration in its metabolic pathway after the glycolysis stage. After glycolysis, the pyruvate produced will undergo either **alcohol fermentation** or **lactic acid fermentation**.



7.3.1

ICT 7.2

Video: Anaerobic respiration
(Accessed on 21 August 2019)

FERMENTATION

The incomplete breakdown of glucose in limited or no oxygen conditions.

ALCOHOL FERMENTATION

The incomplete breakdown of glucose to ethanol, carbon dioxide and energy.

Glucose $\rightarrow$ Ethanol + carbon dioxide + energy (210 kJ)

YEAST

- Ethanol is used in the making of beer and wine.
- The released carbon dioxide makes bread dough rise.

PLANTS

- Paddy plants that grow in waterlogged areas with less oxygen are able to carry out **alcohol fermentation**.
- Ethanol produced in the tissues during the fermentation process is toxic to most plants but the cells of paddy plants have a higher tolerance for ethanol compared to other species.
- Paddy plants produce plenty of alcohol dehydrogenase enzymes that can break down ethanol molecules into non-toxic carbon dioxide.

Activity 7.2 Produce and market food products produced through fermentation

Project

Procedure

1. Your teacher will divide your class into a few groups.
2. Each group will choose one food product that is produced through the fermentation process and market that product in school. Examples of products are tapai, yoghurt or bread.
3. Each group needs to prepare a proposal before starting the project. The proposal must contain:
   - introduction of the project including the objectives
   - execution cost
   - production and marketing plan
   - expected outcome
4. If necessary, get advice from your teacher or parents to ensure the smooth delivery of the project.
5. Conduct the project as planned.
6. At the end of the project, each group must prepare a complete report.

7.3.2 7.3.3

LACTIC ACID FERMENTATION

The breakdown of glucose into lactic acid and energy.

Glucose → Lactic acid + energy

LACTOBACILLUS

- The bacteria *Lactobacillus* carries out milk **fermentation** to produce **yoghurt**.
- *Lactobacillus* acts on the lactose (milk sugar) and turns it into lactic acid.
- The lactic acid will then coagulate casein (milk protein) to produce yoghurt.
- Lactic acid is the source of a sour taste in yoghurt.

Brainstorm!

Some bacteria can only survive in anaerobic conditions. Predict what can happen to this type of bacteria when oxygen is supplied.

CHAPTER 7

HUMAN MUSCLE CELLS

- This process is carried out by the muscle cells during vigorous training.
- During vigorous training, the rate of oxygen used exceeds the oxygen supplied by the blood circulatory system.
- The muscle is in an oxygen-deficiency state and is said to undergo **oxygen debt**.
- During this process, glucose cannot break down completely. For each glucose molecule that is broken down, only two ATP molecules or 150 kJ energy will be produced.
- The produced lactic acid accumulates until it reaches a level of concentration that can cause fatigue and muscle cramps.
- Once the vigorous activity stops, the intake of excess oxygen will oxidise the lactic acid into carbon dioxide, water and energy. When all the lactic acid has been expelled, the **oxygen debt** is **repaid**.
  - Figure 7.1 shows a lack of oxygen in muscles and oxygen debt is repaid.

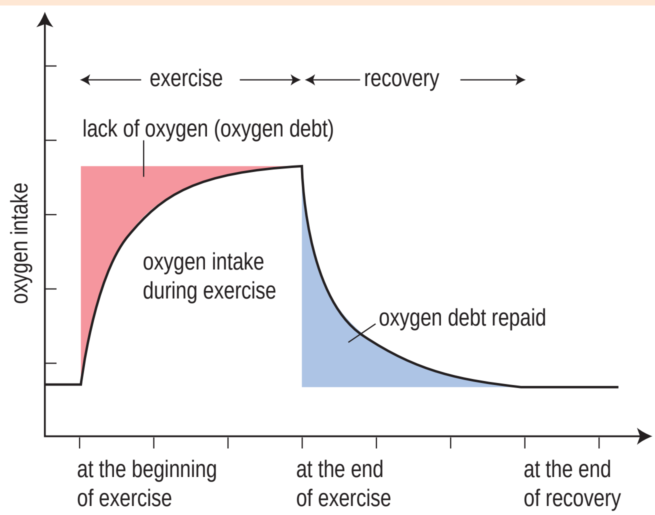


FIGURE 7.1 Lack of oxygen in muscles and oxygen debt repaid

7.3.2 7.3.3

Activity 7.3 To study the process of yeast fermentation

Experiment

Problem statement
What are the products of yeast fermentation?

Hypothesis
Yeast fermentation produces energy, carbon dioxide and ethanol.

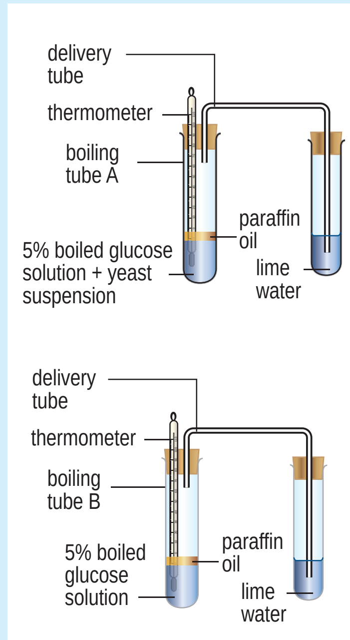
Variables
Manipulated: Presence of yeast
Responding: Changes in temperature, lime water and ethanol smell
Fixed: The volume of boiled glucose solution and the anaerobic condition

Take Note!
Ensure that the end of the delivery tube is soaked in lime water.

Materials
5% yeast suspension, 5% boiled glucose solution, lime water and paraffin oil

Apparatus
Boiling tube, test tube, thermometer, measuring cylinder, delivery tube and cork

Procedure
1. Fill 2 boiling tubes with 15 ml of 5% glucose solution that has been boiled and left to cool.
2. Label the boiling tubes as A and B.
3. Put 5 ml 5% yeast suspension into boiling tube A.
4. Add paraffin oil into both of the boiling tubes.
5. Close both boiling tubes with the cork that has a hole and a delivery tube. Prepare 2 test tubes with 2 ml of lime water respectively. Dip the end of each delivery tube into each test tube that contains lime water.
6. Leave the apparatus for 1 hour.
7. Measure and record the initial and final temperature using a thermometer.
8. Record your observations in the table below.



Apparatus set-up to study the yeast fermentation process

Results

Boiling tube	Temperature (°C)		Change in lime water	Smell of solution
	Beginning of experiment	End of experiment		
A				
B				

Discussion
1. How is the anaerobic condition maintained to ensure that the fermentation process is complete?
2. What is the function of preparing boiling tube B?

3 What is the purpose of boiling the glucose solution earlier?
4 How do the results show that fermentation has taken place in boiling tube A?

Conclusion
Is the hypothesis accepted? Suggest a suitable conclusion.

Comparison between aerobic respiration and fermentation

There are a few similarities and differences between fermentation and aerobic respiration (Figure 7.2 and Table 7.1).

SIMILARITIES BETWEEN AEROBIC RESPIRATION AND FERMENTATION

- The breakdown process of glucose and its conversion to chemical energy
- The process begins in the cytoplasm
- Occurs in yeast, bacteria, animals and plants
- Produces chemical energy in the form of ATP
- The process begins with glycolysis when glucose is converted to pyruvate

FIGURE 7.2 Similarities between aerobic respiration and fermentation

Brainstorm!
Why is aerobic respiration more suitable for yeast compared with fermentation?

TABLE 7.1 Differences between aerobic respiration and fermentation

DIFFERENCES	
Aerobic Respiration	**Fermentation**
The breakdown process of glucose is completed in the presence of oxygen.	The breakdown process of glucose is incomplete without oxygen or in limited oxygen conditions.
Occurs in cytoplasm and mitochondrion.	Occurs in cytoplasm.
Produces water.	Does not produce water.
Glucose is oxidised completely into carbon dioxide and water.	Glucose is not oxidised completely into ethanol and carbon dioxide or lactic acid.
One molecule of glucose generates 2898 kJ of energy	One molecule of glucose generates 210 kJ (alcoholic fermentation) or 150 kJ (lactic acid fermentation) of energy

Formative Practice 7.3

1 State where the process of fermentation usually occurs.
2 Give three examples of microorganisms and food produced by the fermentation process.
3 While helping your father to cut the grass at the farm, you come across a snake. Terrified, you run away from the snake. Explain the cellular respiration that takes place in the muscle cells of your legs.
4 State the differences between aerobic respiration and fermentation.

Summary

CELLULAR RESPIRATION

- Production of energy through cellular respiration
  - The main substrate in energy production is glucose
- Aerobic Respiration
  - The breakdown of glucose in the presence of oxygen to produce chemical energy
    - Occurs in cytoplasm
      Glucose → Pyruvate
    - → Occurs in mitochondrion (pyruvate oxidation)
      Carbon dioxide + water + energy
- Anaerobic Respiration
- Fermentation
  - The incomplete breakdown of glucose in limited oxygen or no oxygen
    - Alcohol fermentation
    - Lactic acid fermentation

Self Reflection

Have you mastered the following important concepts?

- The necessity of energy in metabolic processes
- The main substrate in the production of energy
- Types of cellular respiration
- Energy production from glucose during aerobic respiration in cells
- Word equation for aerobic respiration in cells
- Factors that cause fermentation to occur in cells
- Example of energy production from glucose during fermentation
- Lactic acid fermentation and alcohol fermentation
- Yeast fermentation process
- Differences between aerobic respiration and fermentation

Summative Practice 7

1 What are the uses of alcohol fermentation products?

2 Why do muscles carry out cellular respiration that produces lactic acid during vigorous training?

3 Why does cellular respiration in muscles that produce lactic acid supply less energy compared to aerobic respiration?

4 Explain why an individual usually feels tired faster compared with an athlete, when both of them are running together.

5 A 100-metre sprinter usually holds his breath while running compared with a long-distance runner. After running, the sprinter needs seven litres of oxygen to remove the lactic acid in his muscle cells. Explain this difference between the sprinter and the long-distance runner.

6 Photograph 1 shows the activities by two individuals, P and Q.

PHOTOGRAPH 1

(a) (i) Based on Photograph 1, identify the respiration that occurs in the muscles of individuals P and Q.
(ii) State the products of respiration in P and Q.

(b) During the 100-metre sprint on Sports Day, a pupil experienced muscle cramps and had to stop running. Explain why muscle cramps happen.

(c) Paddy plants grown in waterlogged areas have tolerance to ethanol compared with other plants.
(i) State the type of fermentation that occurs in paddy plant cells.
(ii) Write the word equation for the fermentation process that occurs in the paddy plant cells.
(iii) Suggest another cell that can carry out the fermentation process as in question c(ii).

Essay Questions

7 (a) Explain why energy is required in metabolic processes.

(b) Compare aerobic respiration with fermentation.

(c) Microorganisms such as yeast and bacteria usually play an important role in the fermentation process to produce food. Explain why yoghurt can spoil if it is not kept in the refrigerator.

Enrichment

8 A person who is not used to exercising will experience muscle cramps when doing vigorous exercise because of the accumulation of lactic acid in the cells. However, for high-performance athletes, such problems do not occur because their bodies have a high tolerance for lactic acid. In your opinion, how do high performance athletes overcome the problem of lactic acid accumulation? Give your reasoning.

9 Studies have shown that intake of sodium bicarbonate or baking powder (*baking soda*) can increase muscle efficiency during intense activities that involve muscle fermentation. Give your justification.

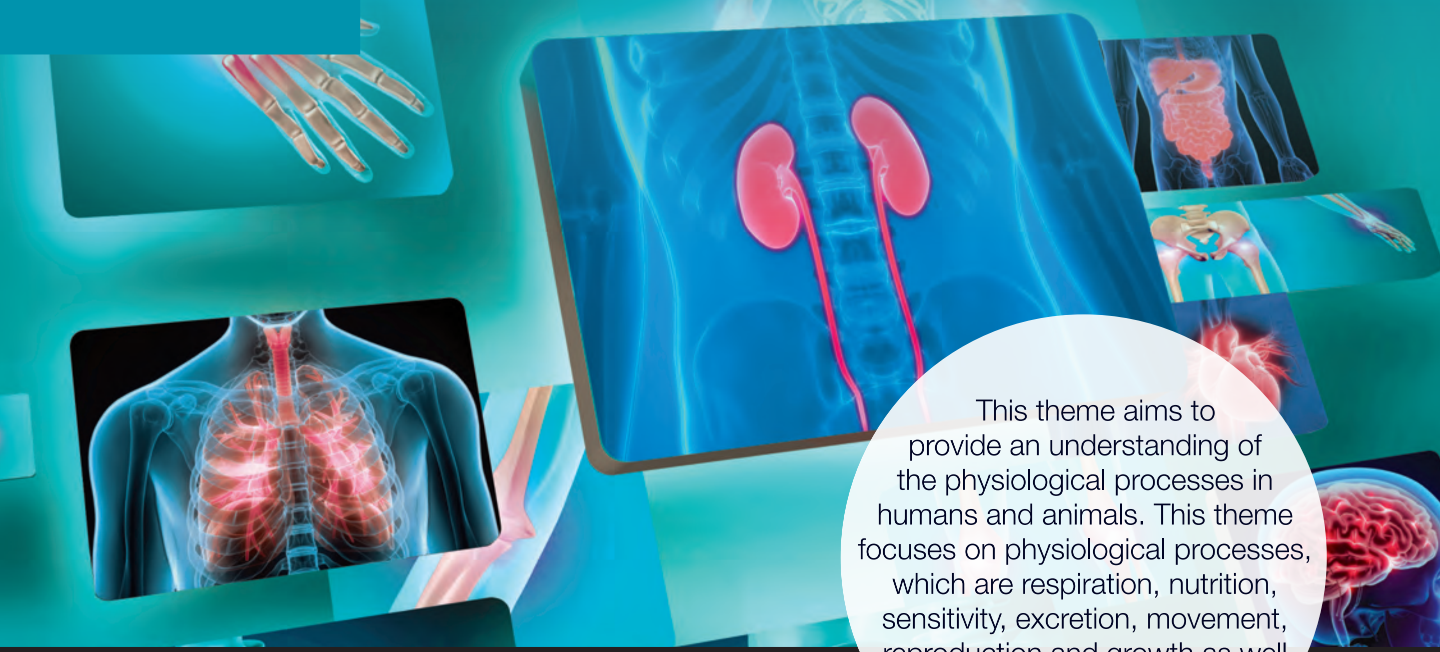
10 While conducting an experiment using yeast, Mei Ling found that if grape juice is kept with yeast in a covered container, the yeast will slowly break down the glucose in the grapes. However if the container does not contain any oxygen, the yeast will break down the glucose at a faster rate, and the alcohol content in the container will rise very fast. At the end of the experiment, Mei Ling found that the breakdown rate of glucose becomes slow again even though there are some grapes that have not been oxidised. Explain Mei Ling's observation.

11 Susan tried to make bread using dry yeast bought from a shop. When she mixed the yeast with plain flour, she found that her bread did not rise after half an hour. Explain how you can help Susan solve her problem.

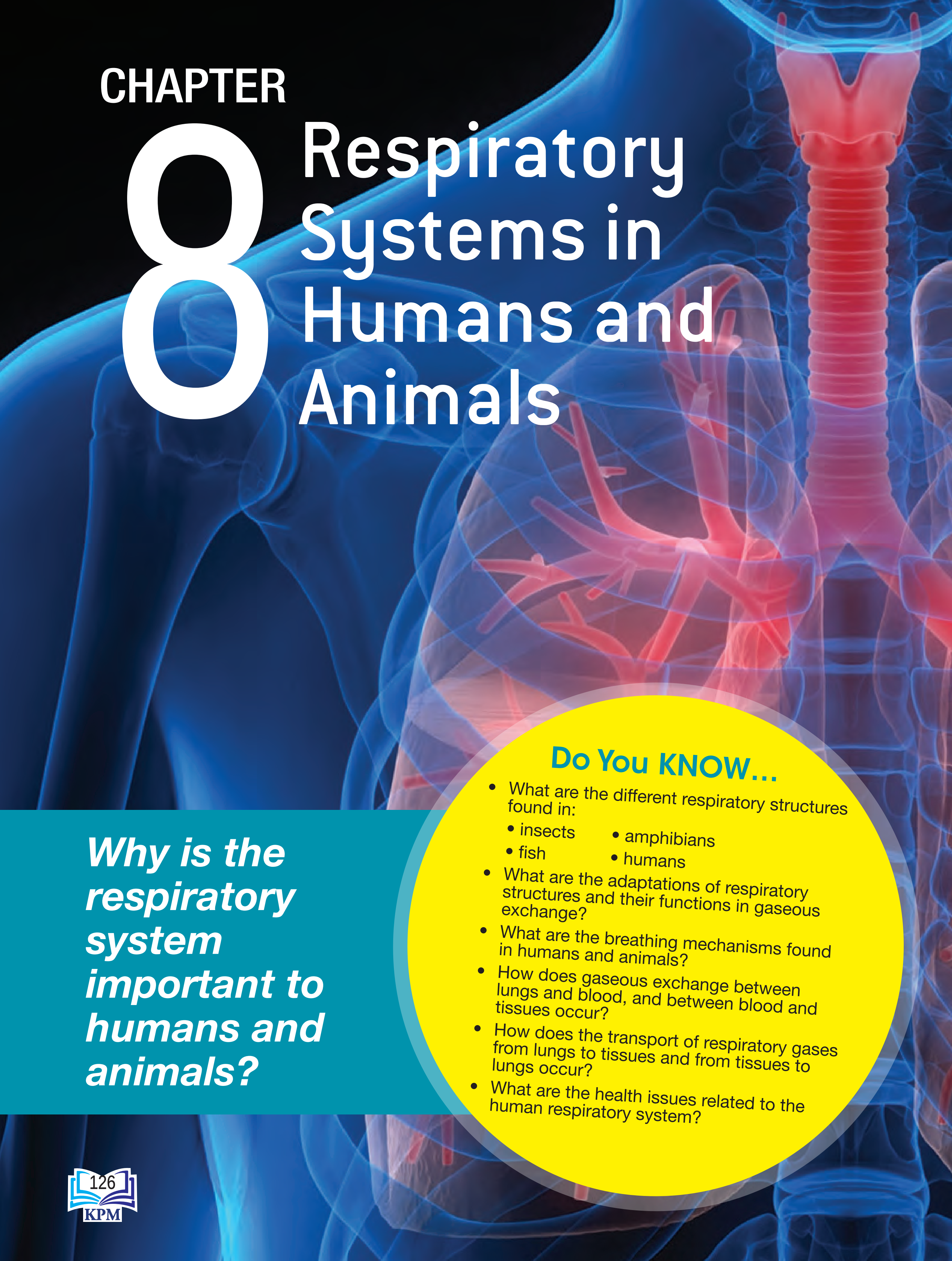
Complete answers are available by scanning the QR code provided

THEME

2 PHYSIOLOGY OF HUMANS AND ANIMALS



This theme aims to provide an understanding of the physiological processes in humans and animals. This theme focuses on physiological processes, which are respiration, nutrition, sensitivity, excretion, movement, reproduction and growth as well as cell division.



CHAPTER

8 Respiratory Systems in Humans and Animals

Why is the respiratory system important to humans and animals?

Do You KNOW...

- What are the different respiratory structures found in:
  - insects
  - fish
  - amphibians
  - humans
- What are the adaptations of respiratory structures and their functions in gaseous exchange?
- What are the breathing mechanisms found in humans and animals?
- How does gaseous exchange between lungs and blood, and between blood and tissues occur?
- How does the transport of respiratory gases from lungs to tissues and from tissues to lungs occur?
- What are the health issues related to the human respiratory system?

8.1 Types of Respiratory System

8.1.1 Identify respiratory structures in:
- insects
- fish
- amphibians
- humans

8.1.2 Describe the adaptation of respiratory structures and their functions for gaseous exchange in:
- animals
- humans

8.1.3 Compare and contrast respiratory structures in humans and animals.

8.2 Mechanisms of Breathing

8.2.1 Compare and contrast breathing mechanisms in humans and animals.

8.3 Gaseous Exchange in Humans

8.3.1 Communicate about external and internal respiration:
- gaseous exchange between lungs and blood
- transport of respiratory gases from lungs to tissues
- gaseous exchange between blood and tissues
- transport of respiratory gases from tissues to lungs

8.4 Health Issues Related to the Human Respiratory System

8.4.1 Narrate the effects of *Chronic Obstructive Pulmonary Disease* (COPD) on the human respiratory system:
- asthma
- chronic bronchitis
- emphysema

8.1 Types of Respiratory System

Respiratory structures and their adaptations for gaseous exchange

ICT 8.1

Activity: To study the respiratory structure in insects, frogs and rats

You have learned about respiratory organs and systems in humans and animals in Form 3. **The respiratory structure** is the **respiratory surface** that enables gaseous exchange to occur between respiring organism cells and their outer environment. You have also learned in Theme 1, that unicellular organisms such as *Amoeba* sp. do not need a special respiratory structure because it has a large total surface area to volume ratio for gaseous exchange through **diffusion**.

The ratio of total surface area to volume (TSA/V) depends on the size of the organism. The bigger the size of the organism, the smaller the ratio of total surface area to volume. This means that for large and complex organisms, the volume of the body that requires oxygen will increase more than its total surface area. This explains why large and complex organisms cannot maintain gaseous exchange by diffusion through body surface only. Large organisms require a special respiratory structure for the efficient exchange of gases.

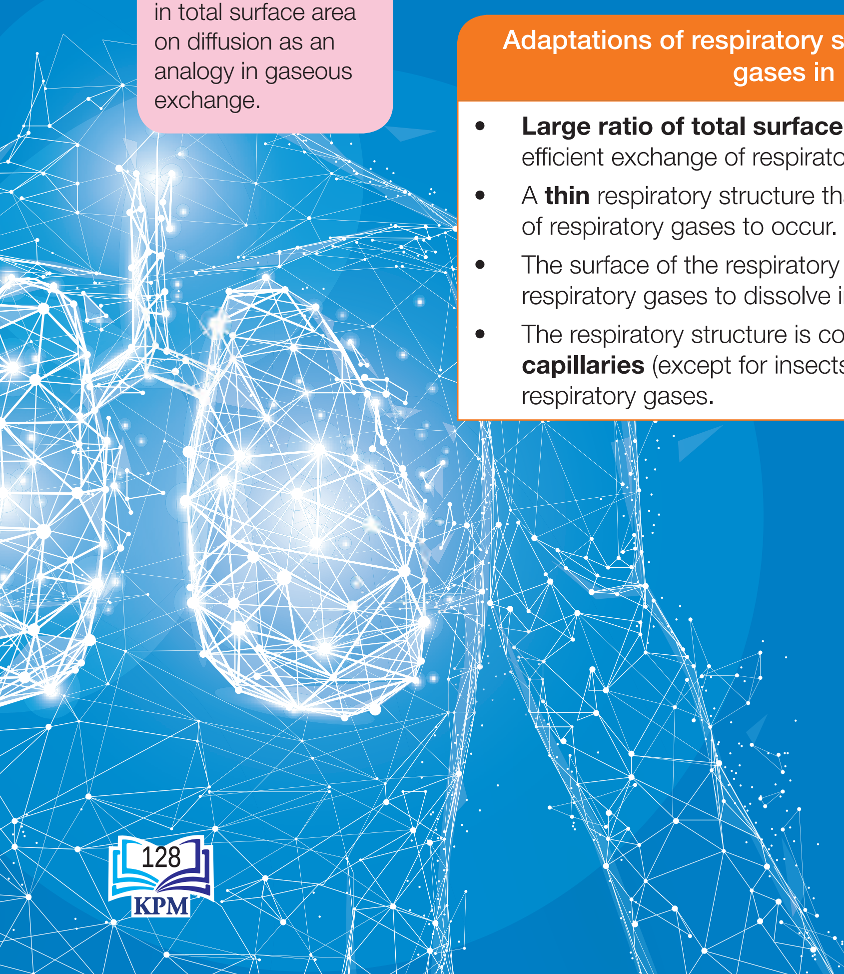
How are the respiratory structures of large-sized organisms adapted for efficient exchange of gases?

Activity Zone

Study the effects of an increase in total surface area on diffusion as an analogy in gaseous exchange.

Adaptations of respiratory structures for efficient exchange of gases in big organisms

- **Large ratio of total surface area to volume (TSA/V)** for the efficient exchange of respiratory gases.
- A **thin** respiratory structure that is one cell thick, allows the diffusion of respiratory gases to occur.
- The surface of the respiratory structure is always **moist** for respiratory gases to dissolve in them.
- The respiratory structure is complete with a **network of blood capillaries** (except for insects), that allows for the efficient delivery of respiratory gases.



8.1.1 8.1.2

The insect respiratory structure and its adaptations

The breathing system of insects is the **tracheal system** (Figure 8.1).

- There are small pores in the thorax and abdomen of insects called **spiracles**. The spiracle allows the intake of air into the air tube system, which is the **tracheal system**.
- The trachea branches out to form finer tubes called the **tracheole**. Tracheole is the respiratory surface. The tracheole has the following characteristics that allow for efficient respiratory gaseous exchange.
  – **A large number of tracheoles** provides a large total surface area for the exchange of gases.
  – The tracheole wall is **thin** and **moist**. This allows oxygen gas to diffuse into the cells while carbon dioxide quickly diffuses out of the cells into the tracheole.
- Some insects have **air sacs** in their trachea system. This sac is filled with air to speed up the delivery of respiratory gas during active body movements.

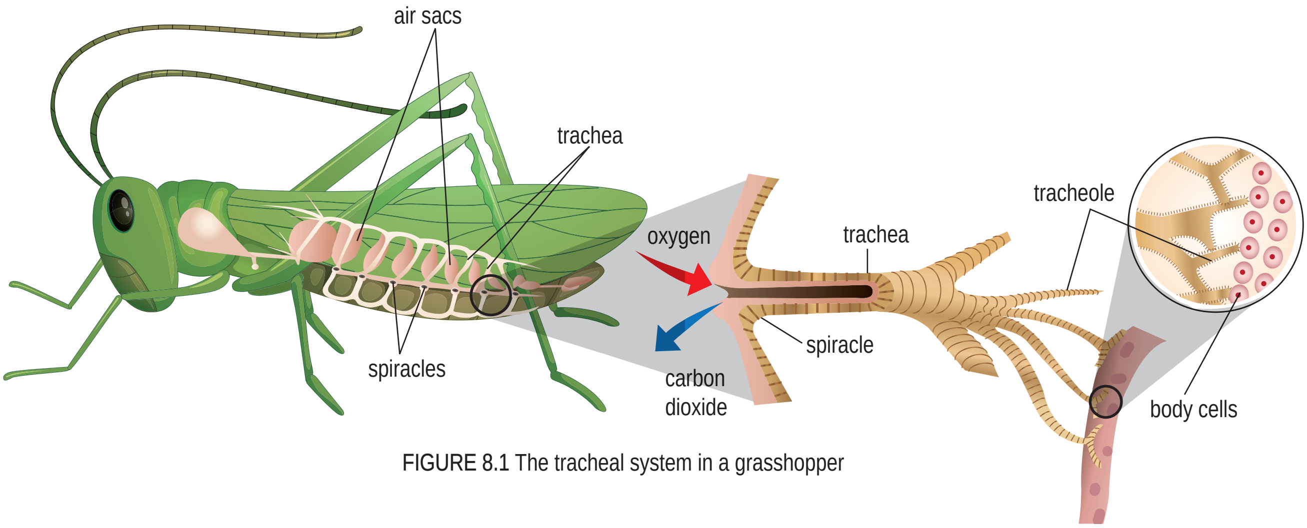


FIGURE 8.1 The tracheal system in a grasshopper

The fish respiratory structure and its adaptations

Brainstorm!
Why can't fish gills function if the fish is not in the water?

The respiratory structure of fish is the **gills** (Figure 8.2). The gills are made up of a line of **filament** that is supported by the **gill arch**. The following characteristics of filament enable the rapid exchange of respiratory gases.

- The filament has many **thin** and **flat** projections called **lamella** (plural: **lamellae**). A large number of filaments and lamellae gives a large total surface area for an efficient gaseous exchange process.
- The lamella membrane is **thin** and supplied with **many blood capillaries** for easy absorption and transport of oxygen and carbon dioxide.

8.1.1 8.1.2

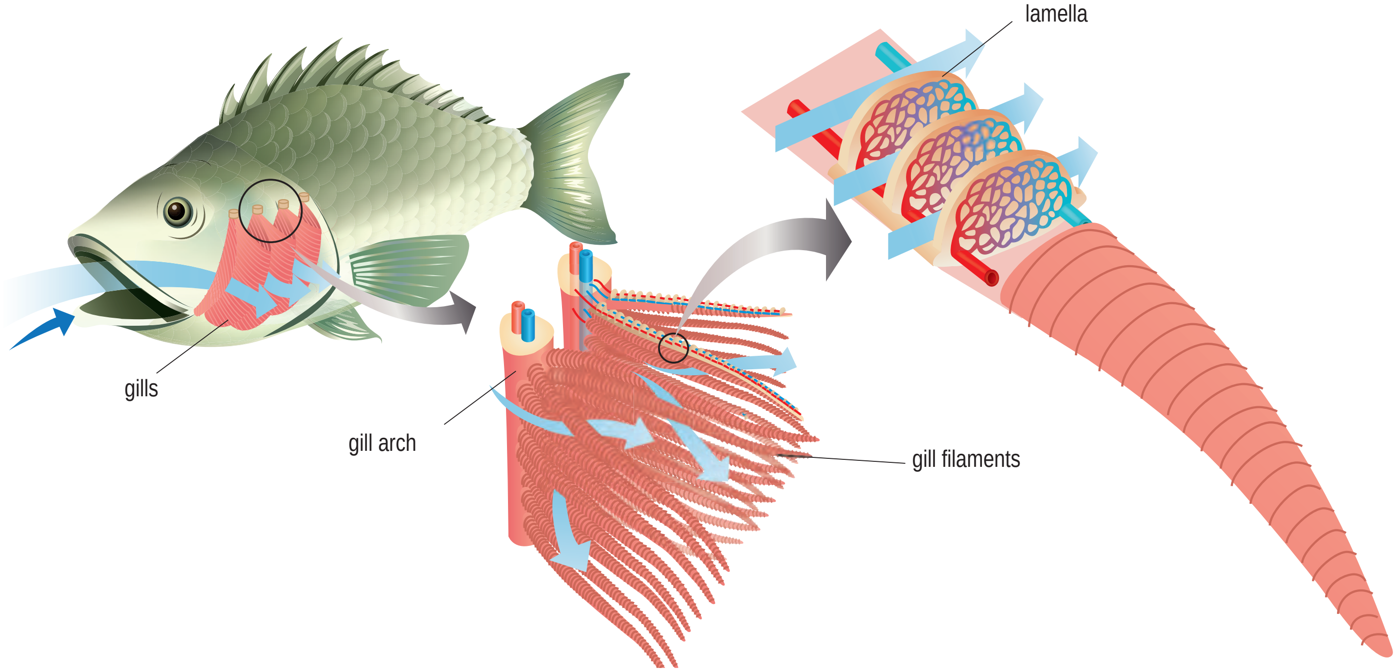


FIGURE 8.2 Respiratory structure of a fish

The frog respiratory structure and its adaptations

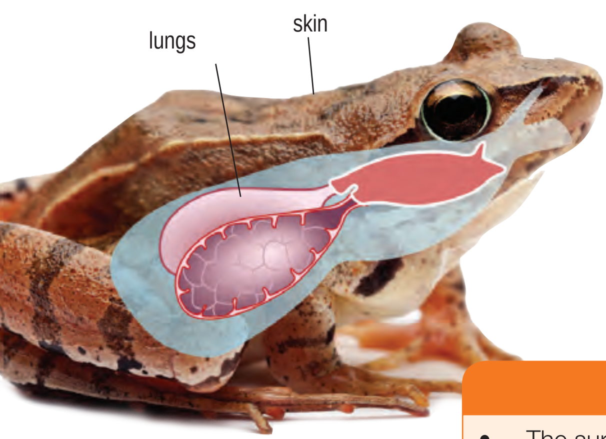


FIGURE 8.3 The respiratory structure of frogs

Skin

In an **inactive** state, the frog uses its **skin** for gaseous exchange (Figure 8.3).

- The skin is **thin** and highly **permeable** to respiratory gases.
- The **moist skin** allows respiratory gases to dissolve in it.
- Beneath the skin, there are many networks of **blood capillaries** to transport respiratory gases.

Lungs

- The surface of the lungs is **folded** to increase the total surface area for the exchange of gases (Figure 8.3).
- The **thin** lung membrane eases the diffusion of respiratory gases.
- The **moist** lung walls enable respiratory gases to dissolve in them.
- The lungs are also rich with **a network of blood capillaries** to transport respiratory gases.

8.1.1 8.1.2

The human respiratory structure and its adaptations

The human respiratory structure is the **alveolus** which has the characteristics for efficient respiratory gaseous exchange (Figure 8.4):

- A large number of alveoli provides **a large total surface area** for the diffusion of respiratory gases.
- The alveolus wall is always **moist**. Oxygen and carbon dioxide can dissolve easily, and diffuse through the walls into the blood capillaries.
- The alveolus is surrounded by a large **network of blood capillaries** to hasten the diffusion of respiratory gases.
- The thin alveolus wall, that is **as thick as one cell**, makes the diffusion of gases much easier.

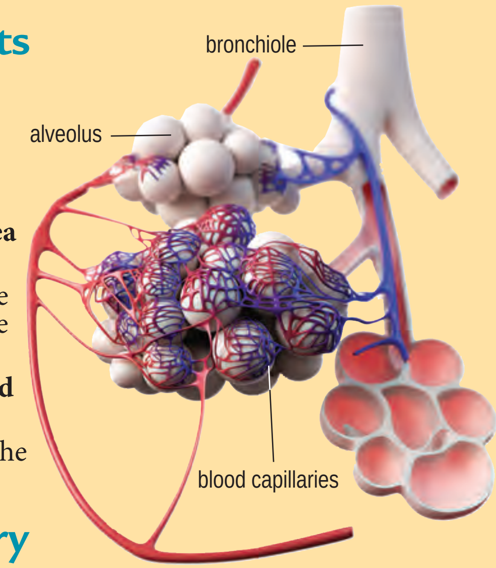


FIGURE 8.4 Alveolus

Comparison and contrast of respiratory structures in humans and animals

Table 8.1 shows the similarities and differences between the respiratory structures of humans and animals.

TABLE 8.1 Similarities and differences between the respiratory structures of humans and animals

Similarities

- All respiratory structures have a large ratio of total surface area to volume for an efficient exchange of respiratory gases.
- All respiratory structures are thin and this makes the diffusion of respiratory gases much faster.
- All respiratory structures are moist and this allows respiratory gases to dissolve in them.
- The respiratory structure is complete with a network of blood capillaries (except insects), that allows for efficient transport of respiratory gases.

Differences

Characteristics	Insects	Fish	Frogs	Humans
Respiratory structure	Tracheole	Filament and lamella	Skin and lungs	Alveolus
How the large ratio of total surface area to volume for the respiratory structure is achieved	Large number of tracheoles	Large number of filaments and lamellae	• The surface in the lungs is folded • Overall skin surface	Large number of alveoli

Formative Practice 8.1

1 State the adaptations of the human respiratory structure.

2 Explain how the frog skin is adapted for efficient exchange of gases.

3 State the characteristics of tracheoles that help with gaseous exchange in insects.

4 Predict what will happen to a fish if its gills are torn after being caught in a net.

8.1.1 8.1.2 8.1.3

8.2 Mechanisms of Breathing

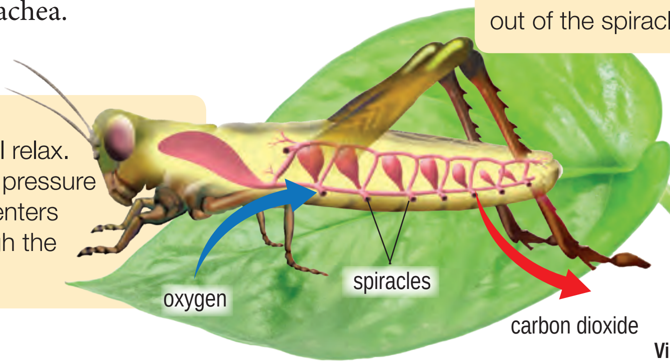
Humans and animals have different breathing mechanisms. **Breathing** refers to the repetitive inhalation and exhalation process.

Breathing mechanism of insects

Abdominal muscles that relax and contract enables air to go in and out of the trachea.

The abdominal muscles will contract when air is exhaled. This will increase the air pressure in the trachea and subsequently forces air out of the spiracle.

When inhaling air, the abdominal muscles will relax. This will reduce the air pressure in the trachea and air enters into the trachea through the spiracle.

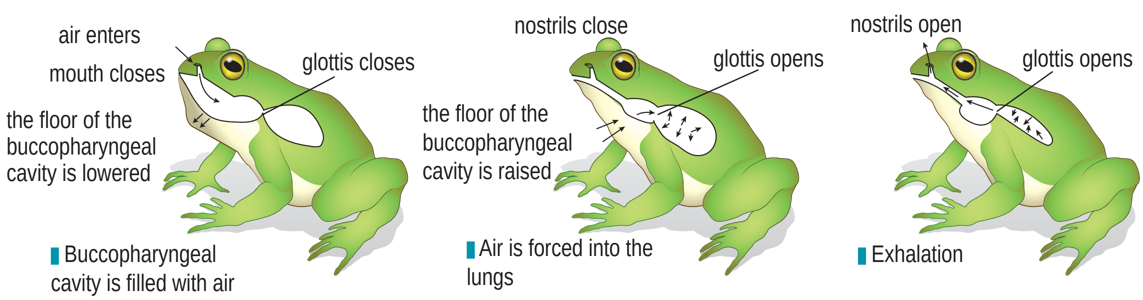


ICT 8.2

Video: Breathing mechanism of insects
(Accessed on 21 August 2019)

Breathing mechanism of frogs

Frogs breathe through the mouth and lungs while in an active state. The sequence of inhalation and exhalation is summarised below.



Buccopharyngeal cavity is filled with air

Air is forced into the lungs

Exhalation

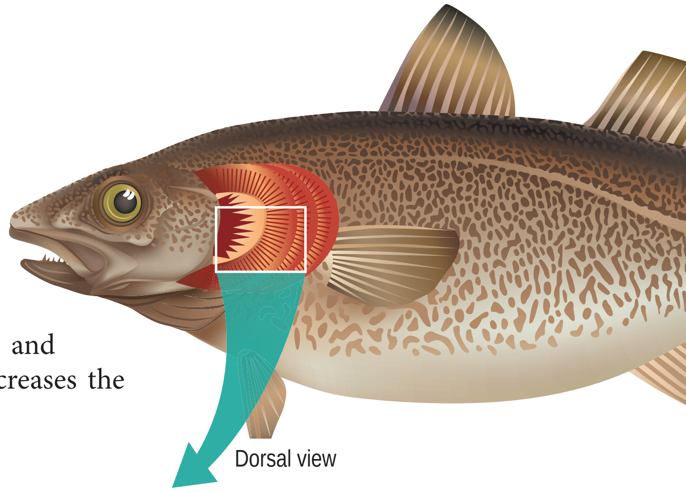
Inhalation

- When the frog breathes through the nostrils, the mouth and glottis are closed and the floor of the buccopharyngeal cavity is lowered.
- The low air pressure in the mouth cavity draws air into the buccopharyngeal cavity through the nostrils.
- When the glottis opens, the nostrils close and the floor of the buccopharyngeal cavity is raised.
- The increased air pressure pushes air into the lungs.

Exhalation

- When the lungs contract, air is expelled from the lungs.
- This is helped by the abdominal pressure and the elasticity of the lungs.
- Some air is expelled through the nostrils while the rest is mixed with the air in the buccopharyngeal cavity.

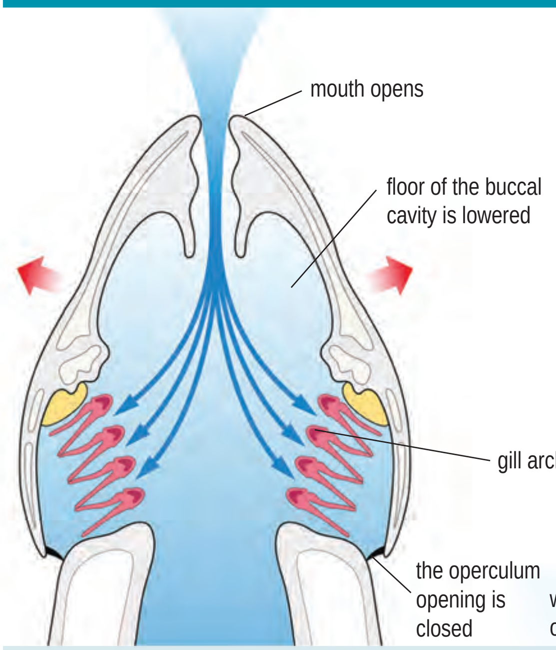
8.2.1



Breathing mechanism of fish

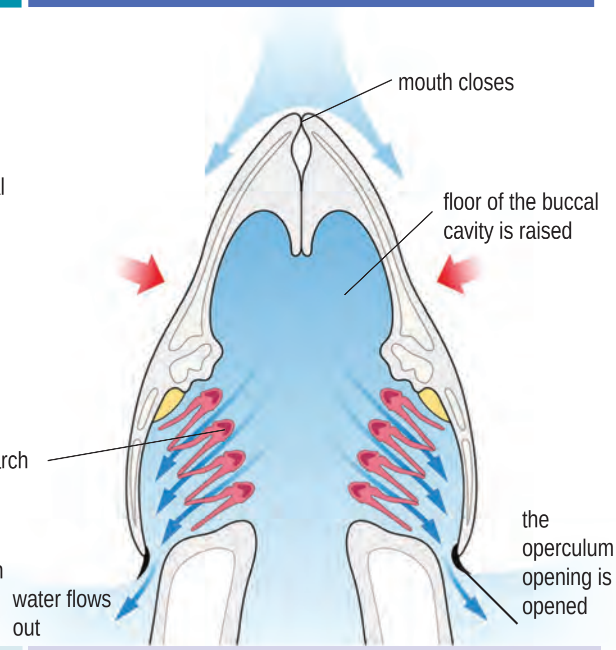
The breathing mechanism of fish is aided by its mouth movement and operculum. Ventilation takes place when the fish swims by opening and closing its operculum. This pushes water into the mouth and subsequently through the gills. The ventilation increases the flow of water in the respiratory surface.

INHALATION



- When the mouth opens, the floor of the buccal cavity is lowered.
- At the same time, the opercular cavity is enlarged and the operculum opening is closed.
- This reduces the pressure in the buccal cavity.
- Water from the outside which contains dissolved oxygen enters the mouth.

EXHALATION



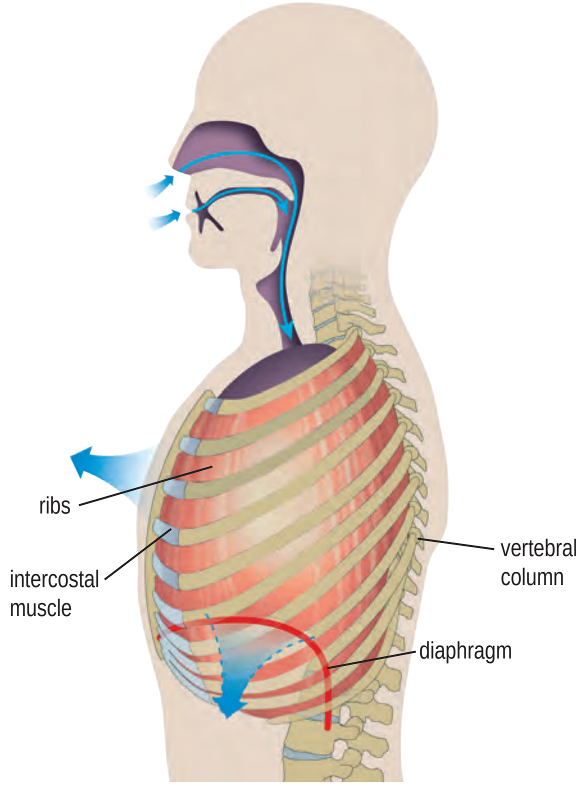
- When the mouth is closed, the floor of the buccal cavity is raised.
- Water enters through the gill lamella and gaseous exchange between blood and water occurs through diffusion.
- At the same time, the operculum muscle relaxes and the opercular cavity becomes smaller.
- The volume of the buccal cavity is reduced and the pressure in the buccal cavity becomes higher than the pressure outside.
- The high pressure causes water to flow through the operculum opening.

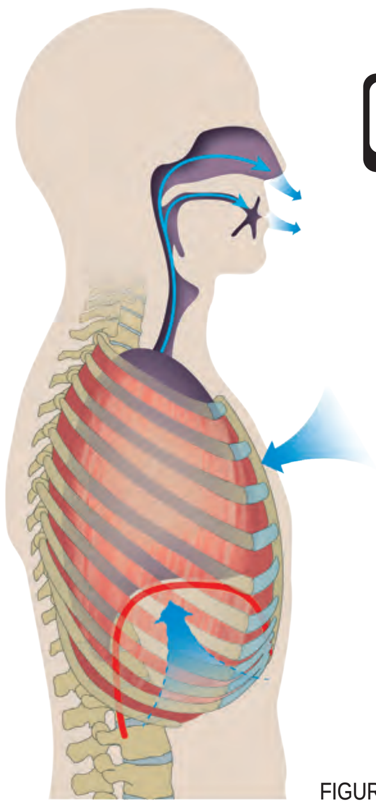
Breathing mechanism of humans

The inhalation and exhalation mechanisms of humans are shown in Figure 8.5.

INHALATION

1. The external intercostal muscles contract while the internal intercostal muscles relax.
2. This action causes the ribcage to move upwards and outwards.
3. At the same time, the diaphragm muscles contract and the diaphragm moves downwards to become flat and horizontal.
4. Both mechanisms cause the volume of the thorax cavity to increase and the pressure of the thorax cavity decreases.
5. The higher atmospheric pressure from outside forces air into the lungs.





AR

EXHALATION

1. The external intercostal muscles relax while the internal intercostal muscles contract.
2. This action causes the ribcage to move downwards and inwards.
3. At the same time, the diaphragm muscles relax and the diaphragm curves upwards to form a dome.
4. Both movements cause the volume of the thoracic cavity to reduce and the pressure of the thorax cavity to increase.
5. Air is pushed out of the lungs.

FIGURE 8.5 The inhalation and exhalation mechanisms of humans

Compare and contrast breathing mechanisms in humans and animals

What are the similarities and the differences between breathing mechanisms in humans and animals? Table 8.2 explains the comparison between the breathing mechanisms in humans and animals.

TABLE 8.2 Comparison between breathing mechanisms in humans and animals

Similarities

- Humans and animals have special muscular structures to expand and contract the respiratory cavity.
- The breathing mechanism involves changes in the volume and pressure in the respiratory cavity.

Differences between breathing mechanisms of insects, fish, frogs and humans

Characteristics	Insects	Fish	Frogs	Humans
Respiratory aperture	Spiracle	Mouth and operculum	Nostrils	Nostrils
Structure that helps breathing	Thorax, abdomen	Operculum and muscular floor of buccal cavity	Muscular buccopharyngeal wall	Diaphragm, ribcage and intercostal muscles
Breathing mechanism	Assisted by the contraction and relaxation of abdominal muscles	Assisted by movements of the floor of the buccal cavity and operculum	Assisted by the rapid movement of the buccopharyngeal cavity floor and elasticity of the lungs	Assisted by the contraction and relaxation of the intercostal muscles and the diaphragm muscles as well as the movement of the rib cage upward and outward, and downward and inward

Formative Practice 8.2

1 State the function of the spiracle in the breathing mechanism of insects.

2 How do abdominal muscles help insects to breathe?

3 State the two differences between the respiratory mechanisms of fish and humans.

4 Explain the mechanism of inhalation in humans.

Activity Zone

Construct a model to show the actions of diaphragm muscles during breathing in humans.

8.2.1

8.3 Gaseous Exchange in Humans

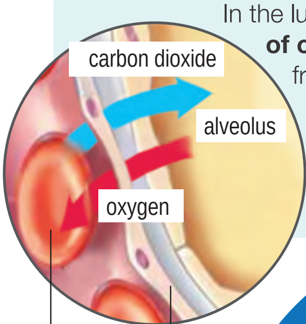
Partial pressure of oxygen and carbon dioxide

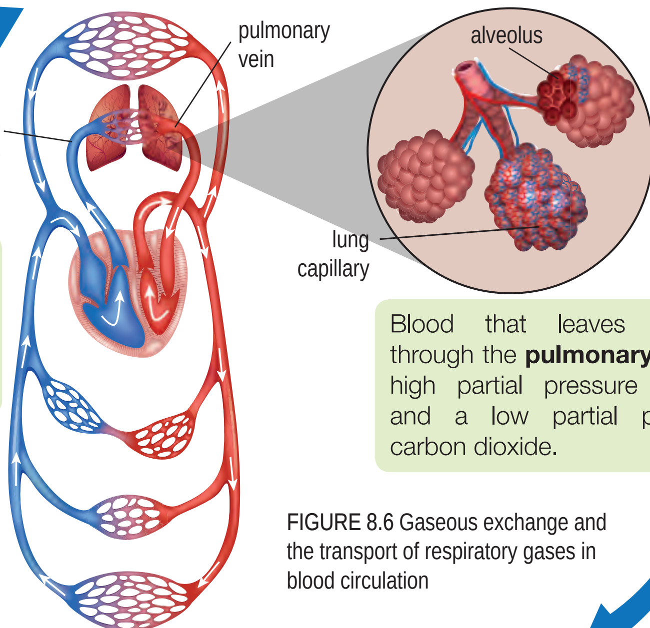
Gas diffusion depends on the partial pressure difference between two areas. The gas diffuses from an area where its partial pressure is higher to an area where its partial pressure is lower, which is down a partial pressure gradient.

Gaseous exchange and the transport of respiratory gases

In the lungs, blood that enters the lung capillaries contains a higher **partial pressure of carbon dioxide** compared to the alveolus. Carbon dioxide diffuses out from the lung capillaries and into the alveolus before it is expelled into the atmosphere through the nose and mouth.

The **partial pressure of oxygen** in the alveolus is higher than the lung capillaries. Oxygen diffuses into the lung capillaries. Oxygen combines with haemoglobin in erythrocytes to form oxyhaemoglobin.





Blood that enters the lungs through the **pulmonary artery** has a low partial pressure of oxygen and a high partial pressure of carbon dioxide.

Blood that leaves the lungs through the **pulmonary vein** has a high partial pressure of oxygen and a low partial pressure of carbon dioxide.

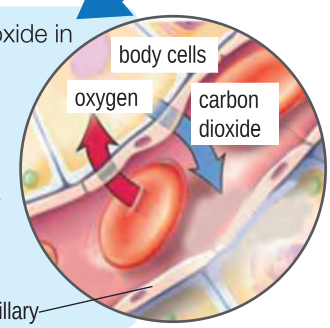
FIGURE 8.6 Gaseous exchange and the transport of respiratory gases in blood circulation

Cellular respiration releases carbon dioxide. The partial pressure of carbon dioxide in cells is higher than tissue capillaries.

Carbon dioxide diffuses out from the body cells into the tissue capillaries and is transported back to the lungs.

When blood reaches the tissue through the tissue capillaries, the partial pressure of oxygen in the blood is higher than that of body cells because cellular respiration uses oxygen.

Oxyhaemoglobin breaks down and oxygen diffuses from the tissue capillaries to the body cells.



Transport of carbon dioxide in the blood circulatory system

Carbon dioxide is transported in three ways:

- 70% is carried in the form of bicarbonate ion (HCO_3^-)
- 23% carbon dioxide combines with haemoglobin to form carbaminohaemoglobin
- 7% is dissolved and carried as carbonic acid (H_2CO_3)

The transport of carbon dioxide from body cells to tissue capillaries

- Carbon dioxide (CO_2) released by the body cells binds with water (H_2O) in the erythrocyte to form carbonic acid (H_2CO_3).
- The carbonic anhydrase enzyme in erythrocyte catalyses this reaction.
- Carbonic acid (H_2CO_3) will break down into bicarbonate ion (HCO_3^-) and hydrogen ion (H^+).
- Then HCO_3^- diffuses into the blood plasma and is carried to the lungs.

The transport of carbon dioxide from lung capillaries to the alveolus

- When the bicarbonate ion in blood plasma reaches the lung capillaries, it diffuses back into the erythrocyte.
- The bicarbonate ion combines again with a hydrogen ion (H^+) to form carbonic acid (H_2CO_3).
- Carbonic acid (H_2CO_3) then breaks down into carbon dioxide and water.
- Carbon dioxide diffuses through the lung capillaries into the alveolus and is expelled during exhalation.

Brainstorm!

Explain why the haemoglobin in foetus has a higher percentage of oxygen saturation compared to haemoglobin in adults.

Biological Lens

Atmospheric pressure at sea level is 760 mm Hg. As the atmosphere consists of 21% oxygen (as per volume), the partial pressure of oxygen is 0.21 x 760 mm Hg or 160 mm Hg. This means that the oxygen pressure in the atmospheric pressure is 160 mm Hg. The partial pressure of carbon dioxide at sea level is 0.23 mm Hg.

Formative Practice 8.3

1. What is the value of the partial pressure of oxygen in the atmospheric pressure?
2. In what form is carbon dioxide transported in human blood circulatory system?
3. Explain how carbon dioxide is transported from the lung capillaries to the alveolus.
4. In what form is oxygen carried to the tissues?

Brainstorm!

Explain why exposure to carbon monoxide for a very short period is more dangerous for an individual as compared to exposure to carbon dioxide.

8.4 Health Issues Related to the Human Respiratory System

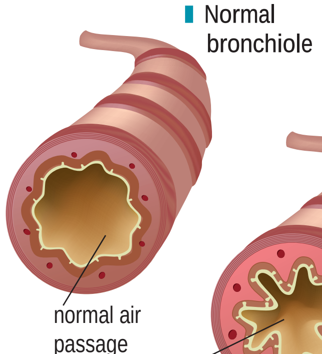
Activity Zone

Discuss the causal factors and methods of treatment for asthma, chronic bronchitis and emphysema.

Chronic Obstructive Pulmonary Disease **(COPD)** comprises **asthma, chronic bronchitis** and **emphysema**. In **emphysema**, the alveolus loses its elasticity and increases in size. The alveolus wall is damaged, the total surface area of alveolus decreases and the gaseous exchange becomes less efficient.

In **chronic bronchitis**, the bronchiole becomes inflamed, swollen and blocked. This reduces the flow of air and causes difficulties in breathing. A large amount of mucus formed will cause continuous coughing. Damaged cilium causes difficulty in expelling mucus.

For an asthmatic patient, the bronchiole walls become swollen and thick. The opening of the bronchiole tube becomes smaller and the air passage becomes narrower. This condition leads to difficulties in breathing and causes breathlessness. Figure 8.7 shows the lungs of a COPD patient.



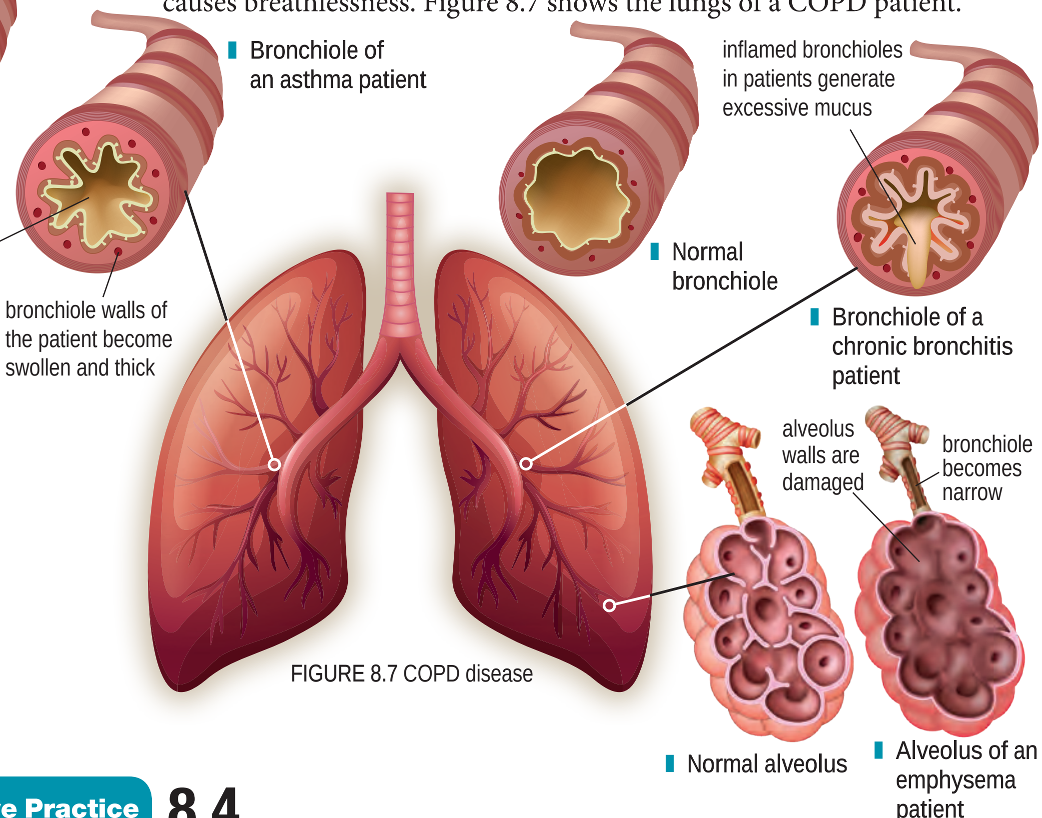


FIGURE 8.7 COPD disease

Formative Practice 8.4

1. What are the effects of chronic bronchitis on the bronchiole?
2. Explain the condition of bronchiole walls in asthmatic patients.
3. How does the usage of an inhaler help an asthmatic patient to breathe?
4. Explain why the gaseous exchange becomes less efficient for an emphysema patient.

Summary

RESPIRATORY SYSTEMS IN HUMANS AND ANIMALS

Types of Respiratory System
- Insects: tracheal system and tracheole
- Fish: gill
- Amphibian: lungs and moist skin
- Human: trachea, bronchus and alveolus

Mechanisms of Breathing

Breathing is the process of inhalation and exhalation

Gaseous Exchange in Humans

Subject to the partial pressure of carbon dioxide and oxygen

- Oxygen is transported in the form of oxyhaemoglobin
- Carbon dioxide is transported in the form of bicarbonate ion, carbaminohaemoglobin and carbonic acid

Health Issues Related to the Human Respiratory System

Chronic Obstructive Pulmonary Disease (COPD): asthma, chronic bronchitis and emphysema

Self Reflection

Have you mastered the following important concepts?
- *The respiratory structure in animals and humans*
- *Respiratory structure adaptations and its function in the exchange of gases*
- *Respiratory structure of humans and animals*
- *Breathing mechanisms in humans and animals*
- *Gaseous exchange between lungs and blood and between blood and tissues*
- *Gaseous exchange from lungs to tissues and from tissues to lungs*
- *Health issues related to human respiration*

Summative Practice 8

1 Explain why a transportation system is not required to transport respiratory gases in insects.

2 Why are the lungs of amphibians not as efficient as human lungs?

3 The diaphragm of an individual no longer functions normally due to an accident. Explain how this condition affects the breathing mechanism of the individual.

4 How does an increase in heartbeat rate during an emergency, help a person to face the emergency?

5 (a) A hardcore smoker can easily suffer from a prolonged cough. Explain how this condition affects the function of the respiratory system.
(b) Describe another illness that may be easily contracted by a hardcore smoker.
(c) Explain the effects of tar that is present in cigarette smoke on the smoker.

6 One of the effects of emphysema is the loss of elasticity in the alveolus. Explain the effect of this on gaseous exchange.

7 (a) Name structures P and Q that help humans and fish, respectively in gaseous exchange.

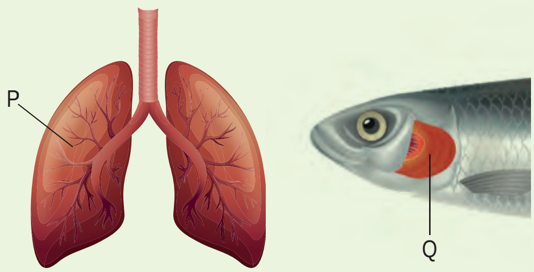


FIGURE 1

(b) Explain the breathing mechanism of fish.
(C) Describe two similarities of structure P and Q that has been adapted to help P and Q function effectively.
(d) Give two reasons why the rate of oxygen supply to human cells is faster than the rate of oxygen supply to fish cells if both are of the same size.

Essay Questions

8 The human respiratory systems of humans and grasshoppers have different adaptations to maximise the rate of gaseous exchange. State the similarities and differences between the human respiratory system and the grasshopper breathing system.

9 (a) Explain how air is inhaled into the lungs.
(b) Explain how a carbon dioxide molecule is carried from the body cell to the alveolus to be expelled.

Enrichment

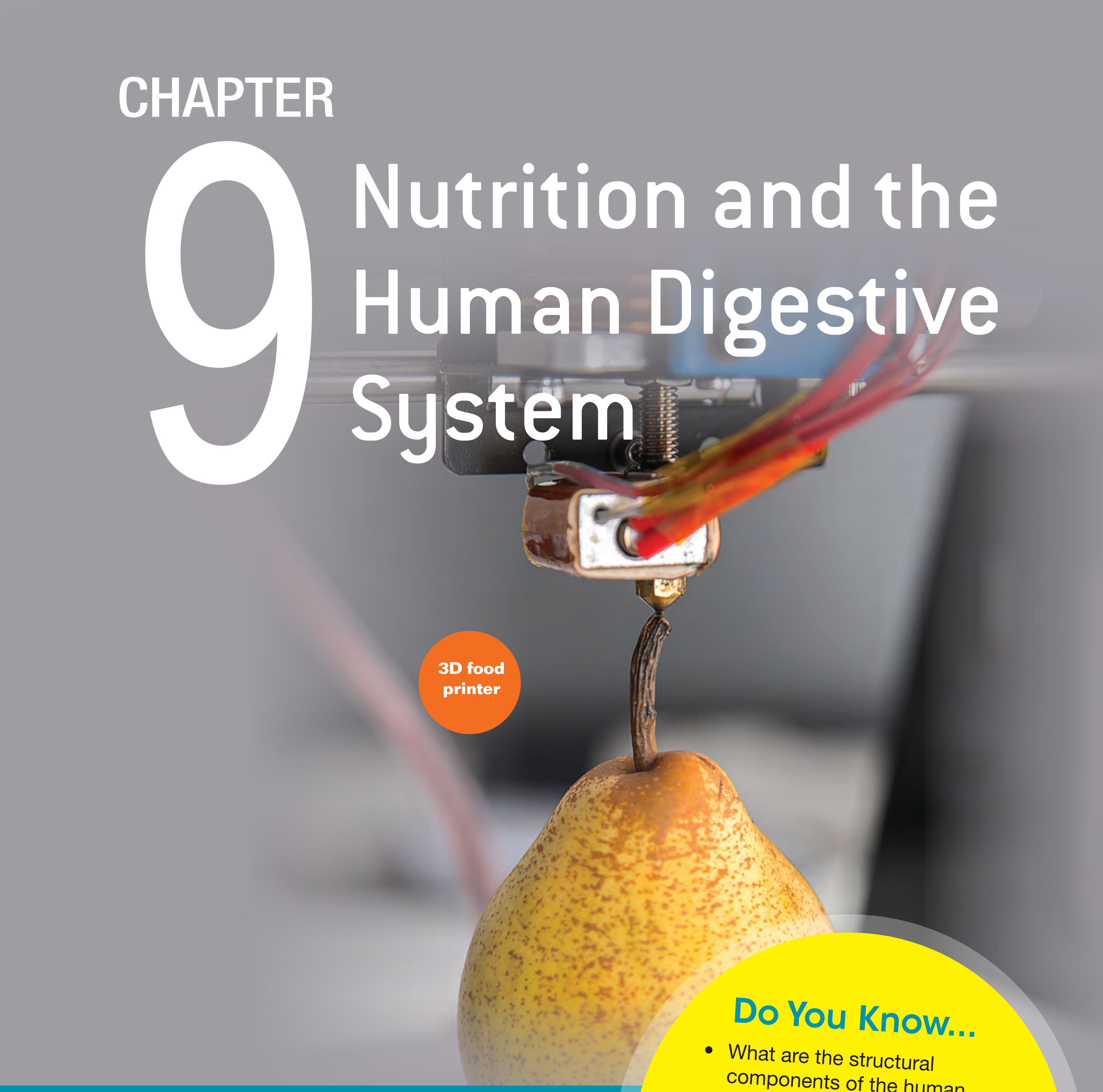
10 Air pollution makes breathing difficult in animals and humans. If you are a scientist, which animal will you choose as an indicator of pollution level in a particular area? Explain the justification of your choice.

11 All mammals breathe through the lungs, as with mammals that live in the sea such as whales. How does the whale breathe in water?

Complete answers are available by scanning the QR code provided

CHAPTER

9 Nutrition and the Human Digestive System



Do You Know...

- What are the structural components of the human digestive system?
- How is food digested and absorbed?
- How does food assimilation occur?
- How does defaecation occur?
- What is a balanced diet?

Can food be designed to meet the nutritional needs of humans?

9.1 Digestive System

9.1.1 Identify structures of the human digestive system.

9.2 Digestion

9.2.1 Describe the types of digestion:
- physical digestion
- chemical digestion

9.2.2 Analyse the process and products of carbohydrate digestion in the mouth.

9.2.3 Analyse the process and products of protein digestion in the stomach.

9.2.4 Describe digestions of carbohydrates, proteins and lipids in the small intestine.

9.2.5 Conduct experiments to study digestions of starch, proteins and lipids in food samples.

9.3 Absorption

9.3.1 Identify the structure of a villus in the ileum.

9.3.2 Communicate about the adaptations of ileum and villus in the absorption of digested food.

9.4 Assimilation

9.4.1 Describe the roles of the circulatory system in the assimilation of digested food.

9.4.2 Discuss the functions of liver in the assimilation of digested food:
- metabolism of digested food (carbohydrates and proteins)
- storage of nutrients
- detoxification

9.5 Defaecation

9.5.1 Explain the functions of the large intestine:
- absorption of water and vitamins
- formation of faeces

9.6 Balanced Diet

9.6.1 Conduct an experiment to study the energy values in food samples.

9.6.2 Conduct an experiment to determine the contents of vitamin C in fruit or vegetable juices.

9.6.3 Justify the modification of diets for individuals who:
- experience obesity
- experience a specific disease
  - diabetes mellitus
  - cardiovascular
  - cancer

9.7 Health Issues Related to Digestive System and Eating Habits

9.7.1 Predict the effects of modifying digestive organs on human health.

9.7.2 Outline health issues related to defaecation.

9.7.3 Correlate health issues that are related to eating habits.

9.1 Digestive System

Structure of the human digestive system

The human digestive system is made up of a long and muscular **alimentary canal** that starts from the mouth to the anus (Figure 9.1).

