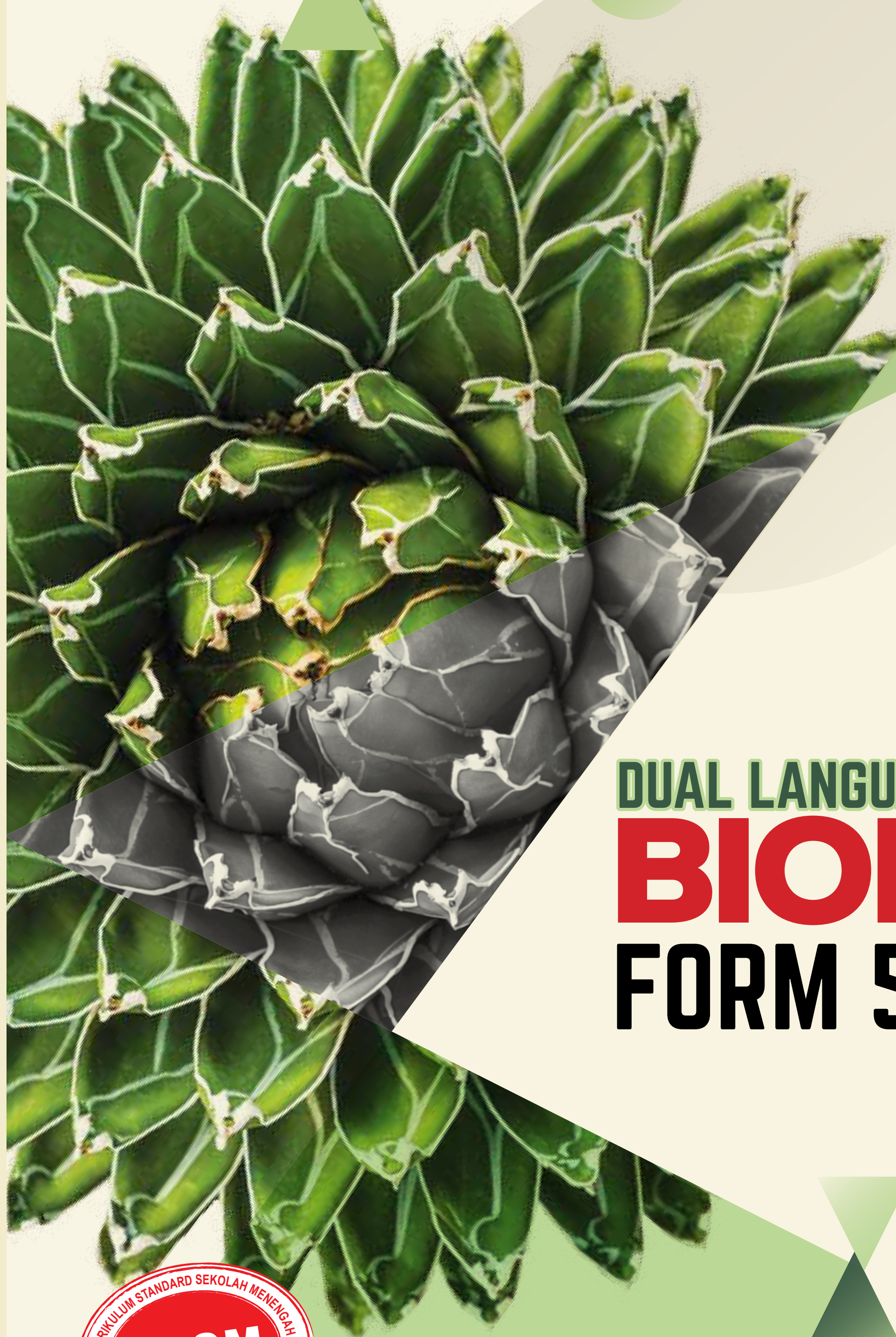
KEMENTERIAN PENDIDIKAN MALAYSIA



DUAL LANGUAGE PROGRAMME

BIOLOGY

FORM 5

KURIKULUM STANDARD SEKOLAH MENENGAH
KSSM
KEMENTERIAN PENDIDIKAN MALAYSIA

BIOLOGY FORM 5

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RUKUN NEGARA

Bahawasanya Negara Kita Malaysia
mendukung cita-cita hendak:

Mencapai perpaduan yang lebih erat dalam kalangan
seluruh masyarakatnya;

Memelihara satu cara hidup demokrasi;

Mencipta satu masyarakat yang adil di mana kemakmuran negara
akan dapat dinikmati bersama secara adil dan saksama;

Menjamin satu cara yang liberal terhadap
tradisi-tradisi kebudayaannya yang kaya dan pelbagai corak;

Membina satu masyarakat progresif yang akan menggunakan
sains dan teknologi moden;

MAKA KAMI, rakyat Malaysia,
berikrar akan menumpukan
seluruh tenaga dan usaha kami untuk mencapai cita-cita tersebut
berdasarkan prinsip-prinsip yang berikut:

KEPERCAYAAN KEPADA TUHAN
KESETIAAN KEPADA RAJA DAN NEGARA
KELUHURAN PERLEMBAGAAN
KEDAULATAN UNDANG-UNDANG
KESOPANAN DAN KESUSILAAN

(Sumber: Jabatan Penerangan, Kementerian Komunikasi dan Multimedia Malaysia)

KURIKULUM STANDARD SEKOLAH MENENGAH

DUAL LANGUAGE PROGRAMME

BIOLOGY

FORM 5

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CONTENTS

INTRODUCTION

The **Form 5 Biology *Kurikulum Standard Sekolah Menengah* (KSSM) Textbook** is written for Form 5 students based on the *Dokumen Standard Kurikulum dan Pentaksiran Tingkatan 5* (DSKP) prepared by the Curriculum Development Division, Ministry of Education Malaysia. KSSM is developed to cater to the new policies under the Malaysia Education Blueprint 2013 - 2025. The KSSM also aims to prepare students to face globalisation based on the 21st century learning skills. In addition, the Science, Technology, Engineering and Mathematics (STEM) teaching and learning approach is also incorporated to develop students' interest in science and technology.

Special feature

Innovation in Malaysia: Innovations in Malaysia related to biology

Formative Practice: Questions to test students' understanding at the end of each subtopic

Malaysian Scientist: Achievements and contributions of scientists in Malaysia related to biology

Think Smart: Stimulate students' mind to think

Bio & Application: Applications of biology in daily life

Career Tips: Provides information on careers related to biology

Bio Exploration: Provides extra information related to the topics studied

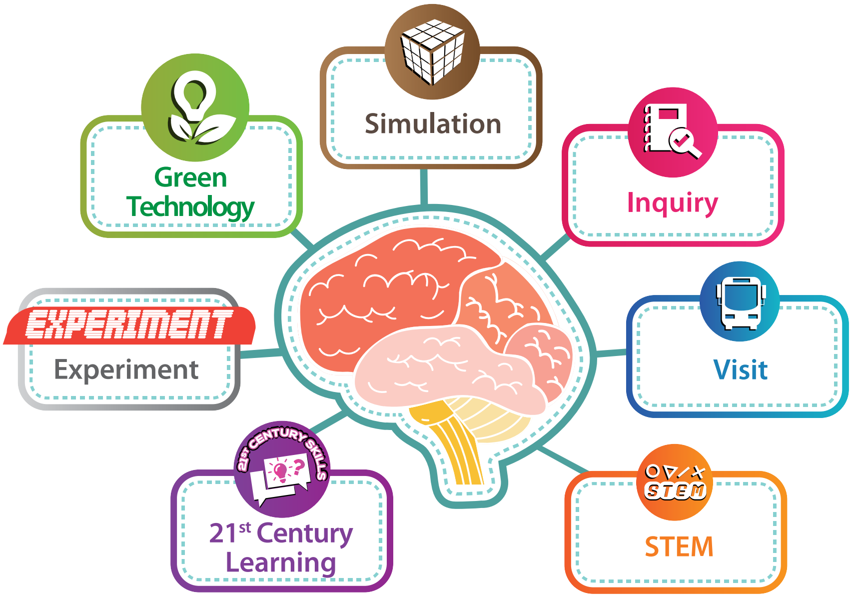
History Corner: Provides historical information related to biology

Term Analysis: Analyses the origin of terms

MEMORI Tips: Provides tips for students to memorise

1.2.3: Learning Standards based on the *Dokumen Standard Kurikulum dan Pentaksiran Tingkatan 5* (DSKP)

Types of activities



Components at the end of a chapter

Memory Flashback

Summary of a chapter in the form of concept maps

SELF-REFLECTION

Simple checklist of learning standards

Summative Practice

Questions to test students' understanding at the end of each chapter

21st Century Mind

HOTS questions level 5 (evaluation) and level 6 (creating)

Digital components

Download the free QR Code reader application from the *App Store* or *Play Store* to access info, videos, interactive quizzes and answers.