The parts of the alimentary canal include the mouth, oesophagus, stomach, small intestine, large intestine and anus. The other organs in the digestive system are liver, gallbladder and pancreas. **Salivary**, **gastric** and **intestinal glands** secrete digestive juices into the alimentary canal.

9.2 Digestion

Types of digestion

Digestion is the process that breaks down large and complex pieces of food into smaller and simple pieces that can be dissolved for easy absorption.

Digestion is made up of two parts, that is, **physical digestion** and **chemical digestion**.

Physical digestion	Chemical digestion
The mechanical breakdown of food to form small particles	The decomposition process of complex molecules into simple molecules
Involves chewing and peristalsis	Involves enzymes reaction

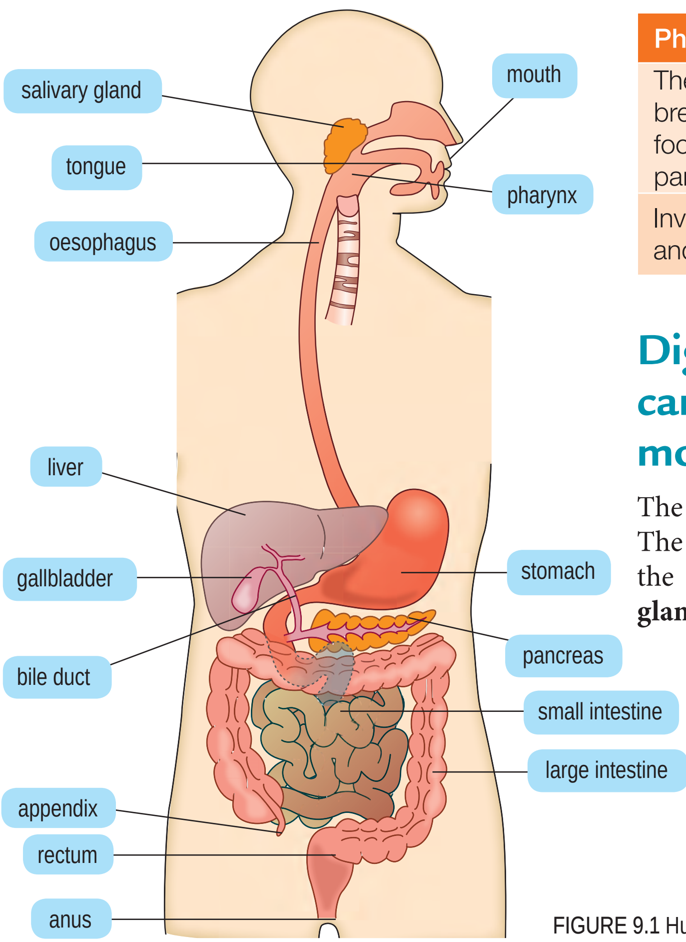


FIGURE 9.1 Human digestive system

Digestion of carbohydrates in the mouth

The digestive process begins in the mouth. The presence of food in the mouth stimulates the secretion of saliva from the **salivary glands**.

AR

9.1.1 9.2.1 9.2.2

- Saliva contains **salivary amylase** that hydrolyses starch to maltose.
- The pH of the saliva ranges between 6.5–7.5, which is suitable for salivary amylase to act at its optimum.

$$\text{Starch + water} \xrightarrow{\text{Salivary amylase}} \text{maltose}$$

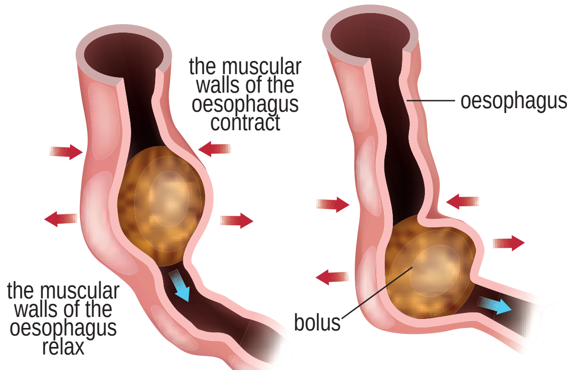


FIGURE 9.2 Peristalsis

Saliva helps food to form bolus and makes it easier to be swallowed. When swallowing, the epiglottis will close the trachea opening to prevent food from entering the trachea. In the oesophagus, the food bolus is moved by peristalsis.

Peristalsis is the rhythmic contraction and relaxation of muscles along the alimentary canal. Peristalsis pushes the bolus through the oesophagus until it enters the stomach (Figure 9.2).

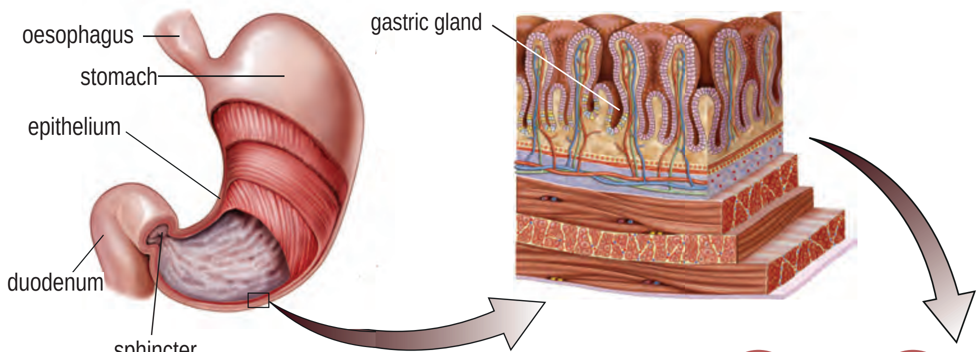
Brainstorm!

Chew slowly a small piece of bread. Observe the taste when you first started chewing and after a few minutes of chewing. Is there any difference in the taste of the bread?

Digestion of protein in the stomach

The surface of the stomach wall is lined with epithelial cells that have undergone adaptations in structure and function to form **gastric glands** (Figure 9.3). These epithelial cells are **chief cells**, **parietal cells** and **mucous cells**.

- Chief cells secrete **pepsinogen**.
- Parietal cells secrete **hydrochloric acid**.
- Mucous cells secrete **mucus**.



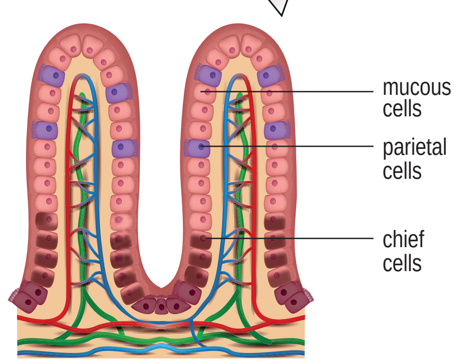


FIGURE 9.3 Structure of stomach and gastric gland tissues

Pepsinogen is an inactive enzyme that is activated by hydrochloric acid to become **pepsin**. Pepsin then hydrolyses proteins into polypeptides.

$$\text{Protein + water} \xrightarrow{\text{pepsin}} \text{polypeptides}$$

9.2.3

The functions of hydrochloric acid are to:

(a) prepare a medium with a suitable pH (pH 1.5–2.0) for pepsin to act
(b) stop the enzymatic action of salivary amylase
(c) kill bacteria in food

The function of mucus is to protect the stomach wall from the reaction of hydrochloric acid and digestive enzymes.

The food in the stomach is mixed with gastric juice made up of hydrochloric acid and pepsin. Food is churned by the peristaltic action of the stomach wall muscles for a few hours. The contents in the stomach finally change to a semifluid called **chyme**. Chyme enters the duodenum slowly when the sphincter muscle relaxes.

Digestions of carbohydrates, proteins and lipids in the small intestine

The small intestine consists of duodenum, jejunum and ileum. Duodenum is the first part of the small intestine which receives chyme from the stomach. Duodenum also receives **bile** produced by the **liver** and **pancreatic juice** secreted by the **pancreas** (Figure 9.4).

PANCREAS

The pancreas secretes **pancreatic amylase**, **trypsin** and **lipase** into the duodenum through the pancreatic duct.

LIVER

- Produces bile
- The gallbladder stores bile.
- The bile flows into the duodenum through the bile duct.
- Functions of bile
  - neutralise the acidic chyme
  - prepare an **alkali condition** (pH 7.6–8.6) for enzyme action in the duodenum
  - emulsify lipids by breaking down lipids into tiny droplets to increase surface area for lipase activity.

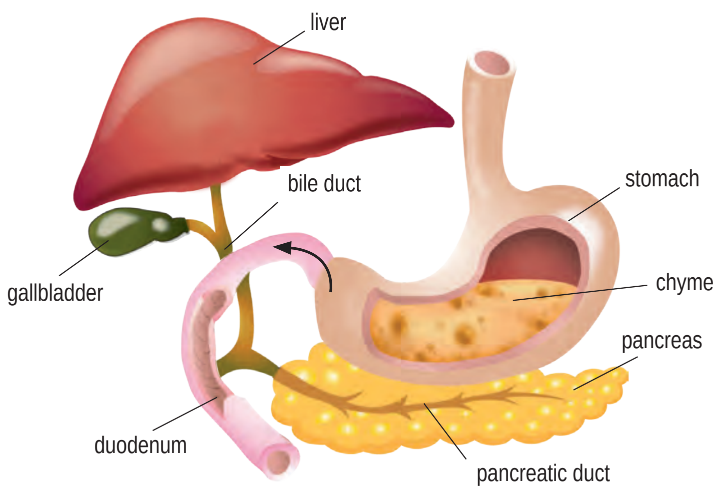


FIGURE 9.4 Components that are involved in digestion that take place in the small intestine

DUODENUM

- Pancreatic amylase hydrolyses starch to maltose
  Starch + water $\xrightarrow{\text{pancreatic amylase}}$ maltose
- Trypsin hydrolyses polypeptides into shorter peptides.
  Polypeptide + water $\xrightarrow{\text{trypsin}}$ peptides
- Lipase hydrolyses lipids into fatty acids and glycerols.
  Lipid + water $\xrightarrow{\text{lipase}}$ fatty acid and glycerol

9.2.4

Glands on the ileum wall secrete mucus and **intestinal juice** that contains **maltase**, **sucrase**, **lactase**, **lipase** and **erepsin**. The alkali medium in the ileum allows enzymes to act at its optimum.

CARBOHYDRATE DIGESTION

- **Maltase** hydrolyses **maltose** into glucose.
  Maltose + water $\xrightarrow{\text{maltase}}$ glucose
- **Sucrase** hydrolyses **sucrose** into glucose and fructose.
  Sucrose + water $\xrightarrow{\text{sucrase}}$ glucose + fructose
- **Lactase** hydrolyses **lactose** into glucose and galactose.
  Lactose + water $\xrightarrow{\text{lactase}}$ glucose + galactose

LIPID DIGESTION

Lipase hydrolyses lipids into **fatty acids** and **glycerols**.

Lipid + water $\xrightarrow{\text{lipase}}$ Fatty acids + glycerol

PROTEIN DIGESTION

Erepsin hydrolyses peptides into **amino acids**.

Peptides + water $\xrightarrow{\text{erepsin}}$ amino acids

ICT 9.1

Video: Processes of digestion, absorption and defaecation (Accessed on 21 August 2019)

Across the fields

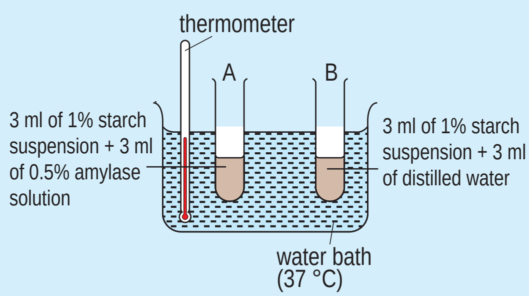
Chemical digestion involves enzyme-catalysed hydrolysis reaction. For example, an enzyme is needed in the decomposition of starch into glucose.

Activity 9.1 Studying the digestion of starch in a food sample

Experiment

Problem statement
What is the effect of amylase on starch?

Hypothesis
Amylase hydrolyses starch to a reducing sugar.



Variables
Manipulated: Presence of amylase
Responding: Presence of reducing sugar
Fixed: Temperature of water bath at 37 °C, concentration of starch suspension and volume of mixture

Materials
0.5% amylase solution, 1% starch suspension, iodine solution, Benedict's solution and distilled water

Apparatus
Tripod stand, Bunsen burner, wire gauze, 500 ml beaker, test tube holder, thermometer, stopwatch, test tube, dropper, glass rod and measuring cylinder

Procedure
1 Label 2 test tubes as A and B.
2 Add 3 ml of 1% starch suspension to each test tube.
3 Fill test tube A with 3 ml of 0.5% amylase solution and test tube B with 3 ml of distilled water.
4 Soak both test tubes in a water bath with a temperature of 37 °C for 10 minutes.
5 After 10 minutes, remove 2 ml of the solution from test tube A and put it into a different test tube. Add 3 drops of Benedict's solution to that test tube and heat the test tube in a boiling water bath for 1 minute. Record the colour of the content.
6 Add 2 drops of iodine solution to the remainder of test tube A. Observe and record the colour of the contents.
7 Repeat steps 5 and 6 for test tube B.

Results

Test tube	Contents	Iodine test	Benedict's test
A	1% starch suspension + 0.5% amylase solution		
B	1% starch suspension + distilled water		

Discussion
1 Explain the reaction that occurs in test tube A.
2 What is the purpose of preparing test tube B?

Conclusion
Is the hypothesis accepted? Suggest a suitable conclusion for this experiment.

Activity 9.2 Studying digestion of protein in a food sample

Experiment

Problem statement
What is the effect of pepsin on protein?

Hypothesis
Pepsin hydrolyses proteins in the albumen suspension into polypeptides.

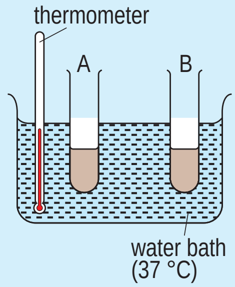
Variables
Manipulated: Presence of pepsin
Responding: Clarity or turbidity of mixture after 20 minutes.
Fixed: Temperature at 37˚C, concentration of pepsin solution and dilute hydrochloric acid

Materials
Albumen suspension (egg white), 1% pepsin solution, distilled water and 0.1 M dilute hydrochloric acid

Apparatus
Test tube, measuring cylinder, 500 ml beaker, water bath at 37 °C, dropper, thermometer and stopwatch.

Procedure

1. Prepare an apparatus set-up as follows.
   Test tube A: 5 ml of albumen suspension + 1 ml of 0.1 M hydrochloric acid + 1 ml 1% pepsin solution
   Test tube B: 5 ml of albumen suspension + 1 ml of 0.1 M hydrochloric acid + 1 ml distilled water



2. Soak all test tubes in a water bath at 37 °C.
3. Observe the condition of mixtures in test tubes A and B at the beginning of the experiment and after 20 minutes.

Results

Test tube	Clarity or turbidity	
	0 minute	20 minute
A		
B		

Discussion

1. Explain the results achieved in test tube A and B.
2. What is the purpose of adding hydrochloric acid into each test tube?

Conclusion

Is the hypothesis accepted? Suggest a suitable conclusion for this experiment.

Activity 9.3 Studying the digestion of lipids in a food sample

Experiment

Problem statement

What is the effect of lipase on lipid?

Hypothesis

Lipase hydrolyses lipids into fatty acids and glycerols.

Variables

Manipulated: Presence of lipase
Responding: Time taken for the phenolphthalein indicator to turn from pink to colourless
Fixed: Temperature at 37°C, volume of cooking oil and combined volume

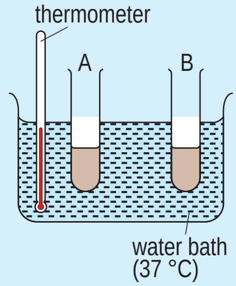
Materials

Cooking oil, 0.2 M sodium carbonate solution, dishwashing liquid, phenolphthalein indicator, distilled water and lipase

Apparatus

Two test tubes, test tube rack, water bath at 37 °C, 5 ml and 1 ml syringes, dropper, stopper and stopwatch

Procedure



1. Prepare two test tubes and label them as A and B.
2. Fill each test tube A and B with the following:
   - 2 ml of cooking oil
   - 1 ml of 0.2 M sodium carbonate solution
   - 1 ml of dishwashing liquid
3. Close both test tubes with stoppers. Shake both test tubes vigorously after adding the dishwashing liquid.
4. Add 3 drops of phenolphthalein indicator to each test tube and shake the test tube.
5. Add 1 ml of lipase into test tube A and 1 ml of distilled water into test tube B.
6. Soak both test tubes in a water bath at 37°C.
7. Record the time taken for the phenolphthalein indicator to turn from pink to colourless.

Results

Test tube	Contents	Time taken for the phenolphthalein indicator to turn from pink to colourless (minute)
A	1 ml of lipase	
B	1 ml of distilled water	

Discussion

1. Why is a phenolphthalein indicator used in this experiment?
2. What is the purpose of adding dishwashing liquid into each test tube?
3. Explain the reaction that happens in test tube A.
4. Explain the results obtained in test tube B.

Conclusion

Is the hypothesis accepted? State the suitable conclusion for this experiment.

Formative Practice 9.1

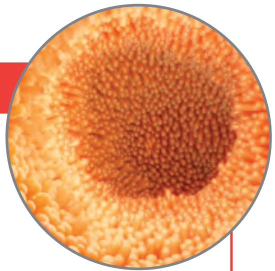
1. Explain the importance of the digestion process for humans.
2. Name the structures in the alimentary canal that are involved in food digestion.
3. Name the main cells in the gastric glands and explain the functions of these cells.
4. The small intestine secretes a few types of enzymes to complete the digestion process. Explain how these enzymes complete the digestion process.

9.3 Absorption

The adaptations of ileum and villus in the absorption of digested food

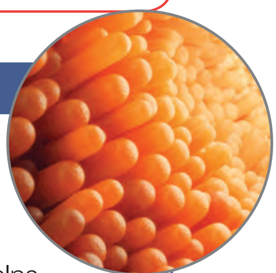
Simple molecules produced from the digested food are absorbed in the **ileum** of the small intestine.

ILEUM



The long ileum is adapted to absorb nutrients because its internal layer is folded and covered by tiny projections called **villi** (singular: villus) (Figure 9.5).

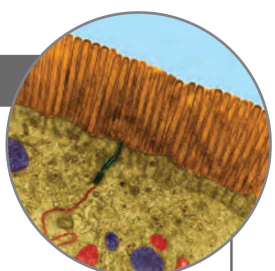
VILLUS (PLURAL: VILLI)



Villus has the following adaptations to absorb nutrients (Figure 9.5):

- The **epithelial layer** of the villus is one cell thick. This helps accelerate nutrient absorption.
- **Goblet cells** secrete mucus to aid digestion.
- The **network of blood capillaries** helps to transport digestive products to the whole body.
- **Lacteal** carries droplets of fatty acids and glycerol.
- The intestinal glands secrete **intestinal juices** that have digestive enzymes.

MICROVILLUS



On the surface of the villus epithelium, there are many tiny projections called **microvillus**. Microvillus provides a **large surface area** to increase the rate of nutrient absorption (Figure 9.5).

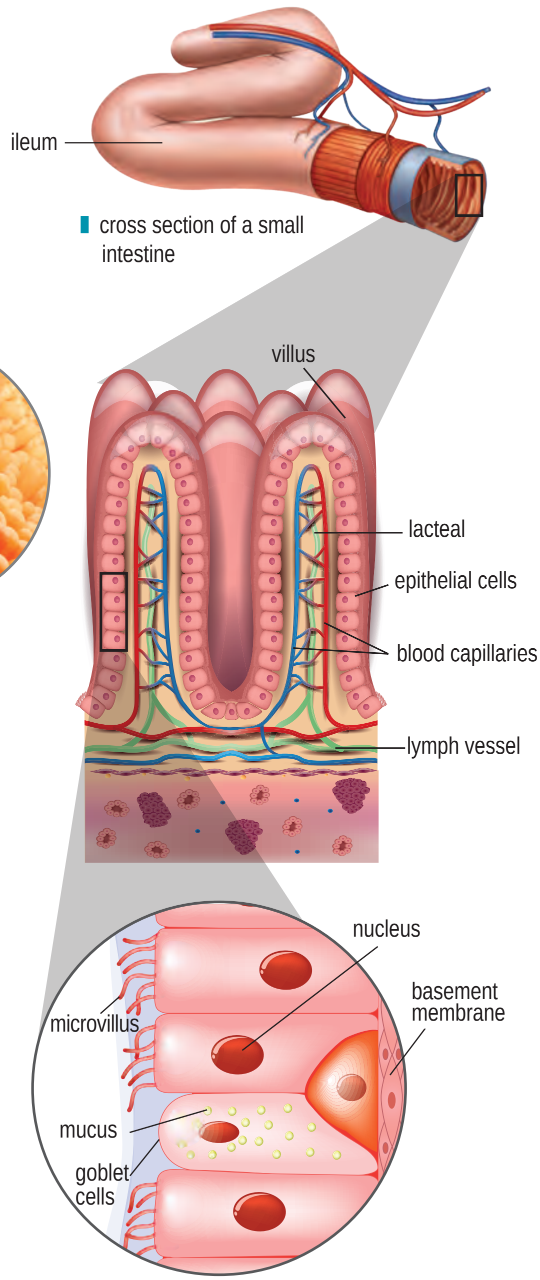


FIGURE 9.5 Adaptations of ileum and villi to absorb digested food.

ICT 9.2

Video: View inside the small intestine (Accessed on 21 August 2019)

Millennial Career

A gastroenterologist is a medical specialist who specialises in the human digestive system.

Activity Zone

Gather information about the absorption of alcohol and drugs.

Absorption of digested food is summarised in Figure 9.6 and Table 9.1.

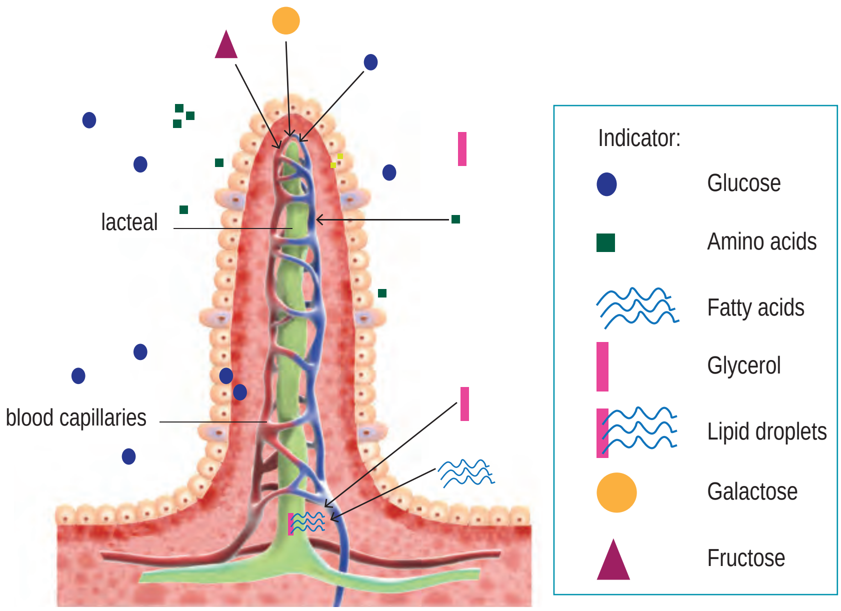


FIGURE 9.6 Absorption of digested food

TABLE 9.1 Method of food absorption in the ileum

Digested food	Absorbed through	Methods of absorption
Fructose	Epithelial cells into blood capillaries	Facilitated diffusion
Glucose and galactose		Active transport
Amino acids		Active transport
Vitamins B and C		Absorbed with water
Water		Osmosis
Fatty acids and glycerols recombine through the condensation process to form tiny droplets of lipids in the epithelial cells	Epithelial cells into lacteal	Simple diffusion
Vitamins A, D, E, K dissolve in the lipid		Simple diffusion

Formative Practice 9.2

1 Name the main structures for the absorption of digested food.

2 Name the structure in the villus involved in the transporting of the following nutrients:

(a) amino acids

(b) vitamins A and E

3 Explain the adaptations of the small intestine to increase the surface area for absorption of nutrients.

4 Explain how the following substances can be transported across the plasma membrane.

(a) Glucose, galactose and amino acids

(b) Fatty acids and glycerol

9.4 Assimilation

The role of the circulatory system

The human circulatory system consists of the blood circulation system and the lymphatic system to help transport nutrients to be assimilated. In the assimilation process that occurs in cells, nutrients are used to form complex compounds or structures of components. The blood capillaries in the small intestine combine to form the **hepatic portal vein** that transports blood to the liver.

Lacteals combine to form bigger lymph vessels in the lymphatic system. Then, the contents of the lymph vessels enter the **thoracic duct** that flows into the left subclavian vein. This lipid is then transported by blood throughout the body.

Biological Lens

Liver cirrhosis is a type of liver disease caused by factors such as alcoholic drinks, toxic substances and hepatitis. Liver cells are replaced by scarred cells that can cause failure in the liver functions. Hepatitis is an inflammation of the liver caused by viral infection, toxic substances or autoimmune reaction (Photograph 9.1).

Functions of liver in the assimilation of digested food

The liver is the regulator that controls the quantity of nutrients that enter the blood circulatory system. The liver carries out the following functions.

METABOLISM OF DIGESTED FOOD

- Glucose is used for cellular respiration. Amino acids are used for synthesising plasma proteins and enzymes.
- Through the deamination process, excess amino acids are turned into urea to be excreted through the urine.

DETOXIFICATION

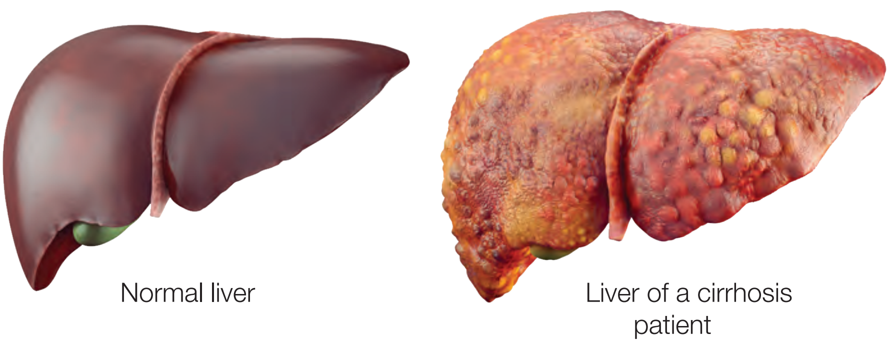
- Liver cells expel toxic substances from the blood.
- Toxic substances are expelled through the urine.

STORAGE OF NUTRIENTS

Excess glucose is converted to glycogen to be stored.

Activity Zone

Conduct a research on the various functions of the liver and produce a scrap book



PHOTOGRAPH 9.1 Normal liver and liver of a cirrhosis patient

9.4.1 9.4.2

ASSIMILATION PROCESS IN THE LIVER

AMINO ACIDS

- The liver synthesises **plasma protein** and **enzymes** from amino acids.
- Excess amino acids cannot be stored in the body and are broken down through the **deamination** process to form urea which is then expelled.
- When the glucose supply is insufficient, the liver converts amino acids into glucose.

GLUCOSE

- Glucose in the liver is used for cellular respiration when required by the body and the excess is converted to glycogen and stored in the liver.
- When the glucose level in the blood decreases and the body needs energy, glycogen is converted to glucose.
- When the glycogen supply reaches a maximum level, the excess glucose is converted to fats.

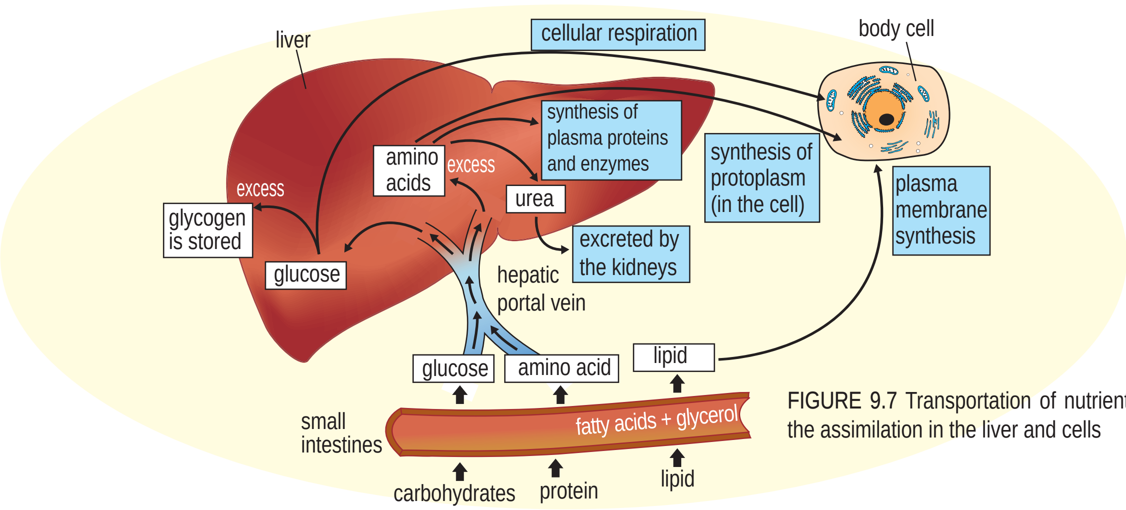


FIGURE 9.7 Transportation of nutrients and the assimilation in the liver and cells

ASSIMILATION PROCESS IN CELLS

AMINO ACIDS

- Amino acids are used to synthesise new **protoplasm** and also **repair damaged tissues**.
- Amino acids are used to synthesise **hormones** and **enzymes**.

GLUCOSE

- Glucose is oxidised through **cellular respiration** to release energy, water and carbon dioxide.
- Excess glucose is kept as **glycogen** in muscles.
- Energy is used for cell processes such as protein synthesis.

LIPIDS

- Lipids such as **phospholipid** and **cholesterol** are the primary components that build the plasma membrane.
- Excess fats are kept in adipose tissues found underneath the skin as stored energy.
- Fat is oxidised to release energy when there is insufficient glucose.

Formative Practice 9.3

1. State the meaning of assimilation.
2. Explain the functions of the liver in the assimilation of digested food.

9.4.2

9.5 Defaecation

Functions of the large intestine

Biological Lens

The large intestine has a huge population of bacteria. There are more than 1000 different species of bacteria in the large intestine and a healthy balance between beneficial and less beneficial bacteria is very important for health and a stable environment in the alimentary canal.

After the absorption of nutrients is completed in the ileum, undigested food, dead cells, epithelial cells, fibre and water enter the large intestine and move slowly through peristaltic action. Fibre consists of cellulose walls of plant cells. The large intestine carries out two main functions:

- absorption of water and vitamins
- formation of faeces

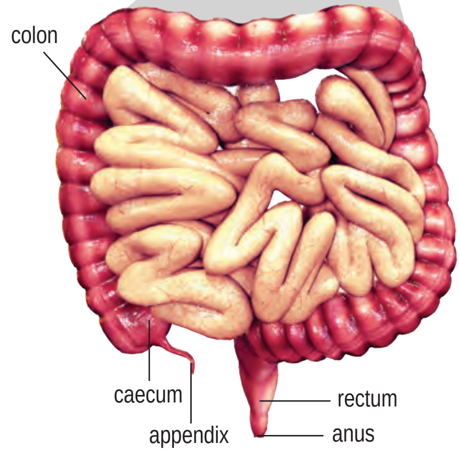


FIGURE 9.8 Large intestines

ABSORPTION OF WATER AND VITAMINS

Substances absorbed are

- water and mineral salts
- metabolic byproducts of some bacteria such as vitamin B, vitamin K and folic acid.

FORMATION OF FAECES

- After the water is absorbed, the remaining waste is a semisolid called **faeces**. Faeces contains dead cells from the inner layer of the intestine, waste products such as bile pigments, bacteria and toxic substances.
- The walls of the large intestine secrete mucus to smoothen the movement of faeces until the anus. The movement of faeces takes about 12 to 24 hours before entering the rectum.
- The faeces will accumulate in the rectum until the pressure in the rectum increases and triggers the need to expel faeces from the body.
- The rectum muscles will contract to expel faeces from the anus. This process is called **defaecation**.

Brainstorm!

What is the effect of antibiotics on the large intestine's bacterial population?

Formative Practice 9.4

1 State the main function of the large intestine.

2 What are the substances absorbed in the large intestine?

3 Explain the importance of water absorption and vitamins in the large intestine.

4 Explain the formation process of faeces.

9.5.1

9.6 Balanced Diet

Energy value in a food sample

A balanced diet refers to a diet that consists of all seven food classes (carbohydrates, lipids, proteins, vitamins, mineral salts, fibre and water) in the correct proportion and balanced quantity according to individual needs so that optimal health can be maintained.

Biological Lens

1 calorie (cal) = 4.2 joule (J)

1 kilojoule = 1000 joule

Across the fields

4.2 J g^{-1} °C^{-1} refers to the specific heat capacity of water, that is, the energy required to increase the temperature of 1 g of water by 1 °C.

ENERGY VALUE

- **Energy value** is the total amount of energy released when one gram of food is oxidised completely.
- The energy value in food is measured in the form of heat energy, that is, in **kilojoule per gram (kJ g^{-1})**.
- Another unit of heat energy is **calorie**.
- 1 calorie or 4.2 joule is defined as the quantity of heat energy needed to raise the temperature of 1 gram water by 1 degree Celsius (°C) at a pressure of 1 standard atmosphere.
- Energy value of food (kJ g^{-1})

$$= \frac{\text{Water mass (g)} \times 4.2\ \text{J g}^{-1}\ {}^{\circ}\text{C}^{-1} \times \text{Increase in water temperature (°C)}}{\text{Mass of food sample (g)} \times 1000}$$

Activity 9.4 Studying the energy value of food samples — Experiment

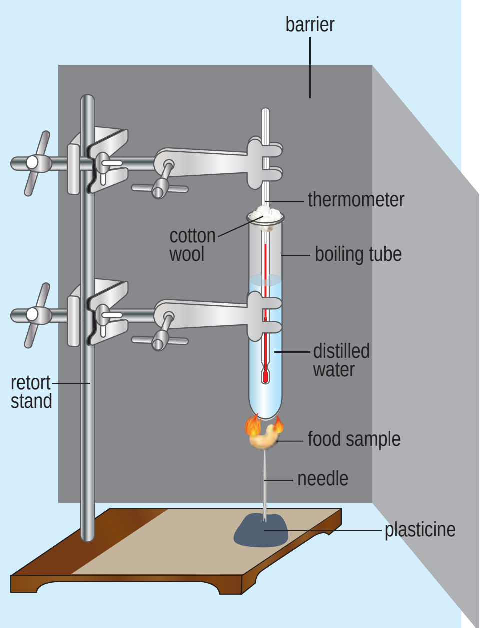
Problem statement
Which food sample has the highest energy value?

Hypothesis
Groundnuts have a higher energy value compared to cashew nuts.

Variables
Manipulated: Types of food samples
Responding: Energy value of food sample
Fixed: Water mass

Materials
Distilled water, food samples (cashew nuts and groundnuts), cotton wool and plasticine

Apparatus
Retort stand with a clamp, thermometer, boiling tube, long needle, electronic weighing scale, barrier, measuring cylinder and Bunsen burner



Procedure

1 Weigh a cashew nut using an electronic weighing scale and record its mass.
2 Measure 20 ml of distilled water using a measuring cylinder and pour it into a boiling tube.
3 Clamp the boiling tube to the retort stand and put in the thermometer.
4 Fix the position of the thermometer using cotton wool.
5 Record the initial temperature of the distilled water.
6 Stick the cashew nut on the needle and hold the needle upright using plasticine.
7 Place the barrier around the apparatus set-up.
8 Light the cashew nut using a Bunsen burner and place it below the boiling tube.
9 Stir the water in the boiling tube slowly and record its highest temperature after the cashew nut has completely burned.
10 Replace the water in the boiling tube.
11 Repeat steps 1 to 9 using groundnuts.
12 Calculate the energy value for each food sample using the following formula:

$$\text{Energy value of food (kJ g}^{-1}\text{)} = \frac{\text{Water mass (g)} \times 4.2\ \text{J g}^{-1}\ {}^{\circ}\text{C}^{-1} \times \text{Increase in water temperature (}^{\circ}\text{C)}}{\text{Food sample mass (g)} \times 1000}$$

13 Record your results in the table below.

Results

Food sample	Food sample mass (g)	Initial temperature of water (°C)	Final temperature of water (°C)	Increase of Temperature (°C)	Energy value of food (kJ g^{-1})
Cashew nuts					
Groundnuts					

Discussion

1 Which food sample shows the highest energy value?
2 State two precautionary steps for this experiment.
3 Compare the energy value of food samples obtained from this experiment with their theoretical energy values. Are there any differences? If yes, explain why.

Conclusion

Is the hypothesis accepted? Suggest a suitable conclusion for this experiment.

The contents of vitamin C in fruit or vegetables juices

The nutrient content in various types of food is different. For example, the vitamin C content in fruits and vegetables are different.

Activity 9.5 Determining the contents of vitamin C in fruit juice and vegetable juice.

Experiment

Problem statement
Which fruit juice or vegetable juice has the highest content of vitamin C?

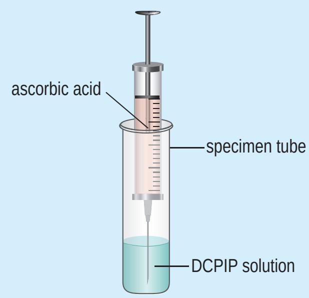
Hypothesis
Orange juice has the highest content of vitamin C compared to lime juice and carrot juice.

Variables
Manipulated: Types of fruit and vegetable juices
Response: Volume of fruit juice or vegetable juice needed to decolourise DCPIP solution
Fixed: Concentration of DCPIP solution and concentration of an ascorbic acid solution

Materials
Orange juice, lime juice and fresh carrot juice, 0.1% ascorbic acid solution, 1% DCPIP solution and distilled water

Apparatus
Syringe needles (1 ml and 5 ml), knife, 50 ml beaker, specimen tube, juicer and sieve

Procedure
1. Put 1 ml of 1% DCPIP solution in a specimen tube.
2. Fill the 5 ml syringe needle with a 0.1% ascorbic acid solution. Ensure that there are no air bubbles trapped in it.
3. Insert the tip of the syringe needle into the specimen tube and drip ascorbic acid drop by drop into the DCPIP solution while stirring slowly until the blue colour of the DCPIP solution is decolourised.
4. Record the volume of the 0.1% ascorbic acid solution needed to decolourise the blue colour of the DCPIP solution.
5. Repeat steps 1 to 4 twice to get the average volume for each different juice.
6. Record the volume of each juice in the table below.
7. Calculate the concentration of vitamin C of each juice using the following formula.



$$\text{Percentage of vitamin C} = \frac{\text{volume of ascorbic acid solution}}{\text{volume of juice used}} \times 0.1\%$$

$$\text{Vitamin C concentration (mg ml}^{-1}\text{)} = \frac{\text{volume of ascorbic acid solution}}{\text{volume of juice used}} \times 1.0\%$$

Results

Solution / Juice	Volume of solution/juice required to decolourise DCPIP solution (ml)				Vitamin C concentration (%)	Vitamin C concentration (mg ml^{-1})
	1	2	3	Average		
0.1% ascorbic acid solution						0.1
Orange juice						
Lime juice						
Carrot juice						

9.6.2

Discussion

1 Which juice has the highest content of vitamin C?
2 Why is a 0.1% ascorbic acid solution used as the standard?

Conclusion

Is the hypothesis accepted? Suggest a suitable conclusion for this experiment.

One of the factors that affect the loss of vitamin C content is temperature. Therefore, fruit or vegetables must be kept at a suitable temperature range to preserve vitamin C.

Activity 9.6 Studying the effect of temperature on vitamin C in orange juice

Experiment

Problem statement

What is the most suitable ambient temperature to keep orange juice?

Hypothesis

Orange juice stored at a low ambient temperature has the highest content of vitamin C.

Variables

Manipulated: Ambient temperature
Responding: Volume of orange juice required to decolourise DCPIP solution
Fixed: Volume of DCPIP solution

Take Note!
Ensure that the juice is not exposed too long to avoid oxidation.

Materials

Oranges, 1% DCPIP solution and ice

Apparatus

Specimen tube, knife, syringe needles (1 ml and 5 ml), beakers (50 ml and 100 ml), Bunsen burner, tripod stand, sieve and wire gauze

Procedure

1 Prepare 60 ml of orange juice.
2 Label the beakers A, B and C. Pour 20 ml of orange juice into each beaker.
3 Soak beaker A in ice, leave beaker B at room temperature and soak beaker C in boiling water for 30 minutes.
4 After 30 minutes, determine the vitamin C content in the orange juice as shown in Activity 9.5.
5 Calculate the concentration of vitamin C in the orange juice at each different temperature.

Results

Record your results in an appropriate table.

9.6.2

Discussion

1. Is there a difference in the vitamin C content for the juice at different temperatures?
2. What is the effect of temperature on vitamin C in the orange juice?
3. Based on the results, suggest the best way to ensure that you get a high content of vitamin C from fruit juice or vegetable juice.

Conclusion

Is the hypothesis accepted? Suggest a suitable conclusion for this experiment.

PHOTOGRAPH 9.2
A sample serving based on *Pinggan Sihat Malaysia*

Diet modifications for specific individuals

A balanced diet for each individual will vary according to lifestyle, health conditions and specific nutritional requirements. Each individual must make wise choices based on a nutrition guide. For example, suggestions for nutritional needs can be made based on ***Pinggan Sihat Malaysia.*** *Pinggan Sihat Malaysia* illustrates the relative quantity of various food classes in a balanced diet (Photograph 9.2).

Excessive food intake that is rich in saturated fats can cause health problems such as obesity and cardiovascular diseases.

Millennial Career

Nutritionists are specialists in the field of nutrition who advise specific individuals on suitable diets.

The cause of obesity

Obesity is caused by the storage of excess fats as a result of imbalanced food intake and use of energy.

Effects of obesity

Individuals who are obese need to reduce the intake of carbohydrates and fats as well as increase the intake of vegetables and fruits. Otherwise, a diet with excessive saturated fats and high cholesterol may cause diabetes mellitus and various cardiovascular diseases such as atherosclerosis and hypertension which may result in heart attacks (myocardial infarction) or stroke if not treated.

Activity Zone

Plan meals based on *Pinggan Sihat Malaysia* for different individuals such as obese individuals, cancer patients and heart patients.

Cancer patients who are undergoing cancer treatment, need to modify their diet to ensure they receive sufficient energy, reduce the risk of infections and enable quick recovery.

9.7 Health Issues Related to the Digestive System and Eating Habits

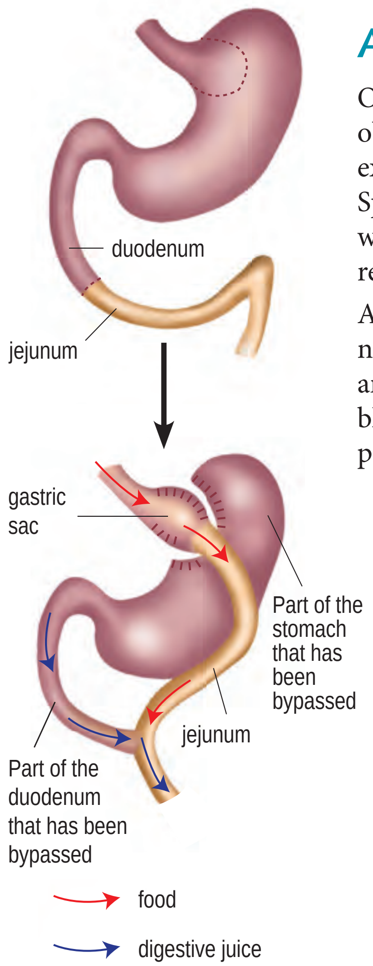


FIGURE 9.9 Gastric bypass

Adaptation of digestive organs

Obesity is a health issue on the rise throughout the world. Although obesity can be controlled through diet management and routine exercise programmes, at times, obesity requires medical treatment. Specialist doctors may suggest surgical procedures to reduce body weight such as **gastric bypass** (Figure 9.9). A gastric bypass involves a reduction of the stomach size using various methods of surgery.

Among the short-term side effects of this surgery are acid reflux, nausea, vomiting, expanded oesophagus, certain food prohibitions and risk of infection. The long-term side effects are dizziness, low blood sugar level, malnutrition, stomach ulcer and defaecation problems.

Health issues related to defaecation

The food class that is most important in the defaecation process is **fibre**. Intake of diet that is high in fibre such as fruits and vegetables can smoothen bowel movements. This can prevent health problems such as constipation, colon cancer, rectum cancer and haemorrhoid.

Some of the functions of fibre are to:

- stimulate peristalsis
- absorb and expel toxic substances
- regulate the absorption of glucose especially for diabetes mellitus patients
- increase the population of beneficial bacteria in the large intestine

Besides, the intake of a large amount of water can ensure that the faeces stay soft and move easily along the large intestine to aid the process of defaecation.

Health issues related to eating habits

Apart from a balanced diet, eating habits also play an important role in fulfilling our energy requirements and maintaining our health. Poor eating habits and an imbalanced diet can cause numerous health problems such as gastritis, muscle dysmorphia, anorexia nervosa and bulimia nervosa.

GASTRITIS

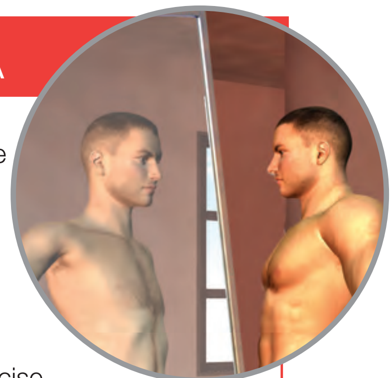
Gastritis refers to the inflammation and corrosion of the stomach epithelial layer by gastric juice when there is no food in the stomach. Untreated gastritis can result in gastric ulcers. The causes of gastritis include eating irregular quantities of food at irregular hours and excessive intake of alcohol or painkillers.

ANOREXIA NERVOSA

Anorexia nervosa is quite common amongst teenage girls who are obsessed with their body weight. Anorexics will avoid food to achieve their ideal body weight. They also suffer from psychological problems and nutrient deficiency because of their normal digestive system is affected.

BULIMIA NERVOSA

For people with **bulimia nervosa** who are also obsessed with controlling their body weight, they will eat a lot and vomit out the food that they have eaten or take laxatives that cause diarrhoea. In the long run, the patient may suffer from dehydration, nutritional problems and eventually cardiovascular disease or kidney failure.



MUSCLE DYSMORPHIA

Some individuals feel that their size is small with not enough growth. So, they subject themselves to extreme weightlifting training and exercise. Sometimes, they consume steroids or muscle building supplements. This health issue is called **muscle dysmorphia**.

Activity Zone

Do a case study about the following health issues related eating habits:
- diabetes type 2
- obesity
- acid reflux
- pica

Formative Practice 9.5

1 In your opinion, why is fibre important in the defaecation process. Explain your answer.

2 Predict the effect of modifying digestive organs such as gastric bypass on human health.

Summary

NUTRITION AND THE HUMAN DIGESTIVE SYSTEM

Digestive System
- Digestion
- Absorption
- Assimilation
- Defaecation

Balanced Diet
- Energy value
- Contents of vitamin C in fruit or vegetables juices
- Diet modifications for specific individuals

Health Issues Related to the Digestive System and Eating Habits
- The effects of modifying digestive organs on human health
- Health issues related to defaecation
- Health issues related to eating habits

Self Reflection

Have you mastered the following important concepts?
- Structure of the human digestive system
- Mechanism of digestion
- Process and products of carbohydrate digestion in the mouth
- Process and products of protein digestion in the stomach
- Digestions of carbohydrates, proteins and lipids in the small intestine
- Adaptations of ileum and villus in the absorption of digested food
- Assimilation of digested food and liver functions
- Defaecation
- Balanced diet and energy value in food samples
- Diet modifications for specific individuals
- Health issues related to the digestive system and eating habits

Summative Practice 9

1 Some people cannot drink milk because it causes diarrhoea and a bloated stomach. Explain why.

2 Amin had some meat dishes for lunch. Explain how the protein is digested in Amin's stomach.

3 An individual has the following eating habits:

Overeating in a short period of time followed by intentional throwing up on purpose after each meal.

Explain how this eating habit can affect the health of this individual.

4 Figure 1 shows the alimentary canal in humans.

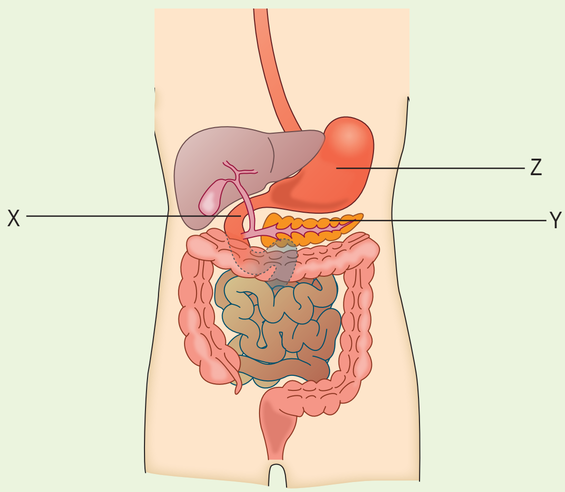


FIGURE 1

(a) Name structures X and Y.

(b) (i) The enzymes in X are only effective in an alkaline environment. Explain how an alkaline environment is maintained in X.

(ii) Explain how Y is involved in the digestion of carbohydrates in X.

(c) Name the enzyme found in Z. Explain how this enzyme functions in the digestion of proteins.

(d) A student enjoys eating a lot of oranges. Explain the effect of eating too many oranges on the digestion of starch in X.

Essay Questions

5 Explain the processes that fat molecules undergo starting from the duodenum until it is finally used by body cells.

6 A teenager had the following for his breakfast.

Buttered bread – 2 pieces	Fresh milk – 1 glass
Hard-boiled eggs – 2	Apple – 1

Explain what happens to the final digested products of his breakfast in his body cells.

7 (a) Explain why a diet rich in fats is not good for health.

(b) Suggest suitable types of food for someone who wants to reduce weight and reduce the risk of contracting cardiovascular disease. Explain your answer.

(c) Explain the processes of starch digestion, absorption and assimilation in the human body.

Enrichment

8 Medicines in the form of capsules are not broken down in the stomach but absorbed easily by the small intestine. When the blood sample of the patient is taken and analysed, it is found that the molecular structure of this medicine is different from its original molecular structure. Explain why.

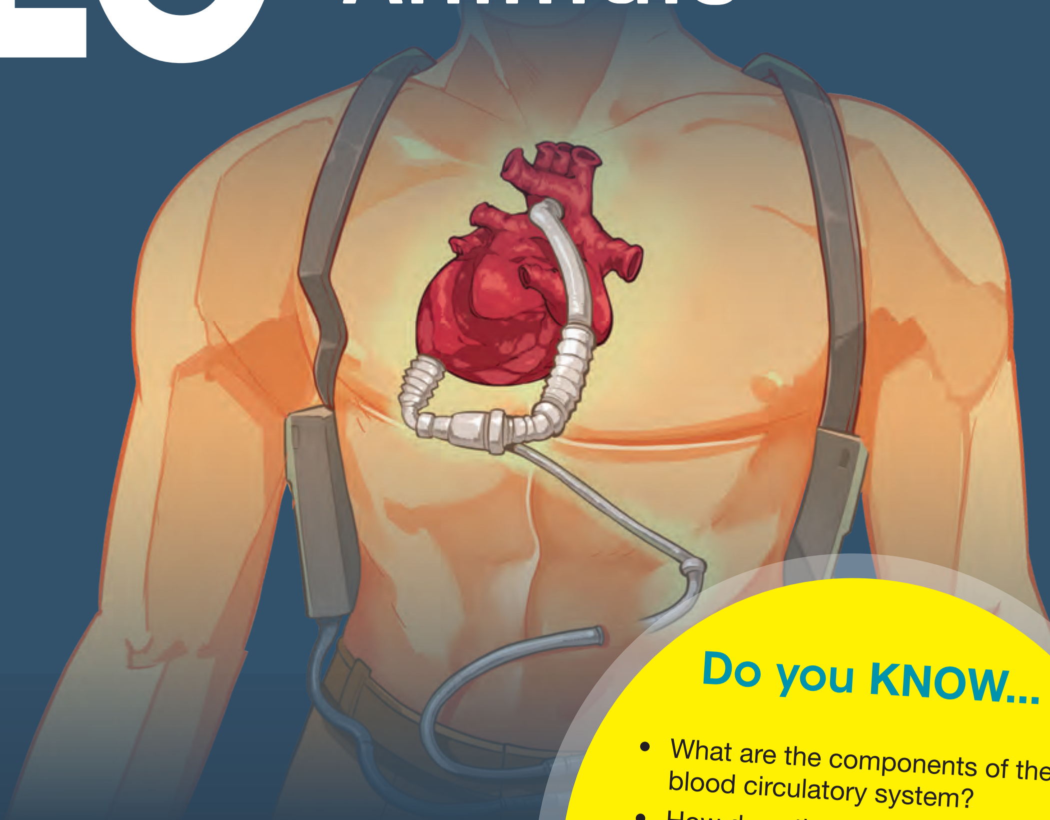
9 How are drinks with added artificial sweeteners produced and marketed?

10 Nowadays, many individuals prefer ready-to-eat or frozen food products due to their busy lifestyles. Predict the health risks that may arise if these foods are taken continuously for a long period of time and in large quantities.

Complete answers are available by scanning the QR code provided

CHAPTER

10 Transport in Humans and Animals



Do you KNOW...

- What are the components of the blood circulatory system?
- How does the heart pump blood?
- How does the lymphatic system return tissue fluids into the blood circulatory system?
- What are the health issues related to the human circulatory and lymphatic systems?

What is a mechanical heart?

10.1 Types of Circulatory System

10.1.1 Justify the necessity of transport systems in complex multicellular organisms.

10.1.2 Identify substances that are transported by the transport system: • substances required by a cell • waste products of a cell

10.1.3 Conceptualise types of circulatory system in complex multicellular organisms.
• open circulatory system
• closed circulatory system

10.1.4 Compare and contrast circulatory systems in complex multicellular organisms: • insects • fish • amphibians • humans

10.2 Circulatory System of Humans

10.2.1 Describe components of the human circulatory system:
• heart • blood vessel • blood

10.2.2 Explain the composition of blood:
• blood plasma • blood cells

10.2.3 Compare and contrast the types of blood vessels:
• artery • vein • capillary

10.2.4 Label the structure of a human heart and associated blood vessels: • aorta • vena cava
• pulmonary artery and pulmonary vein
• coronary artery and coronary vein.
• semilunar valve
• bicuspid valve and tricuspid valve • septum

10.2.5 Describe the functions of parts of the heart.

10.3 Mechanism of Heartbeat

10.3.1 Describe the human heartbeat mechanism:
• sinoatrial node (pacemaker)
• atrioventricular node
• bundle of His • Purkinje fibres

10.3.2 Communicate about forces that cause the blood to circulate in humans: • pumping of the heart
• contraction of skeletal muscles

10.4 Mechanism of Blood Clotting

10.4.1 Justify the necessity for blood clotting mechanism.

10.4.2 Describe blood clotting mechanism.

10.4.3 Describe health issues related to blood clotting: • thrombosis
• embolism • haemophilia

10.5 Blood Groups of Humans

10.5.1 Describe ABO blood group.

10.5.2 Correlate ABO blood group with blood donation.

10.5.3 Describe the Rhesus factor.

10.5.4 Reason out the incompatibility of Rhesus factor in pregnancies.

10.6 Health Issues Related to the Human Circulatory System

10.6.1 Justify the necessity for a healthy circulatory system.

10.6.2 Communicate about cardiovascular diseases.

10.7 Lymphatic System of Humans

10.7.1 Synthesise the process of formation of tissue fluid and lymph.

10.7.2 Compare and contrast the contents of lymph and:
• tissue fluid • blood

10.7.3 Describe components of the lymphatic system: • lymph
• lymphatic capillaries
• lymphatic vessels• lymph nodes
• lymphatic organs

10.7.4 Justify the necessity of the lymphatic system:
• complements the blood circulatory system
• transports lipid-soluble substances
• body defence

10.8 Health Issues Related to the Human Lymphatic System

10.8.1 Describe health issues related to the lymphatic system.

10.1 Types of Circulatory System

The necessity for transport systems in complex multicellular organisms

Each living cell requires **essential substances** such as oxygen and nutrients, and expels **cellular waste products** such as carbon dioxide and nitrogenous wastes.

In Chapter 2, you learned how unicellular organisms such as *Amoeba* sp. get their essentials and expel wastes by diffusion from and to its external surroundings. Unicellular organisms have a small body mass. Therefore, the total surface area to volume ratio (TSA/V) of the organism is large. As such, *Amoeba* sp. does not require a specialised transport system to transport substances in and out of the cell.

What about multicellular organisms? Can multicellular organisms obtain all essential substances and expel wastes by simple diffusion like unicellular organisms?

Large complex multicellular organisms cannot obtain essential substances and expel wastes by diffusion because their TSA/V is small. The distance between the external environment and the cell is too far for direct substance exchange. So, how do complex multicellular organisms get essential substances for their cells?

Substance exchange can occur by diffusion because the cells are in the environment.

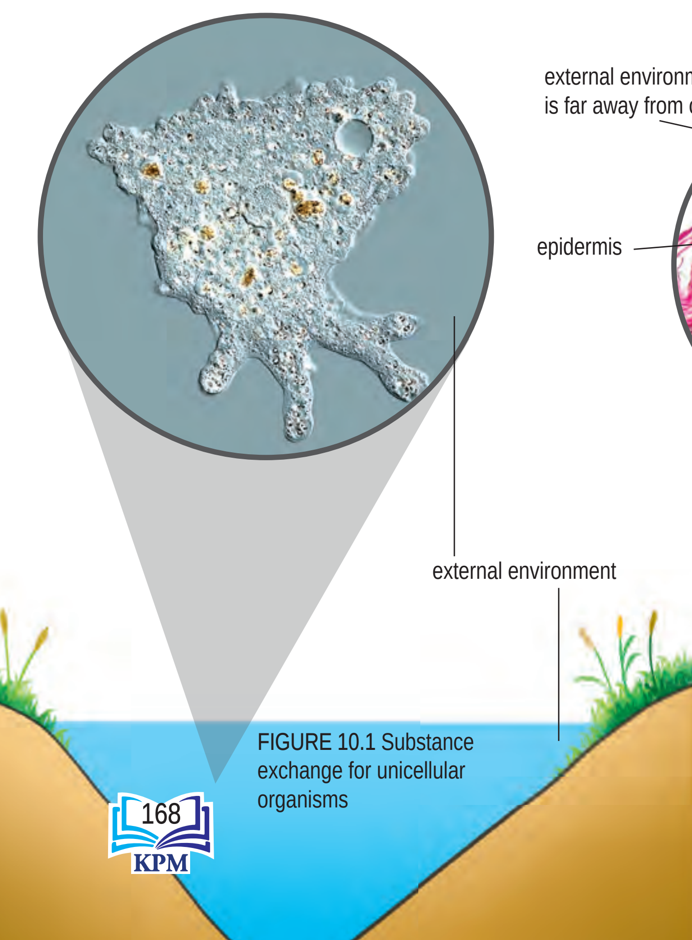
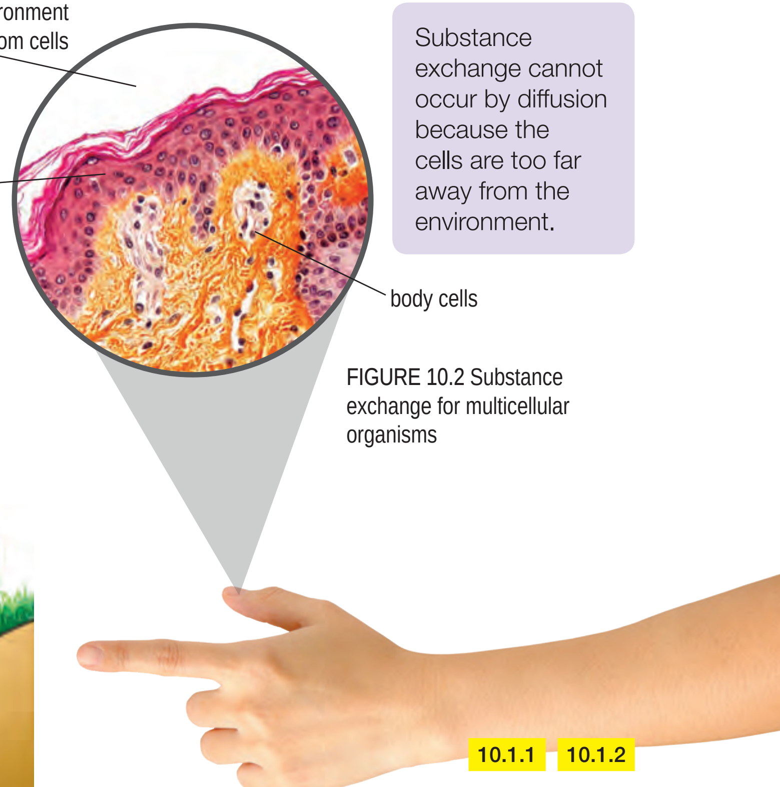


FIGURE 10.1 Substance exchange for unicellular organisms



Substance exchange cannot occur by diffusion because the cells are too far away from the environment.

FIGURE 10.2 Substance exchange for multicellular organisms

To address this problem, multicellular organisms have an internal **transportation system**. In vertebrates, the transportation system is called the **blood circulatory system**.

Before studying further the blood circulatory system, conduct an experiment to study the effects of changes in TSA/V on the diffusion rate.

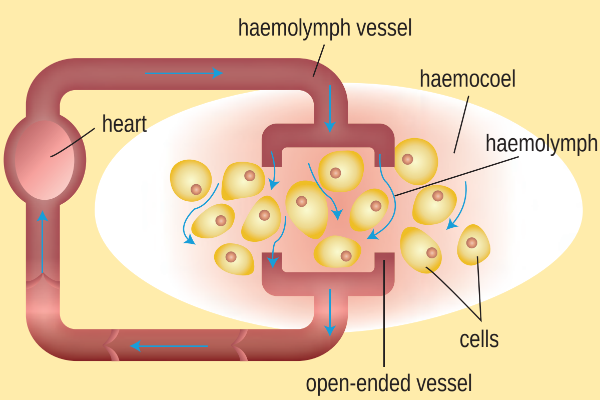
ICT 10.1

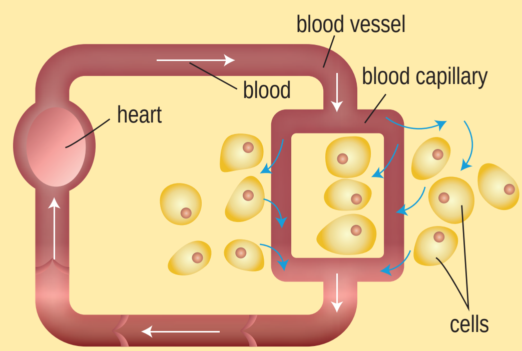
Activity: Studying the effects of changes in total surface area to volume ratio (TSA/V) on the diffusion rate.

Types of circulatory systems in multicellular organisms

The circulatory system in multicellular organisms is divided into two types: **open circulatory system** and **closed circulatory system**.

OPEN CIRCULATORY SYSTEM	CLOSED CIRCULATORY SYSTEM
• In an open circulatory system, haemolymph flows directly into the body cavity (**haemocoel**) and bathes the cells. • **Haemolymph** is a blood-like nutritious liquid found in most invertebrates such as insects and molluscs.	• In a closed circulatory system, blood is always contained in a continuous closed blood vessel and is distributed to the whole body. • The exchange of substances that are essential to cells such as oxygen and nutrients occurs across the walls of blood capillaries.





CIRCULATORY SYSTEM

OPEN CIRCULATORY SYSTEM

Circulatory System of Insects

- The circulatory system of insects is an **open circulatory system**. This means that one or more hearts pump haemolymph through the blood vessels into the haemocoel.
- Haemolymph flows out from the heart into the haemocoel when the heart contracts.
- In the haemocoel, substance exchange between haemolymph and body cells occurs through diffusion.
- When the heart relaxes, haemolymph flows back into the heart through tiny openings called **ostium**.

Circulatory System of Fish

- The heart of the fish has two chambers, that is, an atrium (plural: atria) and a ventricle.
- Blood that leaves the ventricle is pumped to the gill capillaries to enable gaseous exchange.
- The gill capillaries carry blood to the blood vessels that transport oxygenated blood to **systemic capillaries**.
- In the systemic capillaries, oxygen diffuses into the tissues while carbon dioxide diffuses from the tissue into the capillaries.
- The deoxygenated blood is then returned to the heart atrium through the veins.
- As the blood flows in one direction, the fish circulatory system is known as a **single circulatory system.**

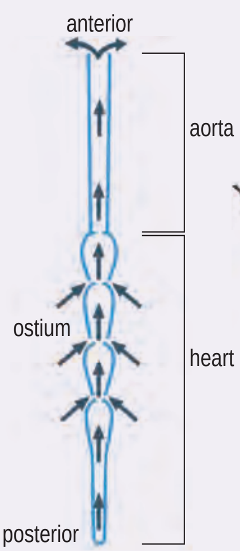


FIGURE 10.3 Dorsal view of insect heart

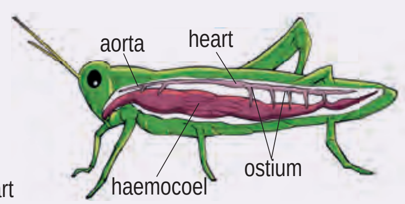
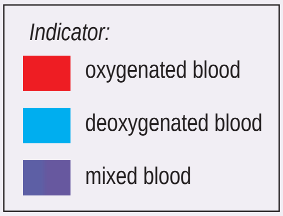


FIGURE 10.4 The open circulatory system in insects



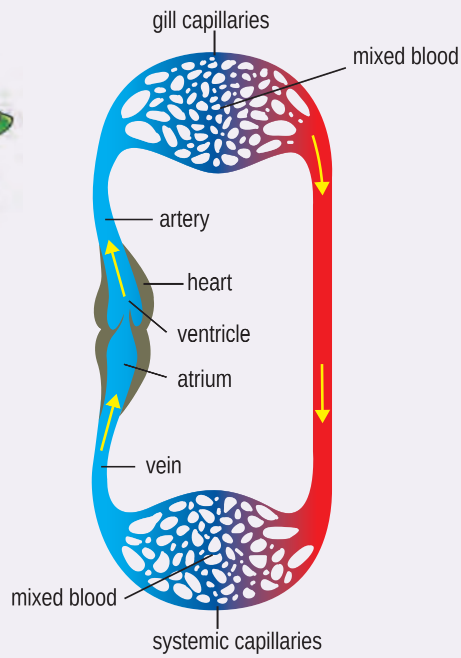


FIGURE 10.5 The blood circulatory system of fish

CLOSED CIRCULATORY SYSTEM

Circulatory System of Amphibians

- The heart of an amphibian has three chambers, that is, two atria and a ventricle. Unlike the single circulatory system of fish, blood flows in two directions: **pulmocutaneous circulation** and **systemic circulation**. Therefore, this system is known as a **double circulatory system**.
- Amphibians are said to have an incomplete double circulatory system because the deoxygenated blood and the oxygenated blood are mixed.
- Pulmocutaneous circulation transports blood to the lungs and skin, and the exchange of gases takes place here. Systemic circulation transports oxygenated blood to the body tissues and returns the deoxygenated blood to the right atrium through the veins.

1 Deoxygenated blood from body is transported to the right atrium.

2 Oxygenated blood from lungs and skin is transported by the pulmonary vein to the left atrium.

3 Blood from both atria enters one ventricle. Although there is some mixing of oxygenated and deoxygenated blood in the ventricle, most of the oxygenated blood remains on the left side of the ventricle while the deoxygenated blood remains on the right side of the ventricle.

4 The ventricle then pumps the blood through the pulmocutaneous (lungs and skin) and systemic circulations.

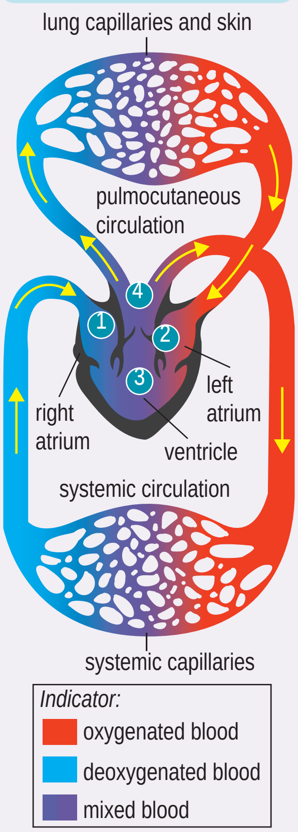


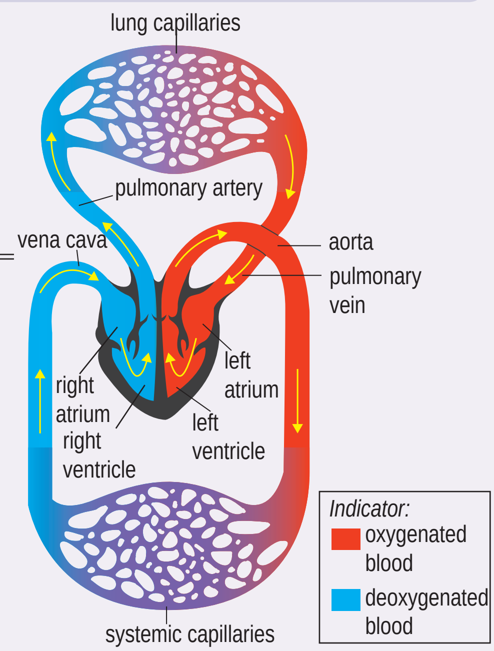
FIGURE 10.6 The blood circulatory system of amphibians

Circulatory System of Humans

- The human heart consists of four chambers: two atria and two ventricles that are separated completely.
- Humans have a double circulatory system. This means that in one complete circulatory cycle, blood flows in the blood vessels through the heart twice. As there are two different circulations, humans are said to have a **complete double circulatory system** because the deoxygenated blood and the oxygenated blood do not mix.

Pulmonary circulation

- Deoxygenated blood is transported through the pulmonary artery to the lungs for gaseous exchange.
- Oxygenated blood from the lungs is returned to the left atrium and flows into the left ventricle.



Systemic circulation

- Blood is pumped from the heart to all the body tissues through the aorta.
- Then the deoxygenated blood returns to the right atrium through vena cava.

FIGURE 10.7 The blood circulatory system of humans

10.1.4

TABLE 10.1 Similarities and differences between circulatory systems in complex multicellular organisms

Similarities
The circulatory system is found in all multicellular organisms.
The circulatory system consists of a heart to pump blood or haemolymph (in insects).
The circulatory system functions to transport nutrients and wastes.
The heart has valves that ensure blood flows in one direction.

Differences				
Organism	Insects	Fish	Amphibians	Humans
Types of circulatory system	Open blood circulatory system	Closed blood circulatory system	Closed blood circulatory system	Closed blood circulatory system
Number of circulations	–	Single (blood flows in the blood vessel and through the heart once in a complete circulation)	Double (blood flows in the blood vessel and through the heart twice in one complete circulation)	Double (blood flows in the blood vessel and through the heart twice in one complete circulation)
Number of heart cavities	The heart is made up of many cavity segments	Two (one atrium and one ventricle)	Three (two atria and one ventricle)	Four (two atria and two ventricles)
Separation of oxygenated blood and deoxygenated blood	–	–	Incomplete (some oxygenated blood is mixed with the deoxygenated blood in the ventricle)	Complete (oxygenated blood does not mix with deoxygenated blood in the ventricle)

Formative Practice 10.1

1 State two differences between the circulatory systems of fish and humans.

2 Explain why the blood circulatory system of amphibians is considered as a closed and incomplete blood circulatory system.

3 The flatworm is a multicellular organism. However, the flatworm does not require a specialised transportation system to move substances in and out of the cell. Explain why.

4 Explain why insects need one separate system (the tracheal system) to transport oxygen.

10.2 Circulatory System of Humans

There are three main components in the circulatory system of humans.

- **Blood**: A type of connective tissue that is made up of blood plasma, blood cells and platelets. Blood acts as a medium of transportation.
- **Heart**: Functions as a muscular pump that circulates blood to the whole body.
- **Blood vessels**: Consist of arteries, capillaries and veins that are connected to the heart, and transport blood to all the body tissues.

Malaysian Innovation

A group of researchers in Malaysia have produced a device called MyThrob that can be used as a smart examination and monitoring tool for heart diseases. The device studies the original algorithm that can detect abnormal heartbeat and is suitable to be used for monitoring at home.

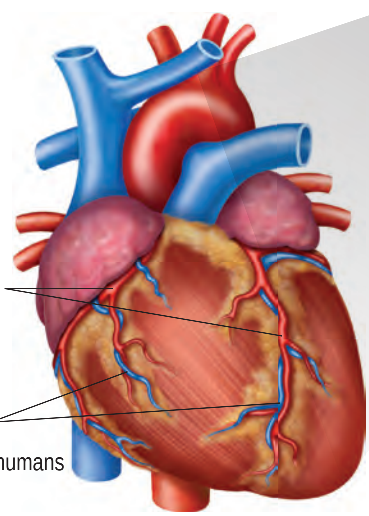
Structure of the heart

Do you know that your heart is as big as your fist? The heart is located between the lungs in the thorax cavity and contains four chambers, namely the **left atrium**, **right atrium**, **left ventricle** and **right ventricle**. The left chamber is separated from the right chamber by a muscular wall called **septum**.

Atrium receives blood that returns to the heart while the ventricle pumps blood out of the heart. The ventricle has thicker walls and contract stronger than the atrium.

The muscular wall of the left ventricle is much thicker than the muscular wall of the right ventricle. This is because the left ventricle has to generate greater pressure to pump blood out of the aorta to the whole body while the right ventricle only has to pump blood to the lungs.

Coronary arteries transport oxygenated blood for heart tissues while **coronary veins** transport deoxygenated blood.



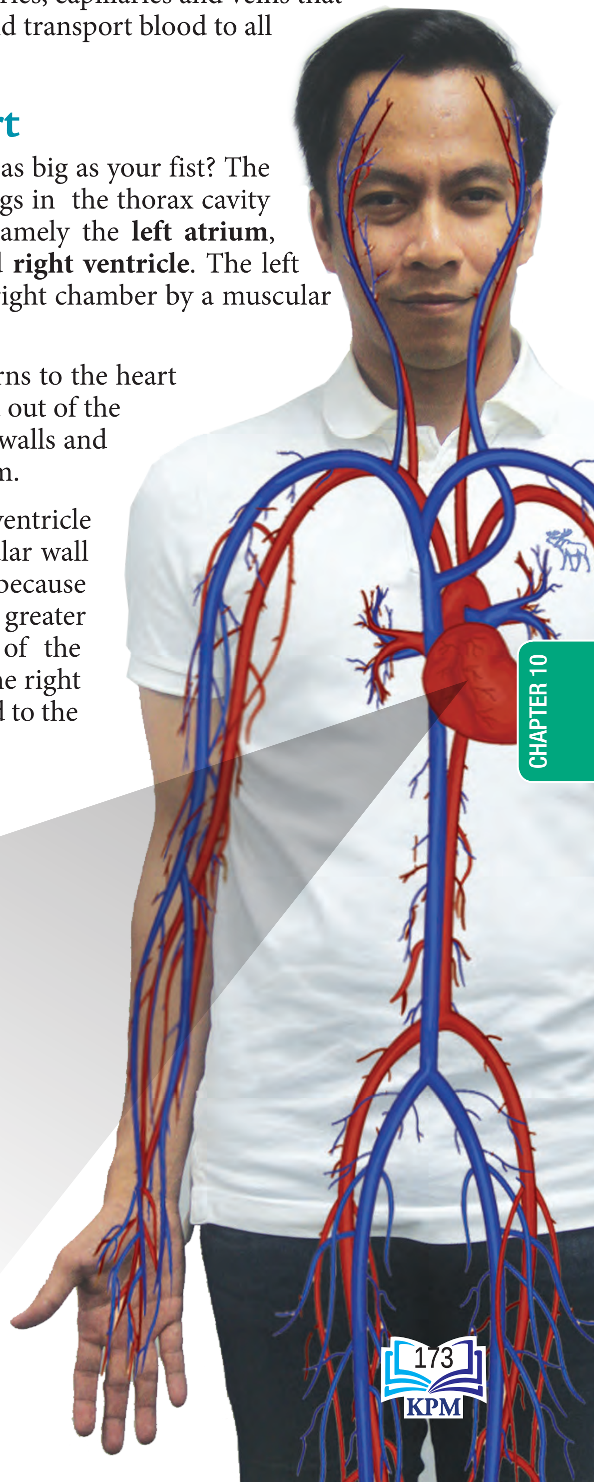


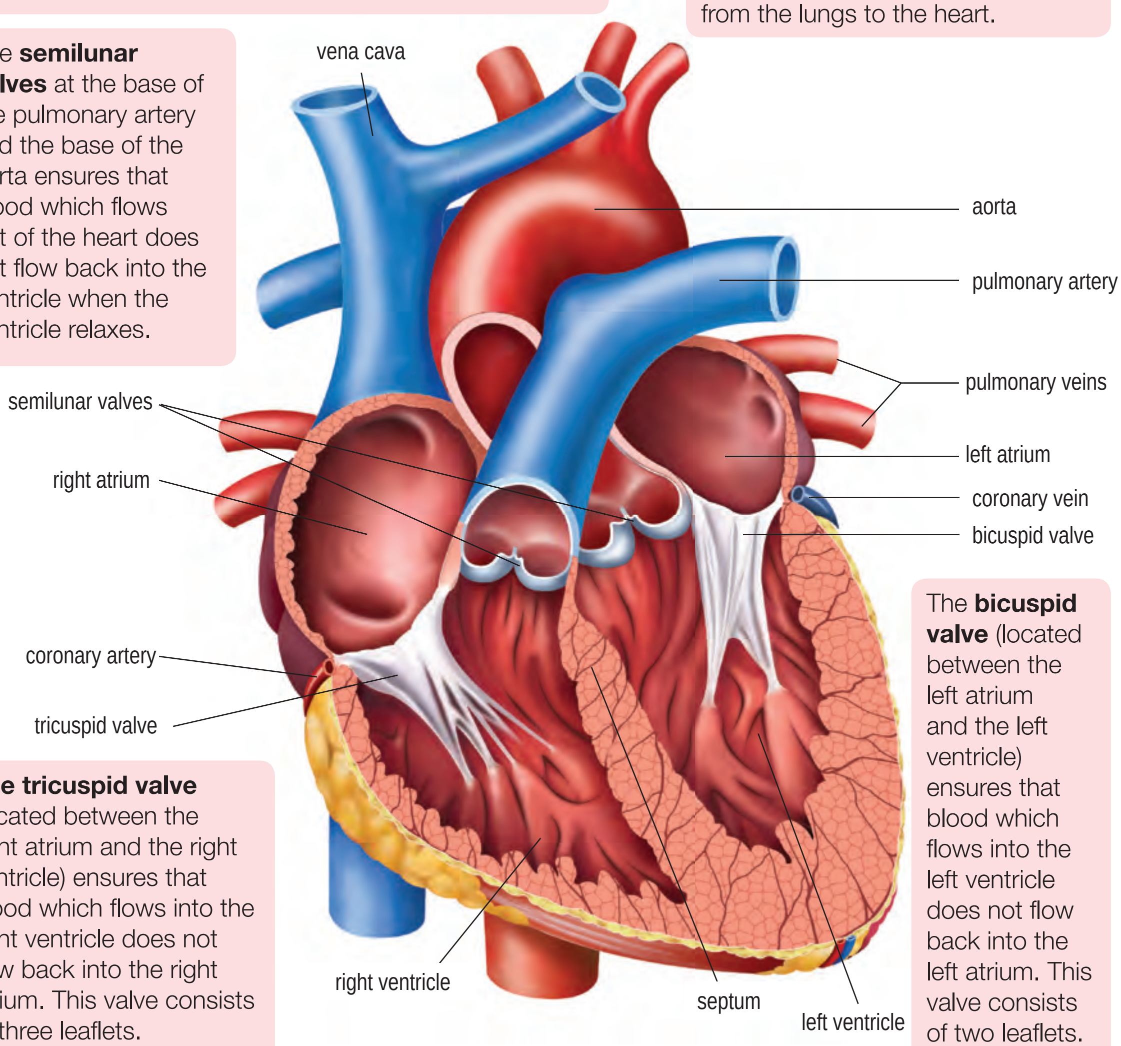
TABLE 10.8 The circulatory system of humans

10.2.1 10.2.4 10.2.5

Aorta is the main blood artery that transports oxygenated blood to the whole body while the **vena cava** is the main vein that transports deoxygenated blood back to the heart.

The **pulmonary artery** transports deoxygenated blood from the heart to the lungs while the **pulmonary veins** transports oxygenated blood from the lungs to the heart.

The **semilunar valves** at the base of the pulmonary artery and the base of the aorta ensures that blood which flows out of the heart does not flow back into the ventricle when the ventricle relaxes.



The tricuspid valve (located between the right atrium and the right ventricle) ensures that blood which flows into the right ventricle does not flow back into the right atrium. This valve consists of three leaflets.

The **bicuspid valve** (located between the left atrium and the left ventricle) ensures that blood which flows into the left ventricle does not flow back into the left atrium. This valve consists of two leaflets.

The **septum** separates the left part of the heart from the right part of the heart and ensures that the oxygenated blood does not mix with the deoxygenated blood.

FIGURE 10.9 Longitudinal section of a human heart

Brainstorm!

What would happen to an individual if the bicuspid valve does not close completely when the ventricle relaxes?

ICT 10.2

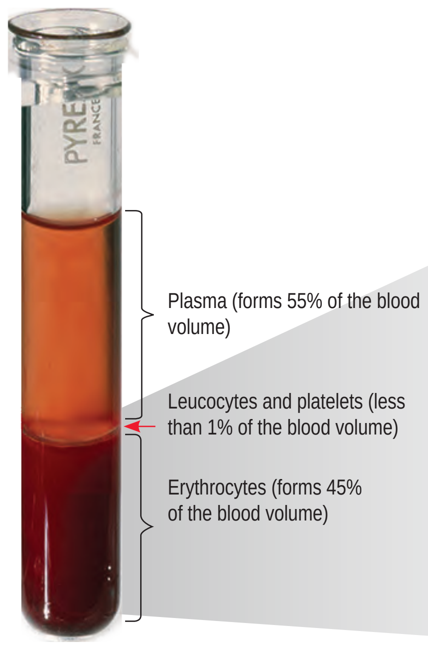
Video: Animation of the heart valves (Accessed on 21 August 2019)

Composition of human blood

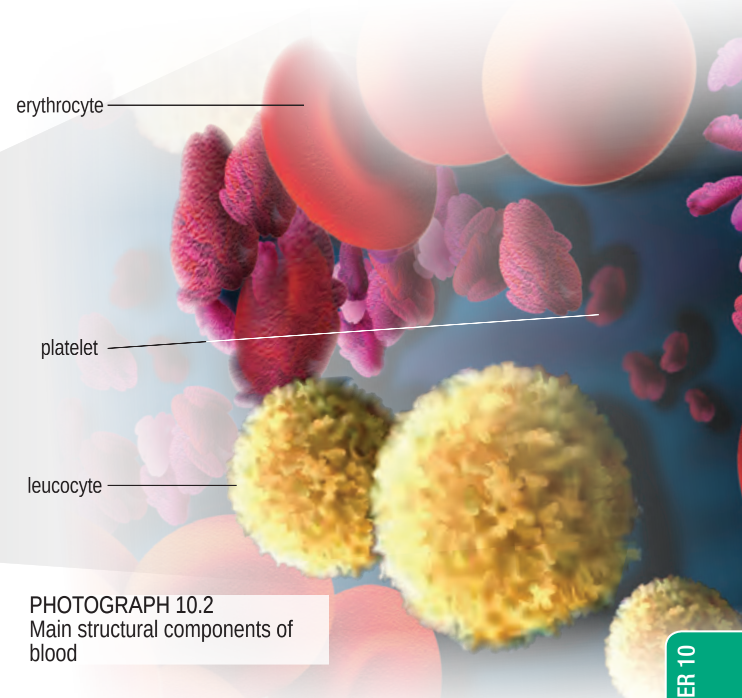
The human blood consists of 55% plasma and 45% cell components. **Plasma** is the medium of transportation in the body. The components of blood cells consist of **red blood cells** or **erythrocytes**, **platelets** and **white blood cells** or **leucocytes** (Photographs 10.1 and 10.2).

Biological Lens

Perfluorocarbon (PFC) emulsions can be potentially used as artificial blood. Studies have shown that PFC has the capacity like blood to transport oxygen and carbon dioxide.



PHOTOGRAPH 10.1 Main components of blood



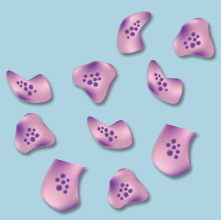
PHOTOGRAPH 10.2
Main structural components of blood

TABLE 10.2 Blood plasma components and the main function of each component

Component	Main function
Water	Blood plasma consists of 90% water. Water is a medium of transportation and a solvent for respiratory gas, ions, digestive products and excretory substances.
Plasma proteins	• Fibrinogen plays a role in blood clotting. • Albumin controls blood osmotic pressure. • Globulin is a type of antibody that is involved in the body's defence.
Solutes – nutrients such as glucose, excretory substances such as urea and respiratory gas	• Nutrients are important for energy, growth and maintenance of health. • Excretory substances are toxic substances that need to be disposed off from the body. • Oxygen is required in the respiration of cells.
Hormones and enzymes	Hormones control physiological activities in the body. Enzymes are involved in the metabolic processes of cells.

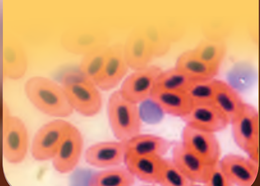
Table 10.3 shows the characteristics and functions of each blood cell type.

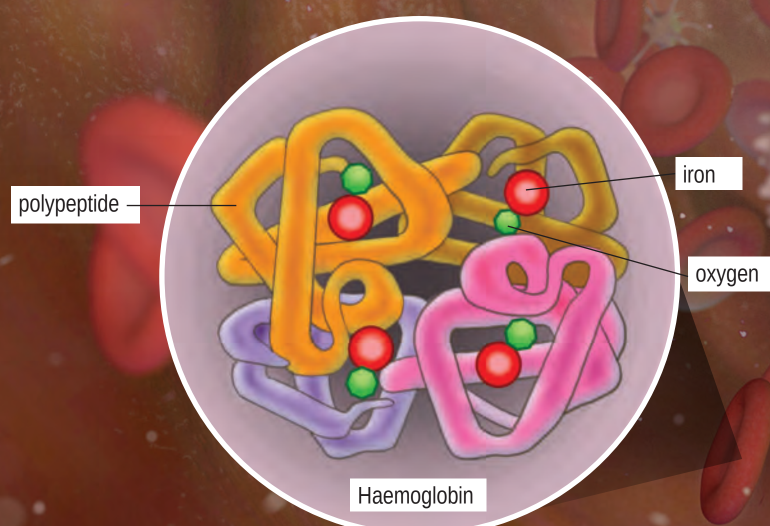
TABLE 10.3 Characteristics and functions of blood cell types

Blood cell type	Characteristics	Functions
Erythrocyte (red blood cell)  FIGURE 10.10 Erythrocyte structure	• Has an elastic plasma membrane • The **biconcave disc** shape enables a large TSA/V for efficient gaseous exchange • It does not have a nucleus at the mature stage so that more **haemoglobin** can be loaded into it • It is produced in the **bone marrow** of bones such as the sternum and ribs • Can live up to 120 days and is destroyed in the **liver** or **lymph** through the phagocytosis process.	• Each erythrocyte has a **haemoglobin** which is the red pigment that gives blood its red colour. • Haemoglobin contains a heme group. The heme group consists of an iron atom which is the binding site for oxygen. • Haemoglobin combines with oxygen to form **oxyhaemoglobin** in high oxygen partial pressure conditions. • Oxyhaemoglobin releases oxygen in tissues or cells when the partial pressure of oxygen is low.
Platelet  FIGURE 10.11 Platelet	• Platelets are produced from fragments or scraps of cell cytoplasm that originate from the bone marrows. • The life span is less than one week.	• Involved in the blood clotting process

Brainstorm!

The red blood cell of frogs has a nucleus and is larger than the red blood cell of humans. What are the advantages and disadvantages of nucleated red blood cells?





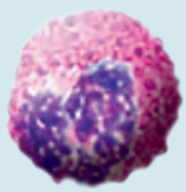
Blood cell type	Characteristics and functions
Leucocyte (white blood cell)	• The shape is irregular and is not fixed • Contains nucleus • Does not contain haemoglobin • Produced in the bone marrow • Life span is less than five days • Leucocyte can diffuse out of the capillary pore and fight pathogens in tissue fluids. It is divided into two types: granulocytes (contain granules) and agranulocytes (no granules). • Granulocytes include neutrophils, eosinophils and basophils. Agranulocytes include lymphocytes and monocytes.

LEUCOCYTES

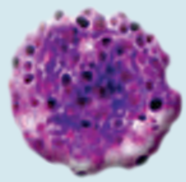
Granulocytes

Neutrophil
- The nucleus is made up of two to five lobes.
- Ingests bacterial cells and dead cells or tissues from wounds by phagocytosis

Eosinophil
- The nucleus is made up of two lobes.
- Releases enzymes that fight inflammation and allergy reaction

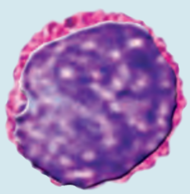


Basophil
- The number of basophils is lowest in the blood
- It contains heparin that prevents blood clotting



Agranulocyte

Lymphocyte
- Contains a large nucleus with very little cytoplasm
- Produces antibodies to destroy bacteria and viruses that enter the body
- Can also produce antitoxins against toxins that are produced by bacteria or viruses



Monocyte
- The biggest leucocyte
- Spherical-shaped nucleus
- Ingests bacteria and dead cells or tissues by phagocytosis

PHOTOGRAPH 10.3 Photomicrograph of leucocytes

CHAPTER 10

Human blood vessels

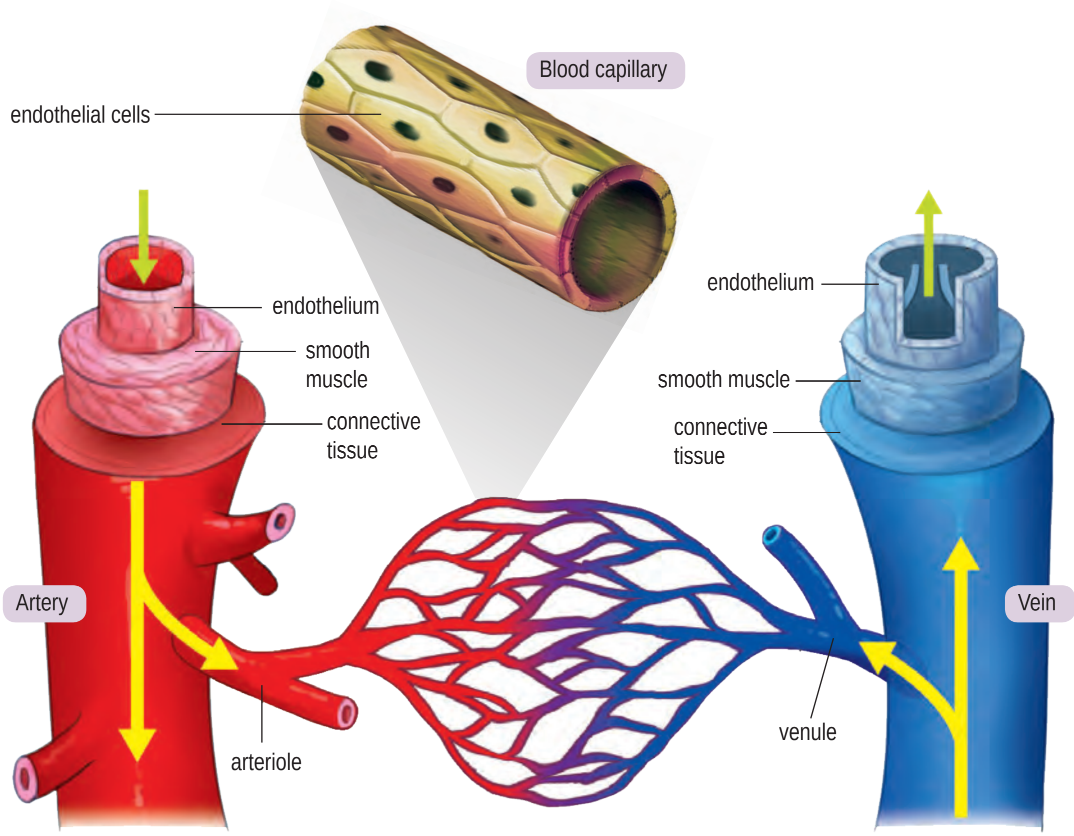


FIGURE 10.12 Relationship between artery, blood capillaries and vein

ARTERY

Arteries are blood vessels that transport blood out of the heart. The function of the artery is to quickly transport blood at a high pressure to the tissues.

The blood in the artery is under high pressure because of the pumping action of the heart.

The aorta is the main artery that leaves the heart. The artery expands when blood is received from the heart. Therefore, the artery wall is elastic to stop it from breaking due to the high-pressured blood that flows through it.

The branches of an artery become small vessels known as **arterioles** when they reach the body tissues. The arteriole continues to branch out and ends at the capillaries. The group of capillaries is called **capillary network**.

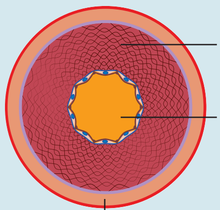
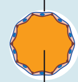
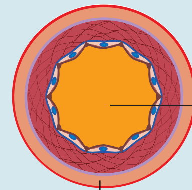
BLOOD CAPILLARIES

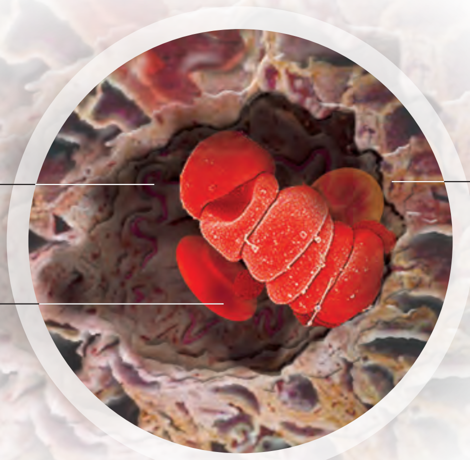
Capillaries are blood vessels with thin walls, as thick as one cell. Blood capillaries allow the exchange of gases to occur between blood and cells through diffusion. Nutrients, excretory substances and hormones diffuse through blood capillaries.

VEIN

Capillaries rejoin to form larger blood vessels called **venules**. The venules combine to form **veins** that transport blood back to the heart. **Vena cava** is the main vein that carries deoxygenated blood back to the heart. The differences between arteries, capillaries and veins are given in Table 10.4.

TABLE 10.4 Differences between arteries, capillaries and veins

Characteristics	Artery	Capillaries	Veins
Wall	Wall is thick, muscular and elastic 	Wall is as thick as one cell, not muscular and not elastic 	Wall is thin, less muscular and less elastic 
Lumen	Small	Very tiny	Large
Valve	No valve except for semilunar valve at the base of the aorta and at the base of the pulmonary artery	No	Contain valves to maintain one-way flow of blood
Blood pressure	High	Low	Very low
The direction of blood flow	From the heart to the entire body	From the artery to the vein	From the whole body to the heart



PHOTOGRAPH 10.4 Scanning electron microscope shows the cross section of an arteriole (4000x magnification)

Formative Practice 10.2

1 What is the function of the bicuspid valve?

2 Explain why some individuals feel nauseous and faint immediately after donating blood? Why do some blood donors need to take iron pills?

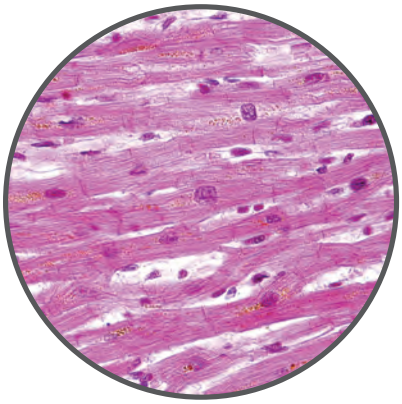
3 State two differences between the structures of erythrocyte and leucocyte.

4 Explain why the left ventricle has a thicker muscular wall than the right ventricle.

CHAPTER 10

10.3 Mechanism of Heartbeat

How is blood circulated to the whole body? In every contraction, the heart acts as a pump that pumps blood to the whole body. How is every heartbeat triggered and sustained?



PHOTOGRAPH 10.5
Cardiac muscle tissue

The heart is made up of cardiac muscles (Photograph 10.5) that intersect and are connected with one another. This arrangement allows electric impulses to spread rapidly through the heart and at the same time, stimulates the cardiac muscle cells to contract simultaneously and uniformly. Cardiac muscles are **myogenic**. This means that the heart contracts and relaxes without receiving any impulse signal from the nervous system. If the cardiac muscles are stored in a warm oxygenated solution that contains nutrients, these muscles will contract and relax rhythmically on their own.

Blood circulation in humans

The produced force that enables blood to circulate in humans is generated by the pumping of the heart and the contraction of the skeletal muscles.

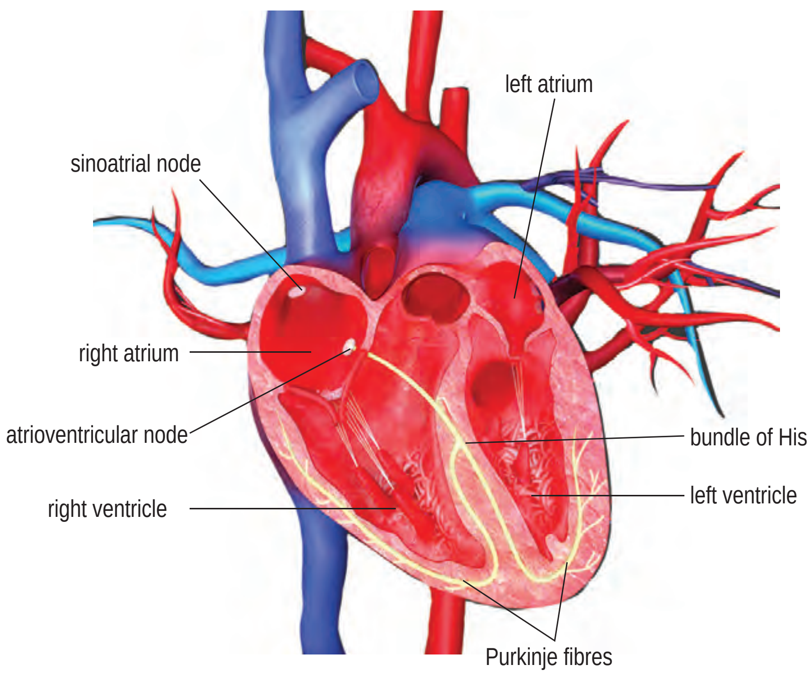


FIGURE 10.13 The location of sinoatrial node, atrioventricular node, bundle of His and Purkinje fibres

Our World of Biology

The "*Medtronic Micra*" pacemaker is the smallest artificial pacemaker in the world. The size is about the size of a vitamin pill and is placed in the heart without surgery. The artificial pacemaker sends small electrical charges to stimulate heartbeat.

Pumping of the heart

The contraction of the heart is initiated and coordinated by the **pacemaker**. The pacemaker is a group of specific heart muscle cells that initiates the rate of heart contraction and is located at the right atrium wall (Figure 10.14).

The pacemaker generates electrical impulses that spread rapidly through both walls of the atrium and causes the atrium to contract rhythmically. The main pacemaker is called **sinoatrial node** (SA). The sequence of heart muscle contraction that causes the pumping is shown in Figure 10.14.

1 The sinoatrial node (SA) generates electrical impulses.

2 Electrical impulses spread rapidly in both the atria, causing the atria to contract simultaneously. The contraction of the atria helps to pump blood into the ventricles.

3 The electrical impulses reach the atrioventricular node. The electrical impulses spread through the bundle of His, and the Purkinje fibres up to the apex of the heart.

4 The electrical impulses spread from the apex of the heart to the whole ventricle wall. As a result, the ventricles contract to pump blood out to the lungs and body.

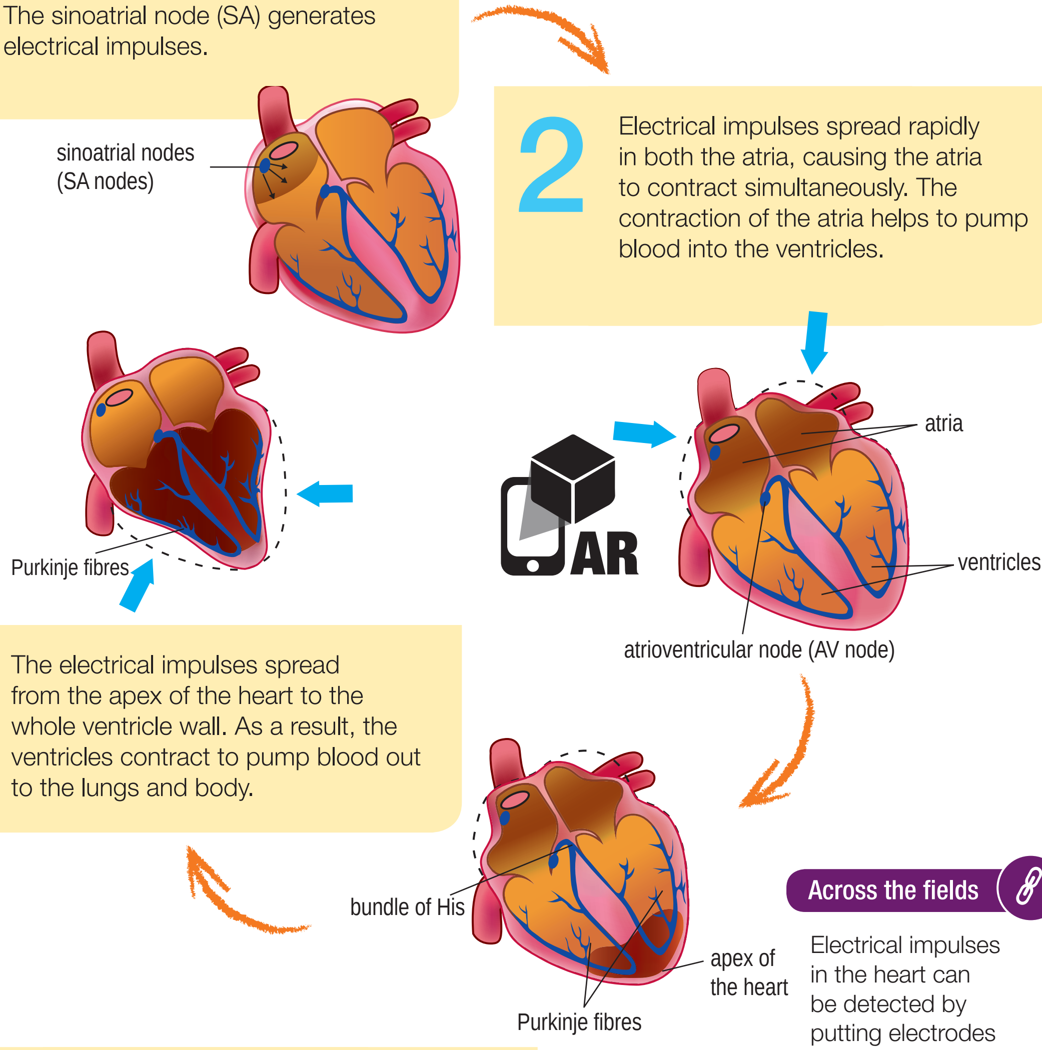
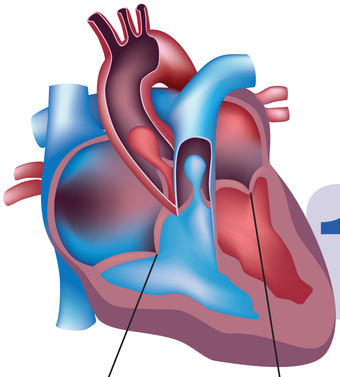


FIGURE 10.14 The sequence of heart contraction that causes the pumping of the heart

Across the fields

Electrical impulses in the heart can be detected by putting electrodes on the skin. The electrocardiogram is a record of the electrical activity that triggers every heartbeat.

During heart pumping, the **lub-dub sound** can be heard. Do you know what causes this lub-dub sound?
The lub-dub sound is the closing sound of the heart valves.



1 The first 'lub' sound is produced when the tricuspid valve and the bicuspid valve close.

2 The second 'dub' sound is produced when the semilunar valves close.

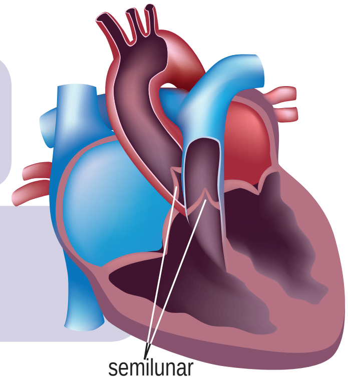


FIGURE 10.15 The lub-dub sound of the heart

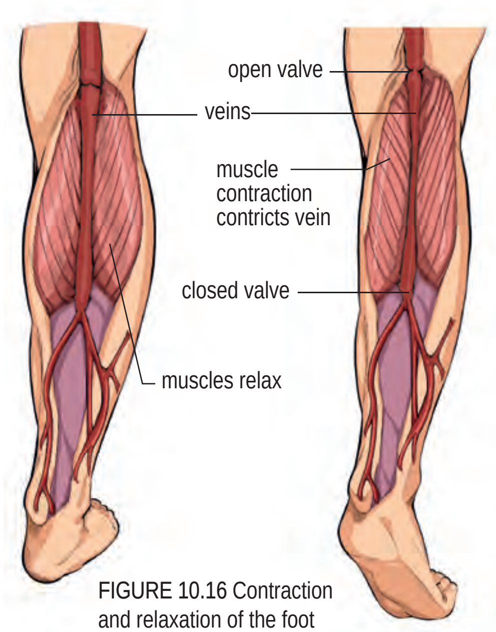


FIGURE 10.16 Contraction and relaxation of the foot skeletal muscles

Contraction of skeletal muscles around the veins

The pumping of the heart helps in the distribution and flow of blood through the arteries, arterioles and blood capillaries. However, the force produced by the pumping of the heart is insufficient for the blood flow to continue through the veins and return to the heart. Besides, the blood is forced to flow against the force of gravity. The presence valve in the veins ensures that the blood flows in one direction to the heart.

The blood flow in the veins is assisted by:

(a) contraction of the smooth muscles found in the venule and vein walls;

(b) contraction of skeletal muscles around the veins. The contraction of skeletal muscles presses and constricts the veins, causing the valve to open and allow blood to flow towards the heart. The valve is then closed to prevent the blood from flowing back towards the foot (Figure 10.16).

Brainstorm!

What would happen to the valve in the blood vessels of our legs if we stand or sit for too long?

Formative Practice 10.3

1 Name the main heart pacemaker.

2 What does the term myogenic mean?

3 Explain why a person who stands too long may faint.

4 In what circumstances would fingers turn pale?

10.3.2

10.4 Mechanism of Blood Clotting

The necessity for blood clotting mechanism

STEM Bulletin

Scientists have developed a nanomagnetic particle that contains thrombin. This nanoparticle is injected into the injured part to trigger blood clotting and to stop bleeding.

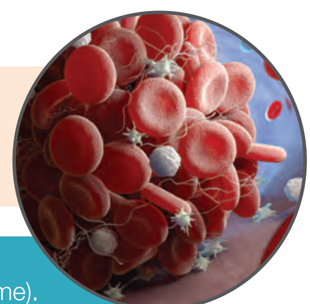
What happens when your finger is injured? Blood will flow from the wound until you apply pressure directly on the wound. The pressure you apply may appear to restrict bleeding temporarily; however, the blood flow is actually stopped by the blood clotting process.

Why must the blood clot on the wound? Blood clotting will stop or minimise the loss of blood on the injured blood vessel. Blood clotting also prevents microorganisms such as bacteria from entering the bloodstream through the damaged blood vessel. The blood pressure is also maintained because excessive blood loss will lower blood pressure to a dangerous level. How does blood clotting occur?

Mechanism of blood clotting

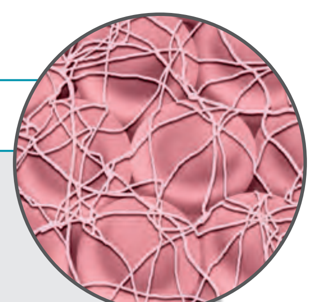
Blood clotting involves a series of chemical reactions that takes place in the blood when someone is injured to prevent excessive bleeding.

The coagulated platelets, damaged cells and clotting factors in the blood plasma will form an activator (**thrombokinase**). Thrombokinase, with the aid of calcium ions and vitamin K, converts prothrombin to thrombin.



Prothrombin (inactive plasma protein) → **Thrombin** (active plasma protein that acts as an enzyme). Thrombin catalyses the conversion of fibrinogen to fibrin.

Fibrinogen (soluble) → Fibrin (insoluble)



Fibrin is a threadlike protein fibre that forms a network on the wound surface to trap erythrocytes and to close the wound to prevent blood loss.

TABLE 10.17
Mechanism of blood clotting

10.4.1 10.4.2

Health issues related to blood clotting

Under normal conditions, blood does not clot in blood vessels that are not damaged because of some anticoagulants such as heparin. What happens when the blood clotting mechanism of an individual does not function?

HAEMOPHILIA

- Haemophilia is an example of an illness that prevents blood from clotting.
- Haemophilia is a hereditary illness caused by the lack of certain clotting factors in the blood.
- Excessive bleeding due to small wounds or bruises can result in death.

Our World of Biology

When you sit for too long, the risk of thrombosis in legs will increase. Make sure that you move your legs once in a while.

THROMBOSIS

- Formation of a blood clot (**thrombus**).
- Thrombosis happens as a result of:
  - damage in blood vessels, or
  - sluggish blood flow that causes clotting factors to accumulate

Activity Zone

Work in groups to collect and interpret information about thrombosis, embolism and haemophilia. Present your findings to the class.

EMBOLISM

- When a blood clot is transported by blood flow, the blood clot is called **embolus**.
- If the embolus gets stuck in a tiny blood vessel, the blood flow will stop.

Formative Practice 10.4

1. At the end of the blood clotting mechanism, fibrin will be formed to trap erythrocytes. Explain the meaning of fibrin and its function.
2. Describe two health issues related to blood clotting.
3. Explain the mechanism of blood clotting.
4. Explain why the formation of blood clots in the blood vessel can cause a heart attack.

10.5 Blood Groups of Humans

ABO blood group

Do you know your blood group? Human blood is classified into **A**, **B**, **AB** and **O** groups. Donation and transfusion of blood is based on the compatibility of the blood group of the donor and the recipient. This is because the recipient has antibodies in the blood serum that can act against the antigen on the red blood cells of the donor. Blood transfusion from a donor to a recipient must take into consideration the blood group type of the donor and the recipient (Table 10.6). If the blood group of both the donor and receiver is not compatible, the red blood cells of the recipient will experience **agglutination** (coagulation).

TABLE 10.5 Antigen and antibody in blood groups

Blood group	Antigen on red blood cells	Antibody in the blood serum
A	Antigen A	Anti-B
B	Antigen B	Anti-A
AB	Antigen A and Antigen B	No
O	No	Anti-A and Anti-B

TABLE 10.6 Compatibility of blood donor group with the recipient

Blood group	Can donate blood to blood groups	Can receive blood from blood groups
A	A and AB only	A and O only
B	B and AB only	B and O only
AB	AB only	A, B, AB and O
O	A, B, AB and O	O only

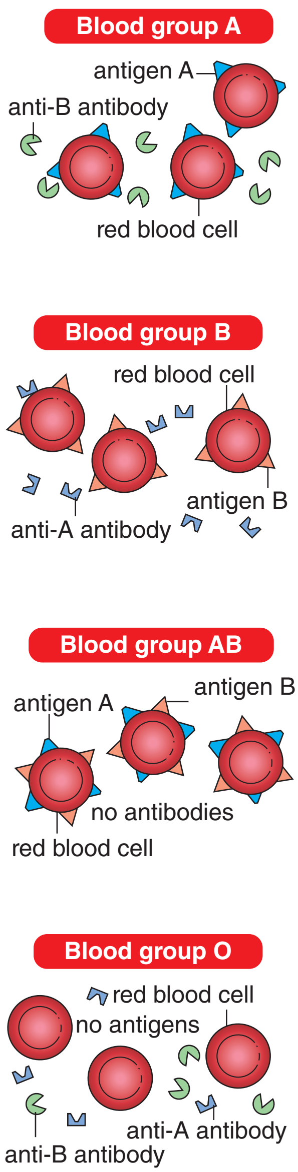


FIGURE 10.18 Antigens and antibodies in different blood groups

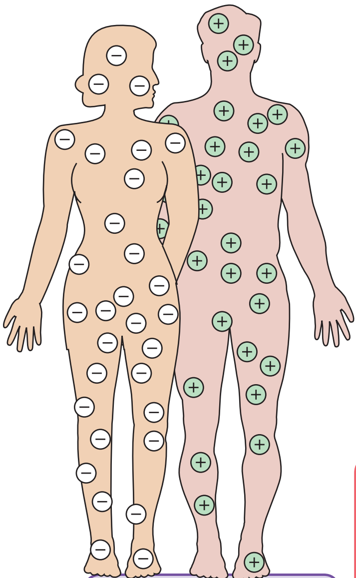
Rhesus Factor

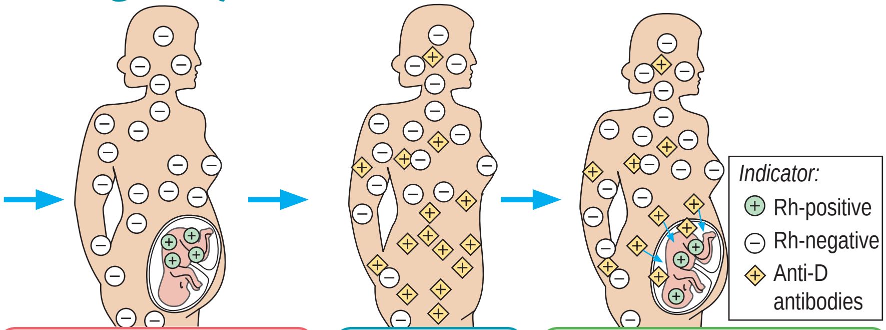
Another antigen found on the surface of the red blood cells is the **Rhesus factor (Rh factor)**. The red blood cells of an individual with the Rh factor or **antigen D** are known as **Rh-positive**. An individual who does not possess the Rh factor or antigen D is known as **Rh-negative**.

If the blood of a Rh-positive donor mixes with the blood of a Rh-negative recipient, the blood of the recipient will react by producing the **Rhesus antibody** or **anti-D antibody**. When the recipient receives another dose of Rh-positive blood, the Rhesus antibody will cause the agglutination of the donor blood cells. This situation could result in the death of the recipient.

10.5.1 10.5.2 10.5.3

Pregnancy and the Rhesus factor





Usually, problems will arise when an Rh-negative mother marries an Rh-positive father and conceives an Rh-positive foetus.

During the last month of pregnancy, fragments of foetal blood cells containing antigen D cross the placenta and enter the blood circulation of the mother.

As a result, the white blood cells in the mother's blood will react and produce anti-D antibodies that will flow back through the placenta into the foetal blood circulatory system.

The antibodies will destroy the red blood cells of the Rh-positive baby before or immediately after birth.

However, the concentration of antibodies produced is not enough to affect the first child. But the anti-D antibodies will last in the blood circulatory system of the mother.

The problem arises when the second child is also Rh-positive. The anti-D antibodies that are present in the mother's blood cross the placenta and destroy the red blood cells of that foetus. The symptoms of this disease are called ***erythroblastosis fetalis***. The second foetus dies if the blood is not replaced with Rh-negative blood through blood transfusion.

In a less serious situation, the baby may suffer from anaemia and mental retardation. However, this problem can now be addressed by treating the affected mother with anti-Rhesus globulins after the first pregnancy to stop the formation of anti-D antibodies.

Formative Practice 10.5

1 State the blood group which is the universal donor.

2 Predict what will happen if the blood group of both recipient and donor is not compatible.

3 Three babies P, Q and R have blood groups B, O and AB respectively. Three pairs of parents have the following blood groups:

The first pair of parents: B and O
The second pair of parents: A and B
The third pair of parents: AB and O

Match the babies with their correct parents.

4 An Rh-positive male marries an Rh-negative female. The first Rh-positive child is alive but the second child who is also Rh-positive did not survive. Explain why.

10.6 Health Issues Related to the Human Circulatory System

The necessity for a healthy circulatory system

Activity Zone

Work in groups and conduct a case study on the practices of maintaining a healthy human circulatory system.

A healthy circulatory system is important to ensure optimum health. How do we ensure that our circulatory system is healthy? Among the practices for maintaining the circulatory system are a balanced intake of food that is low in fat and regular exercise. The practice of not smoking and not drinking alcoholic drinks also ensures a healthy circulatory system.

Cardiovascular diseases

Do you know that cardiovascular diseases are the leading cause of death in our country? **Cardiovascular diseases** include diseases related to the heart and the blood circulatory system such as atherosclerosis, arteriosclerosis, angina, hypertension, myocardial infarction (heart attack) and stroke.

Activity Zone

Discuss a suitable treatment for heart failure.

CARDIOVASCULAR DISEASES
• **Atherosclerosis** is the formation and deposition of plaque on the artery walls. • The plaque is formed from cholesterol, lipid, dead muscle tissues and coagulated platelets. • The plaque will clog and narrow the lumen in blood vessels.
• The restricted blood flow can cause **hypertension**. • Hypertension causes fine arteries to break and the patient can suffer from stroke if this happens in the brain. • **Stroke** is also caused by blood clots (thrombus) that clog the flow of blood in the brain.
• Atherosclerosis is the early stage of **arteriosclerosis**. • Arteriosclerosis occurs when calcium is deposited on the plaque and causes the artery to become hard and lose its elasticity.
• If the lumen of the coronary artery (artery for the heart) is narrowed, the insufficient oxygen supply to the heart muscles can cause **angina** (severe chest pain). • If the artery is completely clogged, **myocardial infarction** (heart attack) will occur.

PHOTOGRAPH 10.6 Myocardial infarction (heart attack)

10.6.1 10.6.2

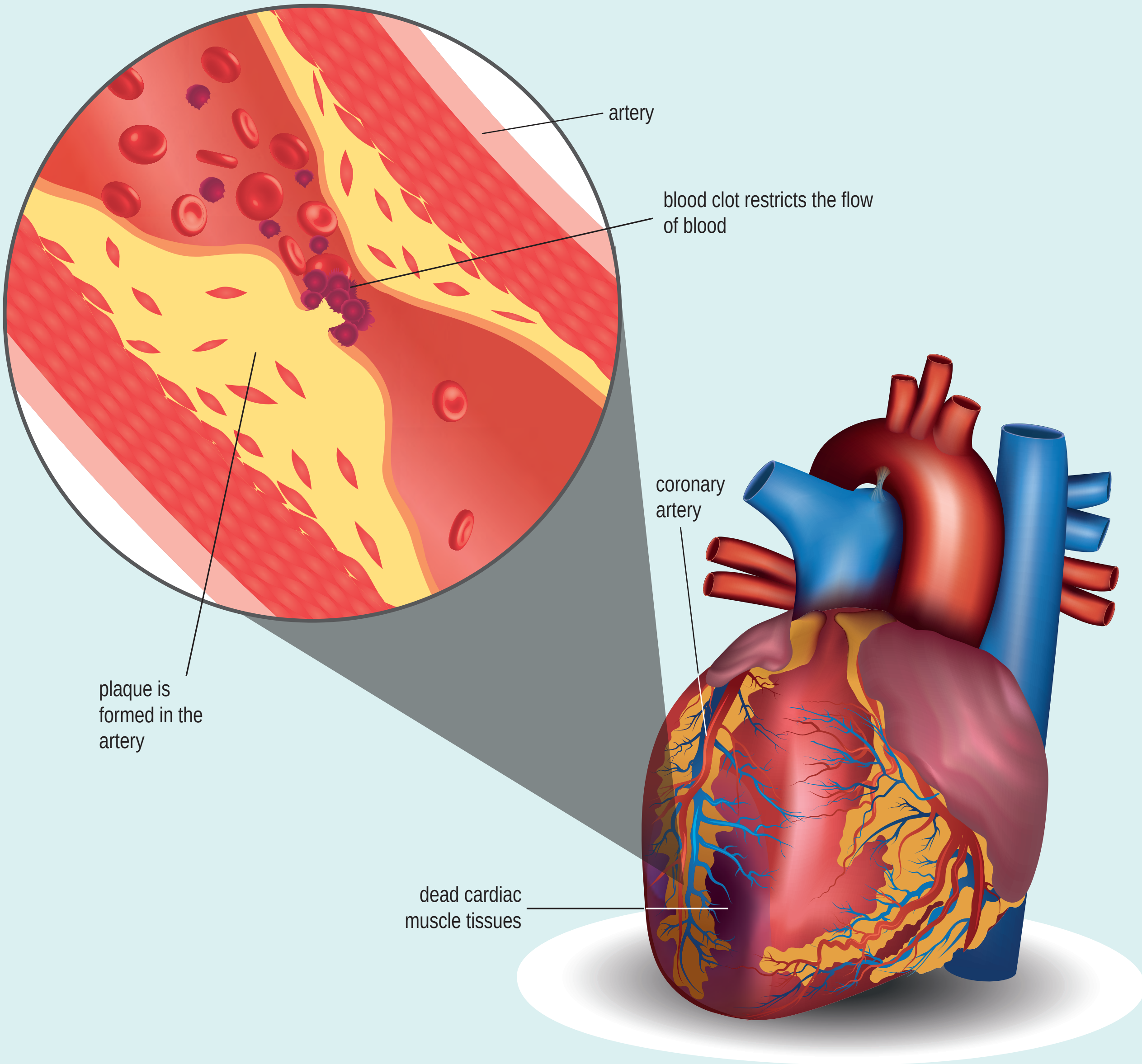


FIGURE 10.19 Formation and deposition of plaque on artery wall

STEM Bulletin

Nanotechnology is used in the diagnosis and treatment of atherosclerosis and plaque formation in arteries. In this technique, nanoparticles are designed to resemble high-density lipoprotein cholesterol (HDL) ("good" cholesterol) to help reduce plaque.

What is the treatment for a patient who suffers from heart failure? What are the risk factors that contribute to cardiovascular diseases and what can we do to ensure that the cardiovascular system is healthy?

Formative Practice 10.6

1. What is the meaning of myocardial infarction?
2. Explain how stroke happens.
3. In your opinion, what are the factors that contribute to an individual's risk of getting cardiovascular disease?
4. Explain how atherosclerosis happens.

10.6.1 10.6.2

10.7 Human Lymphatic System

The formation of tissue fluid

In addition to the blood circulatory system, there is one more system in the body whose function is closely related to the blood circulatory system. This system is called **the lymphatic system**. The formation of tissue fluid is illustrated in Figure 10.20.

1 Blood that reaches the arterial end of the blood capillary has a high pressure due to the small diameter of capillaries and the pumping force of the heart.

2 This pressure allows the blood plasma to diffuse continuously from the blood capillaries to the intercellular space.

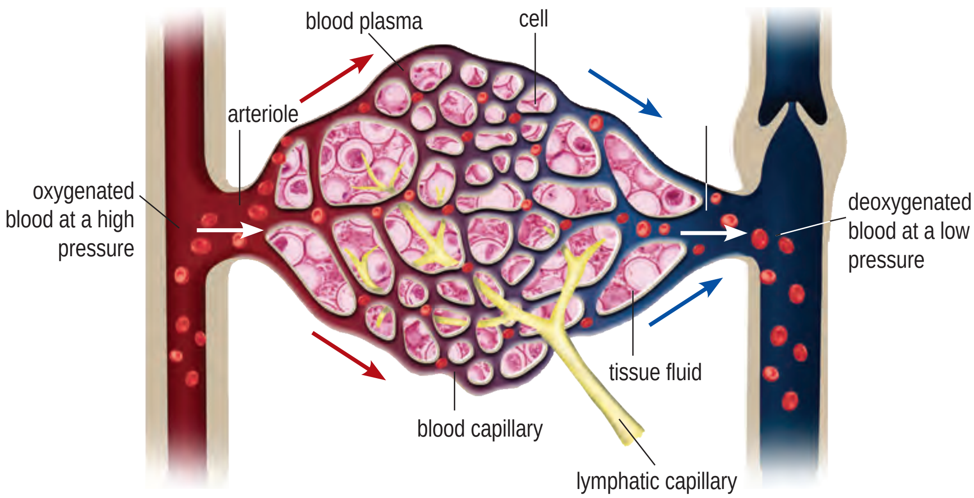


FIGURE 10.20 Exchange of substances between blood capillaries and body cells

3

- Blood plasma that occupies the intercellular space and constantly bathes cells is called **tissue fluid**.
- The tissue fluid does not contain any erythrocyte, platelet and plasma protein because these are too large to diffuse out of the blood capillaries.

4

- Tissue fluid allows the exchange of materials in the blood and cells to occur.
- Nutrients and oxygen diffuse from tissue fluid to body cells.
- Simultaneously, excretory products and carbon dioxide diffuse from body cells to blood capillaries through the tissue fluid.

Lymph formation and components of the lymphatic system

At the venule end of the blood capillary, blood plasma is hypertonic compared to the tissue fluid surrounding it. Blood pressure is also lower. As a result, the reabsorption of water, mineral salts and waste takes place in the venule capillary.

However, only 85% of the fluid that leaves the blood at the arteriole end of blood capillary diffuses back into the venule end. What happens to the remaining 15% that is left in the intercellular space? This remainder forms about 4 litres of fluid that is lost from capillaries each day. How does the blood circulatory system regain this fluid?

10.7.1

The lost fluid is collected and returned to the blood through the **lymphatic capillary,** which is the smallest vessel in the **lymphatic system**. This fluid is known as **lymph** and is pale yellow in colour. Table 10.7 and Table 10.8 show the similarities and differences between lymph with tissue fluid and blood.

TABLE 10.7 Comparison between lymph and tissue fluid

Similarity	
Both contain plasma without the plasma proteins, erythrocytes and platelets.	
Differences	
Lymph	**Tissue fluid**
Higher content of fat and fat-soluble substances	Low content of fat and fat-soluble substances
High content of lymphocytes	Low content of lymphocytes

TABLE 10.8 Comparison between lymph and blood

Similarity	
Both contain all the contents of plasma such as nutrients, hormones, enzymes, cellular wastes, respiratory gases and leucocytes.	
Differences	
Lymph	**Blood**
Does not contain plasma protein, erythrocyte and platelet	Contains plasma proteins, erythrocytes and platelets

The lymphatic capillary wall consists of **one layer of cells** only. The lymphatic capillary differs from blood capillary because one of its end is **blocked** or closed while the other end is connected to the **lymphatic vessel** (Figure10.21). **Lymphatic capillaries** found in intercellular spaces merge to form a larger lymphatic vessel. Along the lymphatic vessel, there are lymph nodes at certain distances.

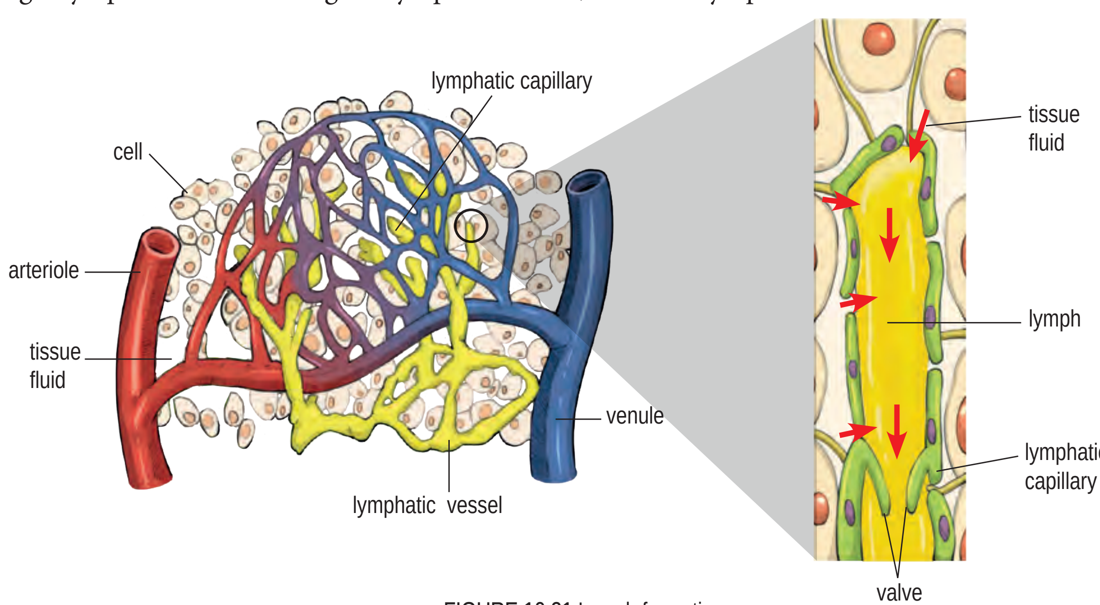


FIGURE 10.21 Lymph formation

10.7.2 10.7.3

The lymphatic system consists of organs such as **lymph nodes**, **spleen**, **thymus gland**, **bone marrow**, **tonsils** and **appendix** (Figure 10.22). The lymphatic system does not have its own pump to circulate the lymph along the lymphatic vessel. The flow of lymph is aided by **heartbeat pulse**, **contraction of skeletal muscles**, **peristalsis in the digestive tract** and changes in pressure during **inhalation and exhalation of breath**. In the lymphatic vessel, one-way valves ensure the lymph flows continuously to the heart. These valves also prevent the lymph from flowing back.

Relationship between the blood circulatory system and the lymphatic system

All lymphatic vessels will eventually join with one of the two main lymphatic vessels which are the **thoracic duct** dan **right lymphatic duct** (Figure 10.22).

The **right lymphatic duct** receives lymph from the right hand, chest and right side of the head and neck.

The **thoracic duct** receives lymph from the left side of the head, neck and chest, and all the body parts below the ribs.

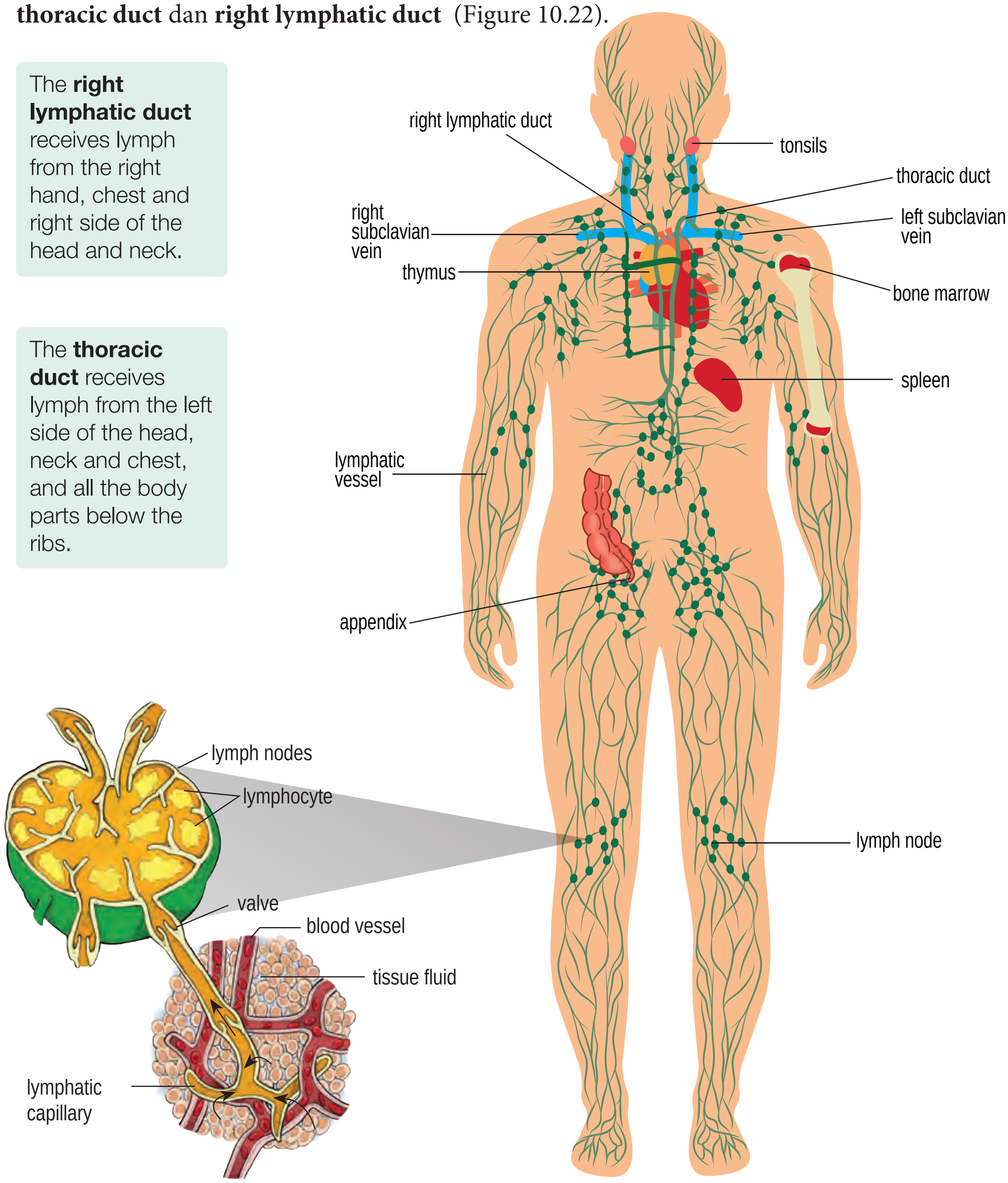
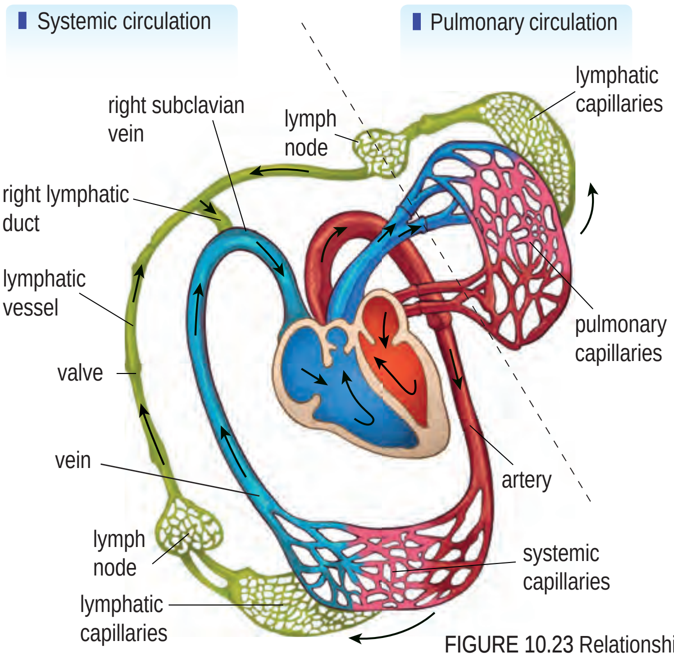


FIGURE 10.22 Lymphatic system



The thoracic duct will deliver its contents into the **left subclavian vein** while the right lymphatic duct will transport lymph into the **right subclavian vein**.