Info	Video	Activity	Quiz
Extra info	Videos with English narrative	Extra activities	Interactive quizzes

Answers

Surf the following website for answers :
http://bukutekskssm.my/Biology/F5/Answers.pdf

Answers

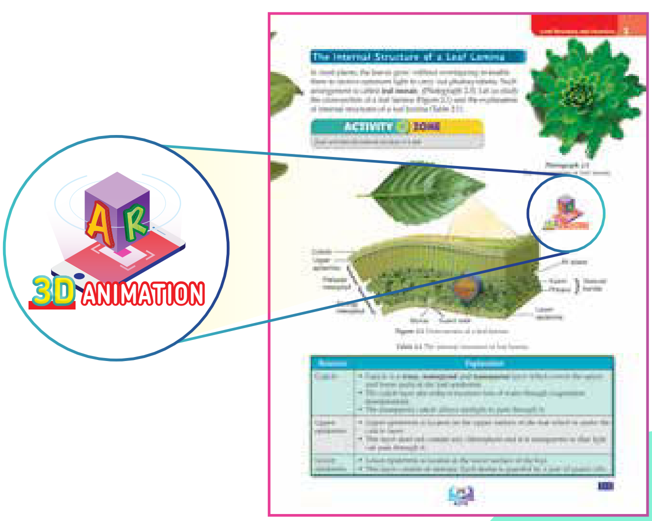
Steps to scan AR

1. Download the *BT Biology Tingkatan 5* AR application by scanning the QR code below:

Download on the Google play

Download on the App Store

2. Scan the relevant page with your smartphone or tablet to enjoy the three-dimensional animations.



Theme 1
Physiology of Flowering Plants

This theme aims to give a basic understanding of plant physiological processes.

This theme introduces tissue organisation, growth, leaf structure and function, nutrition, transportation, response, sexual reproduction in flowering plants and adaptations of plants in different habitats.

- What are the types and parts of tissue involved in plant growth?
- What is the mechanism of stomatal opening and closing?
- What is the importance of macronutrients and micronutrients in plants?
- Can phytoremediation plants control the pollution of water and soil?
- What are the functions of phytohormones in plant responses?
- Where does the formation of pollen grains occur?
- How are plants classified based on their habitats?

Chapter 1

Organisation of Plant Tissues and Growth

Chapter Exploration

- Organisation of Plant Tissues
- Meristematic Tissues and Growth
- Growth Curves

Learning Standards

Do You Know?

- What are the tissues that form plants?
- How does a seed develop into a seedling?
- Can we estimate the age of a plant?
- Why are timbers regarded as our national treasure?
- Why does grass live longer than paddy?

LED Lighting for Plant Factories

A plant factory is a closed production system set up in a building or controlled facility. All required elements such as light, temperature, carbon dioxide and air humidity are provided artificially.

This system produces a constant, high-quality, high-yield supply of crops throughout the year. The closed structure uses stacked hydroponic growing systems that are covered with LED lighting as the main source of light for plants to undergo photosynthesis.

Photograph 1.1 The usage of LED light in a plant factory

LED lighting is a better light source because it produces less heat and reduces electrical consumption. The usage of LED lamps also increases the production of nutrients and antioxidants in leaves apart from improving the shape, texture and colour of leaves.

Keywords

- Pectin
- Growth curve
- Lignin
- Primary growth
- Secondary growth
- Ground tissues
- Epidermal tissues
- Permanent tissues
- Collenchyma tissues
- Meristematic tissues
- Parenchyma tissues
- Sclerenchyma tissues
- Sieve tubes
- Vascular tissue
- Biennial plant
- Perennial plant
- Annual plant
- Zone of cell elongation
- Zone of cell division
- Zone of cell differentiation

1.1 Organisation of Plant Tissues

You have learnt about the levels of organisation in multicellular organisms in Chapter 2 of Form 4. Can you name a few specialised cells in plants?