So the lymph collected from the whole body will flow back into the blood circulatory system. Figure 10.23 shows the relationship between the lymphatic system and the blood circulatory system that complement each other.

FIGURE 10.23 Relationship between lymphatic system and blood circulatory system

The necessity of the lymphatic system

The necessity of the lymphatic system is summarised in Figure 10.24.

NECESSITIES OF THE LYMPHATIC SYSTEM

COMPLEMENTS THE BLOOD CIRCULATORY SYSTEM

The lymphatic system returns the excess tissue fluid in the intercellular space into the blood flow. The composition, pressure and volume of blood are maintained at a normal range.

BODY DEFENCE

Lymph nodes produce and store lymphocytes that are involved in the production of antibodies.

TRANSPORTATION OF FAT-SOLUBLE SUBSTANCES

Fats and fat-soluble substances diffuse into the lacteal in the villus of the small intestine. **Lacteals** are lymphatic capillaries. Lipid droplets are transported to the thoracic duct and blood circulatory system through the left subclavian vein.

FIGURE 10.24 The necessity of the lymphatic system

Formative Practice 10.7

1 Name the two main lymphatic vessels.
2 State three main functions of the lymphatic system.
3 State the differences between the composition of blood plasma, tissue fluid and lymph.
4 After eating fatty food, the number of lipid molecules in the lymph increases by 1%. Explain why.

10.8 Health Issues Related to the Human Lymphatic System

Brainstorm!
Why do our legs swell after we sit for too long?

Have you ever wondered what would happen if our lymphatic system does not function properly? What would happen if the excess tissue fluid is not returned to the blood flow? Tissue fluid that is not returned to the blood circulatory system will accumulate in the intercellular space. This will result in the swelling of the body tissues. This condition is known as **oedema** (Photograph 10.7). Oedema may be caused by a number of factors (Figure 10.25).

PREGNANCY

The body will produce more body fluid to fulfill the needs of a growing foetus.

DEFICIENCY IN PLASMA PROTEIN

Deficiency of albumin in the blood.

PARASITIC INFECTION

- The parasite worm *Brugia* sp. infects the lymphatic vessel and prevents the flow of lymphatic fluid.
- The infected part, for example, leg will swell.
- The patient contracts lymphatic filariasis (Photograph 10.8).
- This worm is transmitted through mosquito bites.

PROLONGED BEDRIDDEN PATIENTS

Paralysed or stroke patients with limited mobility can suffer from oedema in the legs.

CAUSES OF OEDEMA

FIGURE 10.25 Causes of oedema

PHOTOGRAPH 10.7 Oedema


PHOTOGRAPH 10.8 Swollen leg caused by lymphatic filariasis

Formative Practice 10.8

1 How do parasitic infections happen?

2 Explain what would happen when the tissue fluid fails to return to the blood circulatory system.

3 Predict what would happen to the legs of a patient who has been bedridden for a long period of time? Explain your answer.

4 Lipid droplets or fat globules cannot diffuse into the villus blood capillary but must diffuse through the lacteal. Explain why.

10.8.1

Summary

TRANSPORT IN HUMANS AND ANIMALS

Circulatory System

Open Circulatory System
Haemolymph flows into the body cavities (haemocoel) and bathes cells

Insects
One or more hearts pump haemolymph through the haemolymph vessel into the haemocoel

Closed Circulatory System
Blood is contained in the closed blood vessel that is continuous and is distributed to the whole body

Fish
The fish heart has two chambers: an atrium and a ventricle

Amphibians
The heart of an amphibian consists of three chambers: two atria and one ventricle

Humans
The human heart consists of four chambers: two atria and two ventricles that are completely separated

Lymphatic System

Components of the lymphatic system
- Lymph
- Lymphatic capillaries
- Lymphatic vessel
- Lymph nodes
- Lymphatic organs

The necessity of the Lymphatic System
- Complements the blood circulatory system
- Transportation of fat-soluble substances
- Body defence

Health Issues Related to the Human Lymphatic System
- Lymphatic filariasis
- Parasitic infection
- Deficiency in plasma protein
- Pregnancy
- Prolonged bedridden patients

Circulatory System of Humans
- Blood
- Heart
- Blood vessel

Mechanism of Heartbeat

Mechanism of Blood Clotting

Health Issues Related to Blood Clotting
- Thrombosis
- Embolism
- Haemophilia

Blood Groups of Humans
- Blood type A
- Blood type B
- Blood type AB
- Blood type O
- Rhesus factor

Health Issues Related to the Human Circulatory System
- Arteriosclerosis
- Atherosclerosis
- Hypertension
- Angina
- Myocardial infarction
- Stroke

Self Reflection

Have you mastered the following important concepts?

- The circulatory system in a multicellular organism
- Components of the human circulatory system and to compare and contrast the types of blood vessels
- Mechanism of the human heartbeat and the generation of force for blood circulation
- Mechanism of blood clotting
- The ABO blood system and Rhesus factor
- Health issues related to the circulatory system
- The formation of tissue fluid and lymph
- Describe components of the lymphatic system
- Health issues related to the lymphatic system

Summative Practice 10

1 An accident victim with blood group B needs an immediate blood transfusion. Is it safe for the patient to receive blood from individuals with the blood group O? Explain why.

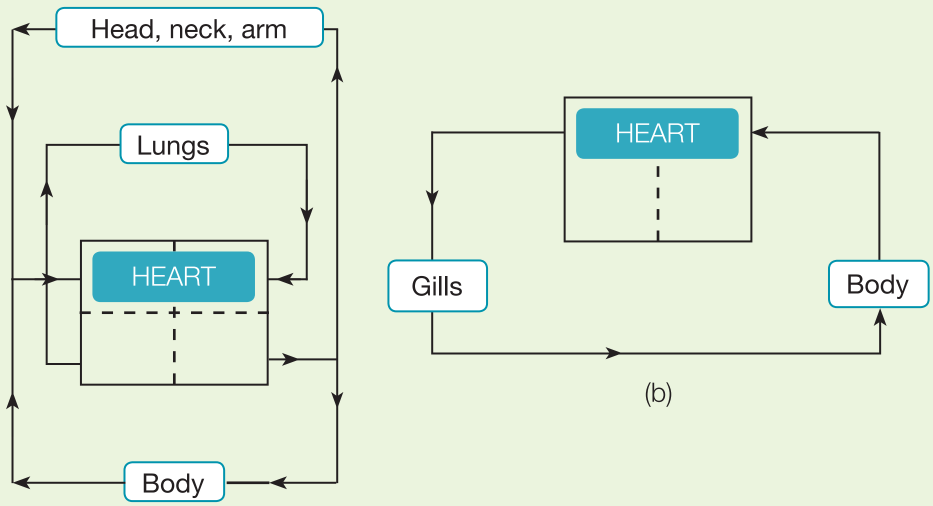
2 An individual has a low number of erythrocytes. Explain the effect of this situation on his/her health. Suggest the types of food that should be consumed by the individual to recover from this situation.

3 The human heart has a pacemaker. The heart pacemaker that is damaged can be replaced by an electronic pacemaker. Explain how the electronic pacemaker functions.

4 Name one example of nutrient found in blood and how the nutrient can be transported to cells.

5 One of the lymphatic vessels of an individual is clogged.
(a) Explain the effects on the lymphatic system of the individual.
(b) Explain what will happen if the lymphatic vessel in the leg is clogged?

6 Figure 1(a) shows a schematic of the blood circulatory system in humans and Figure 1(b) shows the schematic of the blood circulatory system in fish.



(a) (b)

FIGURE 1

(a) Explain the blood circulatory system of fish.
(b) Based on Figure 1, compare the human and fish blood circulatory system.
(c) Explain the similarities between the two blood circulatory systems.
(d) Why does the blood flow in fish encounter more obstacles compared to the blood flow in humans and explain how the fish can overcome this problem?

Essay Questions

7 Coronary heart disease is the main cause of death in our country. The following factors can increase the risk of an individual contracting this disease:

- smoking
- unbalanced diet
- unhealthy lifestyle

Explain how these factors can contribute to coronary heart disease.

8 (a) Explain how the rhythmic contraction of heart muscles occurs.
(b) Ali's leg feels numb after sitting cross-legged for an hour. Suggest the action to be taken and give your reasons.
(c) Elly enjoys eating beef rendang and nasi lemak. Explain why this practice of eating in the long term can affect her health.

Enrichment

9 (a) A baby is born with a damaged bicuspid valve which cannot close tightly. Explain the effect of this condition on the baby.

(b) A normal baby has a thick muscular heart wall that separates the left heart from the right heart. If this muscle is not formed completely, predict the outcome on the quality of blood that flows into the aorta.

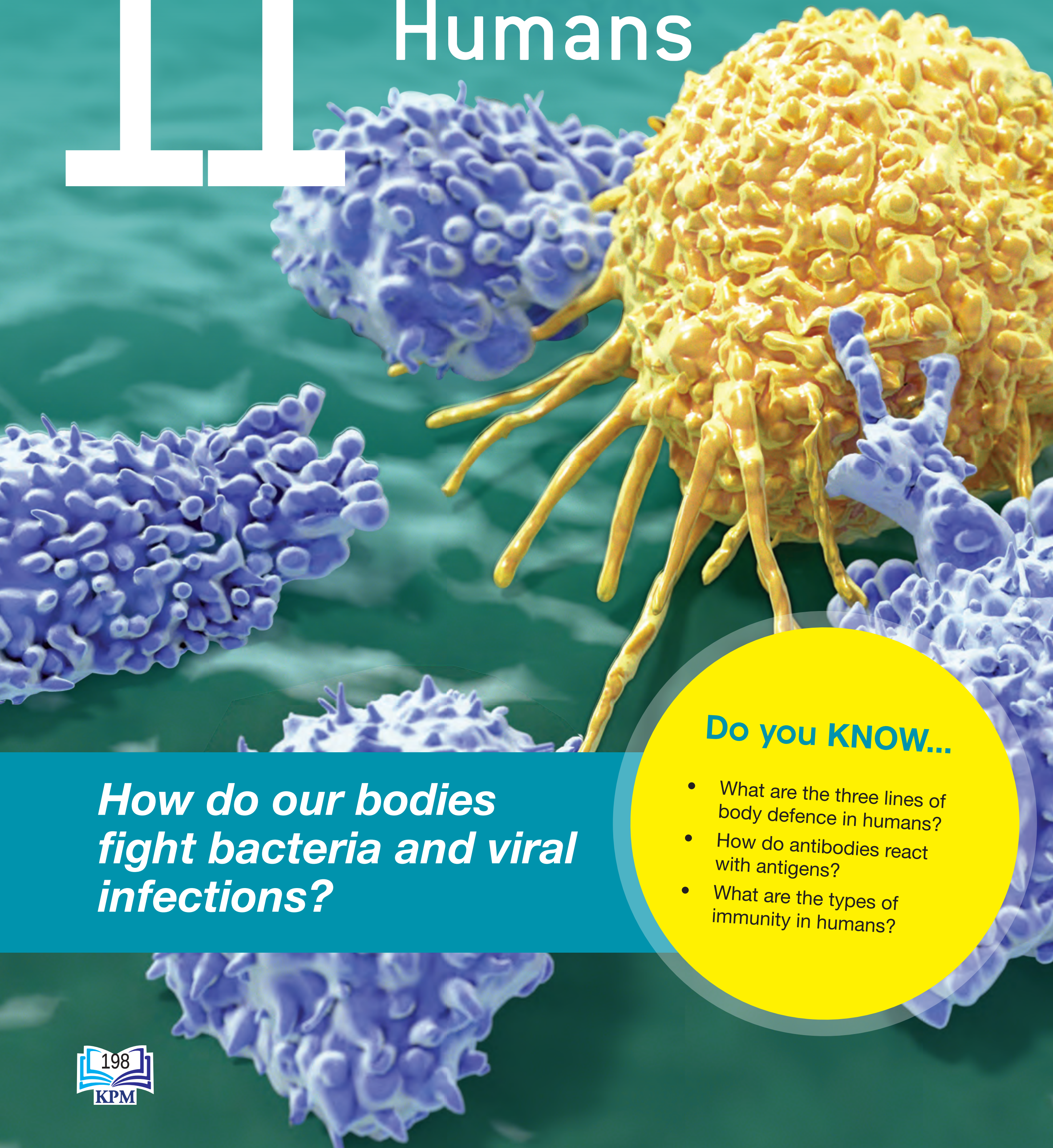
10 How should an individual with a coronary artery that is clogged with cholesterol deposits be treated?

11 Each year, thousands of people die from excessive blood loss caused by injuries during accidents or war. One way to reduce the continuous outflow of blood from the injury is to apply pressure on the wound with a bandage. In your opinion, what adaptations can be done to the bandage to make it more efficient in stopping blood loss temporarily until the patient is admitted to the hospital?

Complete answers are available by scanning the QR code provided

CHAPTER

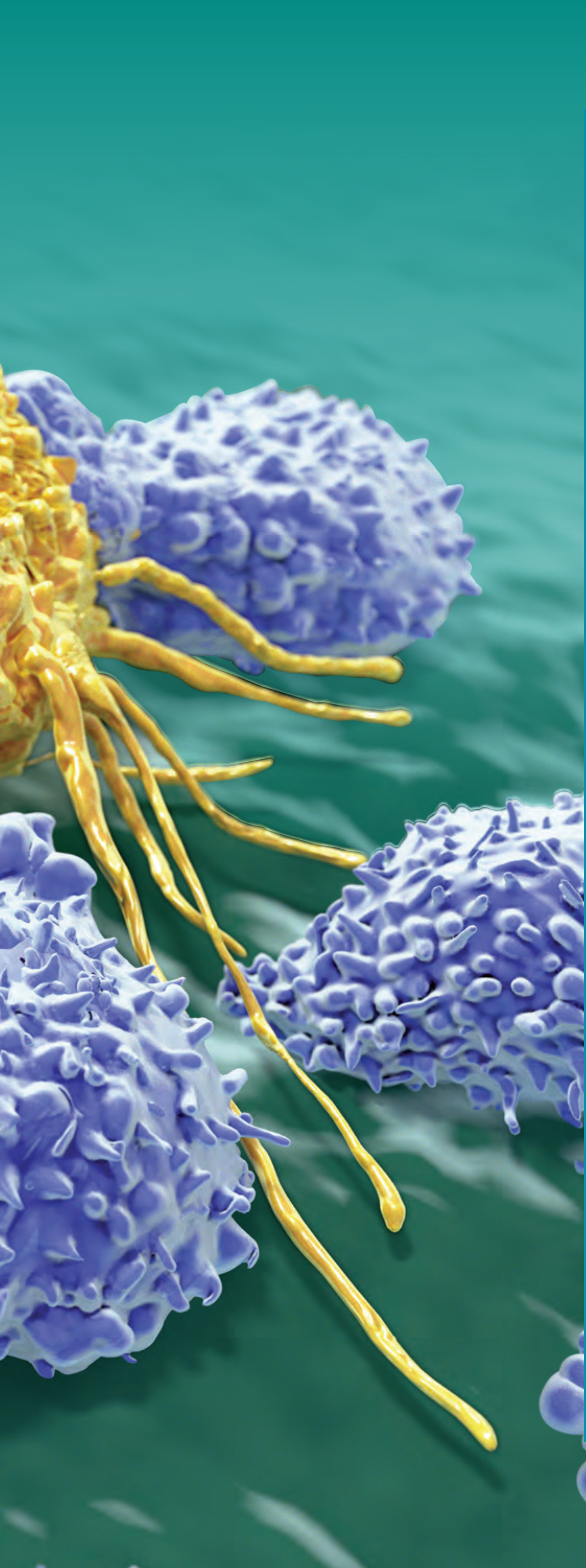
11 Immunity in Humans



How do our bodies fight bacteria and viral infections?

Do you KNOW...

- What are the three lines of body defence in humans?
- How do antibodies react with antigens?
- What are the types of immunity in humans?



11.1 Body Defence

11.1.1 Define:
- immunity
- antigen
- antibody

11.1.2 Describe the three lines of body defence in humans:
- the first line of defence:
  - physical
  - chemical
- the second line of defence:
  - fever
  - inflammation
  - phagocytosis
- the third line of defence:
  - antibody
  - memory cell

11.2 Actions of Antibodies

11.2.1 Discuss the actions of antibodies on foreign antigens:
- neutralisation
- agglutination
- precipitation
- opsonisation
- lysis

11.3 Types of Immunity

11.3.1 Communicate about the types of immunity:
- passive immunity
- active immunity

11.3.2 Compare and contrast passive immunity and active immunity

11.4 Health Issues Related to Immunity

11.4.1 Describe health issues related to Acquired Immuno Deficiency Syndrome (AIDS).

11.1 Body Defence

You may recall learning about the body defence system in Form 2. The body defence system reacts when pathogens infect the body. A **pathogen** is a microorganism that causes diseases. Examples of pathogens include bacteria (singular: bacterium), viruses and parasites. Pathogens can only cause diseases if they successfully infect body cells.

The body defence system recognises pathogens as foreign particles known as **antigens**. Antigens are foreign particles that enter the body and subsequently stimulate the immune response.

Antigens stimulate the lymphocytes to produce antibodies into the blood flow to destroy the antigens. **Antibodies** are proteins found on the lymphocyte surface or proteins released by lymphocytes into the blood plasma. The interaction between antibodies and antigens that cause antigens to be destroyed is called the **immune response** (Figure 11.1).

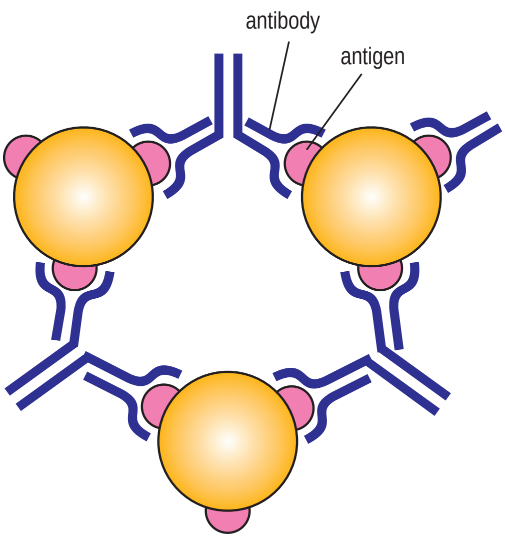


FIGURE 11.1 Interaction between antibodies and antigens

Immunity is the body's ability to fight infections caused by pathogens or other foreign objects, through specific attacks on the pathogens.

When our body can fight a disease, we are said to be immune to that disease.

There are three lines of defence to fight against diseases in our body:

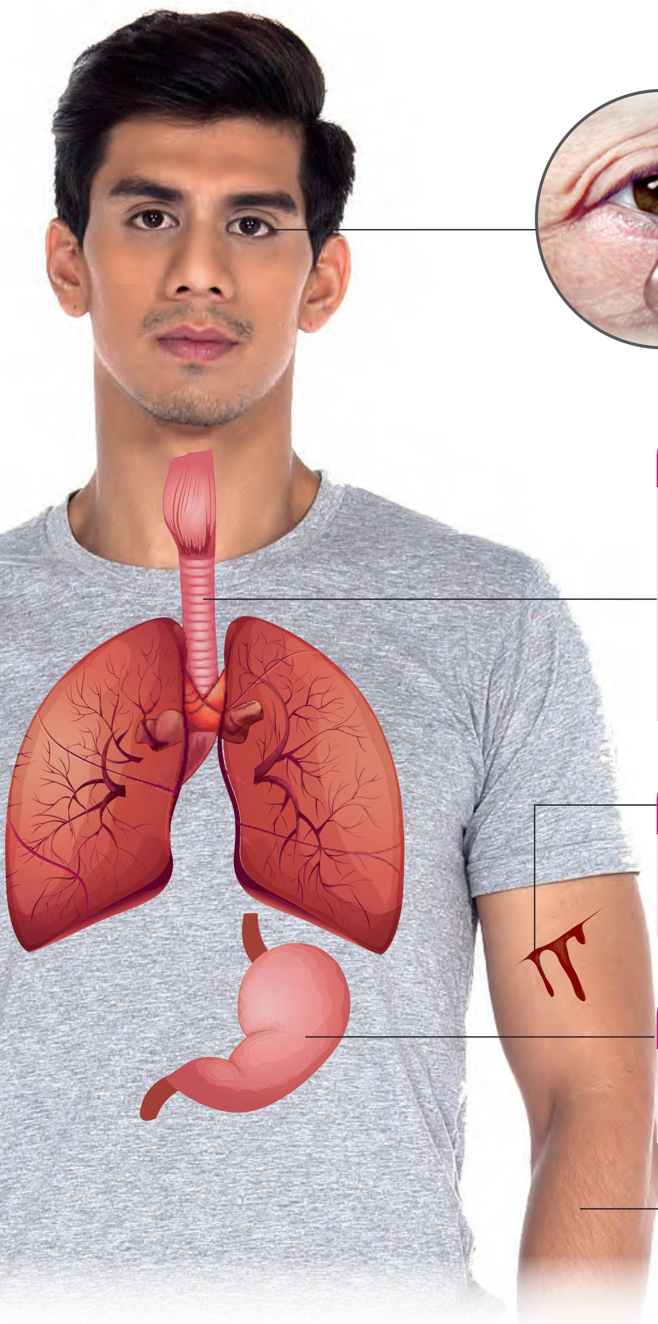
- The first line of defence
- The second line of defence
- The third line of defence

The first line of defence

The first line of defence consists of the physical and chemical line-up that prevent pathogens from entering the body. The first line of defence is the defence line that is not specific and acts to prevent pathogens from entering the body. Figure 11.2 shows the organs and mechanisms involved in the first line of defence.

Activity Zone

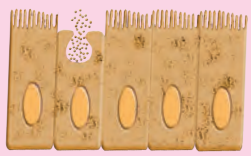
List the physical and chemical defences found in the first line of defence.



LYSOZYME

Lysozyme found in the secretion of tears, nasal mucus and saliva, is an antimicrobial protein that can dissolve and destroy some types of bacteria.

MUCOUS MEMBRANE



The mucous membrane that lines the respiratory tract secretes a sticky fluid called **mucus**. Mucus contains lysozyme that destroys bacteria found in the air that enters the respiratory system.

MECHANISM OF BLOOD CLOTTING

The blood clotting mechanism prevents bacteria from entering through wounds.

HYDROCHLORIC ACID

Hydrochloric acid in the stomach destroys bacteria present in food and drinks.

FIGURE 11.2 The first line of defence

SKIN

- It is the physical defence that prevents the entry of pathogens because it is tough and is difficult for microorganisms to penetrate.
- The continuous shedding of dead cell layers on the skin surface makes it difficult for various types of microorganism to grow.
- Acts as a chemical shield through the secretion of sebum. Oil and acid in the sebum prevent the growth of various types of microorganisms.
- Sweat secreted by the skin contains lysozyme, a type of enzyme that breaks down the cell wall of some bacteria.

The second line of defence

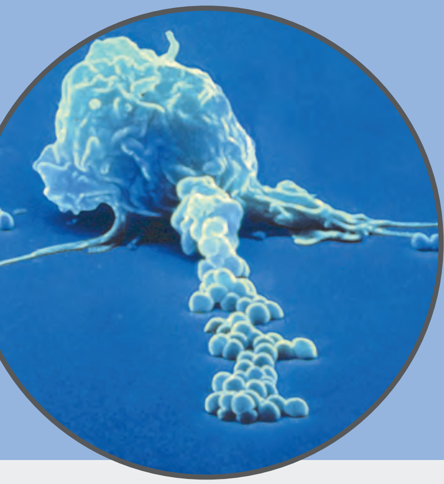
- The second line of defence is **fever, phagocytosis** and **inflammation**.
- The mechanism of the second line of defence is also not specific.

Fever

Fever is the second line of defence mechanism that fights infections. Fever increases phagocytic activity and fights against microorganisms that infect the body.

Phagocytosis

- The phagocyte is a leucocyte that can carry out phagocytosis. Neutrophils and monocytes are phagocytes.
- **Phagocytosis** is the process by which microorganisms or other particles such as dead cells are trapped and digested by phagocytes.
- When an infection occurs, the phagocytes move to the infected area and enter the tissue fluid through the pores of the capillary wall.
- When a phagocyte encounters a pathogen, the phagocyte will engulf the pathogen and the lysozyme in the phagocyte will digest the pathogen (Photograph 11.1).
- The stages of phagocytosis are summarised in Figure 11.3.



PHOTOGRAPH 11.1 The electron micrograph shows a phagocyte extending its pseudopodium to engulf bacteria

ICT 11.1

Video: Phagocytosis (Accessed on 21 August 2019)

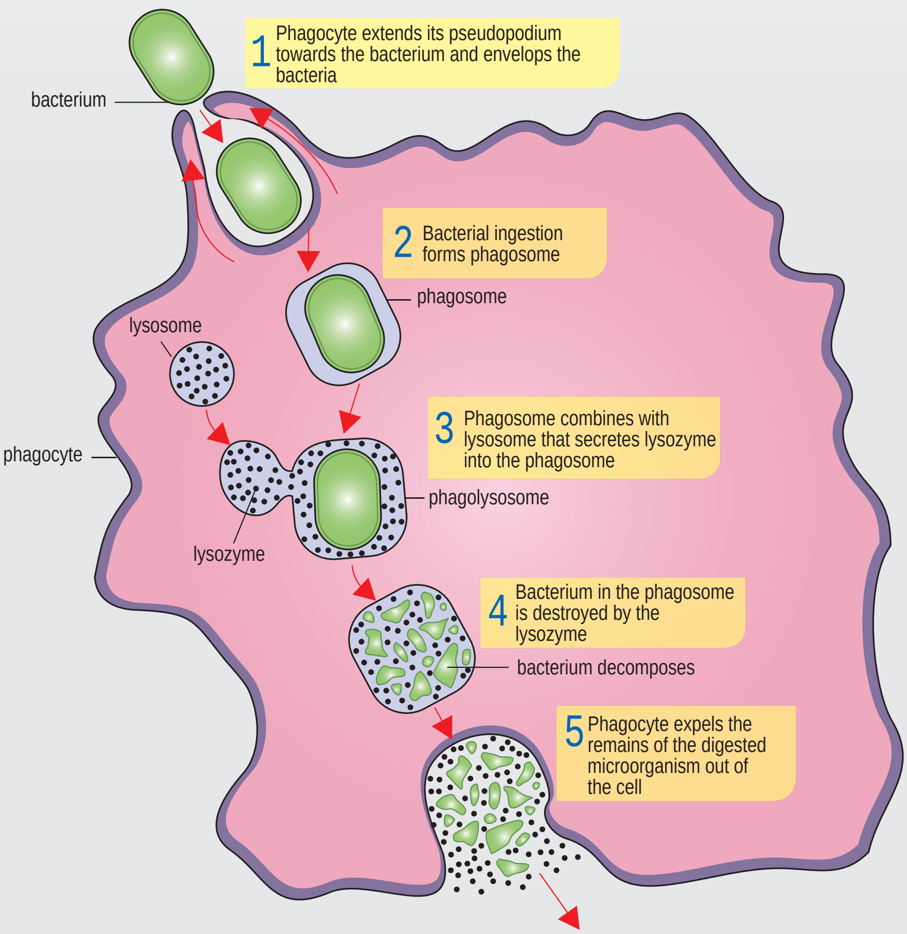


FIGURE 11.3 The phagocytosis stages

Inflammation

Inflammation is the immediate response that destroys and neutralises harmful actions of microorganisms and toxins at the early stages of infection. The inflamed area will swell, turn red and feel painful. The response to inflammation is described in Figure 11.4.

Biological Lens

Pus is a combination of microorganisms, fragments of tissues and white blood cells that can be found in seriously infected areas or damaged tissues.

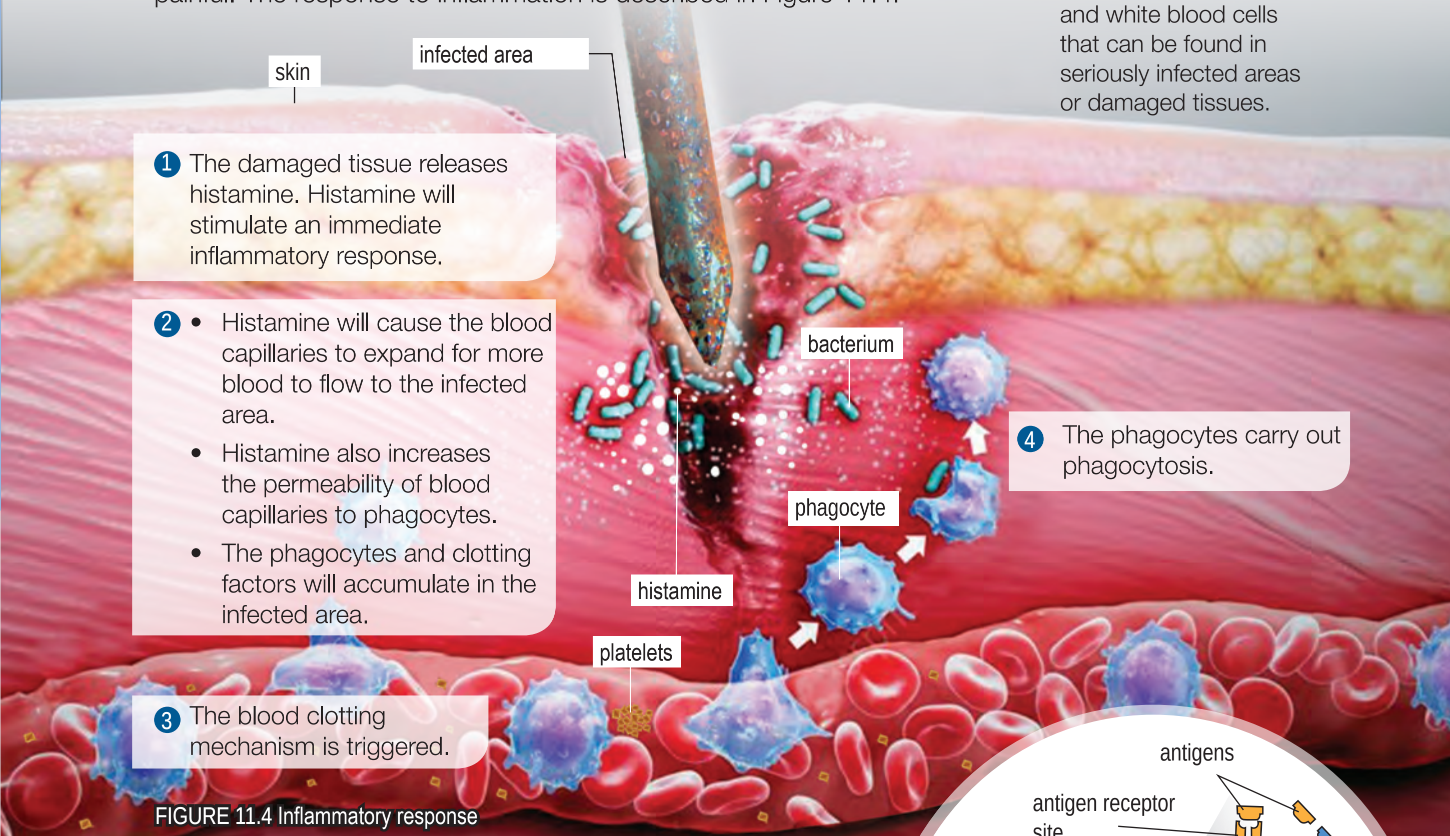


FIGURE 11.4 Inflammatory response

The third line of defence

If pathogens overcome the second line of defence, the third line of defence will be activated. The third line of defence is the **immune response** of the lymphocytes.

- The lymphocytes formed in the lymph nodes produce antibodies.
- The actions of antibodies are specific. Each type of antibody can only combine with a certain type of antigen (Figure 11.5).
- When a person is infected with pathogens, a large number of lymphocytes will accumulate in the lymph nodes to destroy the antigens and foreign particles. This will cause the lymph nodes to swell.
- The lymph nodes also contain macrophages that destroy bacteria, dead tissues and foreign particles through phagocytosis.
- Lymphocytes are divided into two types, T lymphocytes and B lymphocytes.
- The T lymphocyte attacks cells infected by pathogens. T lymphocytes stimulate B lymphocytes to produce memory cells.
- If the same pathogen attacks, the memory cells will be stimulated to produce antibodies immediately.

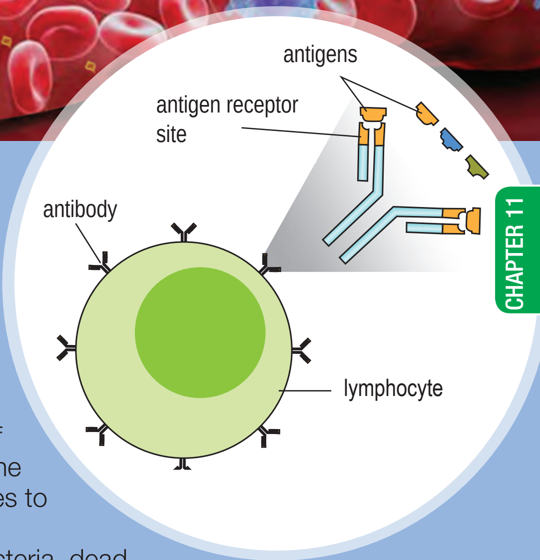


FIGURE 11.5 The antigen molecule will combine with the antigen receptor site found in the antibody molecule

CHAPTER 11

11.1.2

Formative Practice 11.1

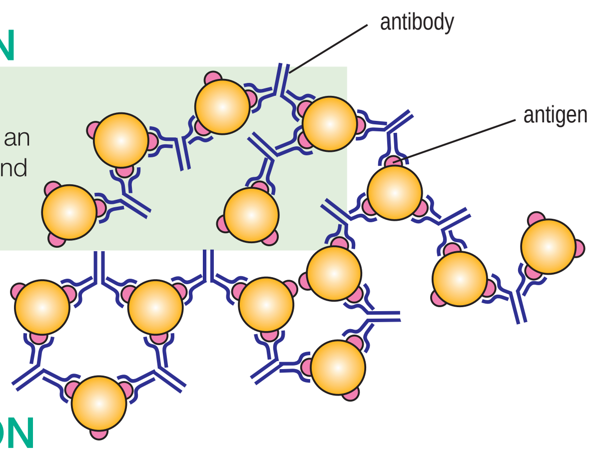
1 What is the meaning of immunity?
2 Name two characteristics of the skin that allows the skin to react as an effective first line of defence.
3 How does the phagocyte destroy pathogens that have penetrated the first line of defence?
4 Differentiate between antigens and antibodies.

11.2 Actions of Antibodies

Antigens are destroyed by antibodies through several mechanisms as illustrated in Figure 11.6.

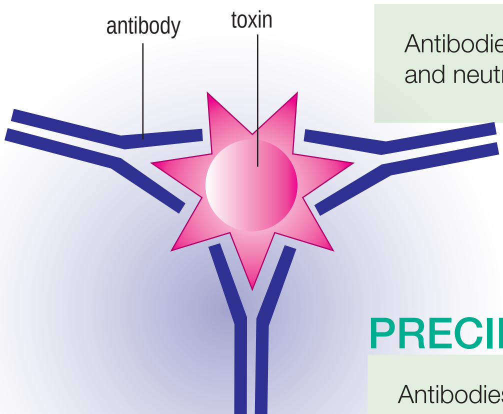
AGGLUTINATION

Antibodies coagulate the pathogens and make them an easy target to be trapped and destroyed by phagocytes.



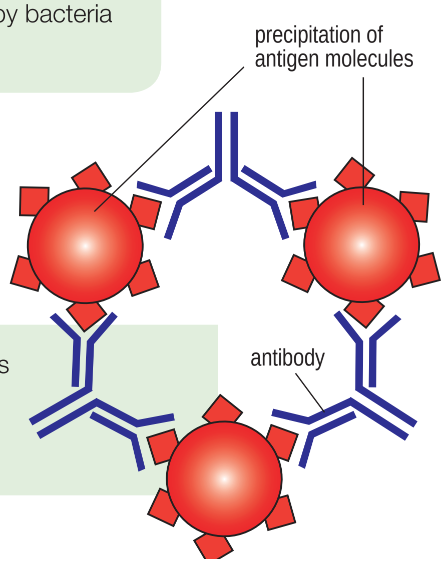
NEUTRALISATION

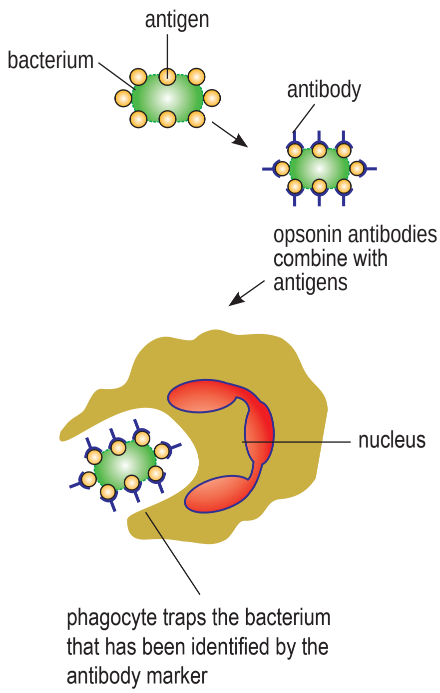
Antibodies bind with toxins produced by bacteria and neutralise the toxin.



PRECIPITATION

Antibodies react with dissolved antigens to form an insoluble complex (precipitate) that is easily destroyed by phagocytes.





OPSONISATION

Antibodies combine with antigens and act as a marker for phagocytes to recognise the antigens and destroy them.

LYSIS

Antibodies combine with antigens and cause bacteria to be broken down and decomposed.

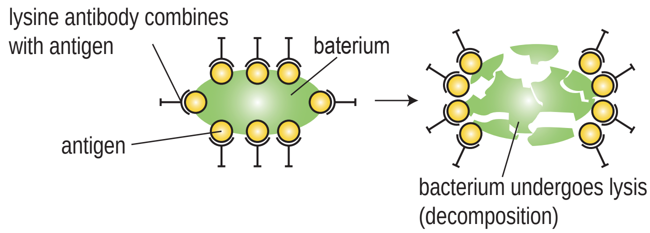


FIGURE 11.6 Action of antibodies on antigens

11.3 Types of Immunity

There are two types of immunity: **active immunity** and **passive immunity.** Active immunity means that lymphocytes produce their own antibodies as a response to stimulation by the antigens. Passive immunity means that the body receives antibodies from an external source. Both of these types of immunities can be naturally or artificially acquired.

Our World of Biology

The Ministry of Health (MOH) recommends that babies aged 2 to 3 months be immunised against diseases such as diphtheria, pertussis, tetanus, poliomyelitis and meningitis.

IMMUNITY

ACTIVE IMMUNITY

- **Natural active immunity**
  Acquired after an individual recovers from an infection
- **Artificial active immunity**
  Acquired when an individual is given a vaccine injection

PASSIVE IMMUNITY

- **Natural passive immunity**
  Acquired through breastfeeding and from the mother to the foetus during pregnancy
- **Artificial passive immunity**
  Acquired through an antiserum injection

Active immunity and passive immunity

Let us examine active immunity and passive immunity in greater detail.

Brainstorm!

Why are only female pupils given the HPV vaccination *(Human papillomavirus)*?

ACTIVE IMMUNITY

- Antibodies are produced naturally by lymphocytes.
- Active immunity remains for a long period of time.

NATURAL ACTIVE IMMUNITY

- When someone is infected by pathogens, lymphocytes will produce **antibodies** as a response to these antigens.
- When an individual recovers from an infection, that individual will gain a permanent immunity against the disease.
- When the individual is attacked again by the same pathogen, the lymphocytes that stored memories of the pathogen, that is, **memory cells** will rapidly produce antibodies to react immediately against the antigens.

ARTIFICIAL ACTIVE IMMUNITY

- To protect oneself from being infected by a highly infectious disease, an individual can be immunised against the disease.
- **Immunisation** refers to the process that stimulates immunity against a specific disease through vaccine injections.
- Vaccine is a suspension of pathogens that are weakened, dead or non-virulent.
- When a vaccine is injected into the body, the vaccine will stimulate lymphocytes to produce antibodies to fight the pathogens.
- The first vaccine injection will usually result in a low level of antibody production which is insufficient to protect an individual from the disease. A booster dose must be administered to increase the antibody production to a level of immunity that can protect the individual from the disease.
- If the individual is infected by actual pathogens, the lymphocytes will produce enough antibodies and immediately destroy these pathogens.
- Examples of vaccines are the Salk vaccine for poliomyelitis, BCG vaccine (*Bacille Calmette-Guerin*) for tuberculosis (TB) and HPV vaccine for cervical cancer.

PHOTOGRAPH 11.2 An individual who has recovered from chickenpox or influenza has gained a natural active immunity

PHOTOGRAPH 11.3 Immunisation protects a person from being infected by infectious diseases

PASSIVE IMMUNITY

- The body does not produce its own antibodies.
- Antibodies are obtained from an external source.
- Passive immunity does not persist and can only give immediate, short-term and temporary protection.

NATURAL PASSIVE IMMUNITY

- This immunity is acquired by a foetus when the **mother's antibodies** diffuse through the placenta into the blood flow of the foetus.
- Antibodies also protect the baby for the first few months after birth through antibodies that are found in the mother's milk or colostrum when breastfeeding.

PHOTOGRAPH 11.4 Babies gain natural passive immunity from the mother's milk

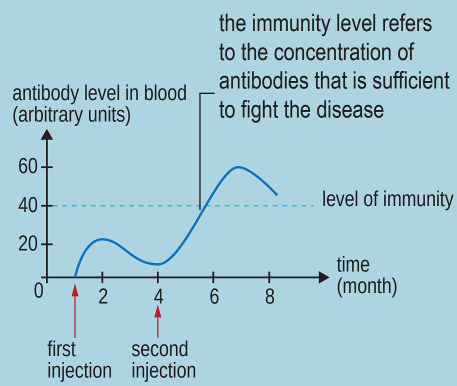
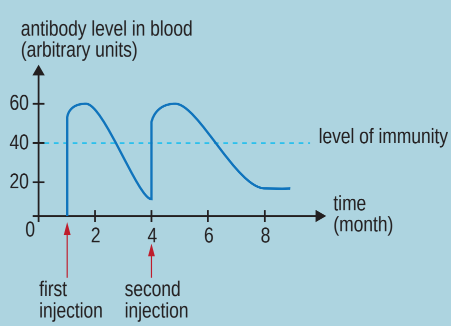
ARTIFICIAL PASSIVE IMMUNITY

- This immunity is acquired through an **antiserum injection** or **serum** that contains specific antibodies to fight specific antigens.
- The antiserum injection gives immediate protection but only for a short period of time.
- Examples of antiserum are antitetanus, anti-rabies and antiserum for poisonous snakes.

FIGURE 11.7 Antitetanus preparation

TABLE 11.1 Comparison between artificial active immunity and artificial passive immunity

Similarities
• Protects the body from infectious diseases • Involves interaction between antibodies and antigens

Differences		
Aspect	**Artificial Active Immunity**	**Artificial Passive Immunity**
Acquired through	Vaccine injection	Antiserum injection
Injected substance	Vaccine is a suspension of pathogens that are weakened, dead or non-virulent.	Antiserum is a serum that contains specific antibodies.
Purpose	Prevention	Treatment or when immediate protection is required
Effect	Does not give immediate protection	Gives immediate protection
Immunity period	Immunity lasts for a long period of time	Immunity is temporary and does not persist
When injection is given	Vaccine injection is administered before being infected	Antibody injection is given in advance if there is a high risk of infection or immediately after being infected by a disease
Antibody	Antibodies are produced by the lymphocytes	Antibodies are obtained from antiserums
The need to give a second injection (booster dose)	Must be given to boost the level of antibodies above the level of immunity as a protection against the disease  FIGURE 11.8 The antibody level in the blood of a person after the first and second vaccinations	Is only given when the antibody level in the blood drops below the level of immunity and the patient is still infected by the disease  FIGURE 11.9 The antibody level in the blood of a person after the first and second antiserum injections

Formative Practice 11.2

1. What are the types of immunity that decrease according to time? Explain why.
2. Propose immediate treatment that can be given to someone who has been bitten by a poisonous snake.
3. State one difference between artificial passive immunity and artificial active immunity.
4. In your opinion, why must we follow and complete the immunisation plan in Malaysia?

11.4 Health Issues Related to Human Immunity

Acquired Immunodeficiency Syndrome (AIDS)

Biological Lens

HIV is able to mutate and change the cell structure when it spreads. This gives the virus a high resistance to drug therapy.

The **human immunodeficiency virus (HIV)** is a virus that attacks the human immune system. HIV infection causes ***Acquired Immunodeficiency Syndrome*** **(AIDS)**.

An AIDS patient is easily infected by other diseases because of the progressive destruction of the individual's immune system. HIV spreads in the lymphocyte and destroys the lymphocyte (Photograph 11.5).

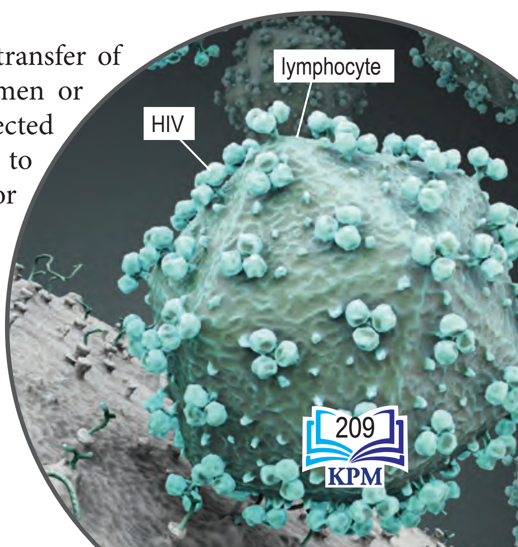
An individual infected with HIV does not show any symptoms for the first few years although HIV has been actively attacking the immune system. Symptoms of the disease include chronic diarrhoea and fungi infection which are only visible after 8 to 10 years. Since the immune system of the individual is already weakened, the body can be easily infected by diseases. Finally, the immune system is paralysed and the patient will die from other infections.

Millennial Career

Immunologists are specialists in allergy diseases and diseases that involve the immune system.

HIV transmission

HIV enters the body through the transfer of body fluids such as blood and semen or across the placenta. Women infected with HIV can transfer the virus to the baby during pregnancy, birth or breastfeeding.



PHOTOGRAPH 11.5 HIV attacks lymphocyte

11.4.1

Nevertheless, HIV infection in the foetus and newborn baby can be avoided with proper medical treatment when the mother is pregnant and during birth.

Individuals can be infected by HIV through unprotected sexual relations with an infected individual. They can also be infected when they share contaminated needles used to inject drugs or tattoo ink. In addition, HIV is also spread through HIV-infected blood transfusion.

There are a few types of diseases and conditions related to the immune system. Conduct the following research study activity to find out more.

Activity 11.1 Conducting a research study on issues related to the human immune system

Research study

Materials

Medical magazines and the Internet

Procedure

1 Conduct a research study with a friend on:
   - *Systemic Lupus Erythematosus* (SLE)
   - Allergy
2 Discuss your findings with friends from other groups and present the findings of each group.

Formative Practice 11.3

1 What is the meaning of AIDS?
2 Explain how HIV infection can cause someone to suffer from AIDS.
3 Why is a person who is infected with HIV, may not necessarily suffer from AIDS?
4 How can AIDS be prevented?

Summary

IMMUNITY IN HUMANS

Body Defence

The first line of defence
- Physical
  - Skin
- Chemical
  - Sebum
  - Sweat
  - Lysozyme
  - Mucous membrane
  - Hydrochloric acid
  - Mechanism of blood clotting

The second line of defence
- Fever
- Inflammation
- Phagocytosis

The third line of defence
- Antibody
- Memory cell

Actions of Antibodies

- Neutralisation
- Agglutination
- Precipitation
- Opsonisation
- Lysis

Types of Immunity

Active immunity
- Active natural immunity (when someone is infected by pathogens, lymphocytes will produce antibodies as a response to the antigen)
- Artificial active immunity (a process that stimulates immunity through vaccine injection)

Passive immunity
- Passive natural immunity (acquired by the foetus in the mother's womb and during breastfeeding)
- Artificial passive immunity (serum injection that contains antibodies that fight against certain antigens)

Health Issues Related to Human Immunity

- Acquired Immunodeficiency Syndrome (AIDS)
- Systemic Lupus Erythematosus (SLE)
- Allergy

Self Reflection

Have you mastered the following important concepts?

- *Definition of immunity, antigen and antibodies*
- *The first, second and third lines of defence in a human body*
- *Antibody action on antigen*
- *Active and passive immunities*
- *Health issues related to human immunity*

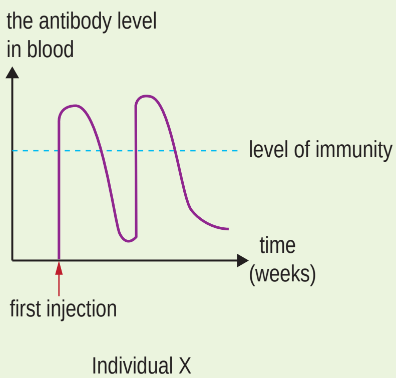
Summative Practice 11

1 Suggest an immediate treatment to an individual bitten by a very poisonous snake.

2 Explain how a mother who has HIV can infect a foetus in her womb.

3 (a) State the type of immunity a foetus receives from its mother.
(b) Explain how the placenta helps in the immune system of the foetus.

4 Figure 1 illustrates the changes in the antibody levels in the blood of individuals X and Y for a specific period of time.



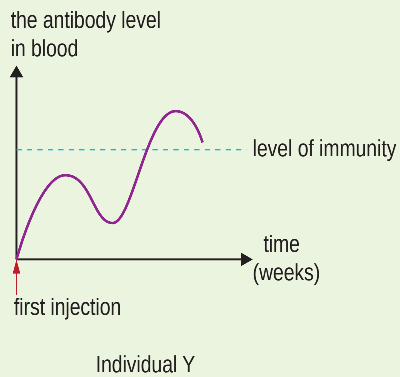


FIGURE 1

(a) (i) What type of immunity did individuals X and Y acquire?
(ii) State the substance injected in individuals X and Y.
(iii) Explain the differences in the content of the substances you mentioned in (a)(ii).

(b) (i) On the graph curves of individuals X and Y, mark with an arrow, the time of the second injection is given.
(ii) Why do individuals X and Y need a second injection?
(iii) Based on the graph curves for individuals X and Y, state two differences in the immunity achieved by individuals X and Y.

Essay Questions

5 Two individuals acquired immunity against chickenpox in different situations. Individual X recovered from chickenpox. Individual Y was injected with a type of suspension and received immunity against chickenpox after a few months.
Explain the immunity acquired by
(a) individual X
(b) individual Y

6 (a) A newborn baby needs to receive immunisation based on the Immunisation Plan recommended by the World Health Organisation (WHO).
Explain why the immunisation programme is required.

(b) (i) Some vaccine injections require only one dose throughout the lifetime of an individual. Explain why.
(ii) Sinti's mother forgot to bring Sinti to the clinic for the third dosage of the hepatitis vaccination. Explain the effects on Sinti's immunity.
(iii) Aziman accidentally stepped on a rusty nail during a mountain climbing expedition. Describe the type of injection that is suitable to be administered by the doctor. Explain your answer.

(c) Explain how HIV can paralyse the immune system of a person infected by the virus.

Enrichment

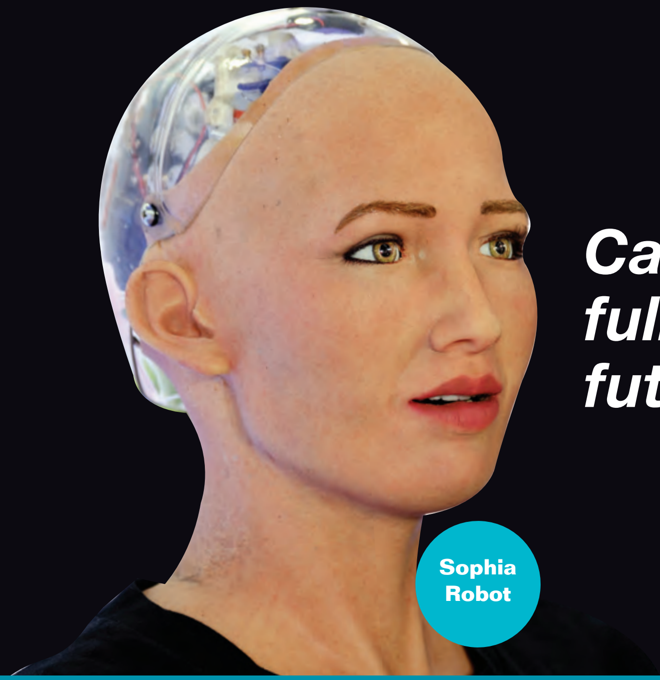
7 Sometimes doctors prescribe antibiotics to treat some infectious diseases. Doctors will advise taking all the antibiotics prescribed for the recommended period. Explain why it is important to follow this step.

8 You visited a sick friend in a hospital. MRSA (*methicillin-resistant Staphylococcus aureus*) is a strain of bacteria that is usually found in hospitals. This bacterial strain is immune to many types of antibiotics due to the numerous types of antibiotics used to treat patients in the hospital. Suggest steps that you can take to prevent the infection of MRSA.

Complete answers are available by scanning the QR code provided

CHAPTER 12

Coordination and Response in Humans



Can robots function fully like humans in the future?

12.1 Coordination and Response

12.1.1 Make a sequence and describe the components in human coordination:
- stimulus
- receptor
- integration centre
- effector
- response

12.1.2 Identify and describe external and internal stimuli.

12.1.3 List the types of sensory receptors based on the stimuli involved:
- chemoreceptor
- mechanoreceptor
- photoreceptor
- thermoreceptor
- baroreceptor
- nociceptor

12.1.4 Justify the necessity to respond to external and internal stimuli.

12.2 Nervous System

12.2.1 Construct an organisational chart and explain the structures of the human nervous system:
- central nervous system
  – brain – spinal cord
- peripheral nervous system
  – sensory receptor
  – cranial nerve
  – spinal nerve

12.2.2 Explain the functions of parts of the central nervous system related to coordination and response:
- brain
  – cerebrum – hypothalamus
  – cerebellum – pituitary gland
  – medulla oblongata
- spinal cord

12.2.3 Communicate about the functions of parts of the peripheral nervous system in coordination and response.

12.3 Neurones and Synapse

12.3.1 Draw and label structures of a sensory neurone and a motor neurone:
- dendrite
- myelin sheath
- axon
- node of Ranvier
- cell body

12.3.2 Analyse the functions of each type of neurone in impulse transmission.

12.3.3 Explain the structure and function of synapse.

12.3.4 Explain the transmission of impulse across a synapse.

12.4 Voluntary and Involuntary Actions

12.4.1 Compare and contrast voluntary and involuntary actions.

12.4.2 Describe the reflex actions involving:
- two neurones
- three neurones

12.4.3 Draw a reflex arc.

12.5 Health Issues Related to the Nervous System

12.5.1 Communicate about the health issues related to the nervous system.

12.5.2 Describe the effects of drug and alcohol abuse on human coordination and response.

12.6 Endocrine System

12.6.1 State the role of endocrine glands in humans.

12.6.2 Identify and label the endocrine glands in humans.

12.6.3 Analyse the functions of hormones secreted by each endocrine glands:
- hypothalamus
  – gonadotrophin-releasing hormone (GnRH)
- the anterior lobe of pituitary
  – growth hormone (GH)
  – follicle-stimulating hormone (FSH)
  – luteinizing hormone (LH)
  – thyroid-stimulating hormone (TSH)
  – adrenocorticotropic hormone (ACTH)
- the posterior lobe of pituitary
  – oxytocin hormone
  – antidiuretic hormone (ADH)
- thyroid – thyroxine hormone
- pancreas
  – insulin hormone
  – glucagon hormone
- adrenal
  – adrenaline hormone
  – aldosterone hormone
- ovary
  – oestrogen hormone
  – progesterone hormone
- testis
  – testosterone hormone

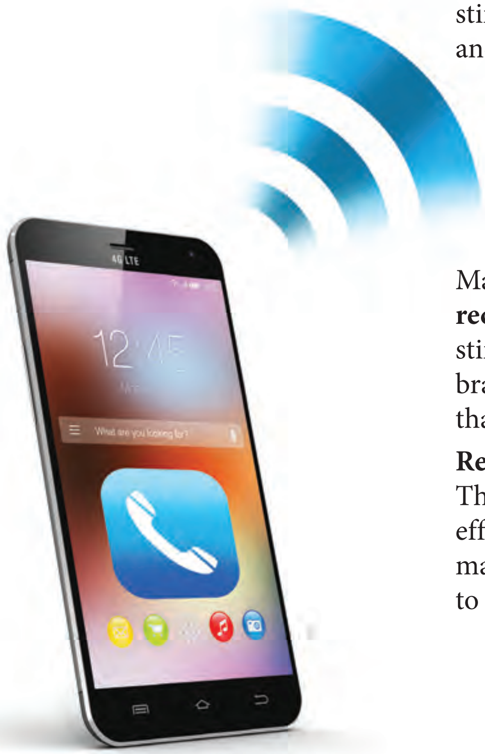
12.6.4 Discuss involvement of the nervous system and endocrine system in a "fight or flight" situation.

12.6.5 Compare and contrast the nervous and the endocrine system.

12.7 Health Issues Related to the Endocrine System

12.7.1 Predict the effects of hormonal imbalances on human health.

12.1 Coordination and Response



Organisms have the ability to detect changes in their environments and respond to these changes. This ability is called **sensitivity** while the change that stimulates the response is known as a **stimulus** (plural: stimuli). The stimulus is divided into two types, that is, **external stimulus** and **internal stimulus**.

(a) Stimuli from the external environment include light, sound smell, taste, surrounding temperature, pressure and touch.

(b) Stimuli from the internal environment include changes in blood osmotic pressure, changes in body temperature and changes in blood sugar level.

Mammals can detect stimuli via the special sensory cells known as **receptors**. When a receptor detects a stimulus such as sound, the stimulus is converted to nerve impulses. Nerve impulses are sent to the brain through nerve cells or neurones. The **brain** is the integration centre that translates nerve impulses and coordinates an appropriate response.

Response refers to the way organisms react after detecting a stimulus. The part of the body that responds is called the **effector**. Examples of effectors are muscles and glands. Figure 12.1 and Figure 12.2 explain the main components and pathways involved in detecting and responding to changes in external and internal environments.

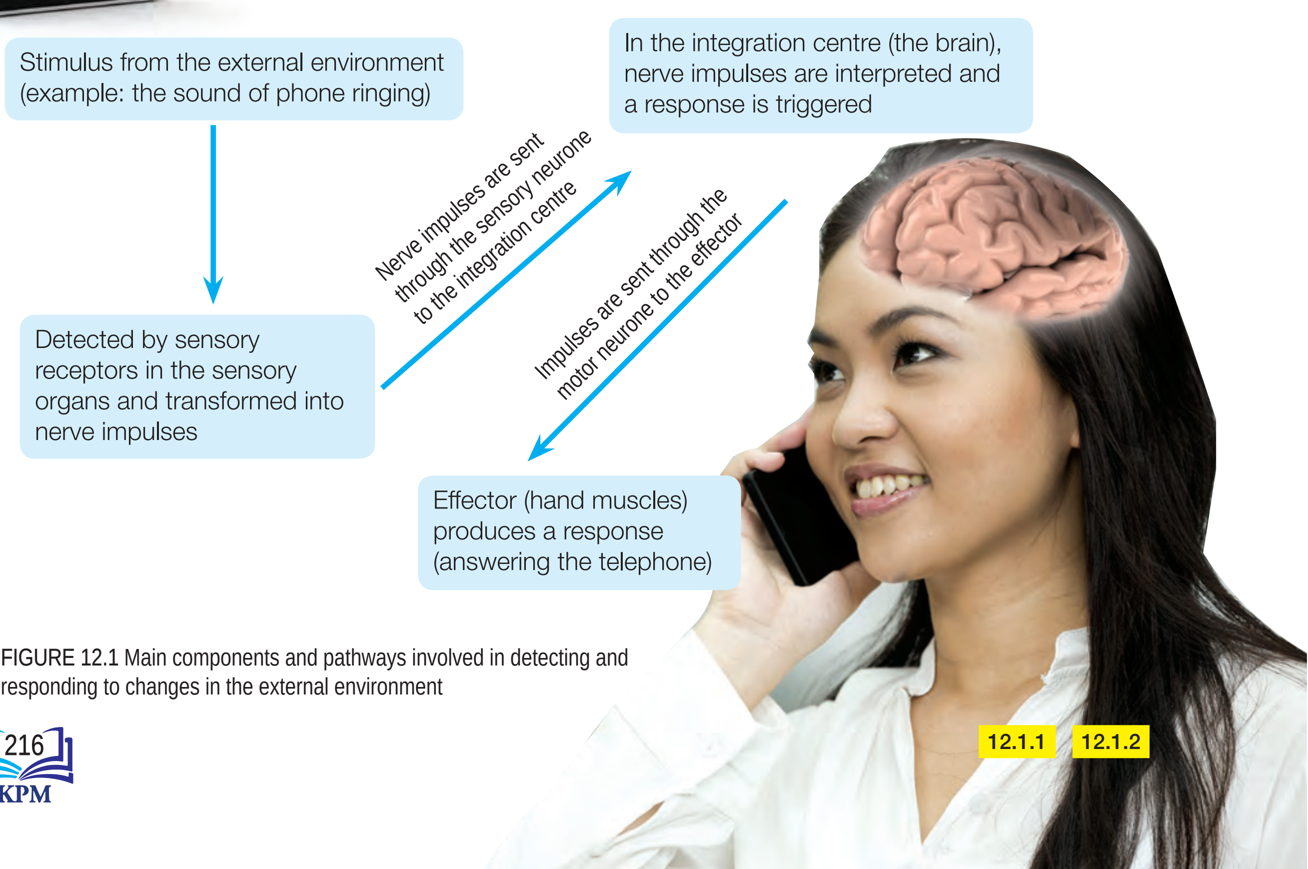


FIGURE 12.1 Main components and pathways involved in detecting and responding to changes in the external environment

12.1.1 12.1.2

Receptors and effectors work together to bring suitable changes depending on the stimulus detected.

Coordination is a stimuli detection process by receptors that ends in appropriate responses by effectors. Coordination ensures that the overall activities and systems of an organism function and are synchronised perfectly as a complete unit. The role of coordination and response is conducted by two separate systems, that is, the nervous system and the endocrine system.

Both systems work together to coordinate and control responses.

Activity Zone

Conduct a role play activity to explain coordination and responses.

FIGURE 12.2 The main components and pathways involved in detecting and responding to changes in the internal environment

12.1.1 12.1.2

Types of receptors

Sensory receptors found at the end of the nerve fibres detect information in the external and internal environments. The location of receptors will depend on the type of stimulus detected. Each type of receptor is usually sensitive to a specific stimulus. For example, the sensory receptors that detect external stimuli are found in special sensory organs such as eyes, nose, tongue and skin. The sensory receptors that detect internal stimuli are present in specific internal organs such as the pancreatic cells that detect blood sugar level.

Across the fields

All receptors can be considered as energy converters, that is, receptors can convert one form of energy into another. For example, the eye photoreceptor converts light energy into electrical signals, which is a form accepted by the nervous system.

TABLE 12.1 Types of sensory receptors and stimulus involved

Sensory receptor	Stimulus
Photoreceptor	Light
Thermoreceptor	Change in temperature
Chemoreceptor	Chemical substances
Baroreceptor	Change in pressure
Mechanoreceptor	Touch and pressure
Nociceptor	Pain

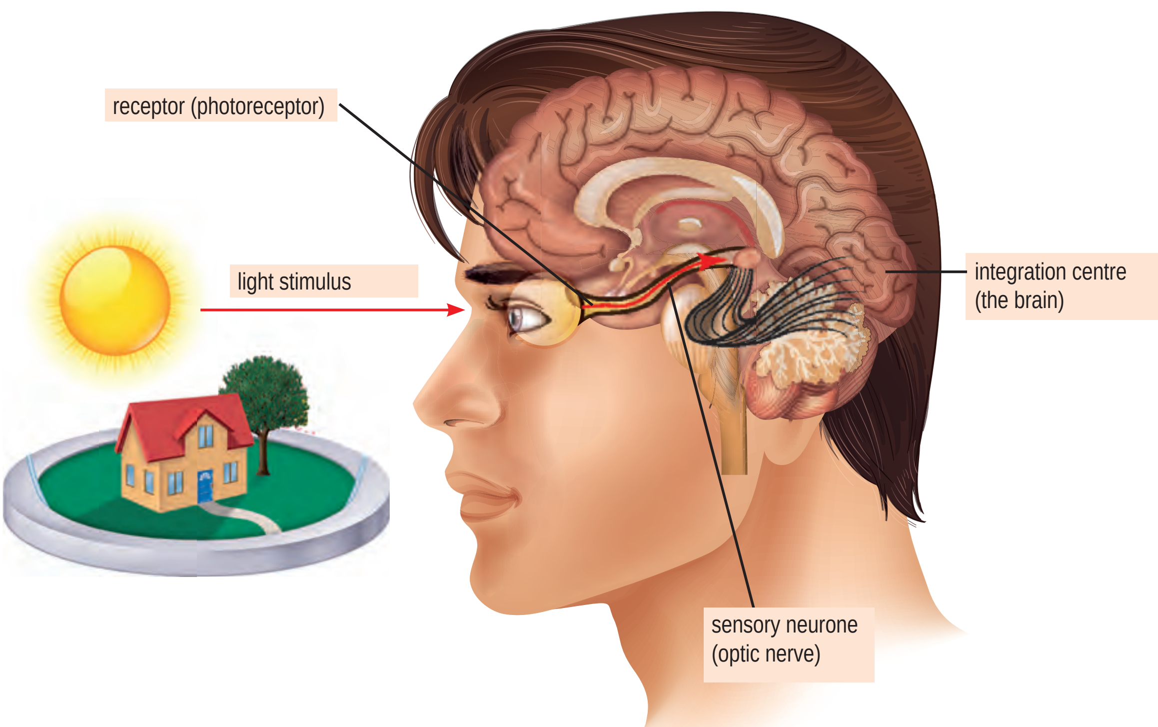


FIGURE 12.3 Detection of external stimulus by the photoreceptor

PHOTOGRAPH 12.1 Animals migrate when they sense changes in the climate

Necessity of response

Why do organisms have to respond to stimuli and internal stimuli? The ability of organisms to detect changes in the external environment and its response to the stimuli is very important for the survival of organisms. For some animals, a sudden change in climate conditions motivates the animals to look for new shelters.

The ability of organisms to detect changes in the internal environment is also crucial so that the information can be transmitted to the integration centre. The integration centre will then transmit this information to the effectors to respond to the changes. For example, when the body temperature increases above the normal range, this information will be transmitted to the integration centre by a receptor. The integration centre will send nerve impulses to the effectors to decrease the temperature back to its normal range. In conclusion, humans and animals need to respond to adapt to the changes in the environment.

PHOTOGRAPH 12.2 A fast response is necessary to save a goal

Formative Practice 12.1

1 What is the meaning of response?

2 Which sensory organ has the mechanoreceptor as a sensory receptor?

3 In your opinion, why is coordination crucial to humans?

4 You feel a mosquito bite on your leg and you hit it. Desribe the pathway involved in detecting and responding to the stimulus of the mosquito bite.

12.2 Nervous System

The human nervous system is made up of a network of nerve cells or neurones. This system is divided into two main subsystems: the **central nervous system** and the **peripheral nervous system** (Figure 12.4).

The central nervous system includes the **brain** and **spinal cord**. The peripheral nervous system consists of 12 pairs of **cranial nerves** and 31 pairs of **spinal nerves**. The cranial nerves send nerve impulses from and to the brain. Spinal nerves send nerve impulses from and to the spinal cord.

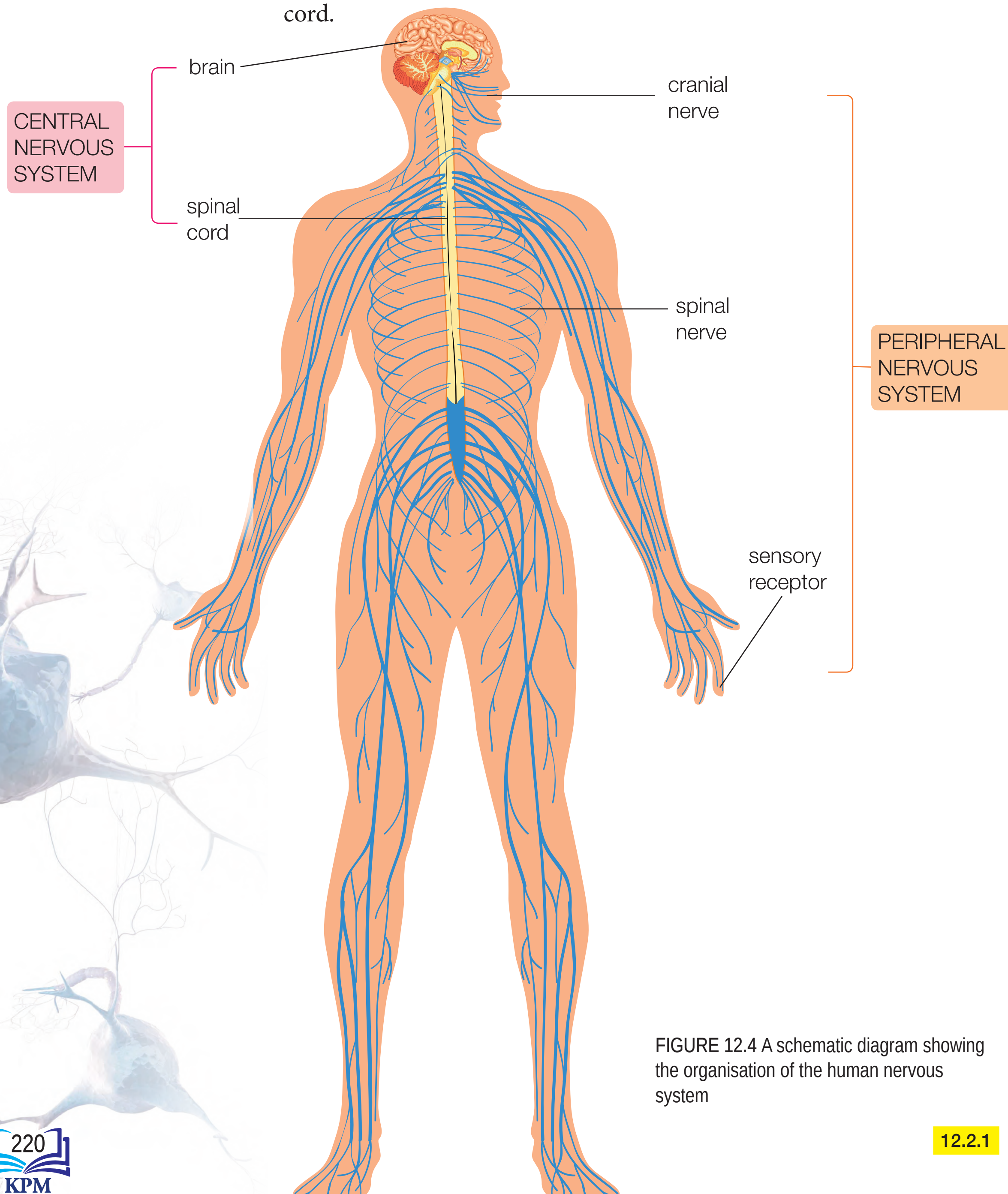


FIGURE 12.4 A schematic diagram showing the organisation of the human nervous system

12.2.1

Brain

Do you know that the brain is made up of more than 100 billion neurones? The brain is the **coordination** and **control centre** for humans. The main components of the brain are the **cerebrum**, **hypothalamus**, **cerebellum**, **medulla oblongata** and **pituitary gland** (Figure 12.5).

CEREBRUM

- The largest and most complex structure present in the frontal part of the brain.
- The surface is folded to increase the surface area to hold more nerves.
- It is the centre that controls emotions, hearing, sight, personality and controlled actions.
- The cerebrum receives information and stimulus from the receptor.
- This information is analysed, integrated and correlated to produce sensory perception.
- The response is determined and instructions are given to the effectors.
- The cerebrum is also responsible for higher mental abilities such as learning, memorising, linguistic skills and mathematics skills.

HYPOTHALAMUS

- Coordinating homeostasis.
- It is the control centre that regulates body temperature, water balance, blood pressure, and senses hunger, thirst and fatigue.
- The hypothalamus connects the nervous system to the endocrine system through the pituitary gland.
- Controls the secretion of a few types of pituitary gland hormones.

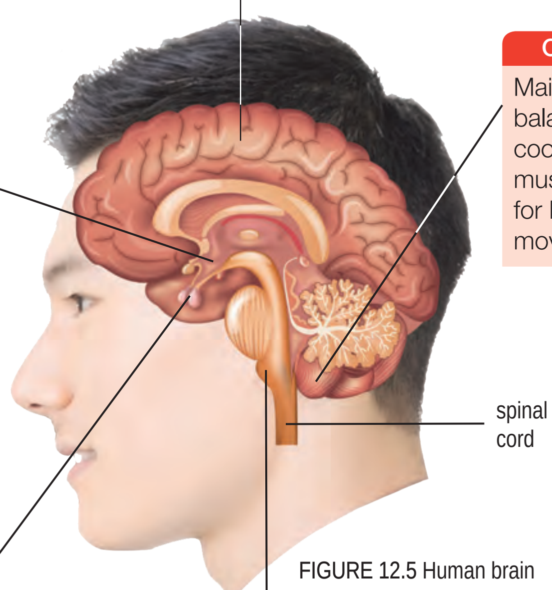


FIGURE 12.5 Human brain

CEREBELLUM

Maintains body balance and coordination of muscle contraction for body movement.

PITUITARY GLAND

- Located at the base of the hypothalamus.
- The main gland in the endocrine system.
- This gland secretes hormones that control the secretion of hormones by other endocrine glands.

MEDULLA OBLONGATA

- Located at the anterior of the cerebellum.
- Controls involuntary actions such as heartbeat, breathing, food digestion, vasoconstriction, blood pressure, peristalsis, vomiting, coughing, sneezing and swallowing.

Brainstorm!

In a newly operated section of the spinal cord, the white matter appears white and the grey matter appears grey. Can you explain why?

Spinal cord

The spinal cord is contained within the vertebral column and is surrounded by cerebrospinal fluid that protects and supplies the spinal cord with nutrients. The spinal cord is made up of **white matter** and **grey matter** (Figure 12.6). In a cross section, the grey matter looks like a butterfly or the letter 'H'. Grey matter comprises mainly of cell bodies and is surrounded by white matter. White matter consists of axons covered in myelin sheath and extends up and down the spinal cord. The **spinal nerve** extends from the spinal cord through two short branches or roots which are the **dorsal root** and **ventral root.**

The function of the spinal cord is to

(a) process a few types of sensory information and to send responses through the motor neurones

(b) control reflex action

(c) connect the brain with the peripheral nervous system

The detailed functions of the spinal cord structure is summarised in Figure 12.6.

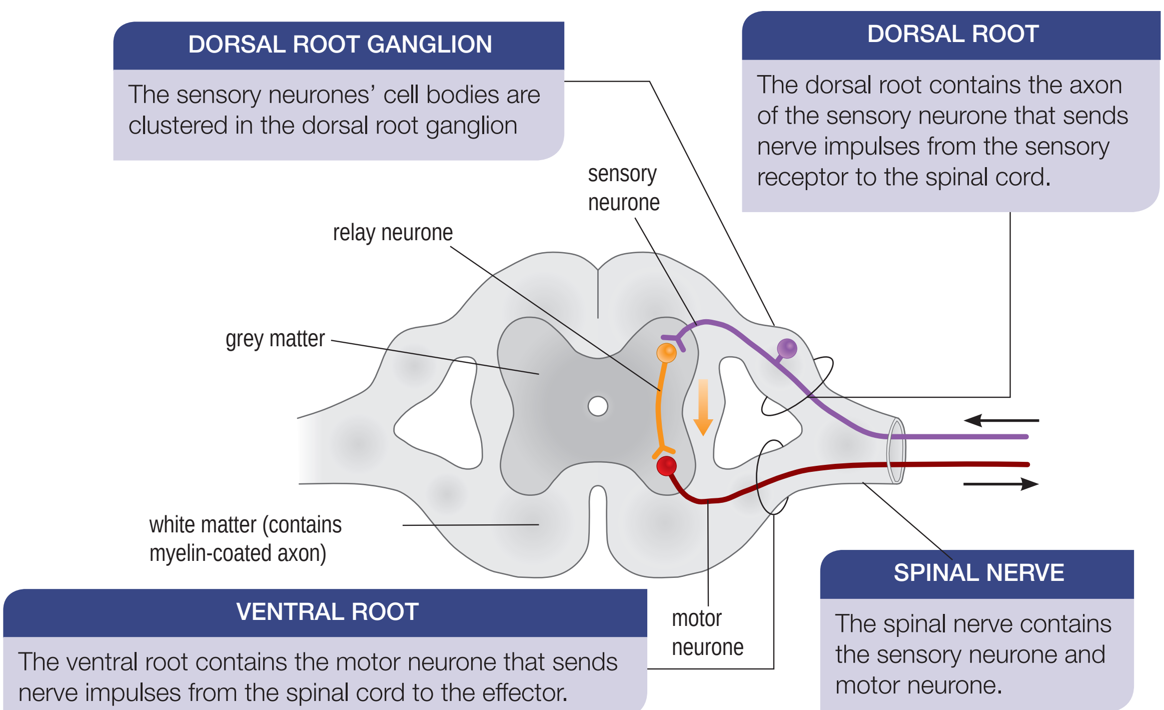


FIGURE 12.6 Cross section showing the detailed structure of the spinal cord, white matter and grey matter

Peripheral nervous system

The peripheral nervous system consists of the **somatic nervous system** and **autonomic nervous system**. The somatic nervous system regulates all controlled actions. The autonomic nervous system controls involuntary actions such as heartbeat and contraction of the blood vessel. The function of the peripheral nervous system is to connect **sensory receptors** and **effectors** to the central nervous system.

Formative Practice 12.2

1 Explain the role of the brain in body coordination.
2 Compare the functions of the cerebellum and the medulla oblongata.
3 State one difference between the functions of the somatic nervous system and the autonomic nervous system.
4 Explain why we cannot resist sneezing.

Brainstorm!

A person suffering from a stroke is having difficulty in moving his left hand. Which part of the brain is damaged?

12.3 Neurones and Synapse

The nervous system is made up of millions of nerve cells known as **neurones**. The basic structure of a neurone consists of a **cell body**, **axon**, **dendrite**, **myelin sheath**, a **node of Ranvier** and a **synaptic knob** (Figure 12.7). There are three types of neurones which are **sensory neurones**, **relay neurones** and **motor neurones** (Figure 12.8).

DENDRITE

Dendrites are short branches of the cell body. Dendrite receives nerve impulses from other neurones or the external environment and sends them to the cell body.

CELL BODY

A **cell body** consists of a nucleus and many cytoplasmic projections called dendrites. The cell body integrates signals and coordinates metabolic activities.

NODE OF RANVIER

Certain neurones have parts that are not insulated by the myelin sheath at regular gaps along the axon. This gap is known as a **node of Ranvier**. The node of Ranvier helps to accelerate the flow of nerve impulses by allowing the nerve impulses to jump from one node to the following node.

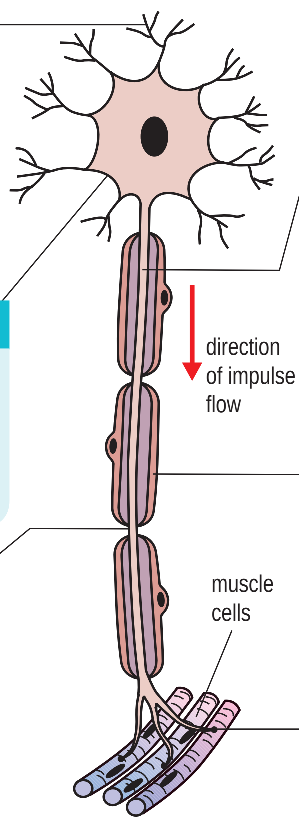


FIGURE 12.7 The basic structures and functions of the the parts of the neurone

AXON

Axon is an elongated branch of the body cell. Axon carries impulses out of the cell body to other neurones or effectors.

MYELIN SHEATH

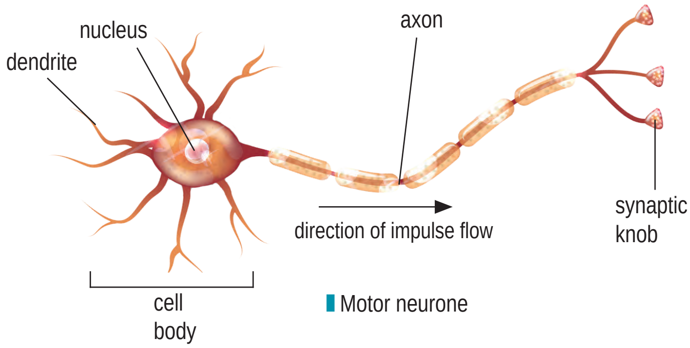
Myelin sheath is an insulating membrane that coats the axon. Function of the myelin sheath:

- protects neurones from injury
- functions as an insulator for electrical impulses
- provides nutrients to the axon

SYNAPTIC KNOB

The **synaptic knob** is a swelling at the end of the axon branch. The synaptic knob sends signals to muscle cells, gland cells or other neurone dendrites.

12.3.1 12.3.2



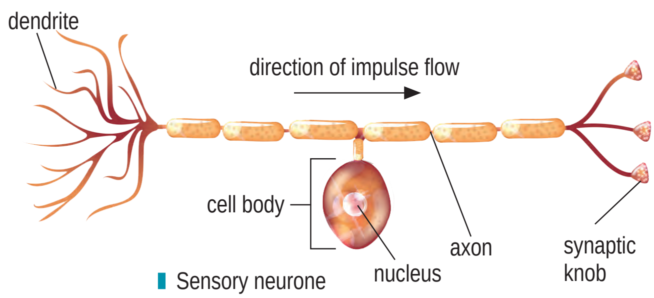
Motor neurone

MOTOR NEURONE

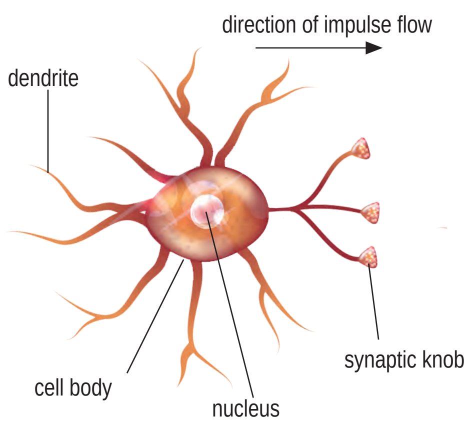
- Can be found in the ventral root of the spinal nerve.
- Receives nerve impulses from the **relay neurone** of the central nervous system and sends nerve impulses to **effectors** such as muscles or glands to produce the appropriate response.
- The cell body is present in the grey matter of the spinal cord.

SENSORY NEURONE

- Present in the dorsal root of the spinal nerve.
- Carries nerve impulses from the **sensory organ receptors** to the **central nervous system.**
- The cell body is found in the **dorsal root ganglion.**
- Dendrites receive nerve impulses from receptors and send them to the cell body.
- The nerve impulses are transferred from the cell body through the axon to the next neurone.



Sensory neurone



Relay neurone

RELAY NEURONE

- Nerve fibres found in the central nervous system.
- Connects the **sensory neurone** to the **motor neurone**.
- The cell body can be found in clusters in the grey matter of the central nervous system.
- Sends nerve impulses from the sensory neurone to the central nervous system and from the central nervous system to the motor neurone.

FIGURE 12.8 Types and functions of neurones

Structure and functions of synapses

Information is sent along the neurone through electrical signals known as **nerve impulses**. Impulses are positively charged waves that flow along the axon to the synaptic knob. There is a narrow gap called **synapse** that separates the synaptic knob from neurone dendrites that receive the impulses. Electrical signals that carry information must be transferred across synapses for impulses to be transmitted to the following neurone.

Synapses play an important role in allowing nerve impulses to travel in one direction. Therefore, synapses control the types of impulses that pass through them.

Biological Lens

The cobra's poison can cause paralysis by preventing the action of the neurotransmitter.

Transmission of impulse across a synapse

Impulses are transmitted chemically across synapses. The chemical substances involved are **neurotransmitters** that are kept in **synaptic vesicles** that are found at the end of the synaptic knob. Two examples of neurotransmitters found in most synapses are acetylcholine and noradrenaline. Other examples are serotonin and dopamine.

The process of transmitting impulses through synapses is slow as it occurs chemically. At first, the electrical signal will be changed to a chemical signal in the form of a neurotransmitter, then the chemical substance is converted again to an electrical signal on the membrane of the receiving neurone. The transmission of impulses across synapses is shown in Figure 12.9.

ICT 12.1

Video: Synapse
(Accessed on 21 August 2019)

1 When electrical impulses reach the synaptic knob, synaptic vesicles are stimulated to release **neurotransmitters** into the synapse.

2 **The neurotransmitters** diffuse through the synapse and combine to a specific receptor protein which is a receptor on the dendrite of the receiving neurone.

3 The binding of the neurotransmitter and the receptor stimulates the initiation of the next impulse so that impulse can be transmitted through the neurone.

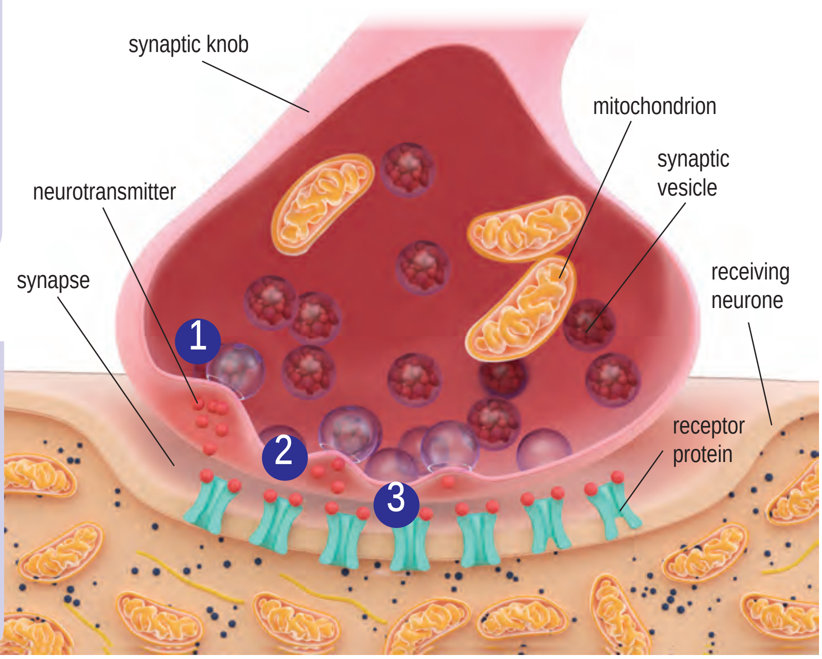


FIGURE 12.9 Transmission of impulses across synapses

Synaptic knobs contain numerous mitochondria to generate the energy required for the transmission of nerve impulses.

12.3.4

Activity Zone

Design a simulation model of the nerve coordination using an electric circuit.

Formative Practice 12.3

1. What is the function of motor neurones?
2. Why do synaptic knobs contain a lot of mitochondria?
3. How are electrical impulses transmitted through synapses?
4. Predict what would happen to the transmission of impulses if the neurone does not have a myelin sheath.

12.4 Voluntary and Involuntary Actions

Responses produced are either **voluntary action** or **involuntary action**. What are the pathways of information transmission involved in both actions? What are the differences between voluntary action and involuntary action? Table 12.2 shows the comparison between voluntary and involuntary actions.

TABLE 12.2 Comparison between voluntary action and involuntary action

Voluntary action	Involuntary action
Similarity	
Both actions involve stimulation, impulse, neurone and an effector organ.	
Differences	
Actions that we are conscious of and done on our own will	Actions that occur automatically and occurs without us being conscious
Involves the somatic nervous system	Involves the autonomous nervous system
Controlled by the cerebral cortex	Controlled by the medulla oblongata and hypothalamus
Involves the reaction of the skeletal muscles	Involves the reaction of the smooth muscle and glands

VOLUNTARY ACTIONS INVOLVING SKELETAL MUSCLES

- Voluntary actions such as walking, talking or brushing teeth are conscious actions.
- For example, you can voluntarily raise your hand to answer a question.
- The voluntary actions involving the skeletal muscles are controlled by the cerebral cortex.
- Since the information reaches the cerebral cortex, that is, our level of consciousness, our perception of the surroundings can be produced.
- The information pathway in voluntary action is demonstrated in Figure 12.10.

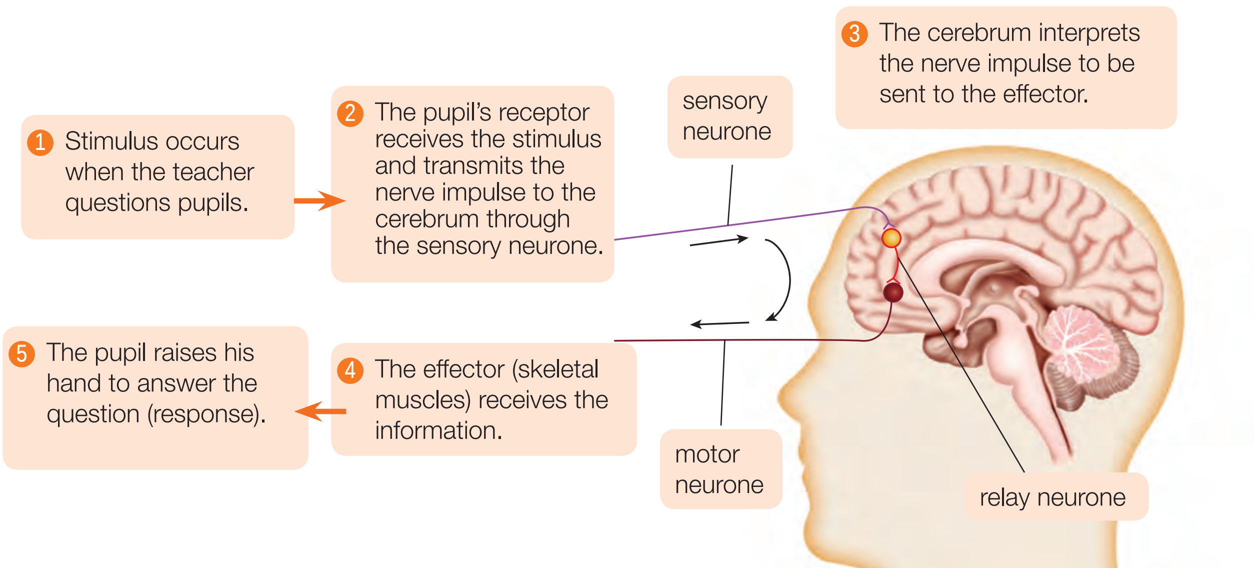


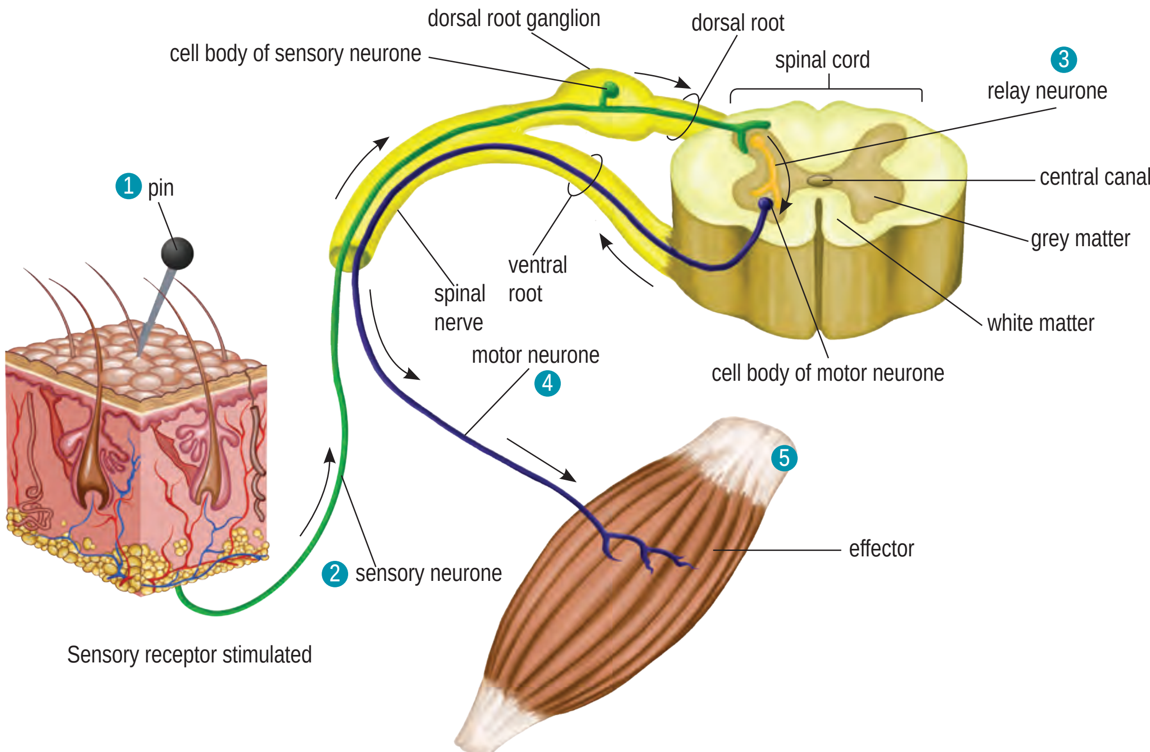
FIGURE 12.10 The pathway of information transmission in voluntary actions that involve skeletal muscles

Involuntary actions involving skeletal muscles: reflex response

Three-neurone reflex arc

- Several situations require immediate and spontaneous action.
- If you accidentally prick your finger on a sharp pin, you will move your finger immediately without much thought.
- This is known as a **reflex action**.
- A reflex action is a fast response a stimulus without being controlled by the brain.
- The nerve pathway involved in a reflex action is called the **reflex arc** (Figure 12.11).
- The reflex action of moving the finger from the sharp pin involves **three neurones** and communication between the neurones in the peripheral nervous system and the spinal cord.

12.4.2



1	2	3	4	5
When a finger is pricked by a sharp pin, the sensory receptor detects the stimulus and triggers a nerve impulse.	→ The nerve impulse is transmitted along the sensory neurone to the spinal cord.	→ In the spinal cord, the nerve impulse is transferred from the sensory neurone through the synapse to the relay neurone.	→ From the relay neurone, the nerve impulse is transferred to the motor neurone.	→ The motor neurone transfers the nerve impulse from the spinal cord to the effector (muscle tissue) so that the finger can be moved quickly.

FIGURE 12.11 The reflex arc that involves three neurones and a spinal cord

The importance of reflex actions

- Reflex actions produce spontaneous responses without waiting for instructions from the brain.
- The additional time that is needed by the brain to analyse information before triggering a response can lead to serious injuries.
- Since reflex actions involve the spinal cord, the brain can focus on higher-level thinking.

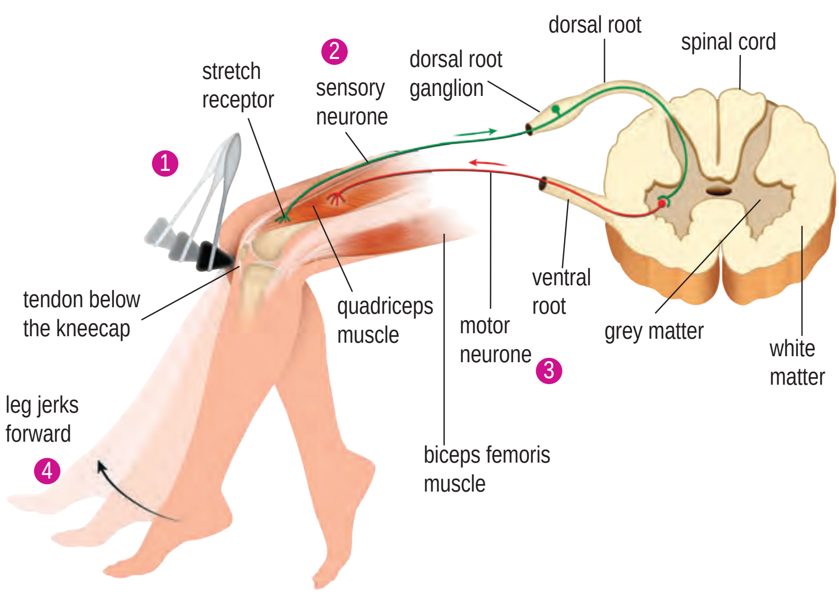
Two-neurone reflex arc

Another reflex action is the **knee jerk** or **patellar reflex** (Figure 12.12). This reflex uses the nerve pathway that involves **two neurones**, that is, the sensory neurone and the motor neurone. The doctor sometimes tests the effectiveness of someone's nerve system by tapping on the knee using a rubber hammer (Photograph 12.3).

PHOTOGRAPH 12.3 Doctor testing knee jerk reflex

1 When the tendon below the kneecap is knocked, the quadriceps muscle stretches and stimulates the stretch receptors to trigger nerve impulses.

2 The sensory neurone transmits the nerve impulses to the motor neurone in the spinal cord.



4 The quadriceps muscle contracts causing the leg to jerk to the front.

3 The motor neurone then transmits impulses from the spinal cord to the quadriceps muscle.

FIGURE 12.12 The reflex arc in knee jerk involving two neurones

Our World of Biology

Reflex actions such as coughing protects the lungs from foreign particles from the external environment. The pupil reflex protects the retina from damage.

Activity Zone

Draw a reflex arc.

Formative Practice 12.4

1 State the sequence of impulse transmission in the knee jerk reflex arc.

2 One example of reflex action is pulling the hand away from a hot object. Define the reflex action and state its importance.

3 Differentiate between voluntary and involuntary actions.

4 Someone who loses a leg due to a certain disease will still feel pain in the area where the limb was amputated. Explain why.

12.4.2 12.4.3

12.5 Health Issues Related to the Human Nervous System

Nervous system disease

We should be thankful for having a central nervous system that functions well. However, the central nervous system can become damaged and stop functioning efficiently.

A few examples of health issues related to the nervous system are given below.

Our World of Biology

The risk of Alzheimer's disease is higher among individuals who rarely challenge their minds to study and think critically.

MULTIPLE SCLEROSIS

A progressive disease as a result of an abnormality in the immune system that attacks the myelin sheath in the brain and spinal cord. The damaged myelin sheath prevents the transmission of impulses from and to the brain.

EPILEPSY

The occurrence of abnormal activities in certain parts of the brain causing the nerve cells to produce unusual signals. A person suffering from epilepsy may become unconscious and experience muscle spasms.

ALZHEIMER'S DISEASE

This disease causes the loss of ability to reason and to take care of oneself. The patient is usually confused, forgetful and disoriented even in a familiar place. If the deterioration of the brain continues, the patient will lose the ability to read, write, eat, walk and talk.

PARKINSON'S DISEASE

It is the shrinkage of the nervous system that causes tremors in the limbs, jaw, foot and face. The patient will also have difficulty maintaining body posture and balance.

BRAIN PARALYSIS (CEREBRAL PALSY)

Brain paralysis occurs because of brain damage before or after a baby is born. It could also possibly occur in children between the ages of 3–5 years old. This disease causes failure in muscles and the ability of motor neurones to function properly.

LOU GEHRIG/AMYOTROPHIC LATERAL SCLEROSIS (ALS)

This disease is caused by the deterioration and death of motor neurones that control the movement of muscles such as chewing, walking and talking.

ATTENTION-DEFICIT HYPERACTIVITY DISORDER (ADHD)

A type of brain disease that causes someone to become hyperactive, unable to concentrate and gets easily bored.

AUTISM

A type of disease related to the development of nerves in the brain. Autism causes an individual to experience problems communicating and interacting.

12.5.1

Activity 12.1	Traditional methods of treatment for health issues related to the nervous system	Research study

Materials
Medical magazines, Internet

Procedure
Conduct a research study on the use of traditional methods (acupuncture, reflexology and others) in the treatment of health issues related to the nervous system.

Discussion
What are the traditional methods that can treat health issues related to the nervous system?

The effects of drug and alcohol abuse on human coordination and response

There are many types of drugs used for medical purposes, for example, marijuana is used by doctors in small quantities to reduce nausea in cancer patients after undergoing chemotherapy treatment. However, drug abuse other than for medical purposes can cause serious side effects and would most likely be fatal. Among the effects of drug abuse on drug addicts are:

- addiction
- an addiction that causes withdrawal symptoms such as shivering, sweating and vomiting if the drug is not taken

Table 12.3 shows the effects of drug and alcohol on human coordination and response.

12.5.2

TABLE 12.3 Drugs and alcohol and their effects on the nervous system

Substance	Effects
Stimulant drugs (stimulants)	• Increases the activity of the central nervous system • Excessive use causes temporary euphoria which is followed by depression
Sedative drugs (depressants)	• Delays the transmission of nerve impulses • Calms the mind
Hallucinogenic drugs	• Causes the user to hallucinate • Relief from pain and anxiety
Narcotic drugs	• Delays the normal functions of the brain
Alcohol	• Disrupts coordination and thinking • Delays the transfer of nerve impulses

Formative Practice 12.5

1 State the symptoms of Alzheimer's disease.

2 Explain how drugs affect the coordination of one's nerves.

3 Why do doctors use drugs in the treatment of cancer patients who undergo chemotherapy?

4 Explain why a drunk individual is not allowed to drive a vehicle.

12.6 Endocrine System

The coordination system of the body needs cooperation between the endocrine system and the nervous system. Both systems play an important role in maintaining homeostasis. Even though both systems have different functions, they interact and complement each other to regulate and coordinate all processes and activities in the body. What is the endocrine system?

Endocrine System of Humans

The **endocrine system** is made up of glands that secrete chemical substances, that is **hormones**. The endocrine glands are **ductless glands.** So, the hormones are secreted directly into the blood flow. Even though the hormones are transported throughout the body in the blood, the hormones only influence and affect specific **target cells**. The hormones bind with specific molecule receptors on the membrane surface of target cells and produce specific responses.

Millennial Career

Endocrinology is a branch of medicine that is related to the diseases of the endocrine system and problems with hormone secretion.

The endocrine system of humans is made up of many glands. The glands secrete different hormones involved in specific physiological processes. The functions of hormones can be divided into three main functions: reproduction, growth and homeostasis. Figure 12.13 shows the endocrine glands.

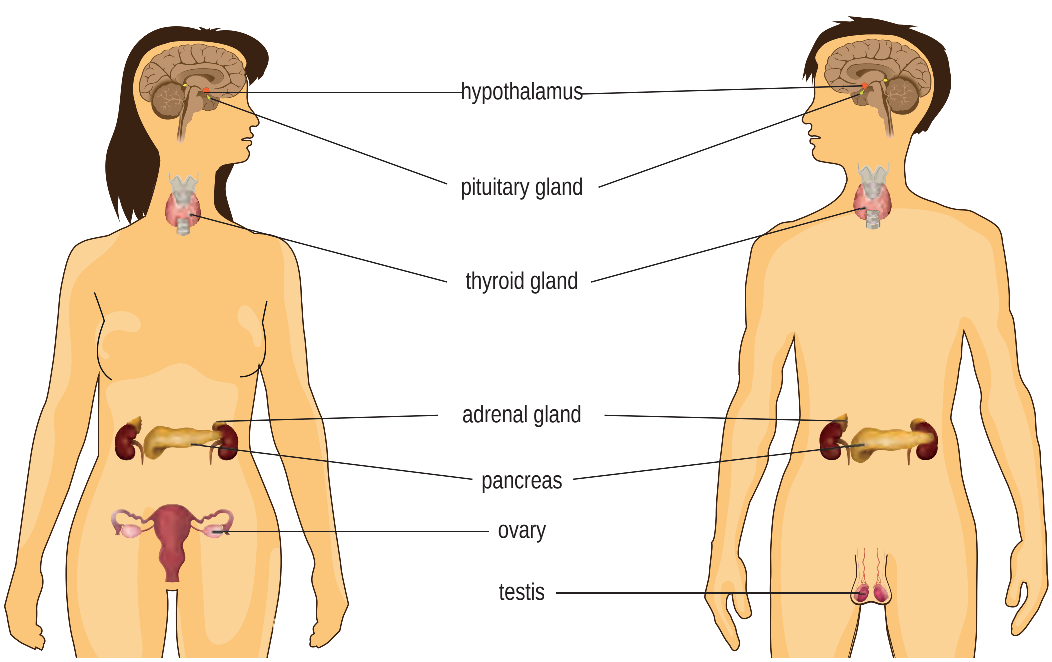


FIGURE 12.13 The endocrine glands in the endocrine system of humans

12.6.1 12.6.2

The functions of hormones secreted by each endocrine glands

The **pituitary gland** is the main gland of the endocrine system because it secretes hormones that control the secretion of other endocrine glands. The pituitary gland is located at the bottom of the hypothalamus in the brain. The pituitary gland is made up of two lobes, which are the **anterior lobe** and the **posterior lobe**. Each lobe secretes hormones that have certain functions (Table 12.4 and Table 12.5).

TABLE 12.4 The functions of hormones that are secreted by the posterior lobe of the pituitary gland

Posterior Lobe of the Pituitary Gland		
Hormone	**Target Tissues/ Organs**	**Function**
Antidiuretic (ADH)	Kidney tubule	Stimulates the reabsorption of water
Oxytocin	• Uterine muscles • Mammary glands	• Stimulates the contraction of uterine muscles during birth • Stimulates the production of milk from the mammary gland

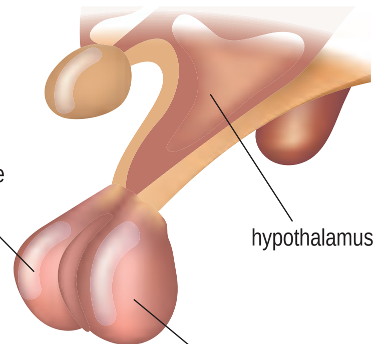


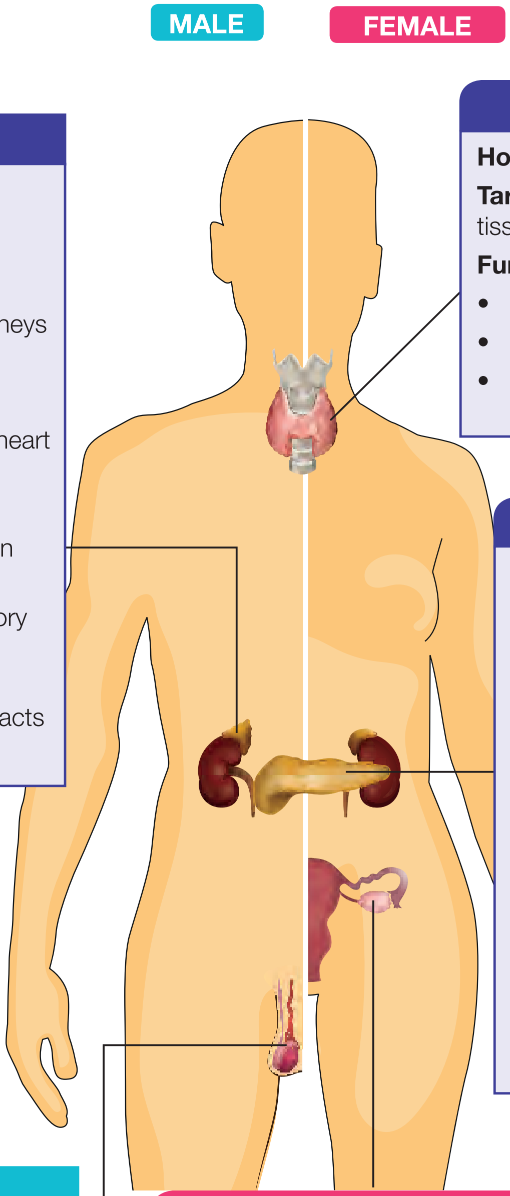
TABLE 12.5 The functions of hormones that are secreted by the anterior lobe of the pituitary gland

Anterior Lobe of the Pituitary Gland		
Hormone	**Target Tissues/ Organs**	**Function**
Luteinizing hormone (LH)	• Ovary • Testis	• Stimulates ovulation, development of corpus luteum, and secretion of oestrogen and progesterone • Stimulates secretion of testosterone
Growth hormone (GH)	Soft tissue, bone	Stimulates growth, protein synthesis and fat metabolism
Adrenocorticotropic hormone (ACTH)	Adrenal cortex	Stimulates the adrenal cortex to secrete hormones
Thyroid-stimulating hormone (TSH)	Thyroid gland	Stimulates thyroid to secrete thyroxine
Follicle-stimulating hormone (FSH)	• Ovary • Testis	• Stimulates the development of follicles in the ovary • Stimulates spermatogenesis

The hormone that regulates the secretion of other hormones is known as the **stimulating hormone.** This includes thyroid-stimulating hormone (TSH) and adrenocorticotropic hormone (ACTH). For example, TSH stimulates the thyroid gland to secrete thyroxine.

Hormones that act directly on **target organs** include growth hormone, oxytocin and antidiuretic hormone (ADH). For example, GH acts directly on the bone.

The hypothalamus secretes **gonadotrophin-releasing hormone (GnRH).** GnRH stimulates the pituitary gland to secrete FSH and LH into the blood.



ADRENAL GLAND

Hormone: Aldosterone

Target tissues/organs: Kidney

Function: Increases the reabsorption of salt in kidneys

Hormone: Adrenaline

Target tissues/organs: Muscle tissues, liver and heart

Function:

- Increases the level of sugar and fatty acids in the blood
- Increases the respiratory rate and heartbeat
- Increases the rate of metabolism and contracts blood vessels

THYROID GLAND

Hormone: Thyroxine

Target tissues/organs: All tissues

Function:

- Increases the metabolism rate
- Increases body temperature
- Regulates growth and development

PANCREAS

Hormone: Insulin

Target tissues/organs: Liver, muscles and adipose tissues

Function: Reduces blood glucose level and promotes the conversion of excess glucose to glycogen

Hormone: Glucagon

Target tissues/organs: Liver, muscles and adipose tissues

Function:

- Increases the blood glucose level
- Promotes the conversion of glycogen to glucose

TESTIS

Hormone: Testosterone

Target tissues/organs: Gonad, skin, muscles and bones

Function: Stimulates the development of secondary sexual characteristics in the male and spermatogenesis

OVARY

Hormone: Oestrogen

Target tissues/organs: Gonad, skin, muscles and bones

Function:

- Stimulates the development of secondary sexual characteristics in the female and maturity of the follicles
- Repairs and stimulates the thickening of the uterus wall

Hormone: Progesterone

Target tissues/organs: Gonad

Function: Stimulates the development of the uterus wall and the formation of the placenta

FIGURE 12.14 The functions of hormones secreted by other endocrine glands

Involvement of the nervous system and endocrine system in a 'fight or flight' situation

Have you ever been in a state of 'fight or flight' situation? For example, when a dog or a goose suddenly chases you? How do you feel in a situation like this? Your heart will beat fast and your palms will sweat. What causes this condition?

In an emergency or a 'fight or flight' situation, the hypothalamus transmits nerve impulses directly to the adrenal medulla and the adrenal medulla cells are stimulated to secrete **adrenaline** and **noradrenaline**. These two hormones act quickly to produce the required responses in a 'fight or flight' situation. This includes an increase in:

- heart rate
- respiratory rate
- blood pressure
- blood glucose level
- metabolic activity

The heart pumps more oxygen and glucose to the brain and skeletal muscles because additional energy is needed to fight or run quickly. In an emergency, both the endocrine system and the nervous system work together to produce an immediate response to deal with the dangerous situation. When this mechanism manages to control this 'fight or flight' situation, bodily changes that have occurred return to the normal range.

What are the similarities and differences between the endocrine system and the nervous system? Figure 12.15 compares and contrasts the two systems.

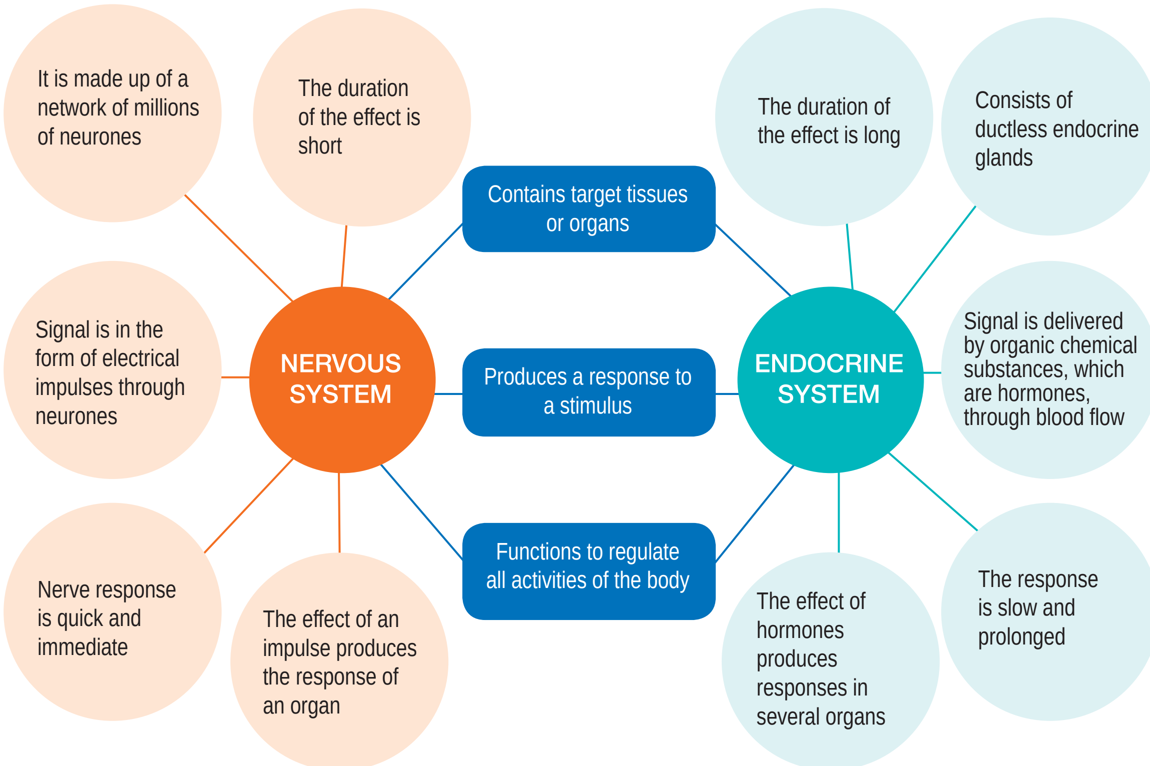


FIGURE 12.15 Similarities and differences between the nervous system and the endocrine system

The endocrine system plays a key role in maintaining the homeostasis of the body. However, an imbalance in hormone production can occur in some individuals when the endocrine gland secretes excessive or insufficient hormone. What is the effect of hormone imbalance to the individual?

Formative Practice 12.6

1 Name the hormone that is related to the function given.

Hormone	Function
	Stimulates the contraction of uterine muscles during birth
	Stimulates water absorption by the kidneys
	Increases the metabolism rate of most of the body cells

2 State three characteristics of hormones.

3 Compare between the nervous system and the endocrine system.

4 A pupil finds herself being followed by a van and suspects there is an attempt to kidnap her. In a state of panic, the pupil is able to run fast and far away from the van. Explain the 'fight or flight' in this situation.

CHAPTER 12

12.6.5

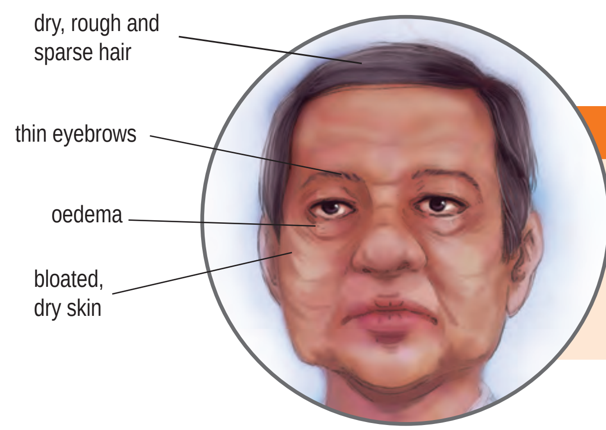
12.7 Health Issues Related to the Human Endocrine System

DIABETES MELLITUS

A **diabetes mellitus** patient does not produce enough insulin or cannot use the insulin produced. As a result, the level of glucose in the blood is high. The patient urinates frequently, is always thirsty, experiences numbness in the soles of the feet, has blurred vision, is tired and their wounds heal much slower. Whereas, the excessive secretion of insulin causes **hypoglycaemia** where the blood glucose level is too low. Among the symptoms of hypoglycaemia are fatigue, difficulties sleeping at night, disordered thoughts, fear, emotional instability, faints easily and headache.

DIABETES INSIPIDUS

For **diabetes insipidus** patients, the posterior lobe of the pituitary gland fails to secrete the antidiuretic hormone (ADH). As a result, patients will produce a large amount of urine and often feel thirsty. Since a large amount of water is lost through the urine, the individual will experience dehydration if they do not drink enough water every day.



PHOTOGRAPH 12.4 An individual who has hypothyroidism

HYPOTHYROIDISM

An adult will experience **hypothyroidism** if there is inadequate thyroxine secretion. Symptoms include extremely slow heartbeat, extremely sensitive to cold, tiredness and gain weight easily.

HYPERTHYROIDISM

Hyperthyroidism refers to a situation that occurs when too much thyroxine is secreted. Symptoms include excessive sweating, heat intolerance, increased frequency of defaecation, fear, heart palpitations and weight loss. Sometimes, the thyroid gland will grow two or three times larger than its original size (Photograph 12.5).

PHOTOGRAPH 12.5 Enlarged thyroid gland

PHOTOGRAPH 12.6 The hands of a 12-year-old boy with gigantism. Observe that his hands are bigger than that of a normal adult

PHOTOGRAPH 12.7 Chandra Bahadur Dangi from Nepal (0.55 m), the shortest man in the world and Sultan Kosen (2.47 m), the tallest man in the world

GIGANTISM

Excessive secretion of the growth hormone (GH) during childhood causes **gigantism** which is a condition characterised by the abnormal elongation of bones (Photograph 12.6). The individual grows to become extremely tall.

DWARFISM

Low secretion of the growth hormone (GH) during the period of growth delays the growth of bones and causes a condition called **dwarfism** (Photograph 12.7). Organs also fail to develop and parts of the body ratio remain as that of a child.

Formative Practice 12.7

1 State the factors that cause a person to contract diabetes insipidus.

2 State two symptoms experienced by people with diabetes mellitus.

3 Goitre is a disease that causes the enlargement of the thyroid gland. In your opinion, why are goitre patients encouraged to eat seafood?

4 Suggest a treatment for children with stunted growth due to growth hormone deficiency.

12.7.1

Summary

COORDINATION AND RESPONSE IN HUMANS

Coordination and Response

- Stimulus
- Receptor
- Integration centre
- Effector
- Response

Nervous System

Central nervous system
Interpreting information and sending a response to an effector through the motor neurones
- Brain
- Spinal cord

Peripheral nervous system
Linking the sensory receptor and effector with the central nervous system
- **Sensory receptor**
  - **Chemoreceptor**: Detects chemical substances
  - **Mechanoreceptor**: Detects touch and pressure stimulation
  - **Photoreceptor**: Detects light
  - **Thermoreceptor**: Detects change in temperature
  - **Baroreceptor**: Detects change in pressure
  - **Nociceptor:** Detects pain
- **Somatic nervous system**
  Controlling voluntary actions
- **Autonomous nervous system**
  Controlling involuntary actions

Neurones and Synapse

- Sensory neurones
- Relay neurones
- Motor neurones

Type of Action

Voluntary action
Actions that we are conscious of and done on our own will

Involuntary action
Action that occurs automatically and involves an autonomous nervous system and controlled by the medulla oblongata

Health Issues Related to the Human Nervous System

- Multiple sclerosis
- Alzheimer's disease
- Parkinson's disease
- Lou Gehrig/ *Amyotrophic Lateral Sclerosis* (ALS)
- *Attention Deficit Hyperactivity Disorder* (ADHD)
- Autism
- Brain paralysis (*Cerebral palsy*)
- Epilepsy

Endocrine System

- Endocrine gland
- Hormone
- Involvement of the nervous and endocrine system in a "fight or flight" situation
- Compare and contrast the nervous and the endocrine system

Health Issues Related to the Human Endocrine System

- Dwarfism
- Gigantism
- Hyperthyroidism
- Hypothyroidism
- Diabetes mellitus
- Diabetes insipidus

Self Reflection

Have you mastered the following important concepts?

- Sequence of components in the coordination of humans
- Structure of the human nervous system
- Functions of the brain
- Function of a neurone in the transmission of impulse
- Structure and functions of synapses
- Transmission of a nerve impulse across a synapse
- Voluntary and involuntary actions
- Reflex arc involving two neurones and three neurones
- Health issues related to the nervous system
- Effects of drug and alcohol abuse on coordination
- Functions of hormones secreted by endocrine glands
- Compare and contrast the nervous and the endocrine system
- The effects of hormonal imbalance on human health

Summative Practice 12

1 Compare the functions of the cerebellum and the medulla oblongata.

2 Define reflex action and state its importance.

3 Name the main endocrine gland in the endocrine system of humans. Why is this gland considered the main gland?

4 State the effects of excessive and insufficient growth hormones (GH) in humans.

5 Figure 1 shows the cross section of a part of the nervous system.

(a) (i) Name structure X.

(ii) State the function of structure X.

(b) Why is part Y swollen?

(c) Complete Figure 1 with neurones involved in a reflex action. Mark the direction of impulse on the neurone.

(d) If the spinal nerve is cut at Z, what is the effect on the organ that is connected to it? Explain why.

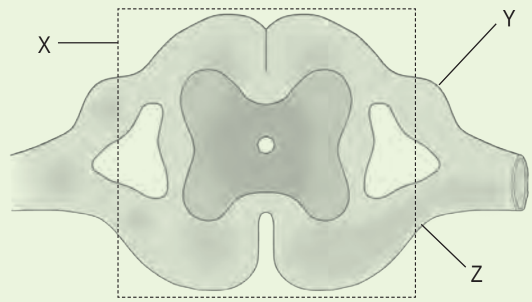


FIGURE 1

6 Figure 2(a) shows part of a motor neurone and Figure 2(b) shows a cross section of a synaptic knob.

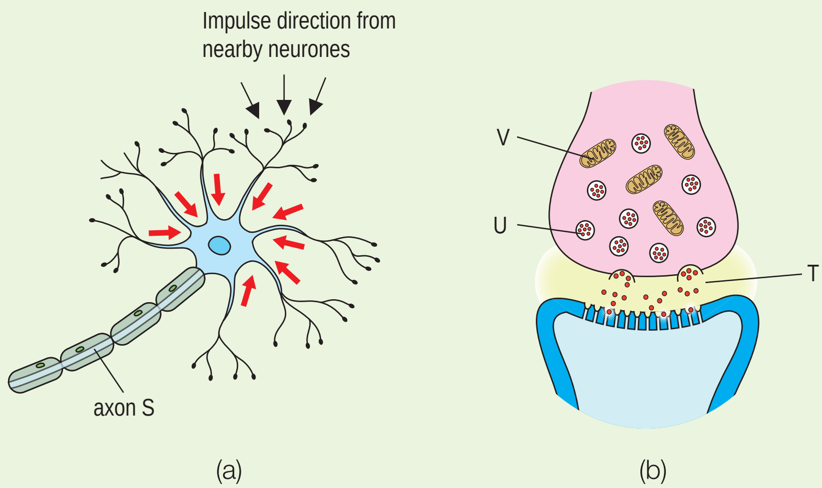


FIGURE 2

(a) Name the parts labelled V, T and U.

(b) Name the chemical substances in U.

(c) The synaptic knob contains a lot of V. What is the function of V?

(d) Draw an arrow that shows the direction of impulse flow along axon S.

(e) Explain

(i) why does the transmission of impulse involve the pathway of impulse through T.

(ii) how transmission of impulse occurs.

(f) Based on Figures 2(a) and (b), explain why transmission of impulse through a neurone occurs in one direction only.

Essay Questions

7 Explain the effects of stimulant drugs and sedative drugs on the transmission of impulse through the synapse.

8 (a) (i) Compare and contrast the nervous system and the endocrine system.

(ii) Nora accidentally stepped on a nail. She screamed while holding on to her injured foot. Describe Nora's reaction when she stepped on the nail.

(b) After tea time, Azman went to the playground to ride his bicycle. While riding his bicycle, Azman is conscious of his action. However, he is not conscious of what is happening to the food that he had just eaten. Describe why Azman is conscious of his action riding the bicycle but is not conscious of the food he had just eaten.

Enrichment

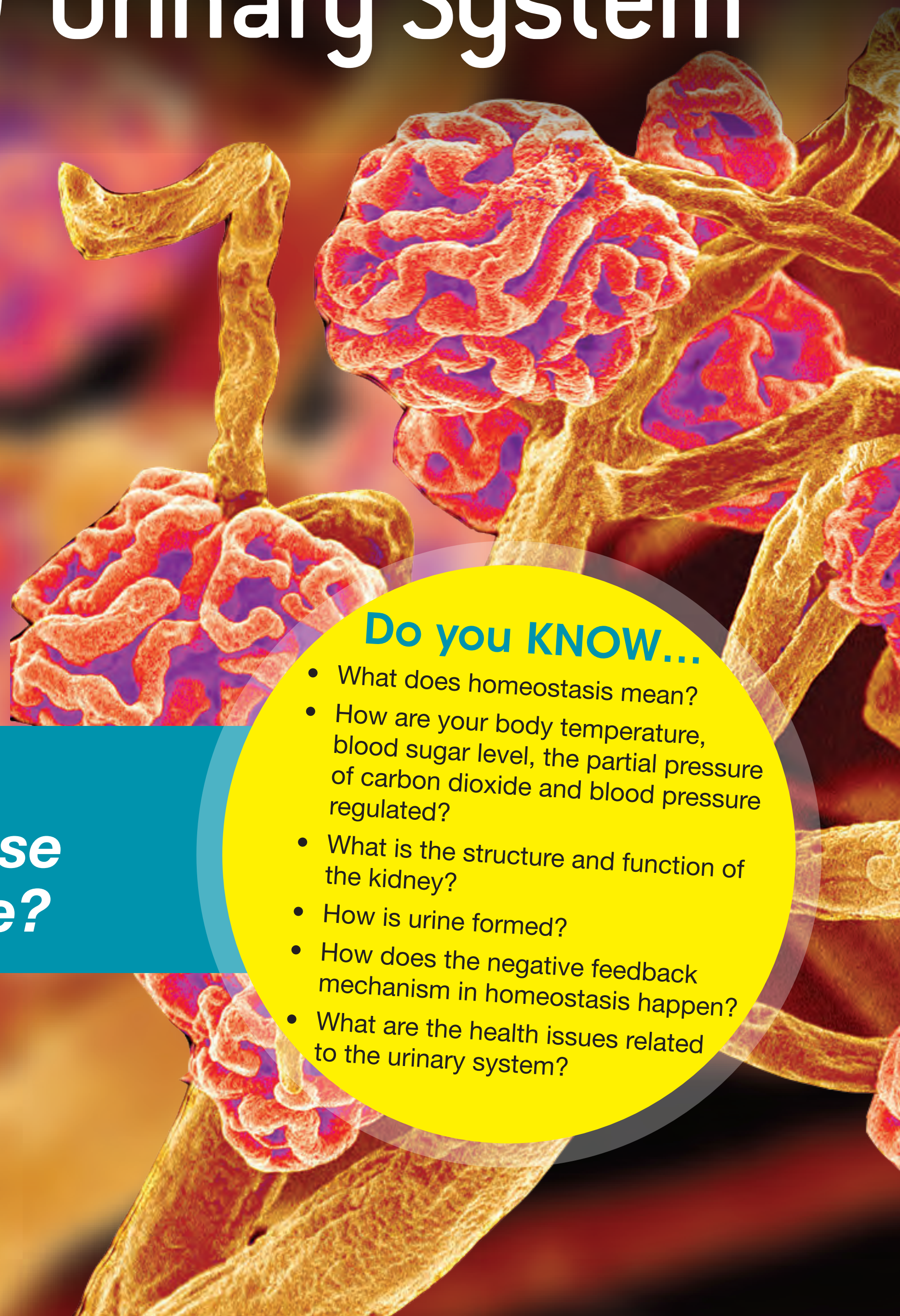
9 How does the brain decide in determining how much energy is needed to lift a piece of paper compared to a book?

10 Explain why we have to understand and display a lot of patience when taking care of an Alzheimer's or Parkinson's patient.

Complete answers are available by scanning the QR code provided

CHAPTER

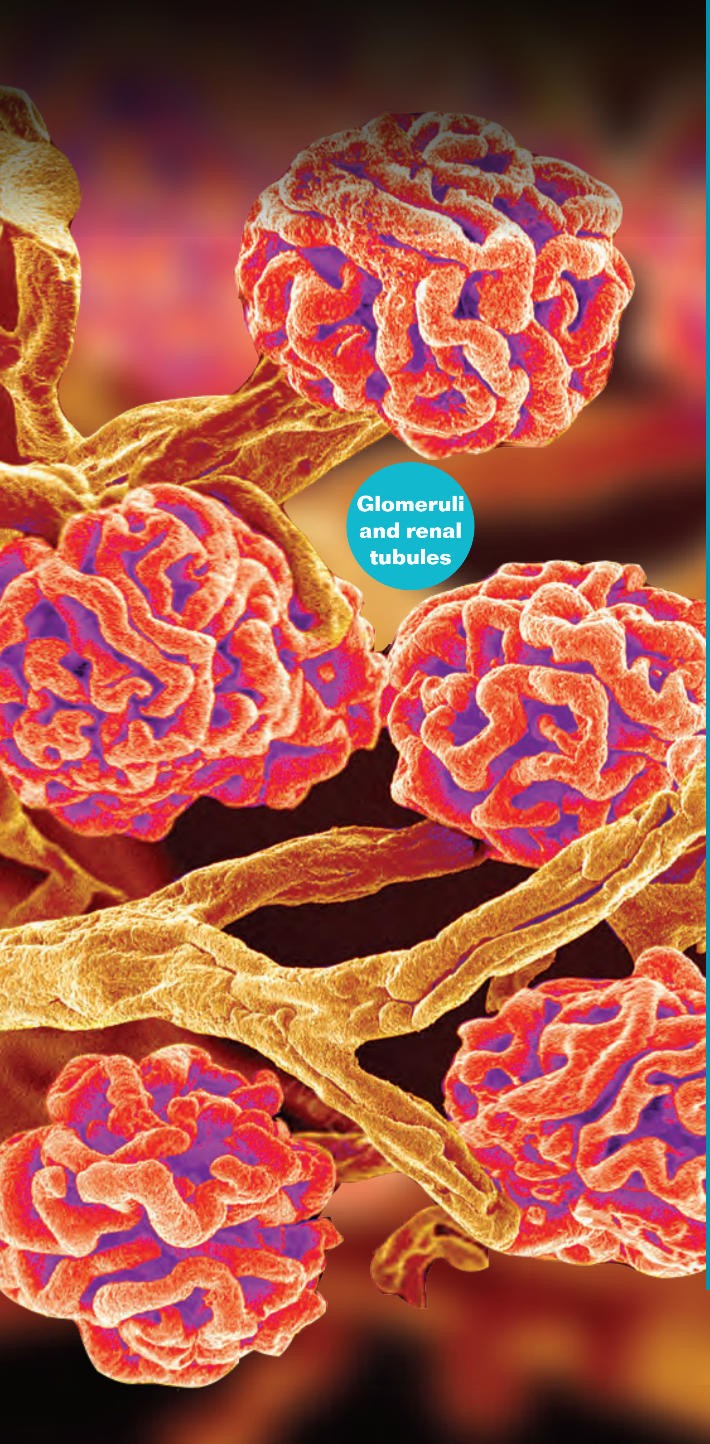
13 Homeostasis and the Human Urinary System



How can diabetes cause kidney failure?

Do you KNOW...

- What does homeostasis mean?
- How are your body temperature, blood sugar level, the partial pressure of carbon dioxide and blood pressure regulated?
- What is the structure and function of the kidney?
- How is urine formed?
- How does the negative feedback mechanism in homeostasis happen?
- What are the health issues related to the urinary system?



13.1 Homeostasis

13.1.1 Explain the meaning of homeostasis.
13.1.2 Justify the necessity to maintain physical and chemical factors in the internal environment.
13.1.3 Describe the involvement of various organ systems in maintaining an optimal internal environment.
13.1.4 Apply the knowledge of homeostasis concept in regulation of:
- body temperature
- blood sugar levels
- the partial pressure of carbon dioxide
- blood pressure

13.2 Urinary System

13.2.1 Identify the structure and functions of a kidney.
13.2.2 Draw, label and explain the structure of a nephron and collecting duct.
13.2.3 Describe the formation of urine:
- ultrafiltration
- reabsorption
- secretion

13.2.4 Synthesise the concept of homeostasis by using negative feedback mechanism in osmoregulation.
13.2.5 Conduct an experiment to study the effects of different volumes of water intake on urine formation.

13.3 Health Issues Related to the Urinary System

13.3.1 Describe health issues that are related to the urinary system.

13.1 Homeostasis

Homeostasis

Homeostasis is the regulation of physical and chemical factors of the internal environment within normal ranges for the cell to function in optimum conditions.

Physical and chemical factors of the internal environment

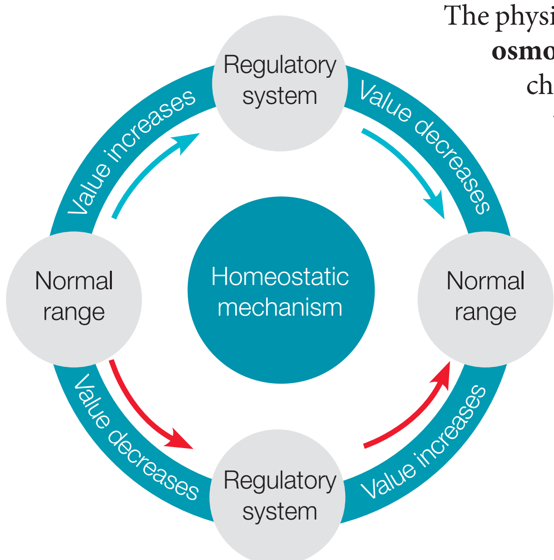


FIGURE 13.1 Deviation from the normal range triggers the mechanism of homeostasis to return a factor's value to the normal range

The physical factors that need to be regulated are **temperature**, **osmotic blood pressure** and **blood pressure**. The chemicals that need to be regulated are **pH value**, the **concentration of minerals** and **blood sugar concentrations**.

Any deviation from the normal range triggers the **homeostatic mechanism** which involves **negative feedback**. Homeostasis regulates the internal environment in order for it to be in a constant state although the external environment changes a lot. This ensures that cell activity continues to function at the optimum level. Figure 13.1 shows the negative feedback mechanism of homeostasis.

In homeostasis,

(a) a factor that exceeds the normal range is brought down to the normal range

(b) a factor that falls below the normal range is increased to the normal range

The organ system involved in maintaining an optimal internal environment

In the body, various organ systems function and interact with each other to maintain an optimum internal environment.

- **Body temperature** is regulated by the integumentary system (skin and sweat glands), nervous system, circulatory system, muscle system and endocrine system.
- **Blood sugar levels** are regulated by the endocrine gland, circulatory system and digestive system.
- The **partial pressure of carbon dioxide** in the blood is regulated by the respiratory system, circulatory system and nervous system.
- **Blood pressure** is regulated by the circulatory system and nervous system.

13.1.1 13.1.2 13.1.3

Regulating body temperature

Maintaining the body temperature at a fixed range is important so that cell metabolism reactions that are catalysed by enzymes occur at optimum levels. Temperatures that are too high will denature enzymes, while temperatures that are too low will slow down the metabolic activity of the cell, and prevent it from carrying out cell processes.

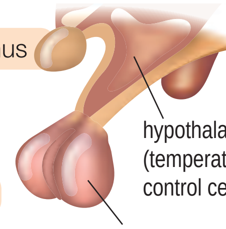
These changes in body temperature are detected by the **thermoreceptors** in the skin and the **hypothalamus**. Figure 13.2 shows the regulation of body temperature by different effectors when the body temperature increases beyond normal ranges. Figure 13.3 shows the regulation of body temperature by different effectors when the body temperature decreases below normal ranges.

Body temperature rises above normal ranges

detected by

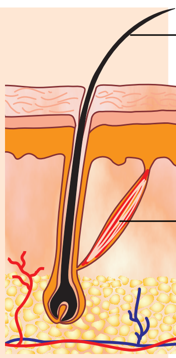
Thermoreceptors in the hypothalamus

Thermoreceptors in the skin

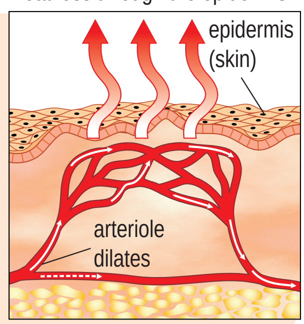


Regulation of Body Temperature by Effectors through Physical Methods

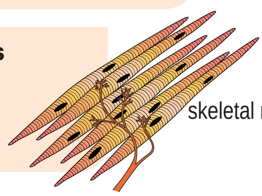
Erector muscles are less stimulated so they **do not constrict** and the fine hair will **lower towards** the skin surface. As a result, a thin layer of air is trapped between the fine hair. Heat can be released quickly.



Arterioles in the skin dilate (**vasodilation**) to allow more blood to flow to the skin surface. More heat is lost to the external environment through radiation.



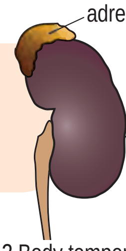
Skeletal muscles contract and relax less. The body does not shiver.



The sweat glands are stimulated to produce **more sweat**. Heat is absorbed to evaporate sweat, and this cools the skin.

Regulation of Body Temperature by Effectors through Chemical Methods

The adrenal glands are less stimulated to secrete adrenaline. Metabolic rate decreases.



The thyroid gland is not stimulated and the secretion of thyroxine is reduced. Metabolic rate decreases. No excess heat is generated.

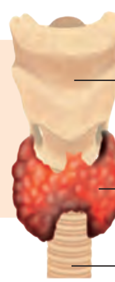
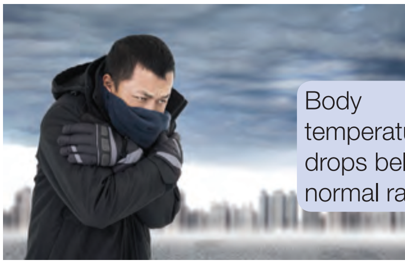


FIGURE 13.2 Body temperature regulation when temperature increases

13.1.4

CHAPTER 13

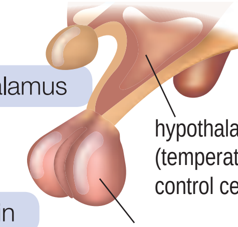


Body temperature drops below normal ranges

detected by

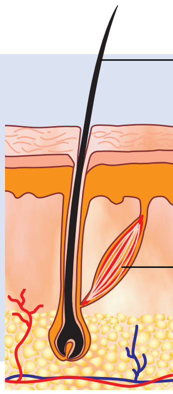
Thermoreceptors in the hypothalamus

Thermoreceptors in the skin

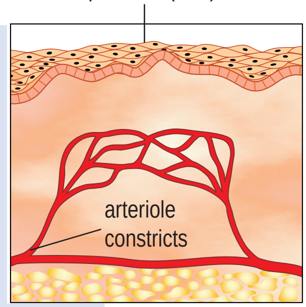


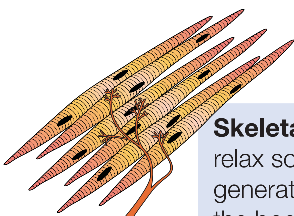
Regulation of Body Temperature by Effectors through Physical Methods

Erector muscles are stimulated so they **contract**, causing **fine hair to stand erect**. A thick layer of air trapped between the fine hairs acts as an insulator that prevents loss of heat from the skin.



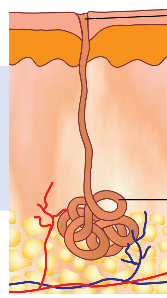
Arterioles in the skin are stimulated to constrict (**vasoconstriction**). The result is less blood flow to the surface of the skin. With that, less heat is lost to the external environment through radiation.





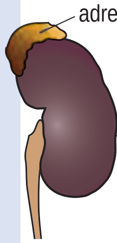
Skeletal muscles will contract and relax so the **body will shiver**. This generates heat which in turn raises the body temperature because the constriction of muscles requires energy.

The **sweat gland** is not stimulated. **Sweating does not happen**.



Regulation of Body Temperature by Effectors through Chemical Methods

The adrenal glands are stimulated to secrete more adrenaline. This hormone speeds up the conversion of glycogen to glucose. Metabolic rate increases. The oxidation of glucose releases heat to warm the body.



The thyroid gland is stimulated to secrete more thyroxine which will increase the metabolic rate. More heat is generated for the body.

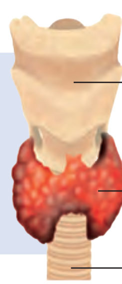


FIGURE 13.3 Body temperature regulation when temperature decreases

Regulation of blood sugar levels

The pancreas is responsible for maintaining blood sugar (glucose) levels within the normal range of 75–110 mg/100 ml. Langerhans cells in the pancreas produce and secrete insulin and glucose continuously into the bloodstream to regulate blood sugar levels. The actions of both these hormones and the mechanism of homeostasis work together to maintain the blood sugar levels within the normal range as described in Figure 13.4.

Malaysian Innovation

Scientific studies have confirmed that cinnamon can lower blood sugar levels.

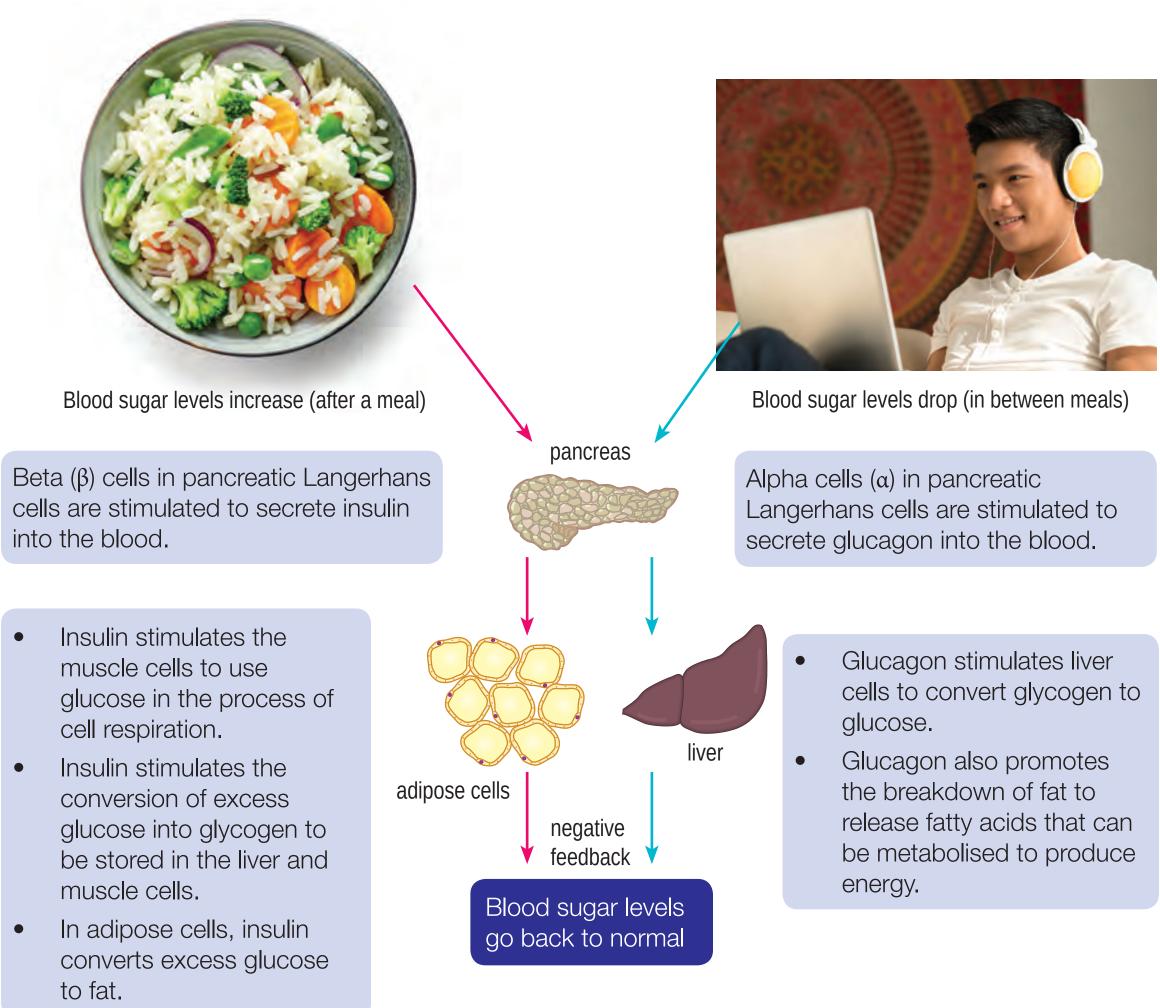


FIGURE 13.4 Regulation of blood sugar levels

ICT 13.1

Video: Regulating blood sugar levels in normal individuals and diabetic patients (Accessed August 21 2019)

Failure in the production, secretion and intake of insulin by target cells can cause **diabetes mellitus**. The blood sugar level of diabetic patients is usually high and unstable after a meal. The patient also feels thirsty, tired, fatigued and suffers weight loss. Diabetes mellitus can be controlled through insulin injections, pills that lower blood sugar levels and a proper diet.

13.1.4

Our World of Biology

Noni fruit (*Morinda citrifolia*) is believed to be able to lower high blood pressure. Juice extracted from this fruit has been marketed on a large scale.

Regulation of partial pressure of carbon dioxide in the blood

Breathing is an involuntary action that is regulated by the **respiratory control centre** in the **medulla oblongata**. The respiratory control centre helps maintain homeostasis by controlling the partial pressure of carbon dioxide in the blood (Figure 13.5).

During vigorous activity, the partial pressure of carbon dioxide increases because of cellular respiration.

→ Carbon dioxide dissolves in blood plasma to form carbonic acid. Carbonic acid is broken down into hydrogen ions and bicarbonate ions.

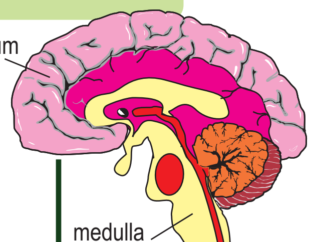
Carbon dioxide + Water ⇌ Carbonic acid ⇌ Hydrogen ion + Bicarbonate ion

↓ pH values of blood and tissue fluid that flood the brain (cerebrospinal fluid) decreases.

↓ This change in pH is detected by the central chemoreceptor in the medulla oblongata (sensory cells that are sensitive to chemicals) and peripheral chemoreceptor in the neck (carotid body and aortic body) (Figure 13.6).

← Nerve impulses triggered and sent

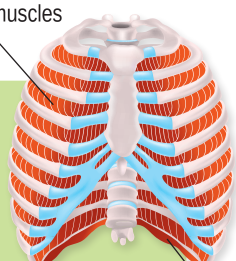
Respiration control centre and cardiovascular control centre inside the medulla oblongata.



↓ nerve impulse sent

Intercostal muscles, diaphragm and cardiac muscles contract and relax quickly.

→ Breathing rate, heart rate and ventilation rate increase. This causes more carbon dioxide gas to be expelled from the lungs.



→ Partial pressure of carbon dioxide and blood pH levels go back to normal.

FIGURE 13.5 Process of regulating partial pressure of carbon dioxide in the blood

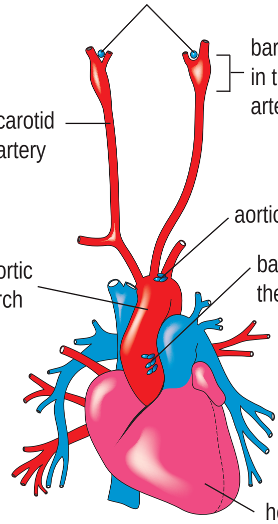


FIGURE 13.6 Aortic body, carotid body and baroreceptor

Blood pressure regulation mechanism

Baroreceptors or pressure receptors are located in the aortic arch and carotid artery (Figure 13.6). **The carotid artery** is the artery in the neck that supplies blood to the head. These receptors detect the pressure of blood flowing through them and continuously send impulses to the cardiovascular control centre in the medulla oblongata to regulate blood pressure (Figure 13.7).

When an individual's blood pressure **drops**, for example, if there is serious bleeding.

↓

Baroreceptors in the aortic arch and carotid artery are less stimulated.

↓

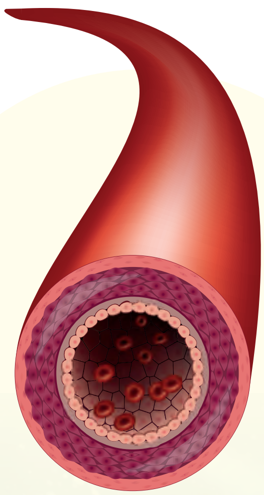
The cardiovascular control centre in the medulla oblongata is less stimulated.

↓

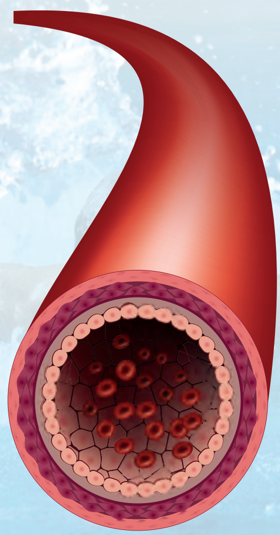
- Arterial **vasoconstriction** occurs. This adds resistance to the flow of blood in the bloodstream.
- Stronger contractions of cardiac muscles occur.

↓ blood pressure increases

Blood pressure returns to the normal ranges.



Vasoconstriction



Vasodilation

When an individual's blood pressure **increases**, for example during vigorous activities.

↓

Baroreceptors in the aortic arch and carotid artery are stimulated.

↓

The cardiovascular control centre in the medulla oblongata is stimulated.

↓

- **Vasodilation** occurs. This reduces the resistance of the flow of blood in the bloodstream.
- Weak contractions of cardiac muscles occur.

↓ blood pressure drops

Blood pressure returns to the normal ranges.

FIGURE 13.7 Blood pressure regulation

Formative Practice 13.1

1 What is the meaning of homeostasis? Explain how homeostasis happens.

2 An employee had to work in hot conditions because the power supply in his office got cut off. Describe the response of the effectors in regulating his body temperature.

3 A 40-year-old man was diagnosed by a doctor as unable to produce enough insulin. Describe what has happened to the man.

4 Ahmad has just finished a 100 m sprint run. Explain how his blood pressure is lowered back to normal range.

13.2 Urinary System

The human urinary system plays an important role in homeostasis. The urinary system is made up of the kidneys, ureters, bladder and urethra (Figure 13.8). The function of the urinary system is to excrete nitrogenous compound wastes such as urea, as well as regulate the volume of body fluids, blood osmotic pressure, ion concentration in body fluids, electrolyte content and blood pH.

Structure and function of the kidneys

The kidneys consist of the **cortex** and **medulla**. Urine that is formed in the kidneys flows into the **pelvis**.

The kidneys have two main functions:

(a) **excretion**
(b) **osmoregulation**

As an excretory organ, the kidneys **excrete toxic wastes** (nitrogenous compounds) such as urea, uric acid, ammonia and creatinine.

As an osmoregulatory organ, the kidneys control:

- the total volume of water in body fluids
- the concentration of ions in body fluids
- **blood osmotic pressure**, which is the concentration of dissolved materials and volume of blood and body fluids
- **electrolyte content** and **pH** of blood and body fluids

Biological Lens

Do you know that the right kidney is located lower than the left kidney? This difference in position is because the liver takes up a lot of space above the right kidney.

13.2.1

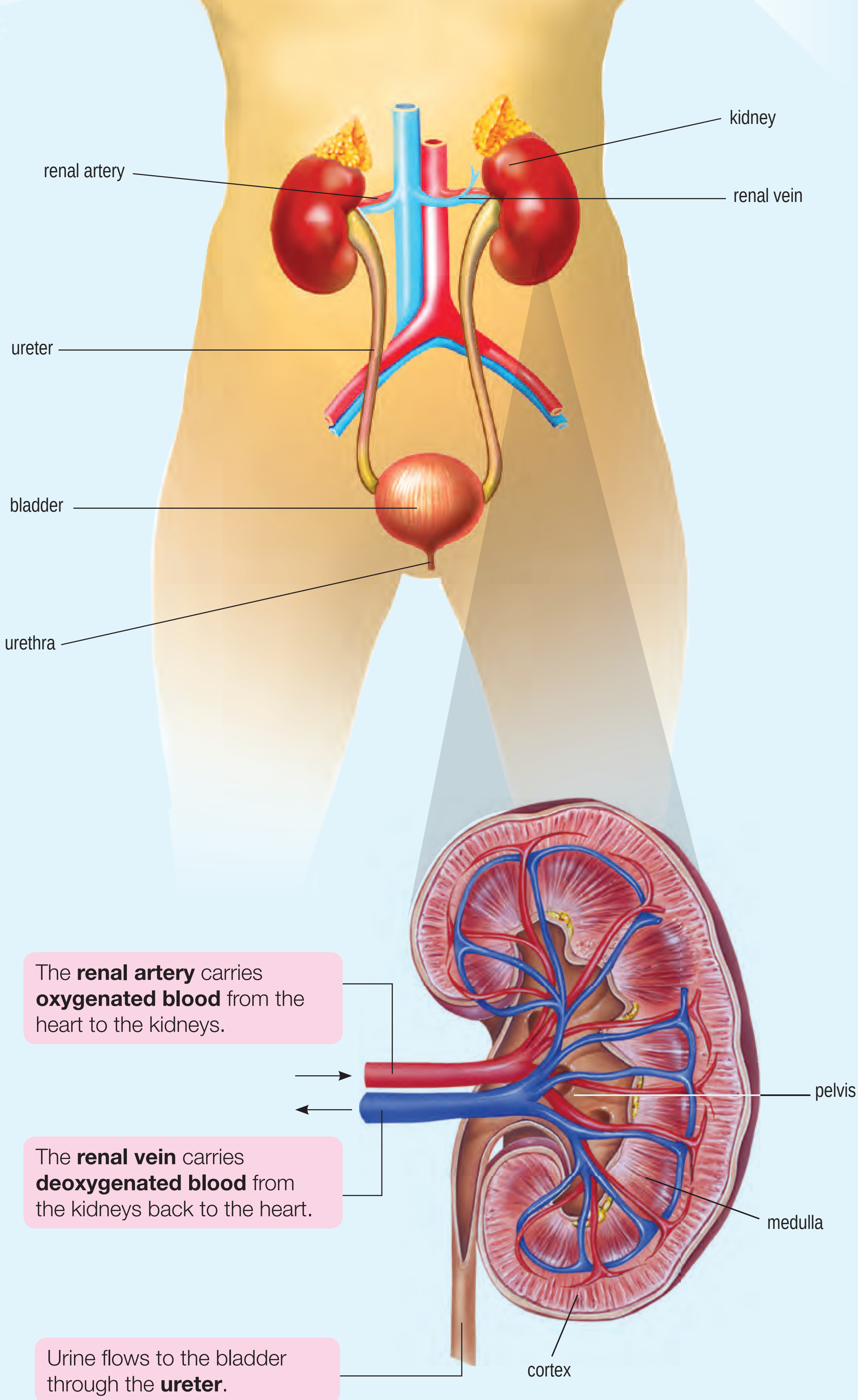


FIGURE 13.8 Urinary system and cross section of the kidney

13.2.1

Formation of urine

There are three major processes involved in the production of urine, which are ultrafiltration, reabsorption and secretion.

NEPHRON

- Each kidney is made up of millions of functional units called **nephrons** (Figure 13.9).
- Each nephron is made up of the following structures:
  - Bowman's capsule
  - Glomerulus
  - Renal tubule
- **Bowman's capsule** is cup-shaped and contains a cluster of blood capillaries called glomerulus. The glomerulus is formed from the afferent arteriole branching from the renal artery. The glomerulus merge again to form the efferent arteriole.
- The renal tubules are composed of the **proximal convoluted tubules, loop of Henle** and **distal convoluted tubule**.
- The **loop of Henle** is a long U-shaped tubule that extends to the renal medulla. The distal convoluted tubule of several nephrons join together into a **collecting duct**.
- The produced urine will flow from the collecting duct into the ureter.

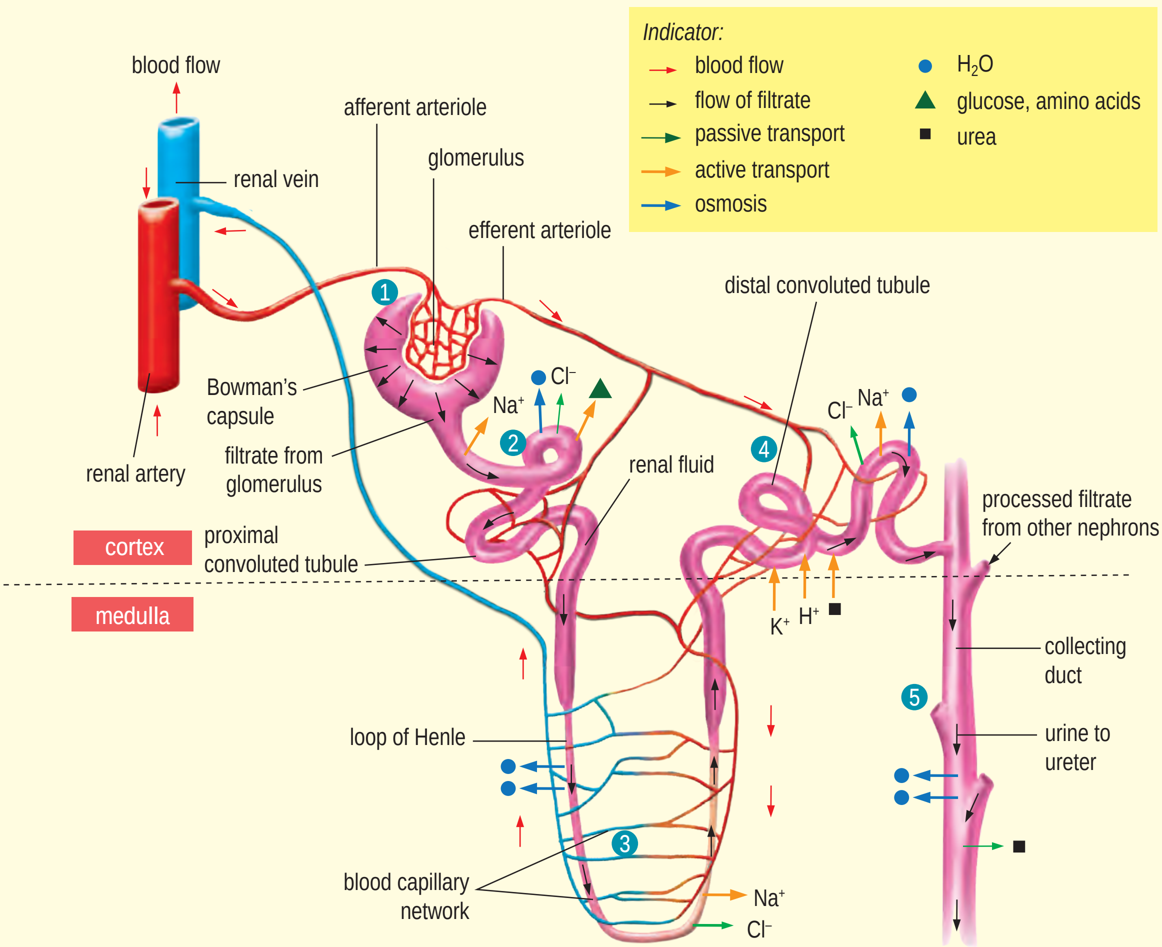


FIGURE 13.9 Structure of the nephron and urine formation

13.2.2 13.2.3

1 ULTRAFILTRATION IN BOWMAN'S CAPSULE

- Blood entering the glomerulus is under high **hydrostatic** pressure because the **diameter** of the afferent arteriole is larger than the diameter of the efferent arteriole. This pressure causes **ultrafiltration** to occur, that is, fluid seeps through the walls of the glomerulus capillaries into the cavity of Bowman's capsule.
- The fluid that enters Bowman's capsule is known as the **glomerular filtrate**.
- The glomerular filtrate has the same composition as blood plasma but does not contain red blood cells, platelets and plasma proteins.
- Red blood cells and plasma proteins remain in the blood flowing to the efferent arteriole because the size of these substances is too large to seep out of the glomerulus.

2 REABSORPTION AT THE PROXIMAL CONVOLUTED TUBULES

- **Reabsorption** of the glomerular filtrate occurs along the renal tubule. The dissolved substances permeate across the renal tubular walls into the blood capillary network.
- In the proximal convoluted tubule, sodium ions (Na^+) are actively pumped into the blood capillary network and chloride ions (Cl^-) are **passively absorbed**.
- The reabsorption of 100% glucose and amino acids also occurs through **active transport**.
- The movement of dissolved substances into the blood capillary network reduces the concentration of dissolved substances in the glomerular filtrate but increases the concentration of dissolved substances in the blood capillaries. As a result, water enters the blood capillaries through osmosis.

3 REABSORPTION AT THE LOOP OF HENLE AND DISTAL CONVOLUTED TUBULES

- In the loop of Henle, water is reabsorbed through osmosis. Sodium ions are reabsorbed through **active transport**.
- In distal convoluted tubules, more water, sodium and chloride ions are reabsorbed.
- The amount of water and salts reabsorbed depends on the water and salt content in the blood.

4 SECRETION

- **Secretion** is the process of secreting waste materials in the blood that were not filtered earlier into the renal tubules.
- This process is opposite to the process of reabsorption.
- Secretion occurs along the renal tubule and collecting duct, but is most active at the distal convoluted tubule.
- Secretion occurs through **simple diffusion** and **active transport**.
- Substances that are secreted include hydrogen ions (H^+), potassium ions (K^+), ammonium ions (NH_4^+), urea, creatinine, toxic substances and some drugs.
- Secretion gets rid of toxic wastes and helps to regulate the levels of ions in the blood.

5 URINE FORMATION

- When the renal fluid reaches the collecting duct, only a small amount of salts are left, and most of the water has been absorbed back into the bloodstream.
- The remaining renal fluid is now called **urine**, flows down the collecting duct. Here, a small amount of urea diffuses out into the surrounding fluid and blood capillaries due to its small molecular size.
- Urine contains water, urea, NaCl salt, uric acid and creatinine.
- After leaving the collecting duct, urine flows through the ureter, bladder, urethra and is finally excreted.

13.2.2 13.2.3

Mechanism of homeostasis and osmoregulation

The body's water content constantly changes depending on the intake of food and drinks. Osmoregulation is the process of regulating water and salts in the body so that the blood osmotic pressure can be maintained at a normal range. **Osmoregulation** is achieved by regulating the volume of urine produced by the kidney. Figure 13.10 illustrates the osmoregulation of blood osmotic pressure.

NORMAL BLOOD OSMOTIC PRESSURE

Drinking **too much water**.	Drinking **too little water** or loss of water due to vigorous activity.
1 Blood osmotic pressure drops to below normal range.	1 Blood osmotic pressure increases above the normal range.
2 Osmoreceptors in the hypothalamus are less stimulated.	2 Osmoreceptors in the hypothalamus are stimulated.
3 The pituitary gland is less stimulated. So, less ADH is secreted from the pituitary gland.	3 The pituitary gland is stimulated. So, more ADH is secreted from the pituitary gland.
4 Low ADH concentrations cause the walls of the distal convoluted tubule and collecting duct to become **less permeable to water**. 5 Less water is reabsorbed from the renal fluid into the blood capillary. 6 Less concentrated urine is generated in high volumes.	4 High ADH concentrations cause the walls of the distal convoluted tubule and the collecting duct to become **more permeable to water**. 5 More water is absorbed from the renal fluid into the blood capillary. 6 Urine that is very concentrated and low in volume is generated.

7 Blood osmotic pressure returns to normal.

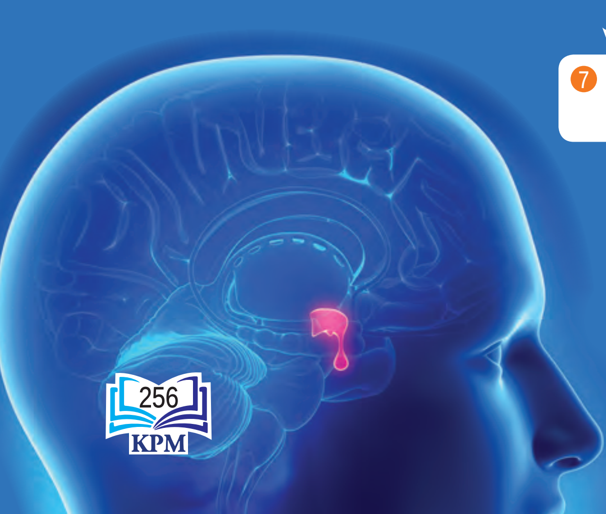


FIGURE 13.10 Osmoregulation of blood osmotic pressure

13.2.4

Carry out the following activity to better understand how consuming different volumes of water can affect urine production.

Activity 13.1 To study the effects of consuming different volumes of water on urine production

Experiment

Problem statement
What is the effect of consuming different volumes of water on the volume of urine produced?

Hypothesis
The higher the volume of water consumed, the higher the volume of urine produced.

Variables:
Manipulated: Volume of water consumed
Responding: Volume of urine collected
Constant: Type of drink, age of pupil and time interval of urine collection

Specimen
Form 4 pupils

Materials
Boiled water that has been cooled

Apparatus
Cup, beaker to collect urine, stopwatch and measuring cylinder

Take Note!
When identifying pupils for this study, choose pupils who are of approximately the same weight.

Procedure
1. Pupils should not eat or drink after 12 midnight the night before the experiment.
2. Pupils are divided into four groups according to their average weight.
3. Pupils are required to urinate before starting the experiment.
4. Each pupil is required to drink the following volumes of water:
   (a) Group 1: drink 250 ml of water (b) Group 2: drink 500 ml of water
   (c) Group 3: drink 750 ml of water (d) Group 4: drink 1000 ml of water
5. During the experiment, pupils should be at rest and are not allowed to carry out vigorous activities.
6. Collect and measure the urine for each pupil after 20 minutes, 40 minutes and 60 minutes.
7. As soon as the urine is measured, it must be discarded into the toilet.
8. Record the average volume of urine collected for each group, for each time interval in the following table.
9. Calculate the total volume of urine produced per group.

Results

Group	Volume of water consumed (ml)	Average volume of urine collected (ml)			Total volume of urine produced (ml)
		20 minutes	40 minutes	60 minutes	
1	250				
2	500				
3	750				
4	1000				

13.2.5

Discussion

1. What is the relationship between the volume of water consumed and the production of urine? Explain your answer.
2. How does the volume of urine change over time?
3. Explain how the volume of urine collected varies between an individual who drank 100 ml of distilled water, and an individual who drank 100 ml of 5% sodium chloride solution.

Conclusion

Is the hypothesis accepted? State a suitable conclusion.

Activity 13.2 Gather information on and discuss haemodialysis

Collecting information

Materials

Internet, reference materials

Procedure

1. In groups of four, gather information about haemodialysis.
2. Discuss the following.
   (a) Study the reasons of renal failure that cause a person to undergo haemodialysis.
   (b) Explain how haemodialysis works.
3. Make a report on your findings and present it to the class.
4. You can also carry out an activity to raise funds for haemodialysis centres through awareness campaigns about the importance of helping patients in need of treatment.

Discussion

1. Why would someone need haemodialysis?
2. How does haemodialysis work?
3. What is the effect on patients who do not receive treatment?

Formative Practice 13.2

1. In which part of the kidney can the proximal convoluted tubule, loop of Henle and distal convoluted tubule be found?
2. Suggest two possible activities that can cause the walls of the collecting duct to become more permeable to water.
3. State how Na^+ ions, water and glucose are reabsorbed into the proximal convoluted tubule.
4. An individual suffers damage in one kidney. Does the individual need to undergo haemodialysis? Suggest steps that this individual needs to take in order to go through his daily life without problems.

13.3 Health Issues Related to the Urinary System

Kidney failure can be caused by illness, bacterial infections or accidents. Diabetes mellitus is the leading cause of renal failure, followed by high blood pressure. Both these conditions damage the glomerulus. Other than that, some individuals may face the problem of kidney stone formation. **Kidney stones** are hard masses made of uric acid, calcium oxalate or crystalline calcium phosphate.

ICT 13.2

Activity: Gather information and discuss health issues related to the urinary system

Kidney stones can block the ureter and reduce the production of urine. To reduce the likelihood of kidney stone formation, you should drink a lot of water every day. Why?

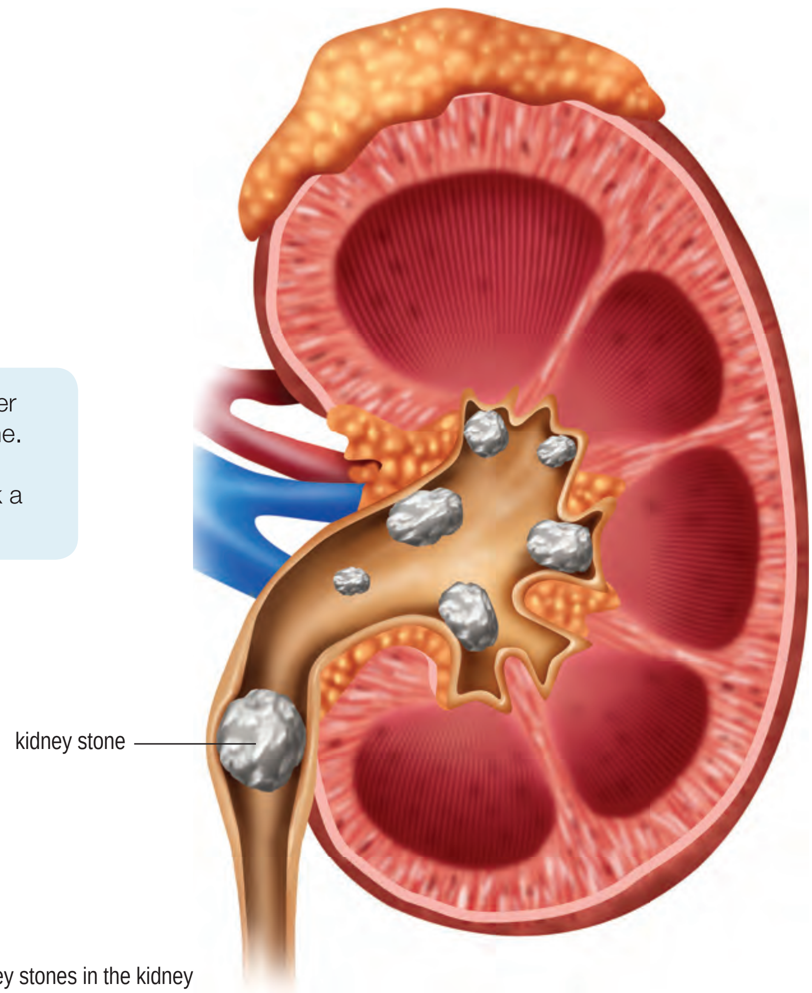


FIGURE 13.11 Formation of kidney stones in the kidney

Formative Practice 13.3

1 Azman suffers from the formation of kidney stones. Explain the effects of kidney stones on his health.

2 Suggest two reasons why a person would have kidney stones.

13.3.1

Summary

HOMEOSTASIS AND THE HUMAN URINARY SYSTEM

Homeostasis

Regulation of physical and chemical factors of the internal environment within normal ranges so that the cell functions at optimum levels

Body temperature
Regulated by the integumentary system, nervous system, circulatory system, muscular system and endocrine system

Blood sugar level
Regulated by the endocrine system, circulatory system and digestive system

The partial pressure of carbon dioxide in the blood
Regulated by the respiration system, circulatory system and nervous system

Blood pressure
Regulated by the circulatory system and nervous system

Urinary System

Kidney:
- Helps regulate water and salts in the body
- The nephron is composed of the Bowman's capsule, glomerulus, proximal convoluted tubule, loop of Henle and distal convoluted tubule

The process of urine formation
- Ultrafiltration
- Reabsorption
- Secretion

Mechanism of homeostasis and osmoregulation
- Osmoregulation of blood osmotic pressure

Health Issues Related to the Urinary System

Kidney stones

Self Reflection

Have you mastered the following important concepts?

- The meaning of homeostasis
- The need to maintain the physical and chemical factors within the internal environment
- The involvement of various organ systems in maintaining an optimum internal environment
- The concept of homeostasis in regulation
- Structure and function of the kidneys
- Structure of the nephron and collecting duct
- The process of urine formation
- The concept of homeostasis and negative feedback in osmoregulation
- Health issues related to the urinary system

Summative Practice 13

1 In which part of the kidney can the loop of Henle be found?

2 State the condition of urine that will be produced after an individual
(a) drinks plenty of water
(b) eats too much salty food

3 State a test that you can perform in the laboratory to determine whether a person has diabetes.

4 Explain the role of the liver when blood sugar levels decrease.

5 Table 1 shows the concentration of amino acids in blood plasma and urine.

TABLE 1

Contents	Concentration in blood plasma that enters the kidneys (g per 1000 ml)	Concentration in urine (g per 1000 ml)
Amino acids	85	0

(a) Explain the difference in the concentration of amino acids in blood plasma and urine.

(b) Both kidneys of a patient have failed. This condition causes water imbalance and an accumulation of urea in the blood. State the effect of kidney failure on the regulation of water balance in the blood.

6 (a) A patient suffered a disease that required the pancreas to be removed. Explain the effect of removing the pancreas on the production of enzymes and hormones, and subsequently on digestion and blood glucose levels in the individual.

(b) What advice can be given to the patient to help him deal with the health problems caused by the removal of his pancreas?

7 Figure 1 shows the structure of a nephron and collecting duct.

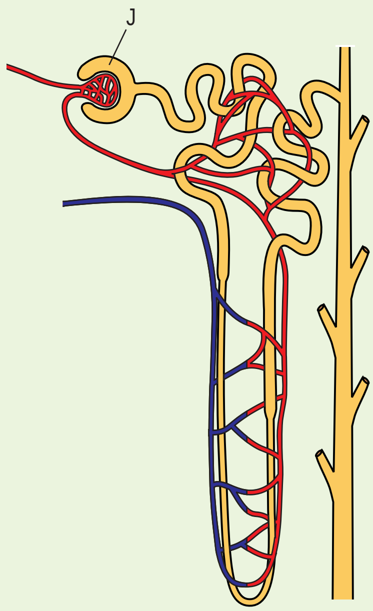


FIGURE 1

(a) Name the process that happens in J.

(b) Name two substances that are not filtered out through the glomerulus.

(c) Explain how the process you named in (a) occurs.

(d) Explain why the fluid flowing in the loop of Henle does not contain glucose even though glucose is present in Bowman's capsule.

(e) Mammals have different kidney structures depending on the presence of water in their habitats. The concentration of urine produced depends on the length of the loop of Henle. The longer the loop of Henle, the higher the salt concentration in the fluid surrounding the loop of Henle. Based on this information, what can you predict about the loop of Henle in animals living in a humid environment compared to animals living in a dry environment?

Essay Questions

8 Describe how the body temperature of a worker who has been in a cold room for 6 hours is regulated.

9 Breathing is an involuntary process that is controlled by the respiratory control centre in the medulla oblongata. Explain what happens to a climber's breathing rate when he is at the peak of a high mountain.

10 Explain the role of erector muscles, fine hair and sweat glands in maintaining the body temperature on hot days.

11 (a) (i) Explain the importance of maintaining the body temperature at 37 °C.

(ii) Describe two physical ways in which the body reacts to regulate body temperature after a person bathes with cold water.

(b) In your opinion, what is the effect on urine excretion if the food consumed contains large quantities of protein?

(c) Explain how the pituitary gland regulates blood osmotic pressure when a person drinks too little water.

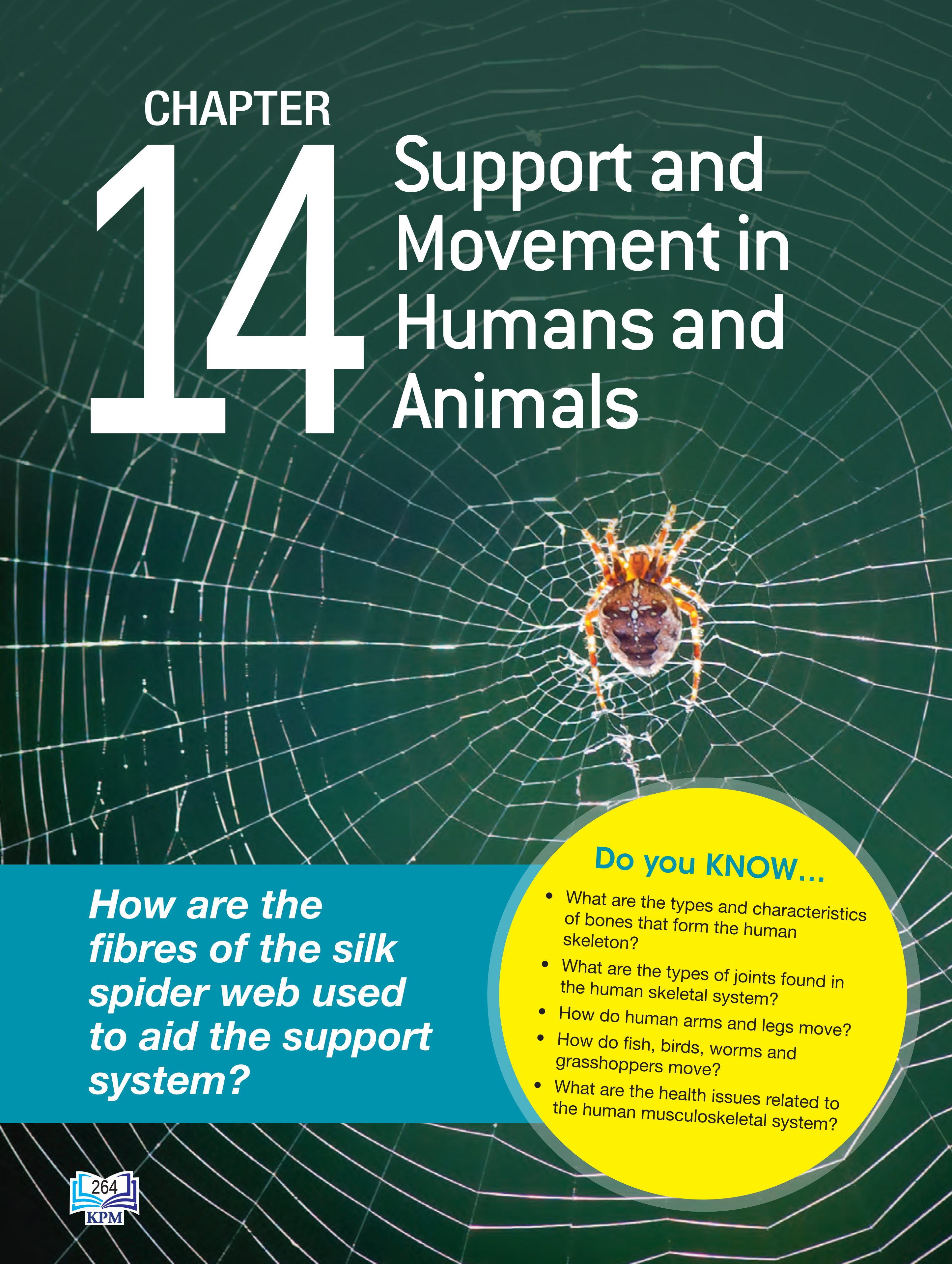
Enrichment

12 Explain how saltwater fish can survive without experiencing dehydration.

13 Why is a urine test conducted to determine if a person has taken drugs?

14 Modern technology has greatly helped patients with kidney problems. For example, haemodialysis machines have helped many patients with kidney failure to survive. Currently, research is underway to produce bioartificial kidneys. This device is believed to be able to carry out all the functions of a healthy kidney. In your opinion, what qualities should a bioartificial kidney have in order to function like a real kidney?

Complete answers are available by scanning the QR code provided



CHAPTER

14 Support and Movement in Humans and Animals

How are the fibres of the silk spider web used to aid the support system?

Do you KNOW...

- What are the types and characteristics of bones that form the human skeleton?
- What are the types of joints found in the human skeletal system?
- How do human arms and legs move?
- How do fish, birds, worms and grasshoppers move?
- What are the health issues related to the human musculoskeletal system?

14.1 Types of Skeletons

14.1.1 List the types of skeletons in humans and animals:
- hydrostatic skeleton
- exoskeleton
- endoskeleton

14.1.2 Justify the necessity of skeletons in humans and animals.

14.2 Musculoskeletal System of Humans

14.2.1 Identify the bones that form the human skeletal system:
- axial skeleton
- appendicular skeleton

14.2.2 Characterise the types of vertebrae in the backbone:
- cervical vertebrae (including the atlas and axial)
- thoracic vertebrae
- lumbar vertebrae
- sacral vertebrae
- caudal vertebrae

14.2.3 Compare and contrast the types of vertebrae.

14.2.4 State the types of joints in the human skeletal system:
- immovable joints
- slightly moveable joints
- freely moveable joints

14.2.5 Draw, label and explain the human forearm hinge joint structure:
- bones
- cartilages
- skeletal muscles
- tendons
- ligaments
- synovial membrane
- synovial fluid

14.3 Mechanism of Movement and Locomotion

14.3.1 Explain the movement mechanisms in:
- human forearm
- human leg (walking)

14.3.2 Describe briefly the locomotion mechanisms in animals

14.4 Health Issues Related to the Human Musculoskeletal System

14.4.1 Describe the health issues related to the human musculoskeletal system:
- osteoporosis
- osteomalacia
- rickets
- arthritis
- scoliosis

14.4.2 Justify the practices to maintain a healthy musculoskeletal system.

14.1 Types of Skeletons

ICT 14.1

Activity: Carry out a brainstorming activity on the necessity of support and movement in humans and animals

The **skeletal system** provides support to humans and animals. There are three types of skeletons, namely, the **exoskeleton**, **endoskeleton** and **hydrostatic skeleton**.

Types of skeletons
- Exoskeleton
- Endoskeleton
- Hydrostatic skeleton

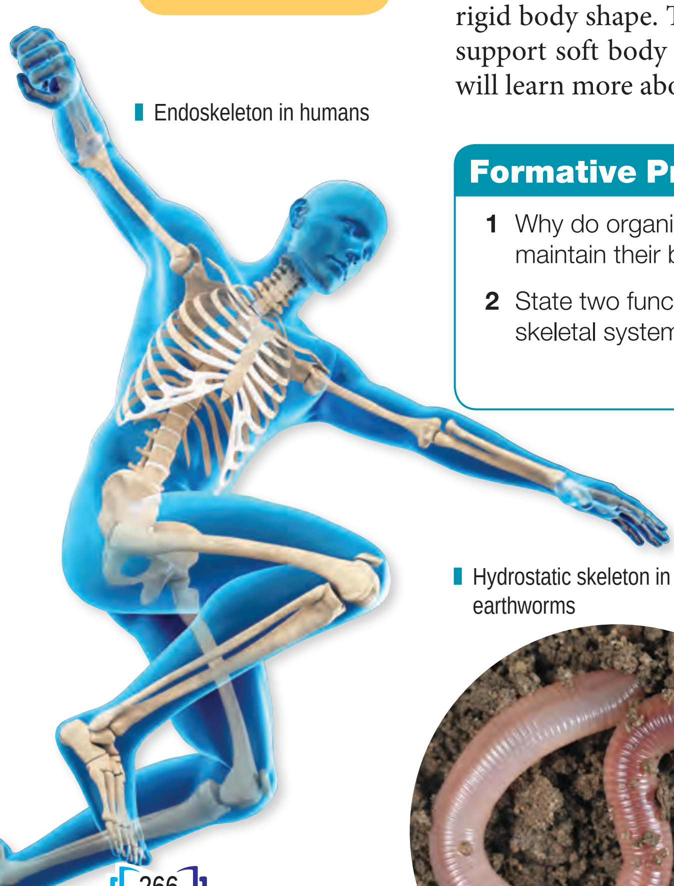
The necessity of skeletal systems in animals and humans

Humans and animals need the skeletal system to enable them to move from one place to another in search of food, partners, or to escape from predators and threats.

Most multicellular organisms need support because of their soft body tissues. The **exoskeleton** found in insects and crabs, support and protect body organs and enable these animals to move. Animals with soft tissues such as earthworms need a **hydrostatic skeleton** to maintain a rigid body shape. The **endoskeleton** functions to maintain body shape, support soft body tissues and protect internal organs from injury. You will learn more about the human skeletal system in the following unit.

Brainstorm!

What are the advantages and disadvantages if humans have exoskeletons like insects?



Endoskeleton in humans

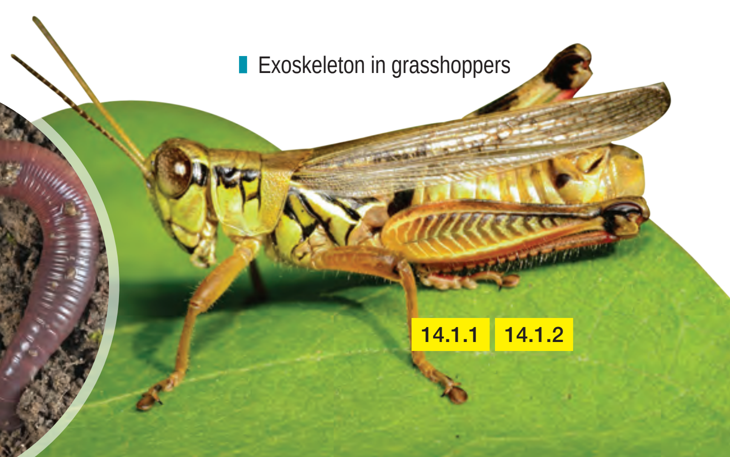
Formative Practice 14.1

1 Why do organisms need to maintain their body shapes?

2 State two functions of the skeletal system to humans.

3 For animals that move on the ground, what is the advantage of having legs below the body (for example, rats) compared to having legs at the side of the body (for example, crocodile)?

Hydrostatic skeleton in earthworms



Exoskeleton in grasshoppers

14.1.1 14.1.2

14.2 Musculoskeletal System of Humans

Skeletal system

The human skeletal system is made up of the **axial skeleton** and **appendicular skeleton**.

Axial skeleton

The axial skeleton comprises the skull, vertebral column, ribs and sternum (breastbone).

Appendicular skeleton

The appendicular skeleton includes the pectoral girdle, pelvic girdle, upper and lower limbs.

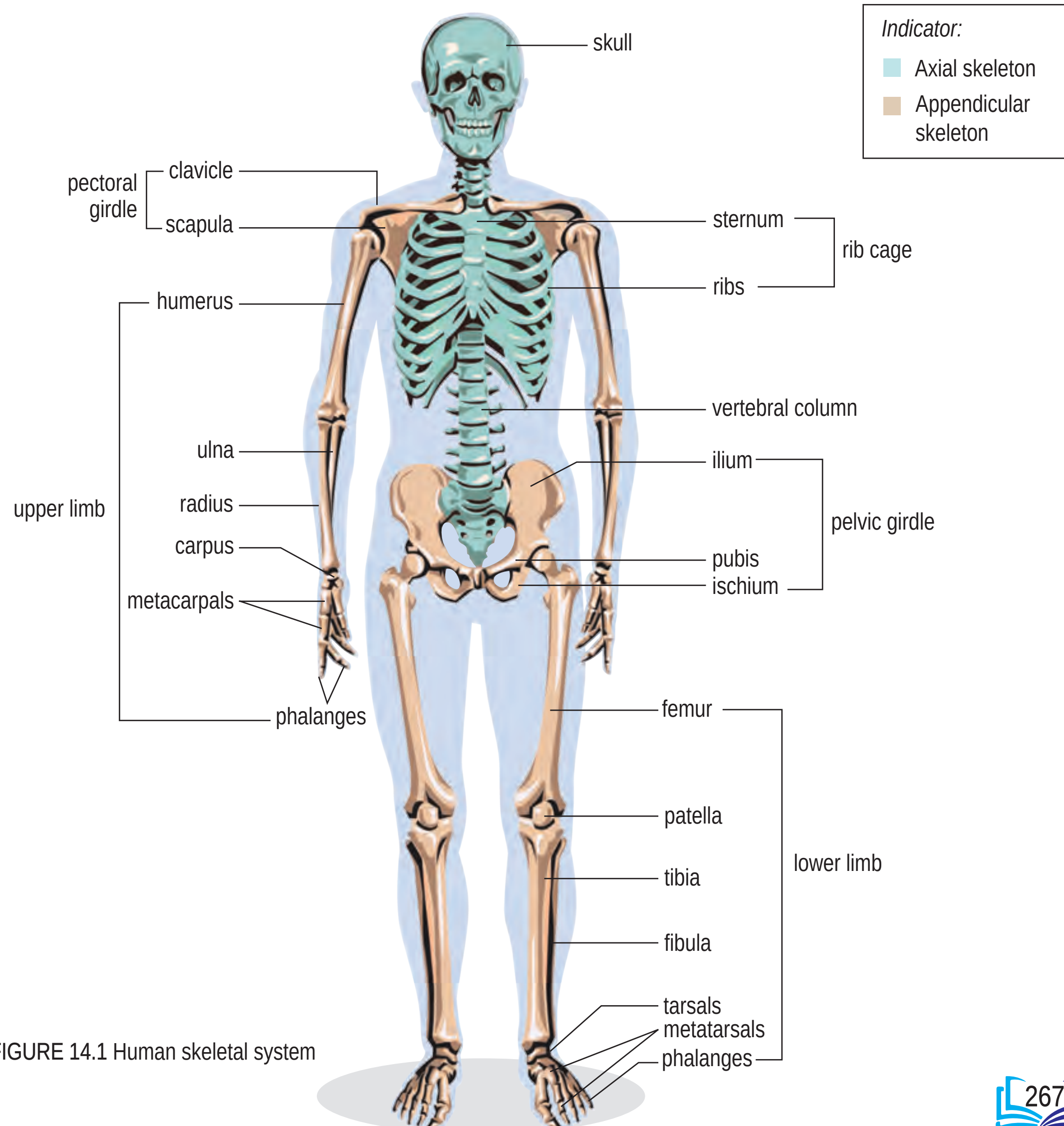


FIGURE 14.1 Human skeletal system

14.2.1

Activity Zone

Carry out a brainstorming activity to explain the importance of skeleton to humans and animals.

Human vertebral column

The vertebrae (singular: vertebra) on different parts of the vertebral column differ in size and shape (Figures 14.2–14.7). Each vertebra has an opening known as the neural canal. The spinal cord is located in the neural canal.

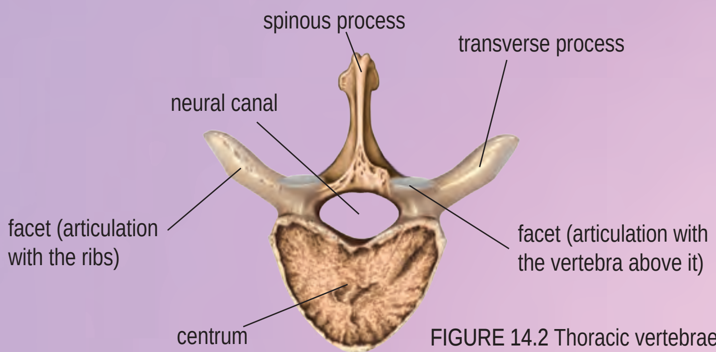


FIGURE 14.2 Thoracic vertebrae

Thoracic vertebrae (Figure 14.2)
- Possess a long spinous process
- Spinous and transverse processes serve as attachment sites for muscles and ligaments
- The transverse processes (except on the 11th and 12th thoracic vertebrae) have facets for articulation with the ribs.

Lumbar vertebrae (Figure 14.3)
- The biggest and strongest vertebrae
- Possess a short spinous process
- Possess a large centrum to bear the weight of the lower back of the body

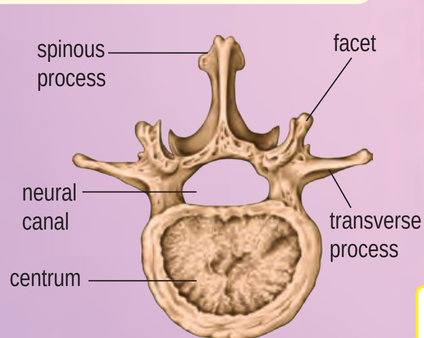


FIGURE 14.3 Lumbar vertebrae

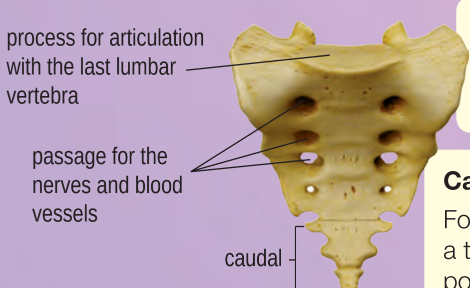
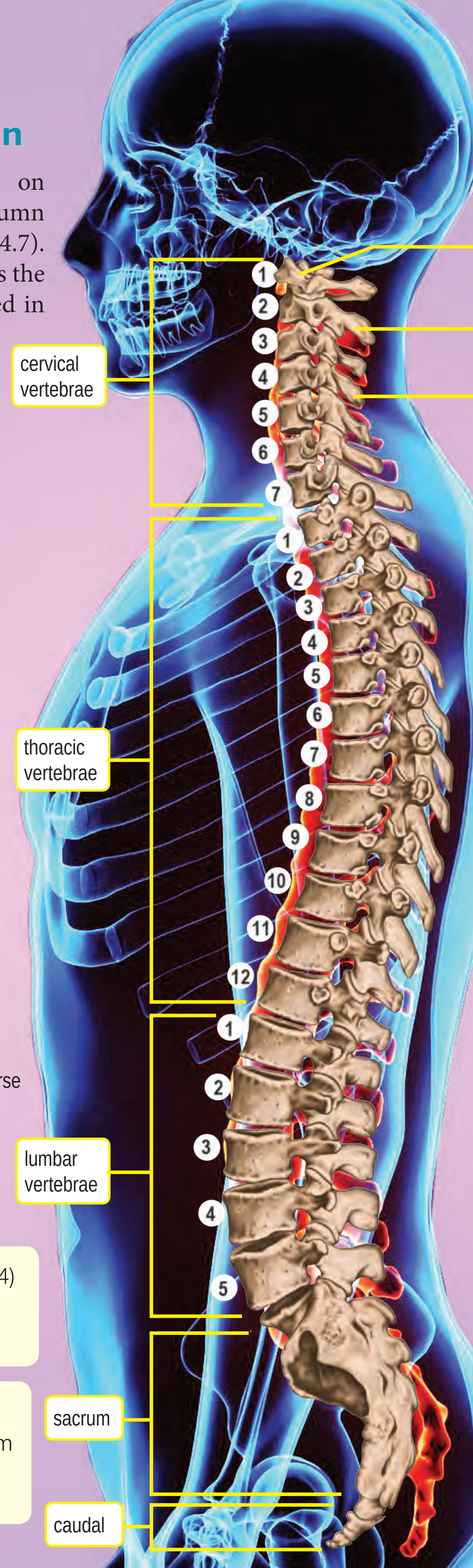


FIGURE 14.4 Sacral and caudal vertebrae

Sacral vertebrae (Figure 14.4)
Five vertebrae fused together to form a triangular bone

Caudal vertebrae (Figure 14.4)
Four bones fused together to form a triangular structure which is pointed at one end.



14.2.2

atlas vertebra

axial vertebra

cervical vertebra

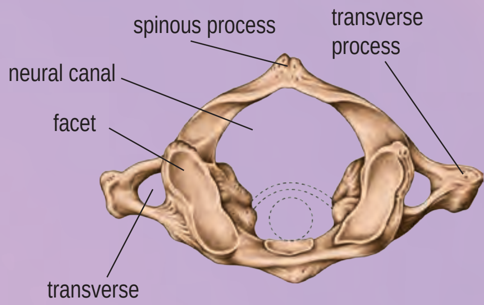


FIGURE 14.5 Atlas vertebra

Atlas vertebra (Figure 14.5)
- The first cervical vertebra.
- The vertebra has a large neural canal, a small spinous process, a pair of transverse foramina (singular: foramen) but with no centrum.
- The vertebra articulates with the skull.

Axial vertebra (Figure 14.6)
- The second cervical vertebra.
- The axial vertebrae has a large spinous process, small transverse process and a pair of transverse foramina.
- It has an odontoid process that articulates with the facet of the atlas vertebra's neural canal.

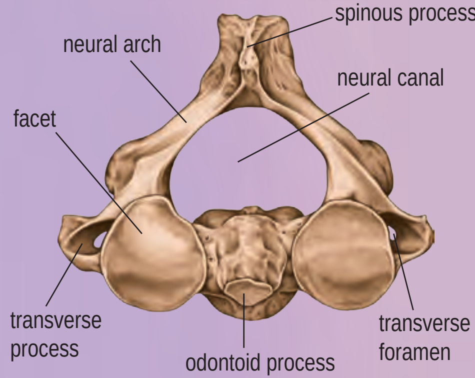


FIGURE 14.6 Axial vertebra

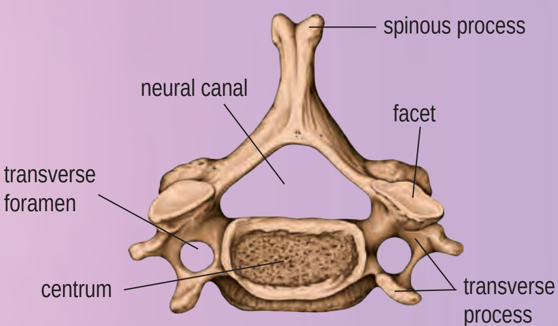


FIGURE 14.7 Cervical vertebrae

Cervical vertebrae (Figure 14.7)
Possess short spinous process, small centrum, wide and short transverse process, and a pair of transverse foramina.

Based on the characteristics shown, can you compare and contrast the different vertebrae? What are the differences between lumbar and thoracic vertebrae? What are the characteristics found on cervical vertebrae but not found on other vertebrae?

SIMILARITY BETWEEN VERTEBRAE

All vertebrae have spinous and transverse processes, centrum (except the atlas vertebra) and neural canal.

DIFFERENCES BETWEEN VERTEBRAE

CERVICAL VERTEBRAE
- Short spinous process
- Wide and short transverse process
- Small centrum
- A pair of transverse foramina

THORACIC VERTEBRAE
- Long spinous process
- Long transverse process
- Medium-sized centrum
- No transverse foramen

LUMBAR VERTEBRAE
- Short spinous process
- Short transverse process
- Large centrum
- No transverse foramen

CHAPTER 14

14.2.2 14.2.3

How are these bones joined together to form the skeleton? Bones are too rigid to be bent without breaking. Flexible connective tissues form joints that hold the bones together so that movement can take place. We will learn about the different kinds of joints in the following section.

Joints

Joints are points where two or more bones meet, or cartilage and bones meet. Most joints allow the bones to move relative to each other. Different types of joints allow different types of movements. The joints are divided into three types, namely,

- **immovable joints** (for example, suture at the cranium of the skull) (Figure 14.8)
- **slightly moveable joints** (for example, cartilage discs between the vertebrae, and cartilage between the first rib and sternum) (Figure 14.9)
- **freely moveable joints** (for example, hinge joint and ball-and-socket joint) (Figure 14.10)

Activity Zone

Dissect a chicken wing to observe the joint's structure.

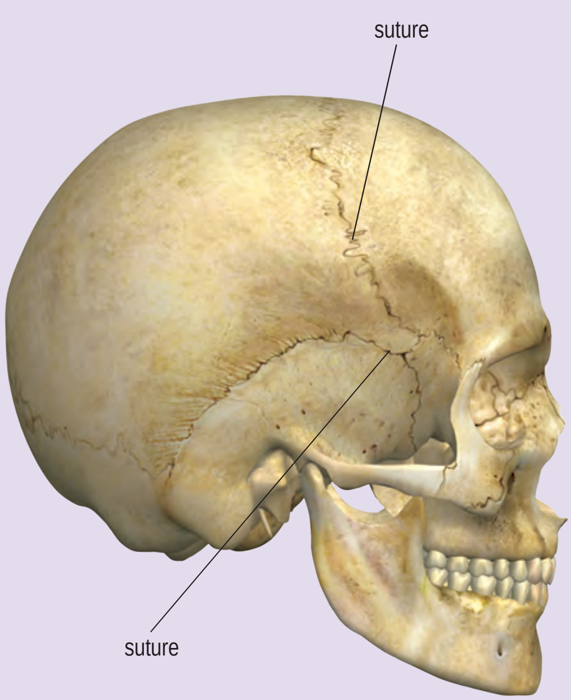


FIGURE 14.8 Immovable joint

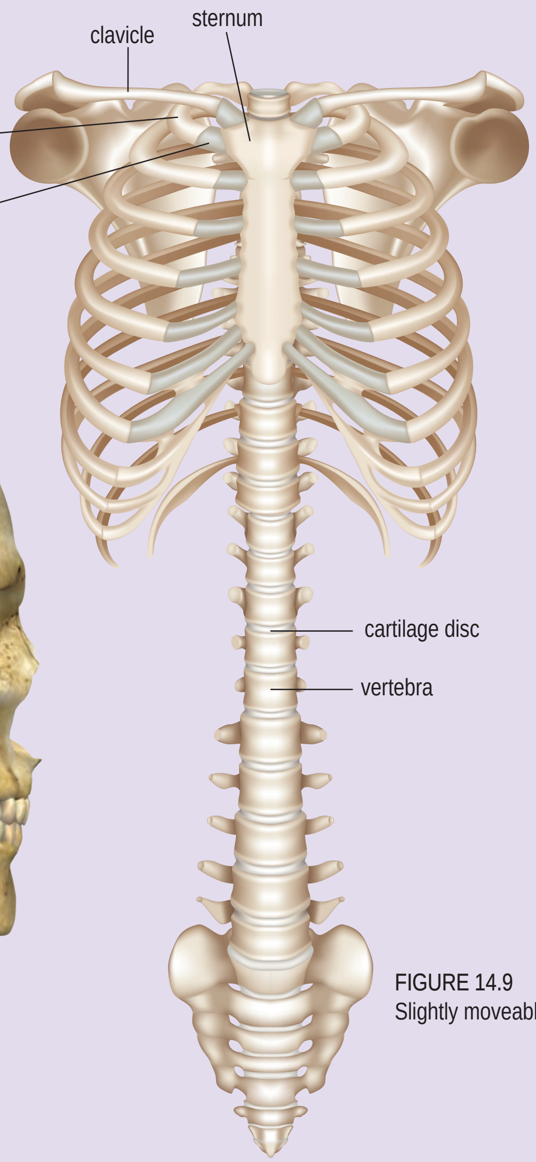


FIGURE 14.9
Slightly moveable joints

14.2.4

Freely moveable joints

The ball-and-socket joint and hinge joint are two examples of freely moveable joints that allow free movements. The general structure of a freely moveable joint and the functions of its parts are shown in Figure 14.10.

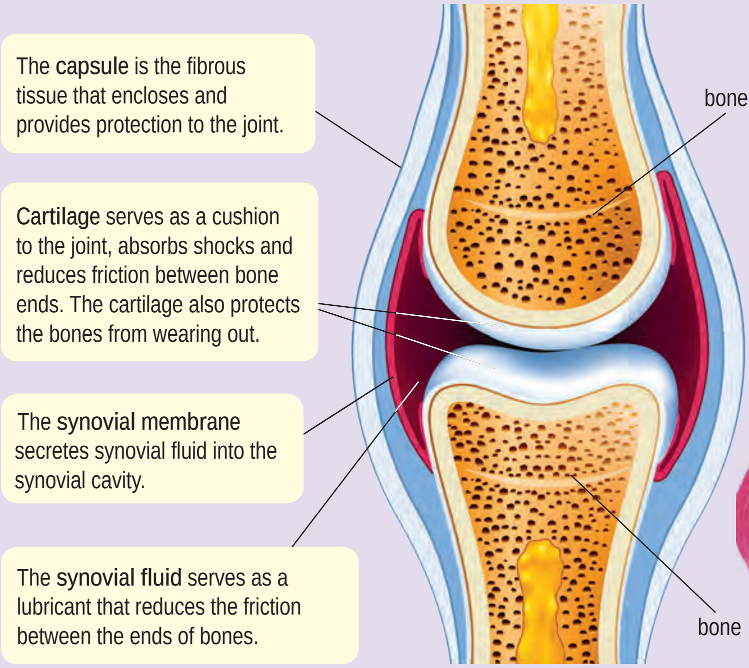
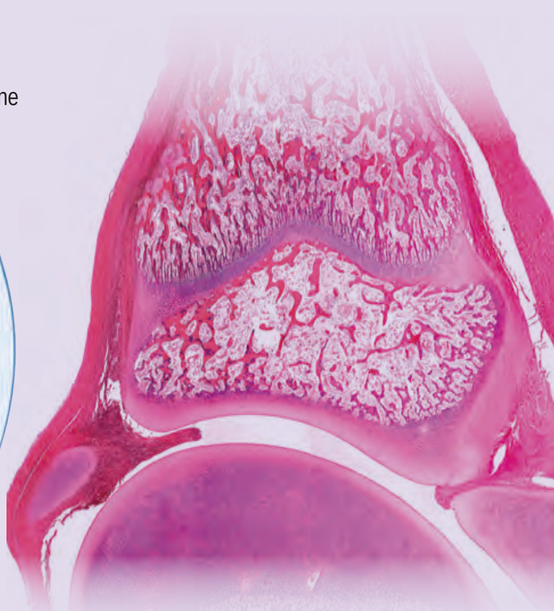


FIGURE 14.10 Freely moveable joint



PHOTOGRAPH 14.1 Joint

BALL-AND-SOCKET JOINT

The ball-and-socket joint allows rotational movement in all directions (Figure 14.11). It allows the arm and leg to swing in a circular motion. Examples of ball-and-socket joints are the shoulder joints between the humerus and pectoral girdle, and the hip joint between the femur and pelvic girdle.

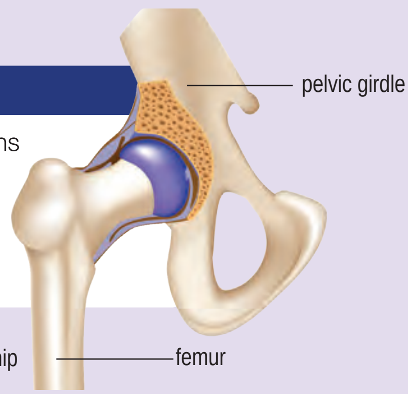
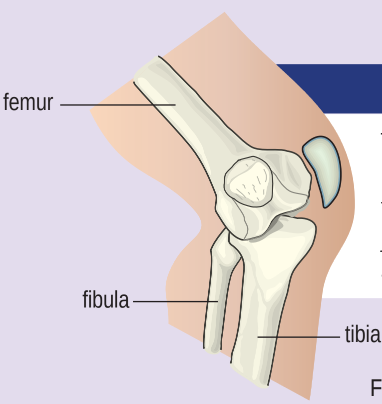


FIGURE 14.11 Ball-and-socket joint at the hip



HINGE JOINT

The hinge joint allows the movement of bones in one plane (Figure 14.12). For example, the knee joint allows the lower leg to swing back and forth, similar to a hinge on a door. The hinge joint can also be found at the elbow and phalanges of the fingers and toes.

FIGURE 14.12 Hinge joint at the knee

14.2.4

Apart from joints and bones, support and movement also depend on the skeletal muscle, tendon and ligament.

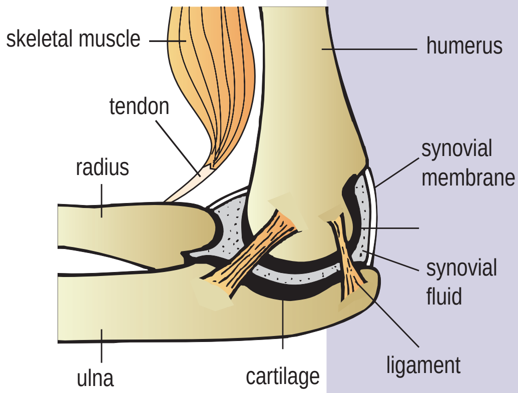


FIGURE 14.13 Skeletal muscle, tendon and ligament

Skeletal muscle

- Comprises bundles of muscle fibres, with a large supply of nerves and blood vessels
- The muscles work in pairs and act in opposite directions, that is if one muscle contracts, the other relaxes, and vice versa. These types of muscles are known as **antagonistic muscles**.
- The biceps and triceps are examples of antagonistic muscles. The muscle that straightens the limbs when it contracts is called the **extensor**. For example, the triceps. The muscle that bends the limbs when it contracts is called the **flexor**. For example, biceps.

Tendon (connects bone and muscle)

- Consists of strong fibres, not elastic but flexible.

Ligament (connects bone to bone)

- Bones are held together at the joints by the ligament which consists of strong, elastic and tough connective tissue bundles.
- The ligament provides support and strength to joints and allows bones to be bent at the joints.

STEM Bulletin

Electroactive plastic polymer is used to produce synthetic muscle. The plastic is used in the production of human-like robots and enables the robots to walk. The synthetic muscle contracts in response to electric current. It is also used to help those with missing limbs.

Formative Practice 14.2

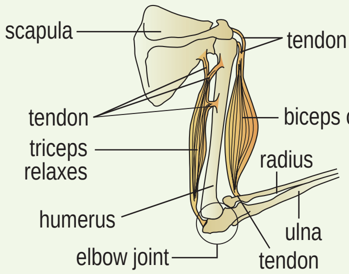
1. Name the bones that form the axial skeleton of the human body.
2. State the function of cartilage and synovial fluid in the joint.
3. State the differences between the structure and function of tendon and ligament.
4. Explain the differences between the ball-and-socket joint and hinge joint.

14.3 Movement and Locomotion

The mechanism for the movement of the human forearm involves biceps and triceps. Figure 14.14 shows the action of both antagonistic muscles resulting in the movement of the forearm.

14.2.5 14.3.1

ARM BENDING	ARM STRAIGHTENING
• When the biceps contracts, the pull force is transmitted to the radius through the tendon. • At the same time, the triceps relaxes. • The radius is pulled upwards, causing the arm to bend.	• When the triceps contracts, the pull force is transmitted to the ulna through the tendon. • At the same time, the biceps relaxes. • The ulna is pulled downwards, straightening the arm.



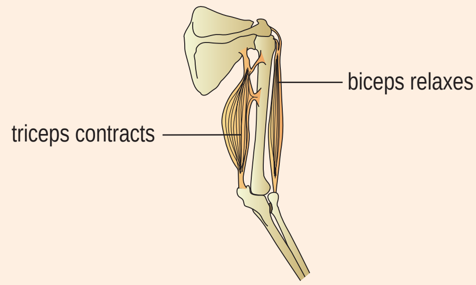


FIGURE 14.14 The action of the muscles results in the movement of the forearm

Leg movement is produced by the action of the antagonistic muscle pair. The **biceps femoris** is the flexor whereas the **quadriceps femoris** is the extensor (Figure 14.15).

Brainstorm!

What would happen if
(a) you only have the quadriceps femoris?
(b) the muscle is attached directly to the bone?

1. The right calf muscle contracts, lifting the heel. The ball of the foot pushes against the ground.
2. At the same time, the biceps femoris contracts, bending the foot at the knee joint. The right leg is lifted.
3. As the right leg leaves the ground, the body weight is now supported by the left leg which is still on the ground. The quadriceps femoris (extensor) contracts to straighten the leg.
4. The tibialis contracts to bring down the heel. As the right heel touches the ground, body weight is shifted to the right leg. The whole sequence is repeated by the left leg.

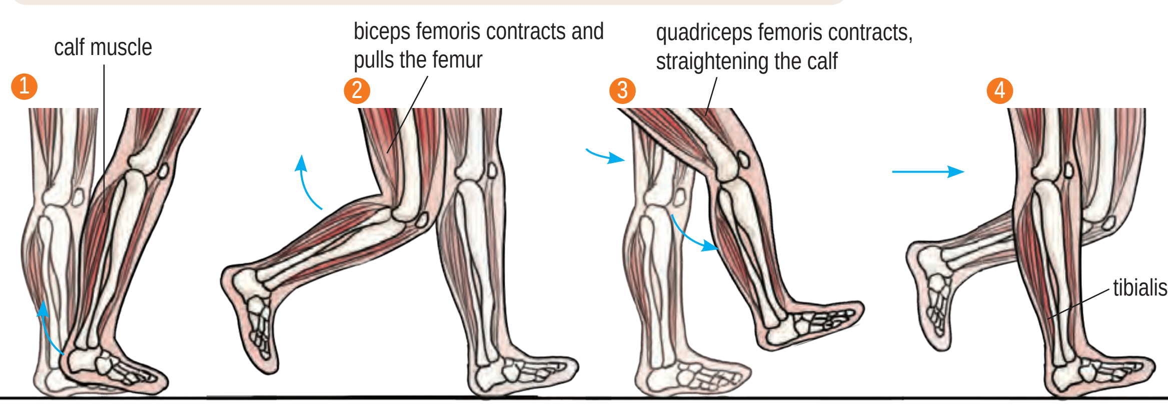


FIGURE 14.15 The action of antagonistic muscles during walking

14.3.1

Mechanism of locomotion in animals

FISH

- The fish vertebral column is flexible and can be moved from side to side by the contraction and relaxation of **myotome**, W-shaped muscle segments.
- These antagonistic muscles act in opposite directions. This enables a fish to whip its tail. As the myotome on the right contracts, the one on the left relaxes.
- The tail will be whipped to the right (Figure 14.17).
- On the contrary, when the right myotome contracts, the left relaxes and the tail is whipped to the left.
- Alternating waves of contraction and relaxation occur along the myotome.
- The action causes parts of the body to move from side to side, pushing water backwards and sideways, and hence moving the fish forward.
- The fins are used to control a fish's movement and direction.

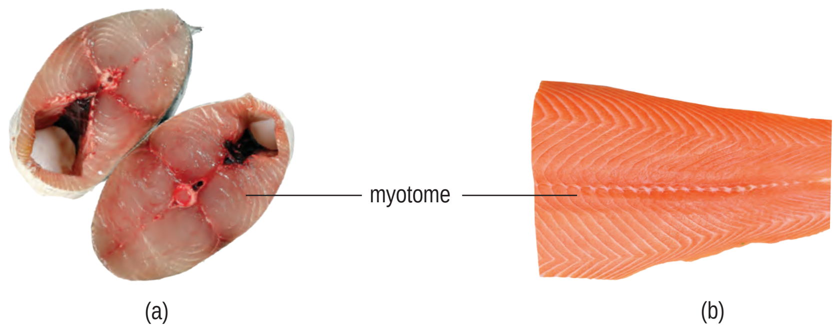


FIGURE 14.16 (a) Cross section and (b) longitudinal section of a fish

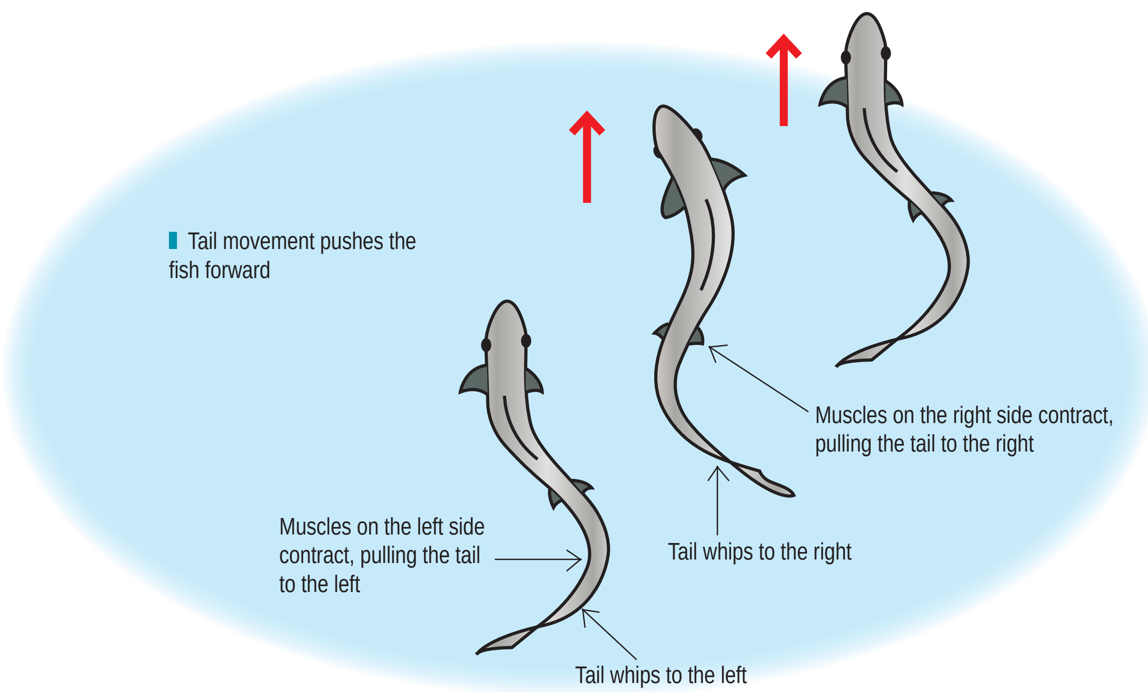


FIGURE 14.17 Fish locomotion mechanism

BIRD (FLIGHT)

- The action of the large and strong antagonistic muscles on a bird's chest assist in the flapping of the wings.
- The mechanism of a bird's wing movement is shown in Figure 14.18.

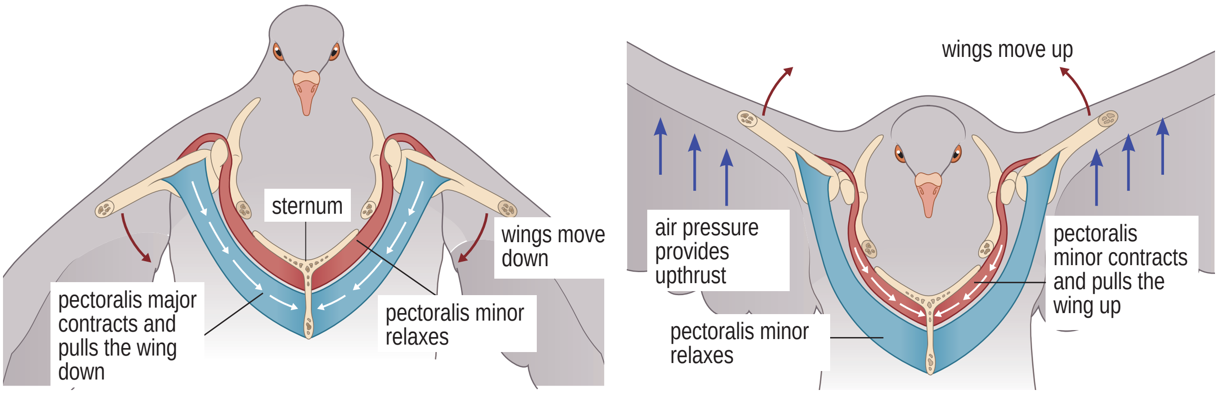


FIGURE 14.18 Bird's locomotion

- When the pectoralis major contracts and the pectoralis minor relaxes, the wings are pulled down.
- When the pectoralis minor contracts and the pectoralis major relaxes, the wings are pulled up.

EARTHWORMS

The alternate contractions and relaxations of the circular and longitudinal muscles result in a wave of peristalsis along the body of the earthworm (Figure 14.19).

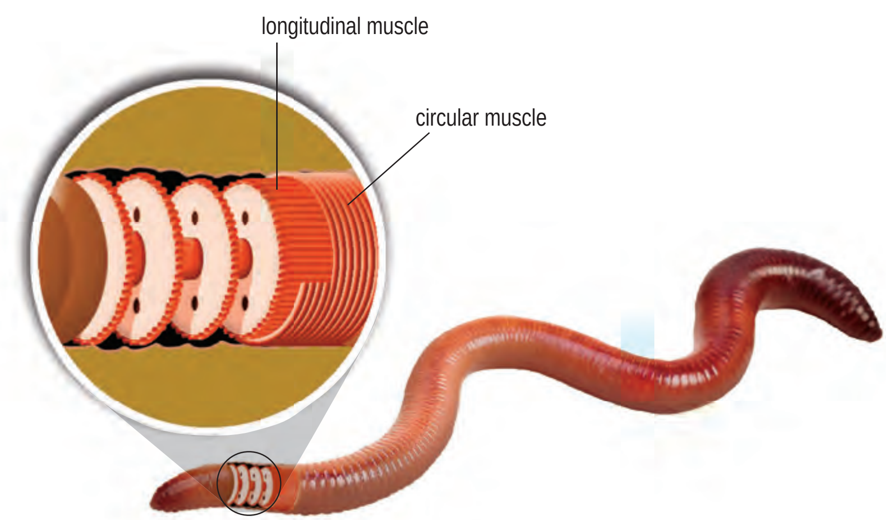
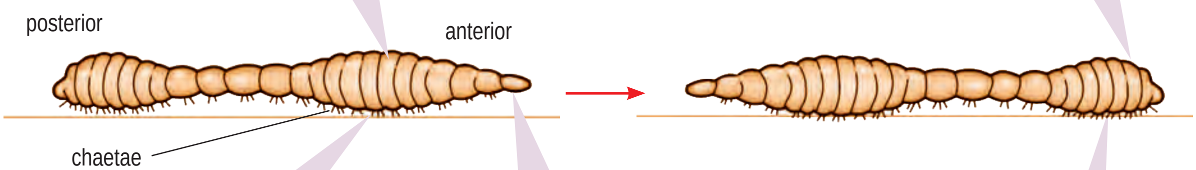


FIGURE 14.19 Longitudinal and circular muscles of an earthworm

14.3.2



1 The posterior longitudinal muscle contracts and the circular muscle relaxes; the earthworm becomes shorter and thicker.

2 The chaetae at the posterior segment anchor to the ground while the chaetae at the anterior segment release their hold of the ground.

3 The circular muscle at the anterior segment contracts and the longitudinal muscle relaxes; the earthworm becomes longer and thinner. The anterior segment (front end) extends forward.

4 The chaetae at the anterior segment anchor to the ground while the chaetae at the posterior segment release their hold of the ground.

5 The posterior segment which is shortened is pulled to the front.

FIGURE 14.20 Locomotion of the earthworm

GRASSHOPPER (JUMP/LEAP)

- The antagonistic muscles of a grasshopper, that is the flexor and extensor are attached to the inner surface of the exoskeleton (Figure 14.21).
- The flexor bends a joint while the extensor straightens it.
- The muscular and long hind legs of a grasshopper are adapted for jumping/leaping (Figure 14.22).

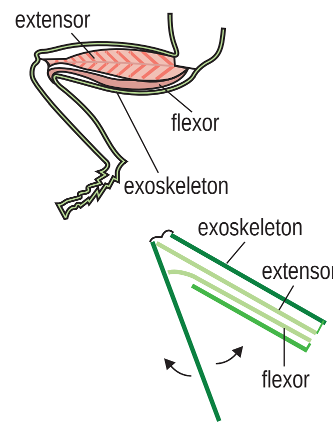
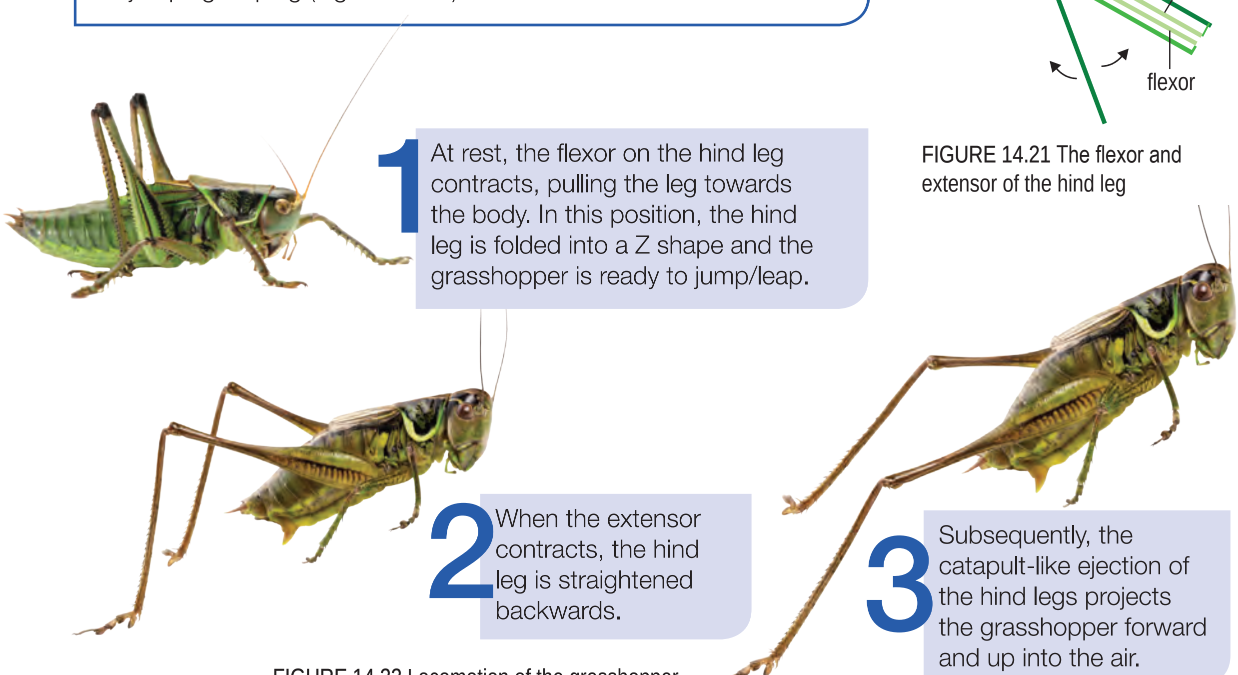


FIGURE 14.21 The flexor and extensor of the hind leg



1 At rest, the flexor on the hind leg contracts, pulling the leg towards the body. In this position, the hind leg is folded into a Z shape and the grasshopper is ready to jump/leap.

2 When the extensor contracts, the hind leg is straightened backwards.

3 Subsequently, the catapult-like ejection of the hind legs projects the grasshopper forward and up into the air.

FIGURE 14.22 Locomotion of the grasshopper

Formative Practice 14.3

1 In your opinion, why do birds have hollow bones?

2 Explain how the forearm is moved upwards.

3 Explain the locomotion mechanism in fish.

4 Describe how a grasshopper performs a jump/leap.

14.4 Health Issues Related to the Human Musculoskeletal System

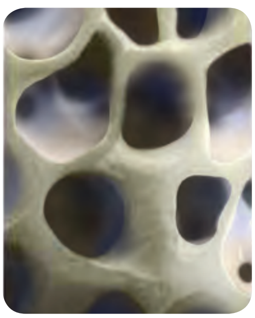
The functions of the musculoskeletal system may be affected by disorders such as osteoporosis (Photograph 14.2), osteomalacia, arthritis and scoliosis.

OSTEOPOROSIS

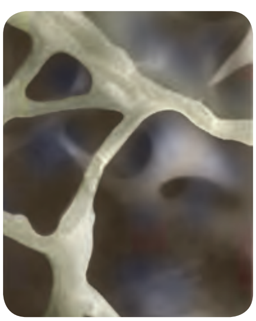
Osteoporosis (Figure 14.23) is a bone disorder characterised by weak bones that may break easily. As a person ages, the rate of calcium loss is higher compared to the rate of calcium absorption, causing a loss in bone mass or density. Among the contributing factors are lack of exercise and low intake of calcium, phosphorus and vitamin D. Osteoporosis is common among women who reach menopause because their oestrogen level is decreased.

Oestrogen is involved in calcium metabolism whereby it helps the body to absorb calcium and reduces calcium loss from the bone.

A low oestrogen level can reduce bone density due to the loss of calcium from bones (Photograph 14.2).



(a) Normal bone



(b) The bone of osteoporosis patient

PHOTOGRAPH 14.2
(a) Normal bone
(b) The bone of an osteoporosis patient is thinner, more brittle and porous.

14.4.1

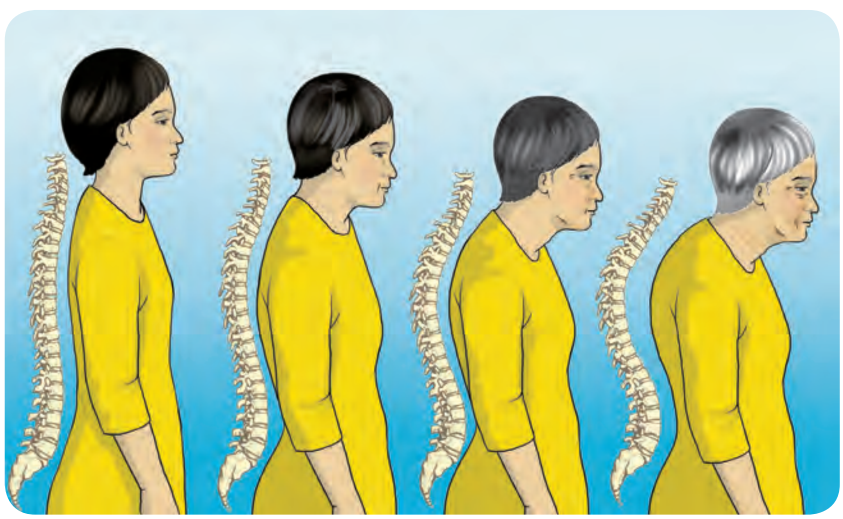


FIGURE 14.23 Bone mass decreases with age. The symptoms of osteoporosis include fragile bones, reduced height and stooped posture.

OSTEOMALACIA

Osteomalacia is a soft bone condition due to lack of calcium, phosphorus and vitamin D. Osteomalacia occurs among adults, especially pregnant women. It is called **rickets** if it occurs among children (Figure 14.24). Rickets causes the softening and weakening of children's bones, resulting in bone defects.

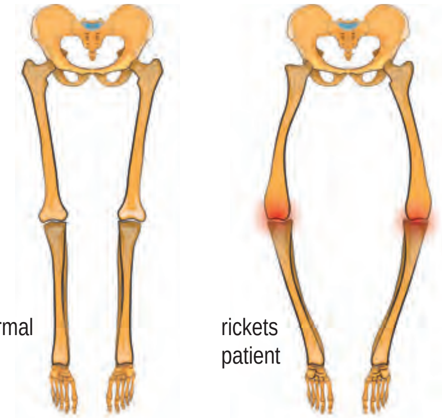
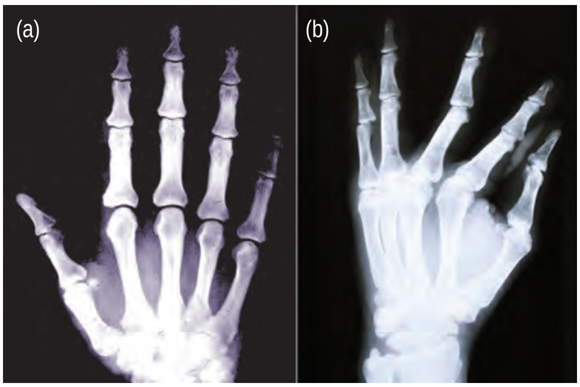


FIGURE 14.24 Normal bone and the bone of a rickets patient



PHOTOGRAPH 14.3 (a) Normal joint (b) Deteriorating joint due to osteoarthritis

ARTHRITIS

A common type of **arthritis** among the elderly is **osteoarthritis**. Osteoarthritis is caused by decreased synovial fluid, and wear and tear of the cartilage in certain joints (Photograph 14.3). The cartilage becomes thinner, and the ligament shortens and loses some of its elasticity. Joints, such as the knee joint becomes swollen, painful and less flexible. Arthritis restricts daily activities such as walking.

Activity Zone

Work in a group and gather information on osteoporosis, osteomalacia, rickets, arthritis and scoliosis. Conduct a scientific study on treatments that may help individuals with health issues related to the skeletal muscle.

SCOLIOSIS

The backbone of a **scoliosis** patient is bent to the side, forming an 'S' or 'C' shape when viewed from the back (Figure 14.25). Scoliosis may be caused by a genetic factor or abnormal growth of the backbone during puberty development.

What is the appropriate treatment to help individuals who experience health issues related to the musculoskeletal system?

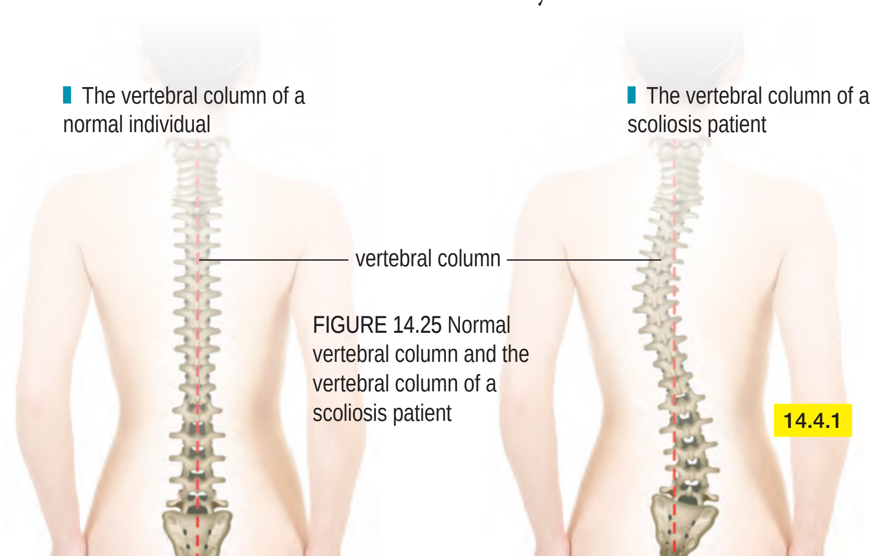


FIGURE 14.25 Normal vertebral column and the vertebral column of a scoliosis patient

Activity Zone

Build a walking aid for an individual with issues of muscle injury and joint pain.

14.4.1

Good posture when using a computer

Practices to maintain a healthy musculoskeletal system

The following are practices to care for the musculoskeletal system.

GOOD BODY POSTURE

Posture refers to a person's body position when sitting, lying, walking and standing. We should not slouch when standing or sitting. Slouching will exert pressure on the vertebral column, resulting in the misalignment of the vertebral column. This will prevent circulation of the blood, suppressing the nerves and vital organs.

Wear comfortable attire and shoes

PROPER ATTIRE

Wear proper, comfortable and loose clothing so as not to restrict blood circulation and affect the musculoskeletal system. A suitable pair of shoes, with low heels and cushion, provides support and prevents injury to the vertebral column.

EXERCISE

Exercise strengthens the joint structure and increases the flexibility of muscles and ligaments. Exercise also increases bone strength and bone mineral deposits among adults, as well as prevents osteoporosis in the elderly.

Millennial Career

Orthopaedics is a specialised medical field that focuses on the diagnosis, care and treatment of the musculoskeletal system. Doctors who specialise in this field are called orthopaedic surgeons.

Engage in various sport activities

BALANCED DIET

Consume a balanced diet, especially foods rich in calcium (milk), minerals (phosphate), vitamin C and D. Vitamin D aids in calcium absorption, while vitamin C increases bone mass.

Activity Zone

Discuss the effects of the following practices on the musculoskeletal system:

(a) Wearing high-heeled shoes
(b) Sitting with your wallet in your back pocket
(c) Carrying a heavy bag
(d) Incorrect body posture when using smartphones and computers

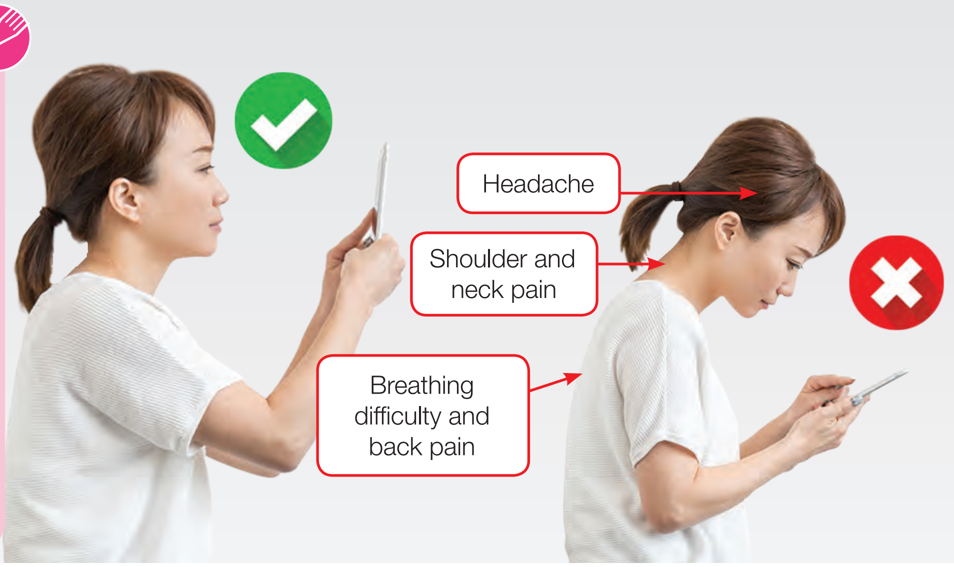
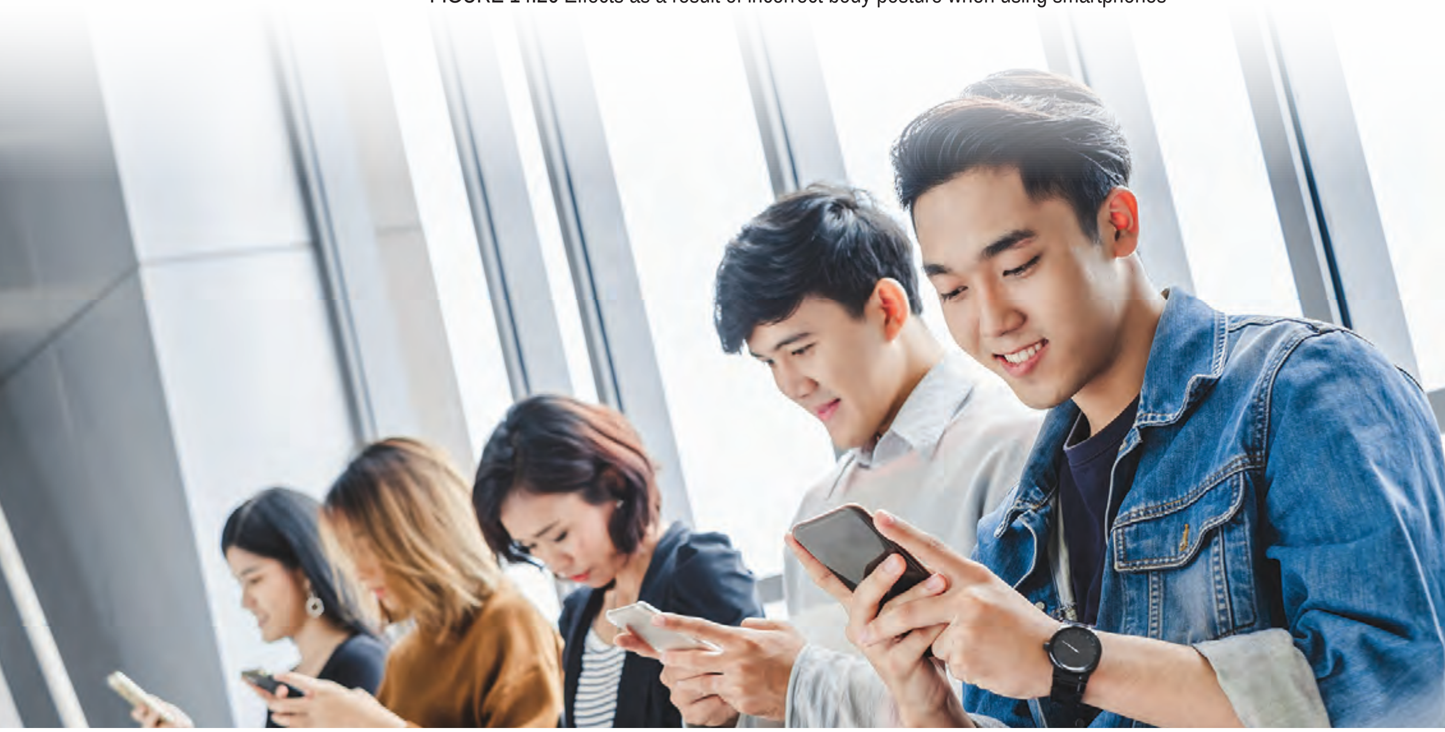


FIGURE 14.26 Effects as a result of incorrect body posture when using smartphones



Formative Practice 14.4

1. Suggest two ways to care for the musculoskeletal system.
2. As a doctor, explain ways to help scoliosis patients go through normal daily life.
3. Define osteoporosis and explain the measures that should be adopted at a young age to prevent osteoporosis at old age.
4. Explain three practices that can help maintain a healthy musculoskeletal system.

Summary

SUPPORT AND MOVEMENT IN HUMANS AND ANIMALS

Types of Skeleton

- Hydrostatic skeleton
- Exoskeleton
- Endoskeleton

Human Musculoskeletal System

Axial skeleton: skull, vertebral column, ribs and sternum

Appendicular skeleton: pectoral girdle, pelvic girdle, upper and lower limbs

Joint structure: bones, cartilage, skeletal muscle, tendon, ligament, synovial membrane and synovial fluid

Types of joints: immovable joints, slightly movable joints, freely movable joints

Mechanisms of movement and locomotion

Mechanisms of movement
- Human forearm (biceps and triceps)
- Human leg (biceps femoris and quadriceps femoris)

Mechanisms of movement in animals
- Fish – myotome
- Birds – pectoralis major and pectoralis minor
- Earthworms – circular and longitudinal muscles
- Grasshopper – flexor and extensor

Health Issues

Osteoporosis, rickets, scoliosis, osteomalacia, arthritis

Practices in caring for the musculoskeletal system: exercise, balanced diet, good body posture and proper clothing and shoes.

Self Reflection

Have you mastered the following important concepts?

- The types of skeleton in humans and animals
- Axial and appendicular skeletons
- Types of vertebrae in the vertebral column
- Types of joints in the human skeletal system
- Hinge joint structure
- How humans move their arms and legs when walking
- The locomotion mechanisms of animals such as earthworms, grasshoppers, birds and fish
- Health issues related to the human musculoskeletal system
- Practices to maintain a healthy musculoskeletal system

Summative Practice 14

1 State the differences between cervical and thoracic vertebrae.

2 Figure 1 shows the locomotion of an earthworm.

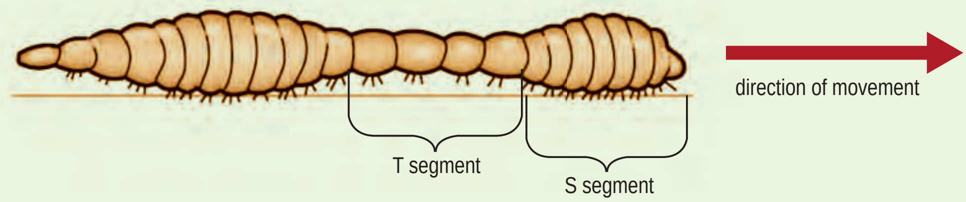


FIGURE 1

Explain the muscle action in segments T and S that enables the earthworm to move in the direction shown.

3 Why is it important for an organism to maintain its shape?

4 Describe the meaning of good posture. Why must we always practise good posture while doing any activity?

5 Explain why muscle contractions require adequate blood supply.

6 Figure 2 shows two types of vertebrae, X and Y in the human vertebral column.

(a) Name vertebrae X and Y.

(b) Explain the role of vertebrae during body movement.

(c) Relate the thoracic vertebrae to the breathing mechanism.

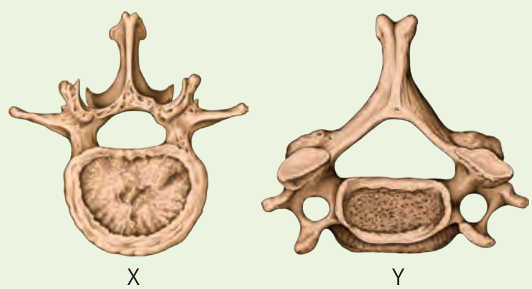


FIGURE 2

7 Figure 3 shows muscles P and Q, bone Y and tissue X that are involved in the forearm movement.

(a) Name muscle P and Q, bone Y and tissue X.

(b) State two characteristics of tissue X that enable it to function.

(c) If tissue X is torn due to an accident, what problems will the victim face?

(d) Suggest a suitable food for a person with fractured bone Y. In your opinion, explain why this particular food is presumed suitable for the individual.

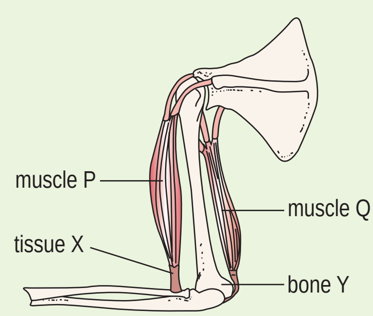


FIGURE 3

(e) Explain how all the parts labelled in Figure 3 react in the condition shown.

Essay Questions

8 Figure 4 shows a human movement.

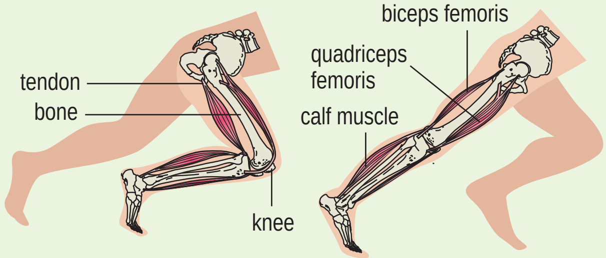


FIGURE 4

Based on Figure 4, describe how muscles, bones, tendons, ligaments and joints enable the above movement to happen.

9 Describe how the earthworm and fish skeletal systems are adapted for locomotion in their respective habitats.

10 (a) Explain the property of muscles involved in human movement.

(b) (i) Explain the measures that can be practised to maintain a healthy musculoskeletal system.

(ii) Describe the factors that may put an individual at a high risk of developing osteoporosis.

(c) Describe how muscles work together with the ligament and tendon to move the forearm.

Enrichment

11 The long bones in mammals are not compact but hollow. Explain the advantages of hollow bones.

12 Birds fly using wings. The wing movement allows birds to exert an upthrust. However, the ability of birds to fly not only depends on its wings but also its support system. Explain how the support system helps birds to fly.

13 The latest research in treating bone fracture includes the use of materials such as carbon nanotube that serves as a scaffolding for bone tissue growth. If you are a scientist looking for new material to treat damaged bones, what are the characteristics that the material should have in order to replace broken bones?

Complete answers are available by scanning the QR code provided

CHAPTER 14

CHAPTER

15 Sexual Reproduction, Development and Growth in Humans and Animals

How does modern technology help in conception?

Do You KNOW...

- What are the features of the anatomical system of human reproduction?
- How is gamete formed?
- How does the period cycle happen?
- How does the development of the human foetus happen?

15.1 Reproductive System of Humans

15.1.1 Characterise the anatomy of the:
- male reproductive system
- female reproductive system

15.2 Gametogenesis in Humans

15.2.1 Justify the necessity of gametogenesis.

15.2.2 Describe gamete formation:
- spermatogenesis
- oogenesis

15.2.3 Identify the structure of:
- sperm
  - head
  - middle piece
  - tail
- Graafian follicle
  - secondary oocyte
  - follicular cells

15.2.4 Compare and contrast between spermatogenesis and oogenesis.

15.3 Menstrual Cycle

15.3.1 Analyse the changes in the levels of hormones involved during:
- menstruation
- follicle development
- thickening of the endometrium
- ovulation
- corpus luteum formation

15.3.2 Correlate the changes in the levels of hormones involved with:
- pregnancy
- miscarriage

15.3.3 State the meaning of premenstrual syndrome and menopausal syndrome

15.4 Development of a Human Foetus

15.4.1 Describe the fertilisation process and the formation of zygotes.

15.4.2 Make a sequence and explain the early development of an embryo until implantation:
- two-celled embryo
- morula
- blastocyst

15.4.3 Explain the role of human chorionic gonadotropin (HCG) hormone in the early stages of pregnancy.

15.4.4 Communicate about the roles of following structures in the development of a foetus:
- placenta
- umbilical cord

15.4.5 Justify the necessity for separate foetal and maternal blood circulatory systems.

15.5 Formation of Twins

15.5.1 Describe the processes in the formation of twins:
- identical twins
- fraternal twins

15.5.2 Compare and contrast identical and fraternal twins.

15.5.3 Correlate cellular division with the formation of conjoined twins.

15.6 Health Issues Related to the Human Reproductive System

15.6.1 State the meaning of impotency.

15.6.2 Communicate about causes of human impotency.

15.7 Growth in Humans and Animals

15.7.1 Explain the meaning of growth in organisms.

15.7.2 Determine parameters to measure growth in humans and animals.

15.7.3 Describe the growth of insects with exoskeleton:
- complete metamorphosis
- incomplete metamorphosis

15.7.4 Analyse the growth phases on sigmoid growth curves of humans and animals.

15.7.5 Analyse the intermittent growth curve of animals with exoskeletons.

15.1 Reproductive System of Humans

The male and female reproductive system

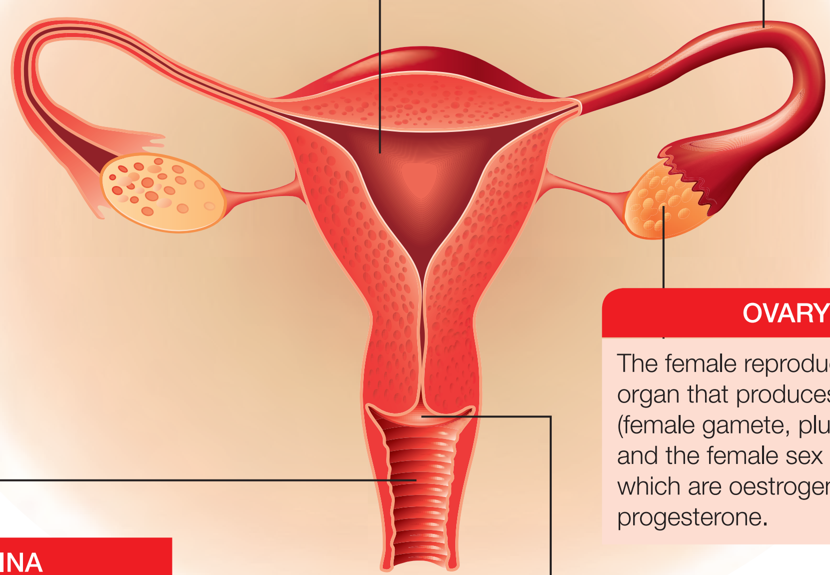
The continuity of a species is dependent on the increase in population through the process of sexual or asexual reproduction. Sexual reproduction involves the production of male and female gametes by individuals who have reached sexual maturity. This process is completed with the fertilisation of both gametes to create new life. The structure and function of the male and female reproductive systems are shown in Figure 15.1 and Figure 15.2 respectively.

UTERUS

- The uterus is an organ with thick muscular walls.
- The inner wall of the uterus is lined with endometrium tissue, which secretes mucus and is rich in blood vessels.
- Embryo implants in the endometrium.
- The endometrial tissue which is thick and rich in blood vessels supplies the embryo with nutrients and oxygen.

FALLOPIAN TUBE

- A thin, muscular tube.
- The inner wall is lined with cilia.
- The action of the cilium, combined with the peristalsis of the Fallopian tube, helps in delivering the secondary oocyte or embryo to the uterus.



OVARY

The female reproductive organ that produces ovum (female gamete, plural: ova) and the female sex hormones, which are oestrogen and progesterone.

VAGINA

A canal where sperms enter, and also serves as a passage for birth and menstruation.

CERVIX

Narrow opening to the uterus which secretes mucus to help sperm swim up to the Fallopian tubes.

FIGURE 15.1 Female reproductive system

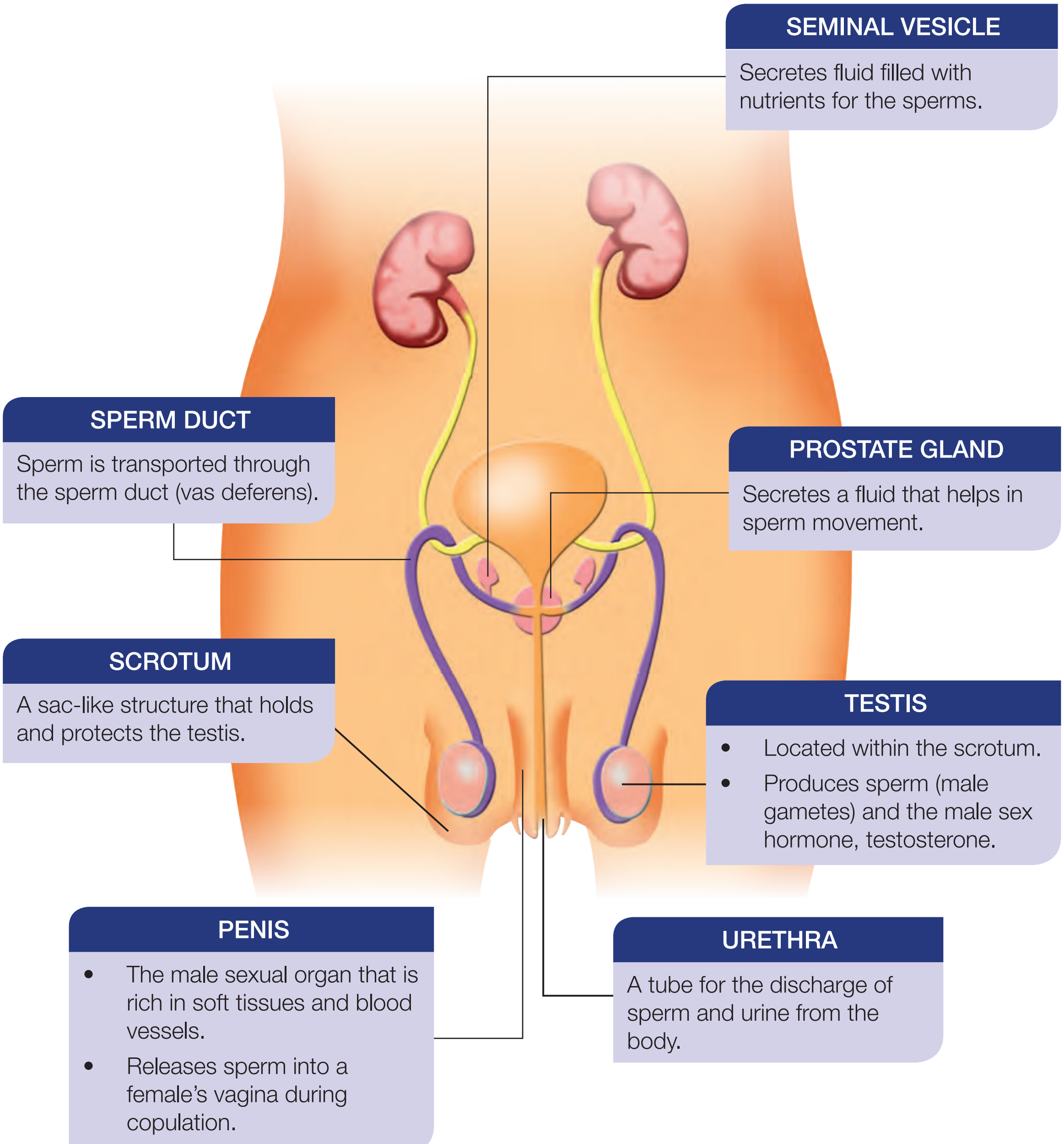


FIGURE 15.2 Male reproductive system

Formative Practice 15.1

1 State the structures of the male reproductive system.
2 Explain the functions of the seminal vesicle and the scrotum.
3 State the structures of the female reproductive system.
4 Explain the functions of the Fallopian tube and uterus.

15.1.1

15.2 Gametogenesis in Humans

The necessity of gametogenesis

The production process of reproductive cells (gametes) is called **gametogenesis.** This process takes place in the **gonads**, which are the testes in males, and the ovaries in females. Gametogenesis produces gametes that are haploid (n). When fertilisation takes place, the nucleus of the sperm will fuse with the nucleus of the ovum in the Fallopian tube to form a diploid zygote (2n).

Spermatogenesis

Spermatogenesis is a process of **sperm production** that takes place in the **seminiferous tubules**. Figure 15.3 shows a longitudinal section of the testes.

Each seminiferous tubule consists of **primordial germ cells**.

Primordial germ cells will undergo cell division to produce sperm. **Sertoli cells** within the walls of the seminiferous tubules provide nutrients throughout this process. Sperm is transported from the seminiferous tubules to the **epididymis** and flows out through the **sperm duct (vas deferens)**.

Spermatogenesis is stimulated by the **follicle-stimulating hormone (FSH)** and **testosterone**. This process is also aided by the **luteinizing hormone (LH)** which stimulates testosterone secretion in the testes.

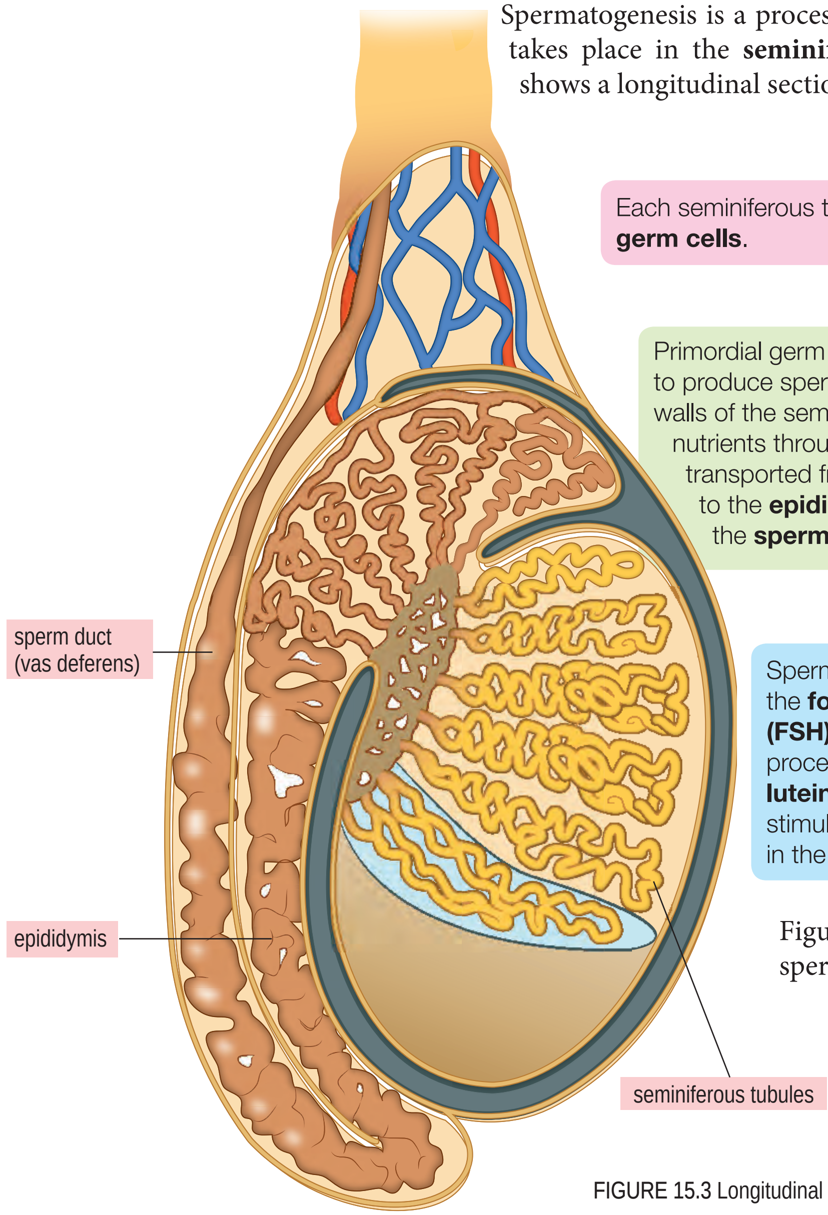


Figure 15.4 summarises the spermatogenesis scheme.

FIGURE 15.3 Longitudinal section of the testes

15.2.1 15.2.2

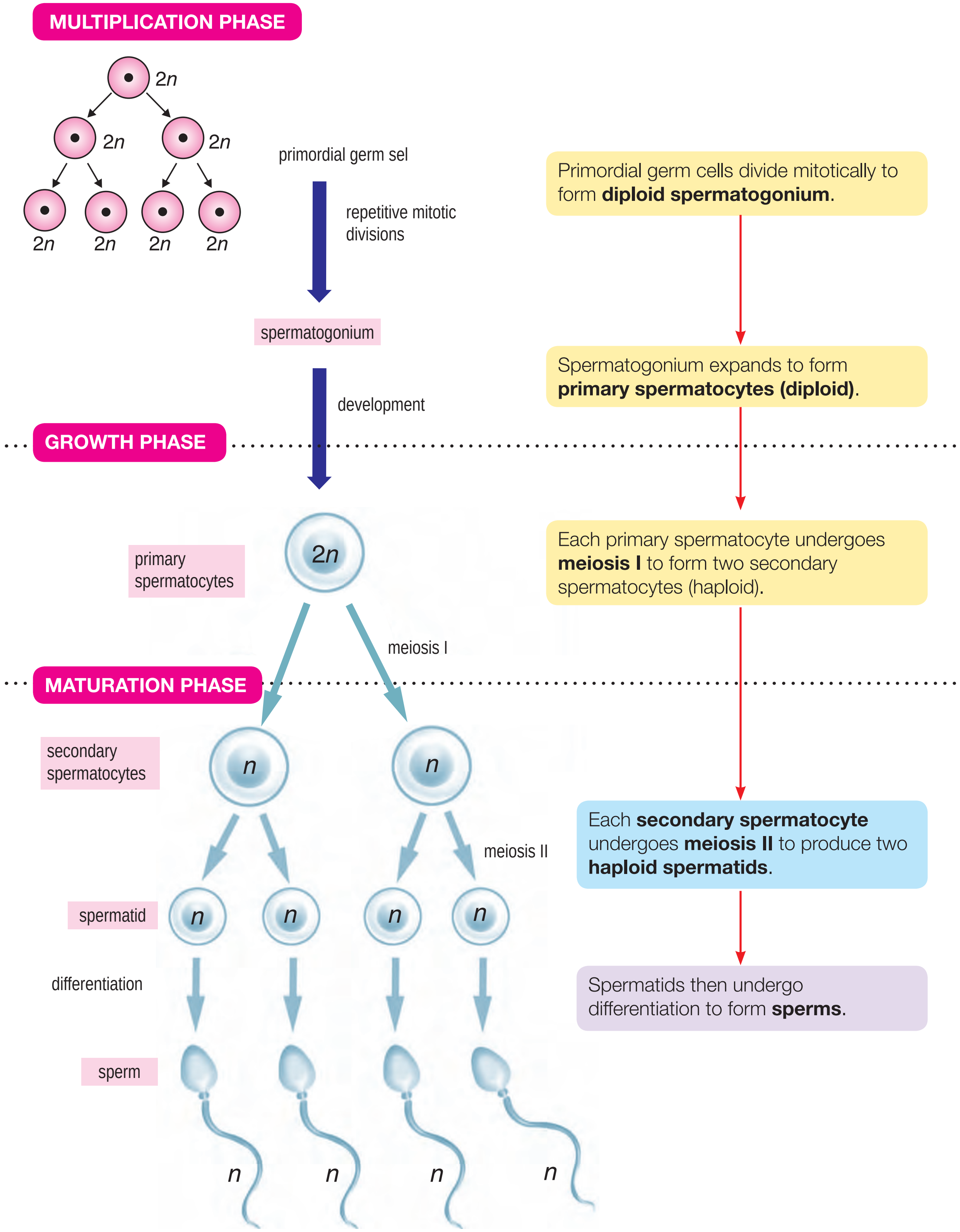


FIGURE 15.4 Spermatogenesis

Oogenesis

Oogenesis is the process of secondary oocyte or female gamete production (Figure 15.5). This process takes place in the ovaries. Unlike spermatogenesis, oogenesis begins in a female's ovaries before they are born.

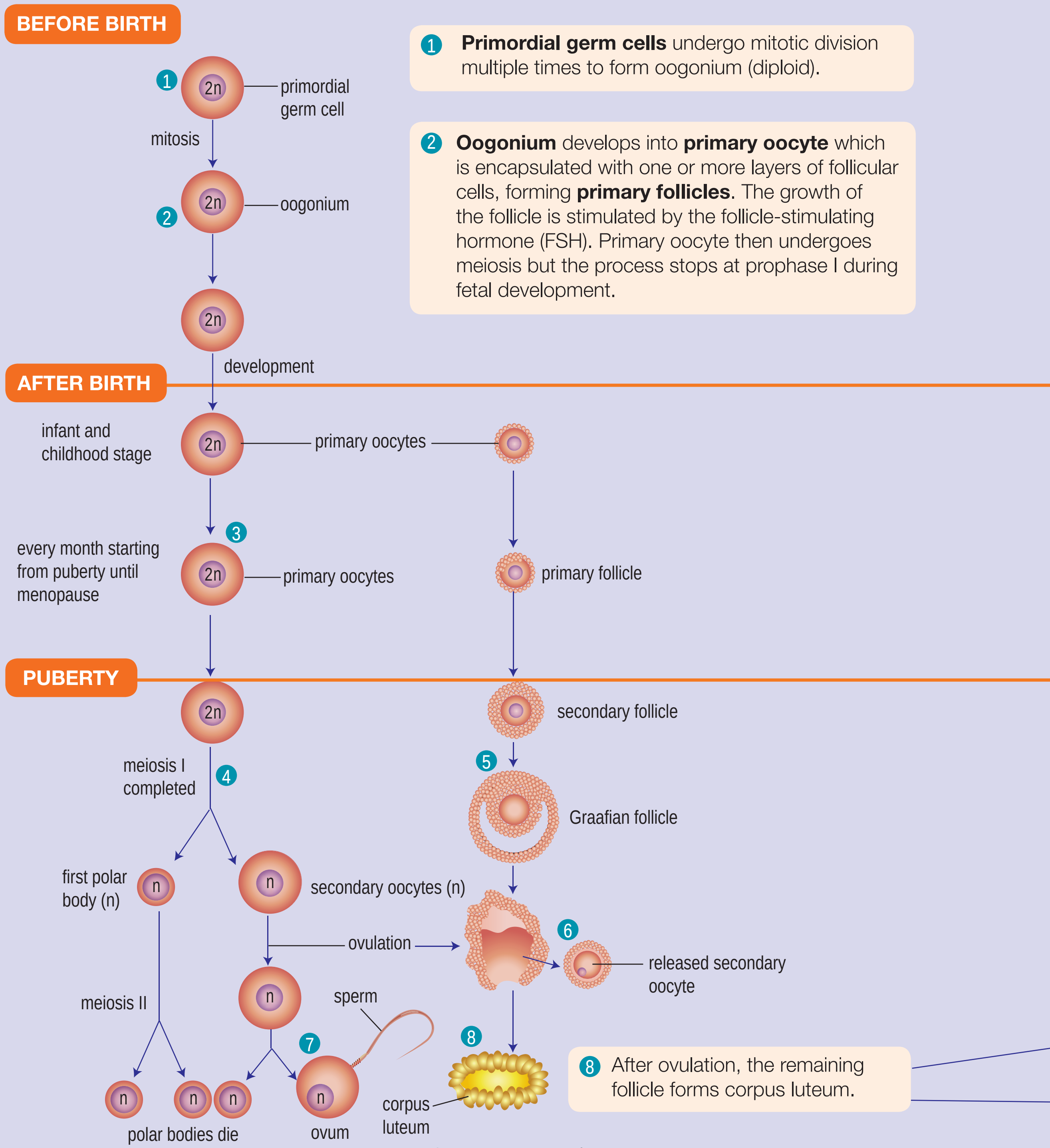


FIGURE 15.5 Oogenesis

FIGURE 15.6 Oogenesis in the ovaries

3 At birth, a baby girl already has millions of primary oocytes that remain dormant in prophase I meiosis I. The number of oocytes will decrease at puberty.

4 Upon reaching puberty, the primary oocytes will continue meiosis I to form **secondary oocyte** and a **first polar body**. Secondary oocyte will begin meiosis II which is then halted at metaphase II. The first polar body will complete meiosis II and form two **second polar bodies**.

5 A layer of follicular cells envelops the secondary oocyte and is called **secondary follicle**. The secondary follicle will then develop into the **Graafian follicle**, which releases oestrogen.

6 A mature Graafian follicle will approach the surface of the ovary and release a secondary oocyte into the Fallopian tube. This process is called **ovulation**.

7 The secondary oocyte (immature ovum) will complete meiosis II once a sperm penetrates it. Meiosis II produces **ovum** (n) and **first polar body** (n). Fertilisation takes place when the sperm nucleus fuses with ovum nucleus and produces a diploid zygote (2n). The rest of the polar bodies will die and will be disintegrated by the ovary.

upon fertilisation

9 Corpus luteum continues to grow and secretes oestrogen and progesterone.

without fertilisation

10 Corpus luteum and secondary oocyte degenerate and dies, and then is removed through menstruation.

Structure of sperm and Graafian follicle

A sperm has three main parts: **head**, **midpiece** and **tail**. The head contains a nucleus whereas the midpiece is packed with mitochondria which generates energy for the sperm to swim to the Fallopian tube for fertilisation.

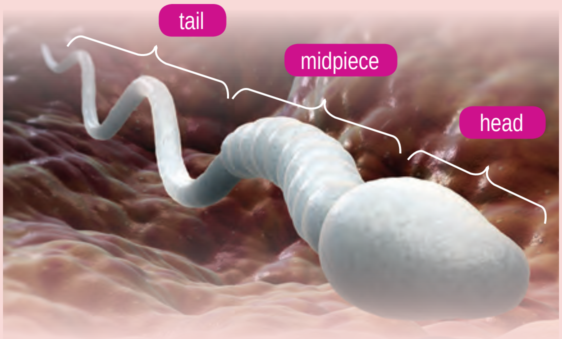


FIGURE 15.7 Sperm

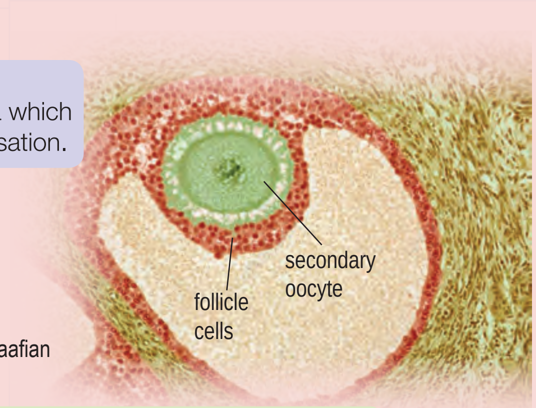


FIGURE 15.8 Graafian follicle

A **secondary oocyte** is a large cell that is surrounded by a gel-like substance and follicular cells. The secondary oocyte and follicular cells will form the **Graafian follicle**.

The comparison between spermatogenesis and oogenesis

The comparison between spermatogenesis and oogenesis are summarised in Table 15.1.

TABLE 15.1 The comparison between spermatogenesis and oogenesis

Spermatogenesis	Oogenesis
Similarities	
• Both are the processes of gametogenesis that take place in the **reproductive organs**. • Produce **gametes** that are **haploid** which are involved in fertilisation.	
Differences	
It takes place in the testis.	It takes place in the ovaries.
Spermatogonium (diploid) produces four sperms (haploid) after meiosis.	Oogonium (diploid) only produces one functional secondary oocyte (haploid) and three non-functioning polar bodies after meiosis.
Sperms are smaller and made up of the midpiece, head and tail.	Secondary oocytes are large and spherical in shape.
After meiosis I, two secondary spermatocytes are produced.	After meiosis I, one secondary oocyte and one polar body is produced.
Meiosis is completed.	Meiosis II is only completed when a sperm fertilises the secondary oocyte.
Spermatids undergo differentiation to become sperms.	Secondary oocyte does not undergo differentiation.
The production of sperm is continuous from puberty until old age.	The production of the secondary oocyte is not continuous. It starts in the female foetus and remains dormant when the baby is born. The process continues once the female reaches puberty and stops during menopause.
Millions of sperms are formed every day.	Only one secondary oocyte is released from the ovaries at every menstrual cycle.

15.2.3 15.2.4

Formative Practice 15.2

1 What could possibly happen if gametogenesis does not take place?

2 Explain three differences between spermatogenesis and oogenesis.

15.3 Menstrual Cycle

Role of hormones in menstrual cycle

MENSTRUAL CYCLE

The **menstrual cycle** involves the production of a secondary oocyte and thickening of the endometrial wall throughout one cycle. In this cycle, the endometrium will become soft, thick and rich with blood vessels. This is to prepare the endometrium for embryo implantation. If fertilisation does not take place, the secondary oocyte will die and the endometrium wall will shed. This will lead to bleeding known as **menstruation**.

Biological Lens

One of the side effects of low oestrogen is calcium loss in the body which leads to a reduction in bone density, making it porous and weak. This condition is called osteoporosis.

The functions of hormones in a menstrual cycle is shown in Table 15.2.

TABLE 15.2 Functions of hormones in a menstrual cycle

Gland	Hormone	Function
Pituitary	Follicle-stimulating hormone (FSH)	• Stimulates follicle growth in the ovary. • Stimulates the release of oestrogen.
	Luteinizing hormone (LH)	• Stimulates ovulation. • Causes the formation of the corpus luteum. • Stimulates the release of progesterone.
Ovary	Oestrogen	• Repairs and stimulates the thickening of the endometrium. • Stimulates follicle growth until it matures. • Stimulates FSH and LH release prior to ovulation.
	Progesterone	• Stimulates the thickening of the endometrium, making it thick, folded and rich in blood vessels to prepare for the implantation of embryo. • Stops the release of FSH and LH to prevent follicle growth and ovulation.

Millennial Career

Obstetricians and gynaecologists are specialists in female reproduction and women's health.

Changes in hormonal level, follicle growth, and changes in endometrial wall thickness throughout one menstrual cycle are shown in Figure 15.9.

15.3.1

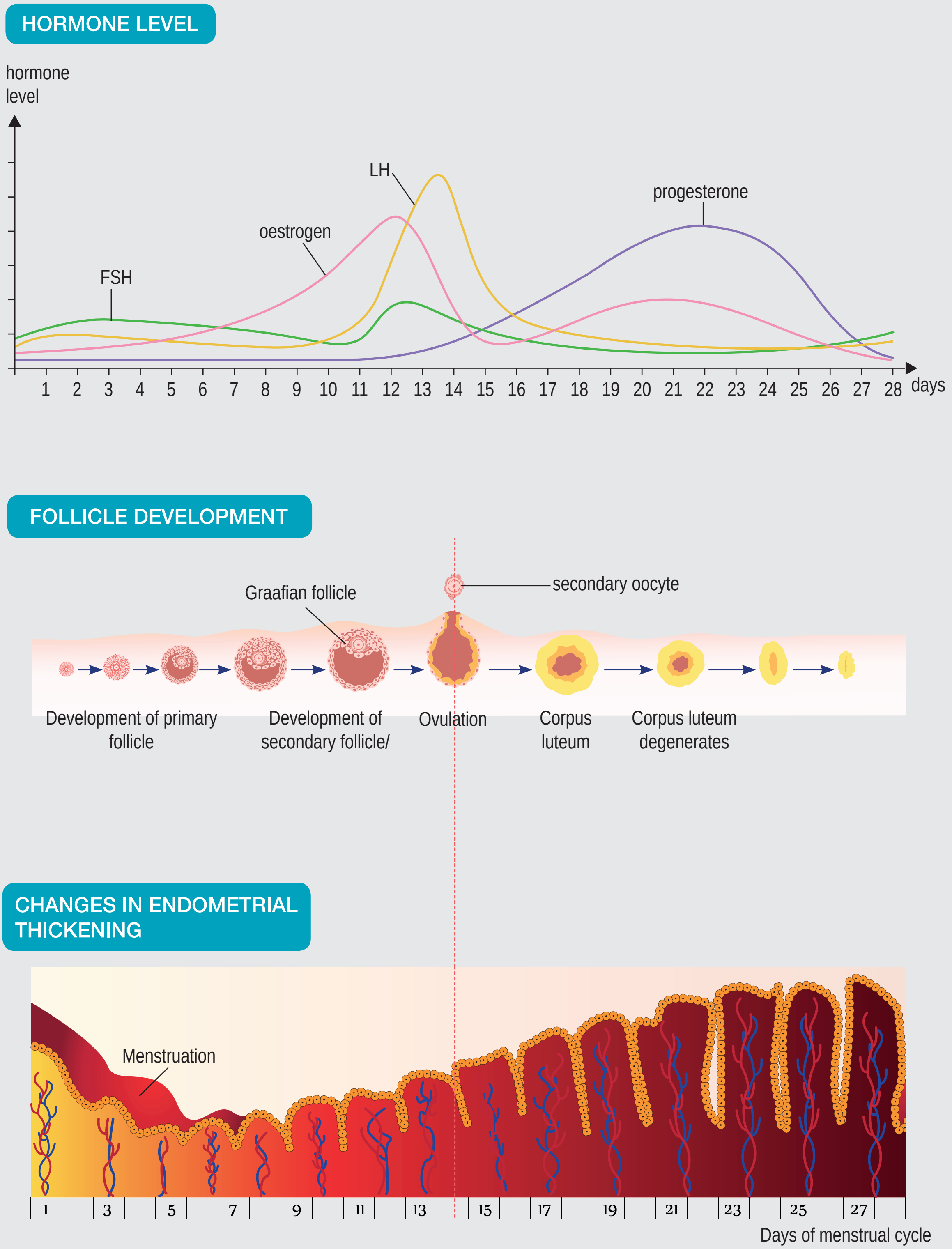


FIGURE 15.9 Stages of events and hormonal level changes in one menstrual cycle

DAY 0–5

- Before a menstrual cycle begins, the level of hormones is low. With the absence of stimulation from progesterone and oestrogen, the thickened endometrium will shed and **menstruation** will begin (first day).
- A menstrual cycle begins a day before menstruation when the hypothalamus releases the gonadotrophin-releasing hormone (GnRH).
- GnRH stimulates the pituitary gland to release the follicle-stimulating hormone (FSH) and luteinizing hormone (LH) into the blood.
- FSH stimulates **follicle growth** in the ovary. Within the primary follicle, the oocyte grows into the secondary oocyte, which is contained within the Graafian follicle.
- Growing follicles release oestrogen.
- Oestrogen encourages follicle maturation and also encourages endometrial wall repair.
- Low levels of oestrogen inhibit the release of FSH and LH via a negative feedback mechanism, which in turn prevents the growth of new follicles.

DAY 6–14

- Oestrogen level rises and peaks on day 12, stimulating the hypothalamus to secrete GnRH via a positive feedback mechanism.
- A high level of GnRH then stimulates the pituitary gland to secrete more FSH and LH.
- The LH level rises until it peaks on day 13, leading to **ovulation** and release of a secondary oocyte from Graafian follicle on day 14.
- LH also stimulates the follicular tissue left behind to transform into the **corpus luteum**.

DAY 15–21

- LH stimulates the corpus luteum to secrete oestrogen and progesterone.
- The combination of oestrogen and progesterone inhibits the release of FSH and LH from the hypothalamus via negative-feedback mechanism so as to stop the growth of new follicles.
- Progesterone stimulates **endometrial wall thickening**, enriching it with blood vessels in preparation for embryo implantation, in the event that fertilisation takes place.

DAY 22–28

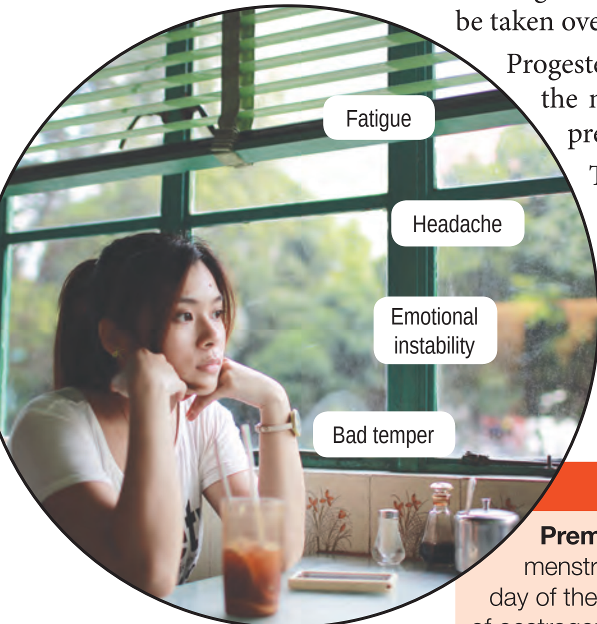
- If fertilisation does not take place, decreasing LH levels will cause the corpus luteum to degenerate, which in turn stops the secretion of oestrogen and progesterone.
- Without stimulation from oestrogen and progesterone, the **endometrium** will **shed** and **menstruation** will begin.
- Low levels of progesterone and oestrogen will no longer inhibit the hypothalamus and pituitary gland, making way for GnRH to be secreted again, which then stimulates secretion of FSH and LH. A new menstrual cycle will begin with new follicle growth.
- If fertilisation occurs, the corpus luteum will continue to grow and secrete progesterone and oestrogen.
- This will cause the endometrial wall to continually thicken in order to support foetal growth.

Role of hormone in pregnancy and miscarriage

The corpus luteum will continue to produce oestrogen and progesterone up to three to four months after pregnancy. Thereafter, the corpus luteum will degenerate, and the production of oestrogen and progesterone will be taken over by the placenta until birth.

Progesterone inhibits the secretion of FSH and LH. Therefore, the menstrual cycle and ovulation do not occur throughout a pregnancy.

The imbalance of progesterone and oestrogen levels may lead to a miscarriage, due to the decrease of progesterone level which causes the uterus to shrink.



PHOTOGRAPH 15.1
Premenstrual syndrome symptoms

Premenstrual syndrome and menopausal syndrome

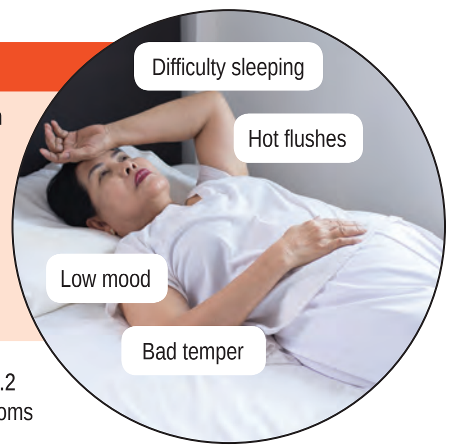
PREMENSTRUAL SYNDROME (Photograph 15.1)

Premenstrual syndrome or symptoms that appear prior to a menstrual cycle usually manifests between 7 to 14 days before the first day of the menstrual cycle. This syndrome occurs due to the imbalance of oestrogen and progesterone hormones within the menstrual cycle.

MENOPAUSE (Photograph 15.2)

Menopause occurs within the ages of 46 to 50 years old, when ovulation and menstruation stop naturally. The increase in age leads to reduced secretion of progesterone and oestrogen, which then causes reduced stimulation of FSH and LH on the ovaries.

At this stage, the ovaries stop producing ovum. After menopause, a woman is not able to conceive a child anymore.



PHOTOGRAPH 15.2
Menopausal symptoms

Formative Practice 15.3

1 State the hormones involved in the menstrual cycle and their functions.

2 Explain the functions of progesterone and its effects on pregnancy.

3 Explain what would happen to the corpus luteum if fertilisation does not occur.

4 In your opinion, what is the best way to overcome premenstrual syndrome?

15.4 Development of a Human Foetus

The process of fertilisation

Biological Lens

Each semen ejaculation contains between 300 to 500 million sperms. However, only about 300 to 500 sperms successfully reach the secondary oocyte in the Fallopian tube.

Fertilisation can occur when one out of the millions of sperm succeeds in penetrating the secondary oocyte in the Fallopian tube. This is followed by changes to the secondary oocyte's membrane that prevents penetration from other sperms. Then, fertilisation occurs when the sperm nucleus fuses with the ovum nucleus to form a diploid zygote.

AR

Early development of an embryo until implantation

- While travelling down the Fallopian tube, the zygote undergoes multiple divisions through mitosis.
- The first cell division produces a two-cell embryo. The following cell divisions will finally produce a **morula**.
- The morula then transforms into a **blastocyst** (Figure 15.10).
- The blastocyst will then implant in the endometrium. This process is called **implantation**. The blastocyst continues to grow into an **embryo**.

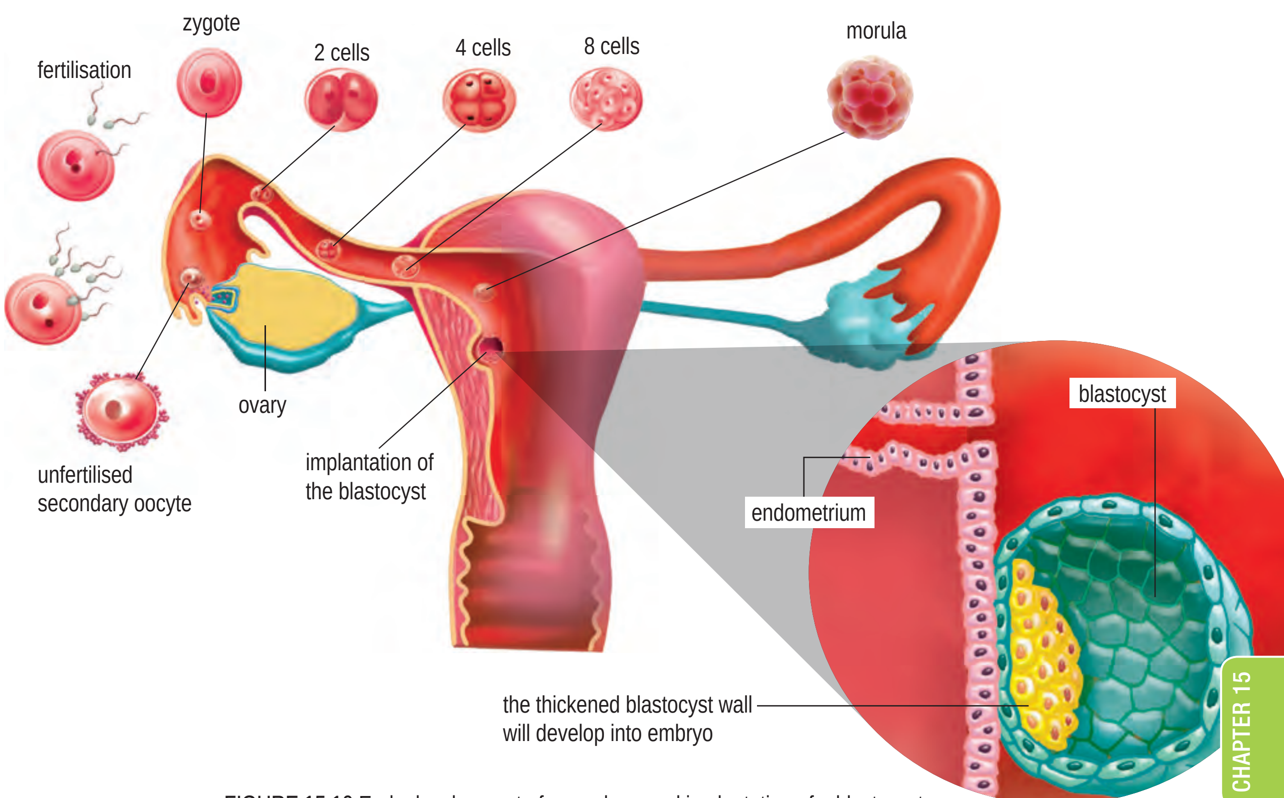


FIGURE 15.10 Early development of an embryo and implantation of a blastocyst

15.4.1 15.4.2

Role of human chorionic gonadotropin (HCG) hormone

PHOTOGRAPH 15.3
Pregnancy test detects HCG in urine

The placenta also produces the **human chorionic gonadotropin (HCG) hormone** during pregnancy. The level of this hormone increases at the early stages of pregnancy and will double every two to three days for the first four weeks of pregnancy. The main function of HCG is to ensure that the corpus luteum continues to secrete oestrogen and progesterone in the early stages of pregnancy. This hormone can be detected in the urine of pregnant mothers.

Role of placenta and umbilical cord in foetal development

The placenta is formed from the mother's endometrial tissue and embryonic tissue. It is connected to the foetus through the umbilical cord which contains blood vessels that carries substance in and out of the foetus.

The **umbilical cord** is a tube that contains the umbilical vein and umbilical arteries.

- The **umbilical vein** carries blood rich in oxygen and nutrients from the placenta to the foetus.
- **Umbilical arteries** carry deoxygenated blood (rich in carbon dioxide) and nitrogenous waste such as urea from foetus to the placenta.

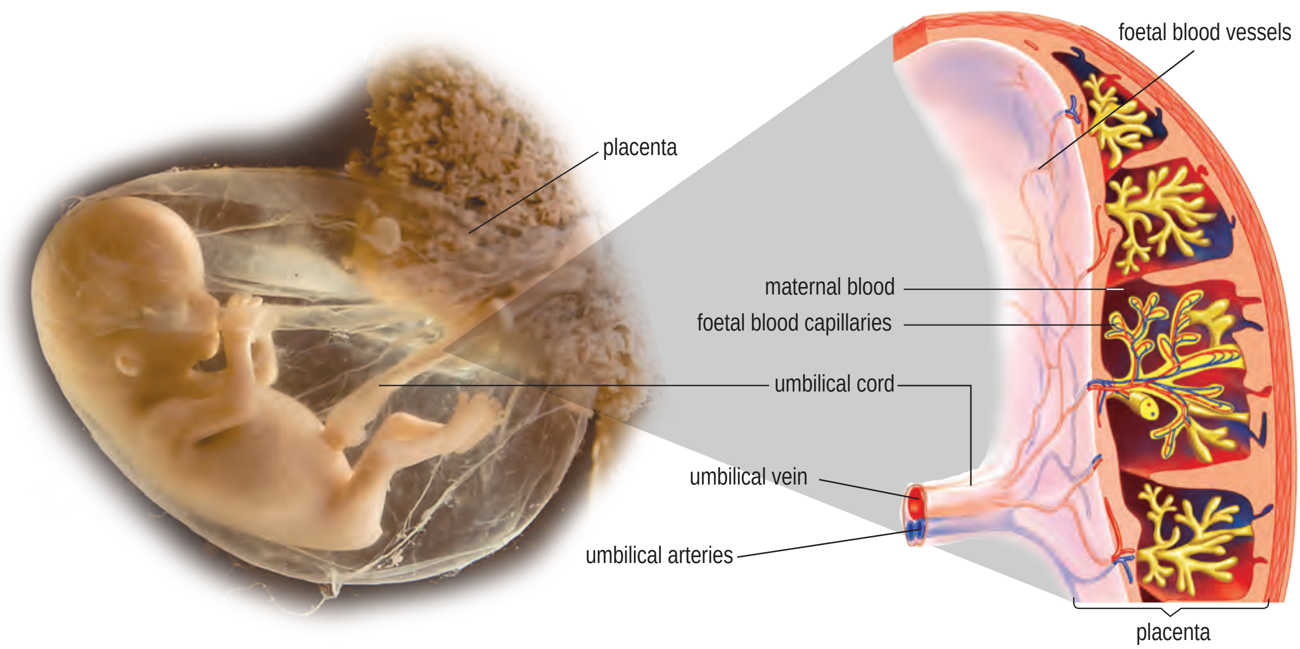


FIGURE 15.11 Placenta and umbilical cord

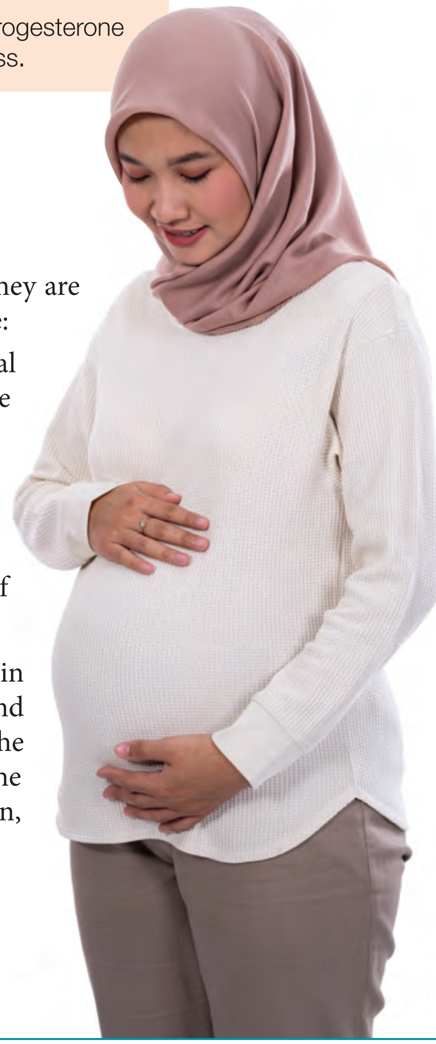
Importance of placenta

The **placenta** is the exchange site of substances between mother and foetus.

- Glucose, amino acids, hormones, antibodies and oxygen are absorbed from the mother's blood into the foetal blood capillaries.
- Carbon dioxide and nitrogenous waste such as urea are absorbed from the foetal blood capillaries into the mother's blood circulation.

The **placenta** also acts as an endocrine organ that secretes hormones during pregnancy.

- In the fourth month of pregnancy, the corpus luteum will degenerate and no longer secrete progesterone.
- The placenta will replace corpus luteum in producing progesterone and oestrogen needed to maintain endometrial thickness.



Foetal and maternal blood circulatory systems

The blood of the mother and the foetus do not mix as they are separated by a thin membrane. This is important because:

(a) It protects the foetus from certain dangerous chemical substances such as toxins and bacteria that can be absorbed into the foetal blood circulation.

(b) It prevents the thin foetal blood vessels from bursting due to the mother's high blood pressure.

(c) It prevents agglutination or blood clots from happening in the foetus, as the foetus might not be of the same blood group as the mother.

The thin membrane layer is not able to prevent certain substances from being absorbed, such as drugs and medication, cigarette smoke and alcohol ingested by the mother. Viruses such as HIV and rubella can also cross the placenta and be absorbed into the foetal blood circulation, which may disrupt the foetal development.

Formative Practice 15.4

1 Explain the early developmental process of the embryo.

2 What is the main function of the HCG hormone?

3 Describe the function of the placenta.

4 State what might happen if maternal blood mixes with foetal blood.

15.4.4 15.4.5

15.5 Formation of Twins

Process of twin formation

Twins refer to two or more children that are born from one pregnancy. There are two types of twins:

- **identical twins**
- **fraternal twins**

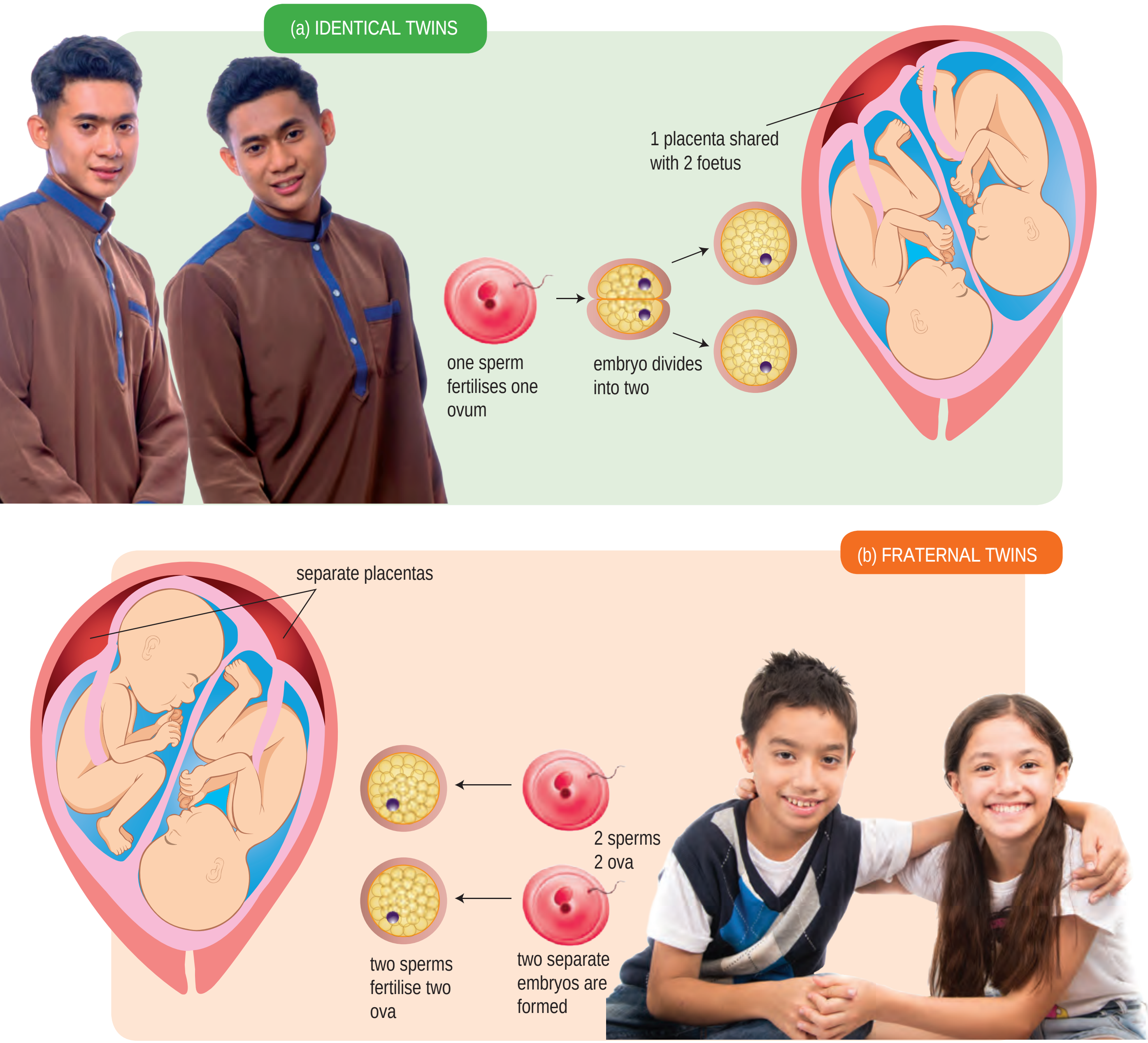


FIGURE 15.12 Development of (a) identical twins and (b) fraternal twins

TABLE 15.3 Differences between identical and fraternal twins

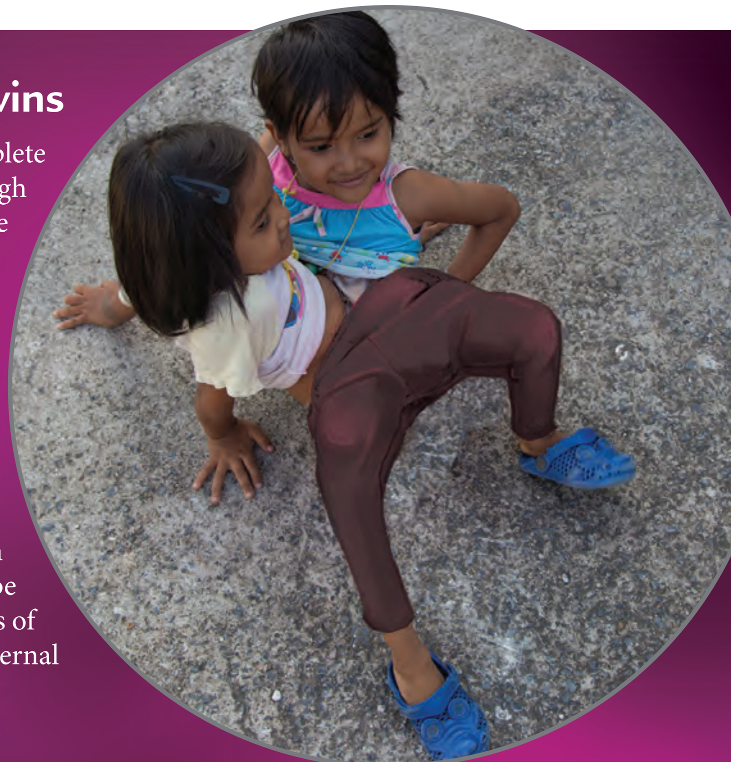
Differences between identical and fraternal twins	
Identical twins	**Fraternal twins**
Product of fertilisation of one ovum and one sperm forming one zygote.	Product of fertilisation of two sperms and two ova forming two zygotes.
Embryo divides into two.	Embryo does not divide into two.
One placenta is shared between two foetus.	Each foetus has its own placenta.
The genetic makeup and physical appearances of these twins are similar as they are from the same zygote.	The genetic makeup and physical appearances of these twins are different as they are from two different zygotes.
The sex of both twins is the same.	The sex of both twins may be the same or different.

Development of conjoined twins

Conjoined twins develop when there is incomplete division of the embryo in identical twins. Although two foetuses are formed from the embryo, some of their physical parts are still fused together, usually the chest, abdomen or buttocks. Conjoined twins may also share one or two internal organs.

The life of conjoined twins may be difficult as they must always be together. They also do not have any time alone. Their movements are limited due to their physical state.

Most conjoined twins die before they are born or have short lifespans. They may be able to be separated through surgery. However, the success of surgery depends on the joined part and what internal organs are shared between them.



PHOTOGRAPH 15.4 Conjoined twins

Formative Practice 15.5

1 State two differences between identical and fraternal twins.
2 State the characteristics of conjoined twins.

15.5.2 15.5.3

15.6 Health Issues Related to the Human Reproductive System

Impotency

Impotency occurs when a husband and wife are unable to conceive. The cause of this might be from the husband or wife, or both.

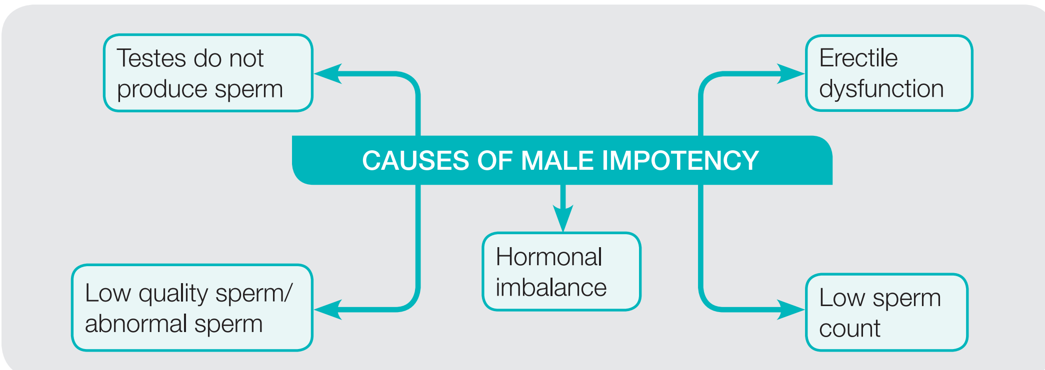


FIGURE 15.13 Causes of male impotency

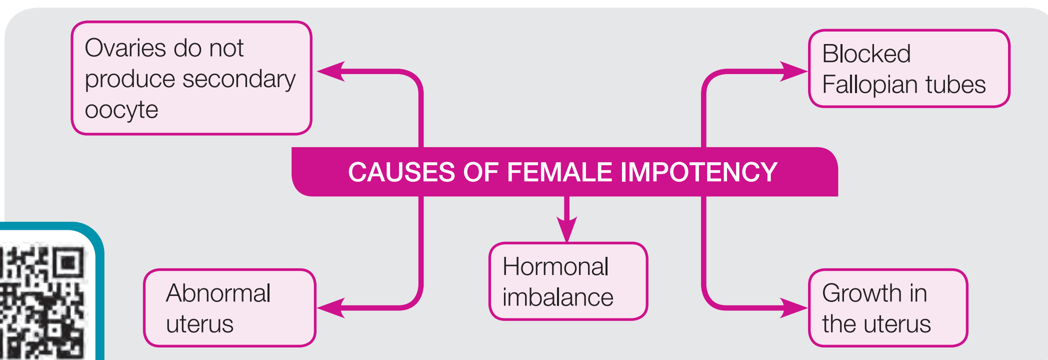


FIGURE 15.14 Causes of female impotency

ICT 15.1

Video: IVF
(Accessed on 21 August 2019)

Activity Zone

What are the benefits and drawbacks of science and technological contributions to human reproduction? What moral issues are related to the application of technological reproduction? Discuss.

TREATMENT FOR IMPOTENCY

- Hormonal imbalance can be treated with hormonal therapy.
- Blocked Fallopian tubes or blocked sperm ducts can be treated via surgery.
- *In vitro* fertilisation (IVF) can be used for women who have blocked Fallopian tubes.

Formative Practice 15.6

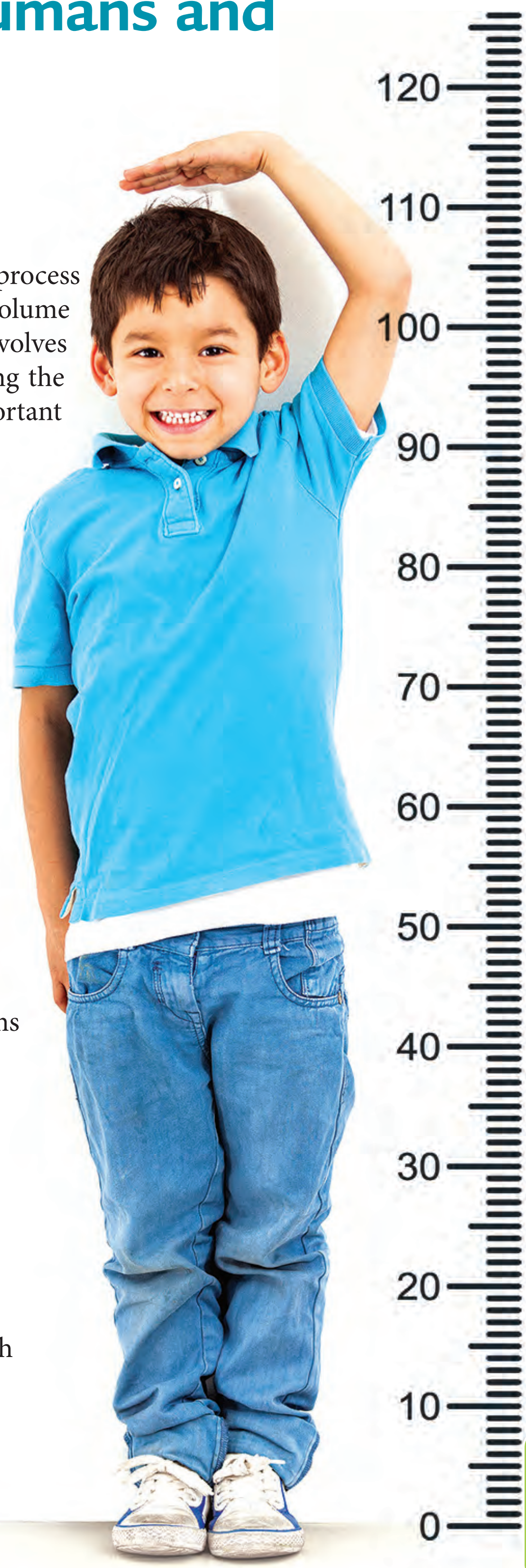
What are the causes of impotency?

15.6.1 15.6.2

15.7 Growth in Humans and Animals

Growth in organisms

Growth in organisms is an irreversible, permanent process that involves the increase in the number of cells, size, volume and weight of the organism's body. Growth also involves differentiation and cell specialisation as well as specialising the shapes and functions of cells. Growth in organisms is important for the development and maturation of bodily systems.



Measuring growth in humans and animals

The parameters that are used in measuring growth are:

(a) **Increase in size** or **volume**, for example, changes in height or length of an organism

(b) Changes in **fresh weight** or **dry weight**:

   (i) **Dry weight** refers to the weight of an organism after all the fluid is removed from its body. This is done by weighing the organism after it has been dried in the oven at 100 °C repeatedly until the weight remains the same. The weakness of this parameter is that the organism has to be killed. However, this method is suitable for plants.

   (ii) **Fresh weight** can be taken whenever and organisms do not need to be killed. However, this method is less accurate because the amount of fluid in the body is dependent on the organism's fluid intake. This parameter is measured for a certain amount of time.

Growth of Insects

Organisms with exoskeletons like insects undergo growth differently. Insects go through two different types of growth which are **complete metamorphosis** and **incomplete metamorphosis**.

15.7.1 15.7.2 15.7.3

Insects like butterflies undergo complete metamorphosis. In complete metamorphosis, there are four different stages of growth, which are egg, larvae, pupa and adult. Figure 15.15 shows complete metamorphosis.

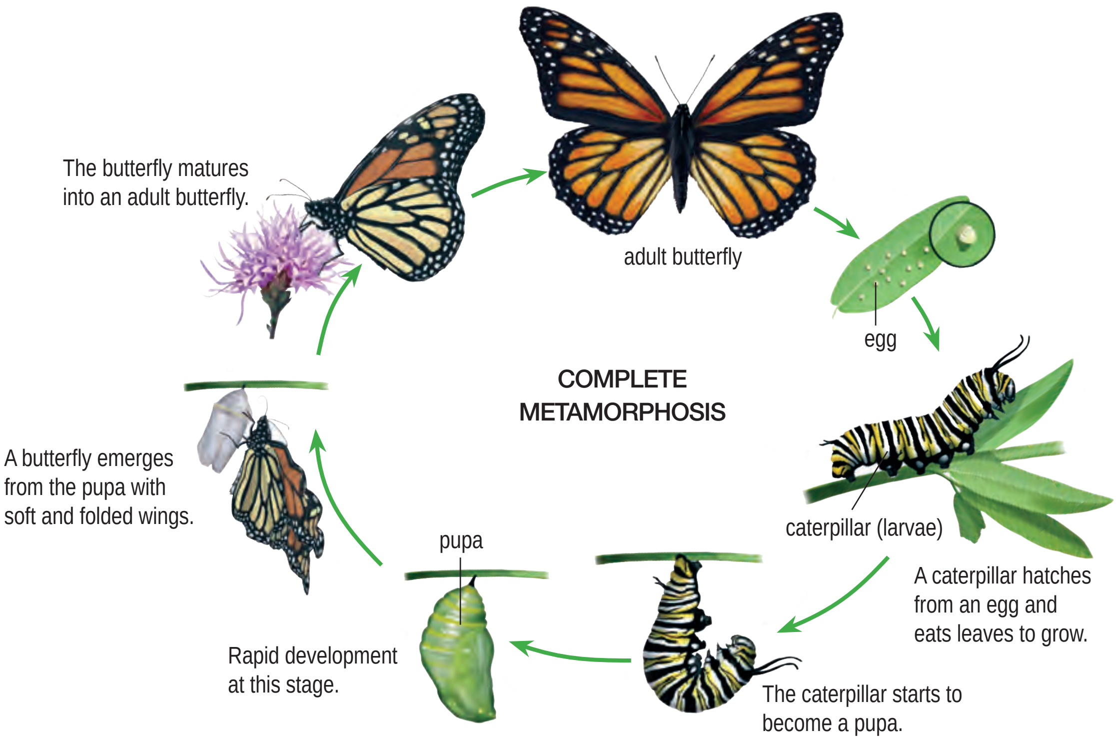


FIGURE 15.15 Complete metamorphosis

Grasshoppers undergo incomplete metamorphosis, where the insect undergoes a few stages of ecdysis before becoming an adult. Figure 15.16 shows incomplete metamorphosis.

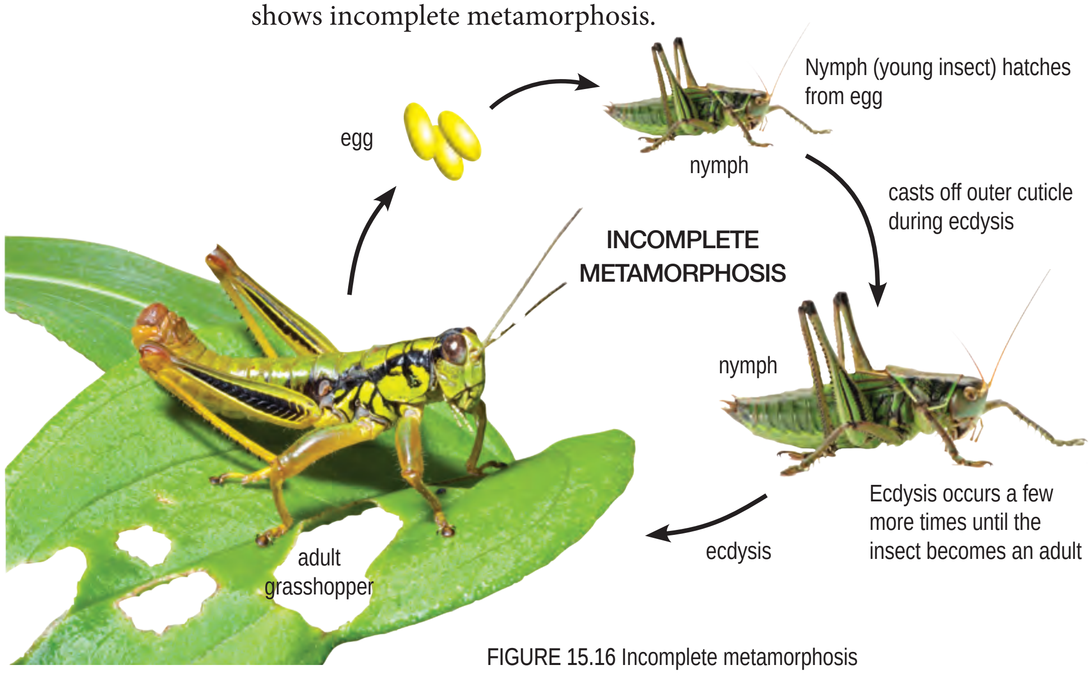


FIGURE 15.16 Incomplete metamorphosis

Growth phases in sigmoid growth curves of humans and animals

The growth curve is achieved by plotting growth parameters against time (Figure 15.17). Most organisms' growth curves show a similar pattern that is a **sigmoid** curve (S-shaped). Growth occurs gradually and continuously. There are six phases in the sigmoid growth curve, which are the **lag phase**, **exponential phase**, **stationary phase**, **maturity phase**, **senescence** and **death phase**.

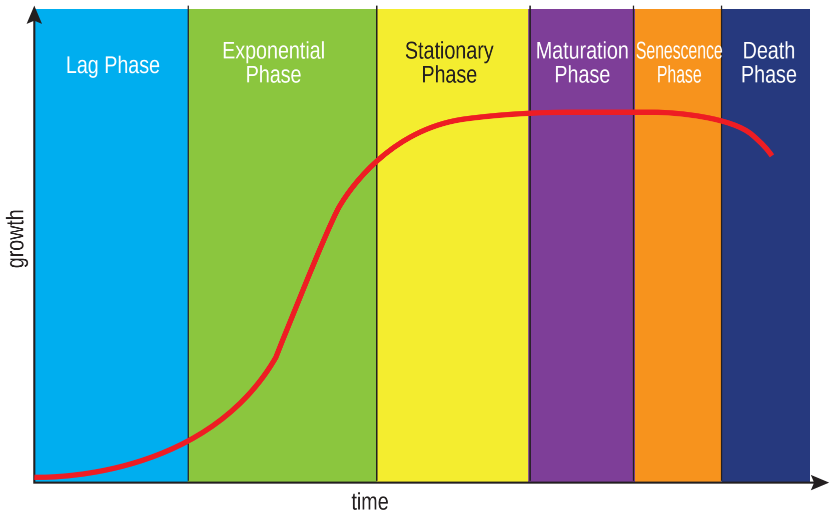


FIGURE 15.17 Sigmoid growth curve

LAG PHASE

- The growth rate is low because it involves little cell division and cell elongation.
- It is the phase of adjustment to new sources available in the environment.

EXPONENTIAL PHASE

- Highest growth rate.
- Cell division and elongation occurs actively.
- Organism's size increases rapidly.

STATIONARY PHASE

- Growth rate slows down and occurs at a constant rate.
- Cells reach maximum size.
- Cells undergo differentiation to form specialised cells.

MATURITY PHASE

- Organism reaches maturity.
- Zero growth rate.
- The rate of cell division is similar to the rate of cell death.
- Cell division only happens to replace impaired or dead tissues.

SENESCENCE PHASE

- Negative growth rate.
- Organism goes through ageing.

DEATH PHASE

Ageing, illness, lack of nutrients or space eventually leads to death of an organism.

15.7.4

ICT 15.2

Video: Insect ecdysis (Accessed on 21 August 2019)

Intermittent growth curve of animals with exoskeletons

Insects such as grasshoppers have an exoskeleton made up of **chitin**. The exoskeleton does not grow proportionately with the growth of the insect. To allow growth and development, animals with exoskeletons must shed their hard exterior.

The moulting process of the exoskeleton that allows growth and development of insects is called **ecdysis**. This process is controlled by hormones.

- The process of ecdysis happens **periodically**. Polar growth is **not continuous** and is **intermittent** (Figure 15.18).
- The horizontal part of the graph indicates zero growth. At this stage, known as **instar**, the insect is not increasing in length.
- The vertical lines of the graph represent **rapid** growth.
- At this stage, the nymph undergoes **ecdysis** and its size increases rapidly
- Ecdysis occurs **multiple times** until the insect reaches adulthood.

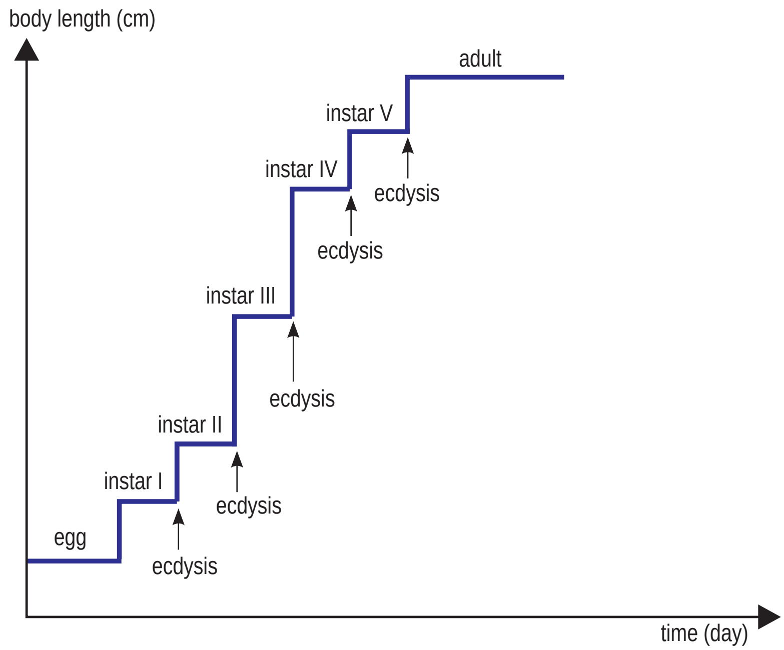


FIGURE 15.18 Growth curve of animals with exoskeletons

PHOTOGRAPH 15.5
A cicada emerging from its old exoskeleton

HOW DOES ECDYSIS HAPPEN?

- A new exoskeleton forms underneath the old exoskeleton
- Before the new exoskeleton hardens, the insect will increase its volume by sucking in air to expand its body
- This action breaks the old exoskeleton and the insect with its new exoskeleton will emerge
- The insect will expand its body one more time before the new exoskeleton hardens

The stages between ecdysis are called **instar** and at this stage, the insect is known as a **nymph**. During instar, the insect is actively building tissue and increasing body volume.

Formative Practice 15.7

1 Describe how to measure growth in animals.

2 Explain the differences between complete and incomplete metamorphosis.

3 Explain the event that happens during the exponential phase.

4 Why must insects go through ecdysis?

Summary

SEXUAL REPRODUCTION, DEVELOPMENT AND GROWTH IN HUMANS AND ANIMALS

- **Reproductive System of Humans**
  - Male reproductive system
  - Female reproductive system
- **Menstrual Cycle**
  - Changes in the levels of hormones during:
    - menstruation
    - follicle development
    - thickening of the endometrium
    - ovulation
    - corpus luteum formation
  - Changes in the levels of hormones during:
    - pregnancy
    - miscarriage
  - Premenstrual syndrome and menopausal syndrome
- **Gametogenesis**
  - Spermatogenesis and oogenesis
  - Gamete structure: sperm and secondary oocyte
  - Comparison between spermatogenesis and oogenesis
- **Development of Human Foetus**
  - Fertilisation process and the formation of zygotes
  - Role of placenta and umbilical cord in the development of a foetus
  - Necessity for separate foetal and maternal blood circulatory systems
- **Formation of Twins**
  - Identical twins
  - Fraternal twins
  - Conjoined twins
- **Health Issues Related to the Human Reproductive System**
  - Causes of human impotency
- **Growth in Humans and Animals**
  - Growth of insects with exoskeleton:
    - complete metamorphosis
    - incomplete metamorphosis
  - Sigmoid growth curves of humans and animals
  - Intermittent growth curve of animals with exoskeletons

Self Reflection

Have you mastered the following important concepts?

- Male and female reproductive systems
- Spermatogenesis and oogenesis
- Gamete structure
- Changes in hormone level, follicle growth, endometrial thickening, ovulation and corpus luteum formation within the menstrual cycle
- Changes in hormone level in a pregnancy and a miscarriage
- Premenstrual syndrome and menopause
- Fertilisation process until the formation of zygote
- Early embryo development until implantation
- Role of human chorionic gonadotropin (HCG) hormone during early pregnancy
- Fetal and maternal blood circulation
- Formation of twins (identical, fraternal, conjoined)
- Health issues related to the human reproductive system
- Sigmoid growth curve of humans and animals
- Growth of insects (complete and incomplete metamorphosis)

Summative Practice 15

1 What causes the premenstrual syndrome in some women?

2 State the differences between the formation of identical and fraternal twins.

3 The foetus has its own blood circulation system, separate from its mother. Explain why.

4 (a) A pair of identical twins were separated at birth. Once they reached adulthood, they found out that they both have different body sizes. Explain the factors that would cause this.

(b) Explain why pregnant mothers must stop smoking.

5 State the changes that occur to a zygote from fertilisation up to birth.

6 A woman took contraceptive pills to prevent pregnancy. The pill inhibits secretions of the Follicle Stimulating Hormone (FSH) from the pituitary gland. Explain the effects of taking contraceptive pills on the menstrual cycle.

7 Figure 1 shows the hormonal regulation of a menstrual cycle.

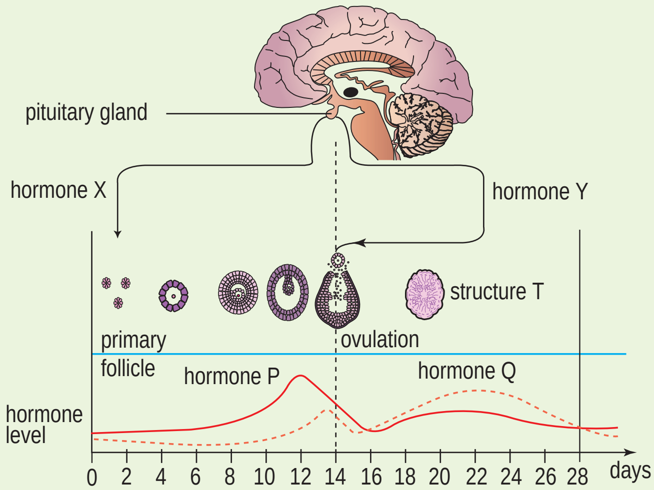


FIGURE 1

(a) State the effect on ovum development if hormone X is not enough.

(b) Explain the effects of hormone P and hormone Y imbalance.

(c) Based on Figure 1, describe the relationship between changes in structure T with the level of hormone P and hormone Q.

(i) from day 16 to day 24

(ii) from day 24 to day 28

8 Figure 2 shows a human foetus inside a uterus.

(a) Name the structures labelled P and Q.

(b) Explain the blood composition that flows through the blood vessel at Q.

(c) Explain the function of structure P.

(d) (i) State the types of immunity a foetus can inherit from its mother.

(ii) Explain how structure P helps in foetal immune response.

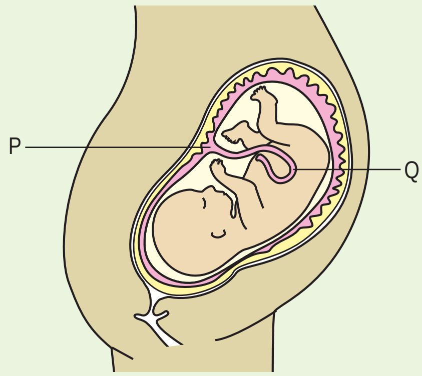


FIGURE 2

CHAPTER 15

Essay Questions

9 A woman having problems getting pregnant needed an injection of hormone X from a specialist. Hormone X has the same function as the luteinizing hormone (LH). After a certain period, the woman was pregnant.
Explain how the hormone X injection can help the woman to get pregnant.

10 (a) Describe the process of sperm production in the testes.

(b) Figure 3 shows the formation of two sets of twins. Compare the formation of the twins R and S.

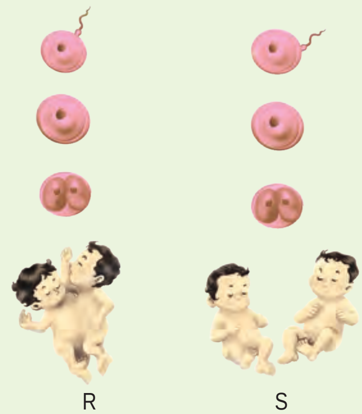


FIGURE 3

Enrichment

11 During ejaculation, approximately 300 million sperms are released. From this amount, only about 300 sperms arrive at the secondary oocyte, and only one will be successful in fertilising the ovum. If only one sperm reaches the secondary oocyte, fertilisation will not take place. Explain why.

12 Describe how changes in different hormone levels in one menstrual cycle prepare a woman for pregnancy.

13 The umbilical cord is the lifeline between the foetus and its mother. Cord blood is blood left in the umbilical cord and placenta after birth. After a baby is born, cord blood is kept as it is a source of stem cells rich in hematopoietic stem cells. Is it important for parents to keep the cord blood for their children's future?

Complete answers are available by scanning the QR code provided

Glossary

Active transport—The movement of substances across the membrane of living cells, against the concentration gradient with the help of carrier proteins and energy from ATP.

aerobic respiration—The complete oxidation of glucose to carbon dioxide, water and energy by using oxygen.

anabolism—The metabolic process that synthesises complex molecules from simpler molecules. The process requires energy.

anaerobic respiration—The incomplete oxidation of glucose without the use of oxygen or in limited oxygen supply.

appendicular skeleton—The part of the skeleton that consists of the pectoral and pelvic girdle, leg bones and arm bones.

axial skeleton—The part of the skeleton that consists of the skull, vertebral column, sternum and rib cage. Forms the main axis of the body.

Balanced nutrition—Food nutrition that contains all nutrients in the right amount to fulfill the requirements of the body.

biohazard—Any chemical or biological agent that poses a threat or risk to humans and the environment.

blastocyst—The early developmental stage of mammalian embrio that consists of a ball of cells with a hollowed centre that is filled with fluid.

bolus—The ball of chewed food that has been mixed with saliva, formed in the mouth through the action of the tongue before being swallowed.

Carbaminohemoglobin—A compound that consists of carbon dioxide and the pigment haemoglobin in the blood.

catabolism—The metabolic pathway that breaks down complex molecules into simpler molecules. The process releases energy.

crenation—The shrunken state of animal cells when the surrounding solution is hypertonic towards the cytoplasm of the cells.

Deamination—The removal of an amino group from an amino acid.

dendrite—The nerve fibre that receives impulses from adjacent neurons and transmits them towards the cell body.

deoxyribonucleic acid (DNA)—Nucleic acid that carries the genetic codes of an organism and is the main component of chromosomes.

diploid—Describes two sets of chromosomes, one set from the male parent and another set from the female parent.

Effector—Parts of the body that receive instructions from the control centre and respond to the stimuli accordingly.

embryo—The early developmental stage of zygote in seeds (in plants), eggs (in animals), or uterus (in humans and animals).

emphysema—A condition where the air sacs in the lungs are damaged and cause difficulties in breathing.

enzyme—The organic catalyst, normally proteins, that catalyse biochemical reactions in living cells.

Gametogenesis—The process of male and female gametes formation in the reproductive organ.

Golgi apparatus—A cellular component in the cytoplasm that processes, packs, and distributes secretory substances such as enzymes and proteins.

Graafian follicle—Mature follicle in the ovary that contains secondary oocyte and produces the hormone oestrogen.

Haemoglobin—Protein in the red blood cell that functions to transport oxygen.

haemophilia—Blood disease that causes the patient's blood clotting to be impaired due to the lack of clotting factors.

homeostasis—The regulation of the internal environment of organisms so that physiological processes can proceed at the optimum level.

hormone—Chemical substances that regulate specific functions in the body.

Immunity—The body's ability to fight infectious diseases carried by pathogens.

implantation—The adhering of the embryo (at the blastocyst stage) to the wall of the uterus.

insulin—Hormone that stimulates the conversion of glucose to glycogen in the liver and muscle cells.

Ligament—Elastic tissues that connect bone to bone.

lysosome—Membrane-bound sacs that contain enzymes that digest substances in the food vacuole.

Meiosis—The cell nucleus division that produces four haploid daughter cells.

mitosis—The cellular division that produces two daughter cells that contain a similar number and type of chromosome as the parent cell.

morula—A solid ball of cells during the development of embryo before the blastocyst stage.

Nephron—The functional unit in the kidney that consists of the glomerulus, Bowman capsule, convoluted tubule, Henle loop and collecting duct.

neuron—Cells in the nervous system that consists of the axon, cell body and dendrites.

nucleic acid—A complex organic compound in living cells that consists of nucleotide chains. There are two types of nucleic acid, which are DNA and RNA.

nucleotide—The basic unit of DNA molecule that contains phosphate group, ribose or deoxyribose, and a nitrogenous base.

nucleus—The largest cellular component in the cell that contains genetic materials. The nucleus acts as the control centre for the cell.

Oogenesis—The formation of the ovum in the ovary.

organism—Living things that are capable of conducting living processes such as feeding, growing, reproducing and breathing.

osmosis—The diffusion of water molecules from a region of higher water potential towards a region of lower water potential, across a selectively permeable membrane.

oxyhaemoglobin—A compound that is formed when oxygen combines with haemoglobin in erythrocytes.

Pathogen—The microorganisms that carry infections and diseases.

phloem—The vascular tissue that is involved in the transport of food materials from the site of photosynthesis to other parts that need them.

placenta—The organ that forms from the tissue of the foetus and the mother to allow for material exchanges between the foetus and the mother.

plasmolysis—The shrinking of cytoplasm from the plant cell wall as a result of water loss through osmosis.

platelet—Fragments of cell cytoplasm in the blood that contain no nucleus and are involved in blood clotting.

Receptor—Specialised sensory cells that detect stimuli.

reflex arc—The stimulus pathway that triggers reflex responses. The pathway consists of receptors, control centres and effectors.

Sacrum—The triangular bone in the hip area of the vertebral column.

skeletal muscle—Muscles that connect a bone to another bone. The movement of the skeleton relies on the contraction of skeletal muscles.

smooth muscle—Non-striated muscles that can be found in intestinal walls and blood vessels.

spermatogenesis—The formation of sperm in the testis.

sternum—The bone in the middle section of the vertebrate chest.

synapse—A site between two nerve cells, or neurons and effector to communicate.

Telophase—The final stage in cell division, when the nuclear membrane envelopes the nucleus of each daughter cell.

tendon—Flexible non-elastic tissue that joins the muscle to the bone.

Ultrafiltration—The filtration process of blood plasma that contains dissolved nutrients, across the wall of blood capillary.

Vacuole—Sacs that contain cell sap that can be found in the cytoplasm.

vertebra—Small bones that form the spine

Zygote—The union of the ovum (female gamete) and sperm cell (male gamete) during fertilisation.

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