Figure 1.1 shows the organisation of tissues in plants. A plant consists of two types of tissues, **meristematic tissues** and **permanent tissues**. Meristematic tissues are actively dividing tissues through mitosis. You will learn more about the meristematic tissues in the next subtopic.

PLANT TISSUES

- Meristematic tissues
  - Apical meristematic tissues
  - Lateral meristematic tissues
- Permanent tissues
  - Epidermal tissues
  - Ground tissues
    - Parenchyma tissues
    - Collenchyma tissues
    - Sclerenchyma tissues
  - Vascular tissues
    - Xylem tissues
    - Phloem tissues

Figure 1.1 The organisation of tissues in plants

Permanent Tissues

Permanent tissues are matured tissues which have experienced or are experiencing differentiation. There are three types of permanent tissues, which include **epidermal tissues**, **ground tissues** and **vascular tissues** (Figure 1.2 and Figure 1.3), each carrying out different functions (Table 1.1).

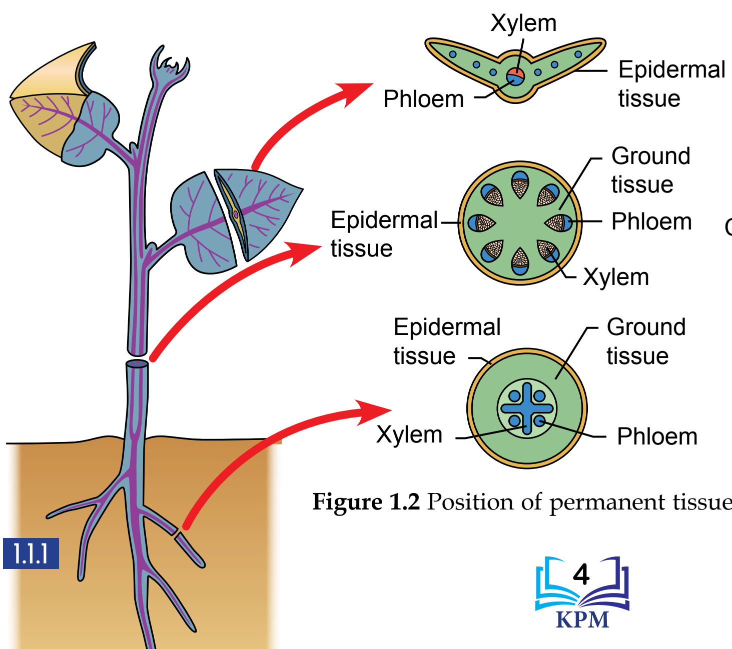


Figure 1.2 Position of permanent tissues

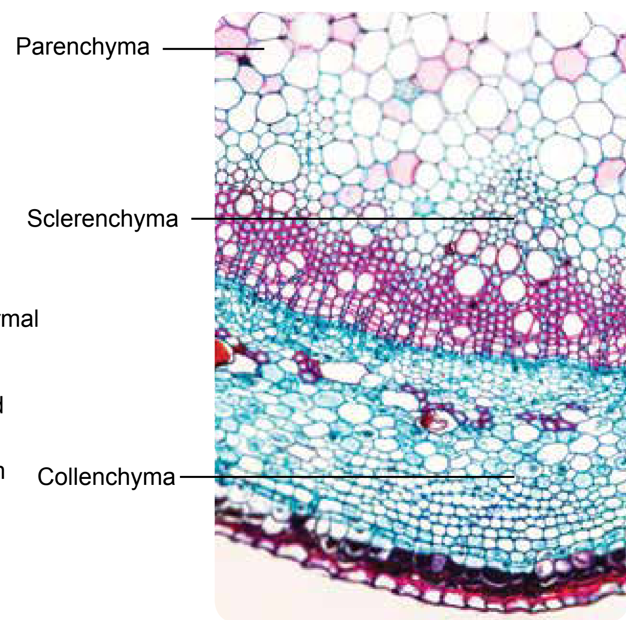


Figure 1.3 Micrograph showing the position of ground tissues in a stem of a plant

1.1.1

Table 1.1 Types of permanent tissues and their functions

Types of permanent tissues		Structure and function

Epidermal tissues		• **Epidermal tissues** layer the outermost surface of stems, leaves and roots of young plants.
		• Epidermal cell walls which are exposed to the air have a waxy and waterproof layer called **cuticle**.
		• The cuticle reduces loss of water through evaporation (transpiration), protects the leaf from mechanical injuries and pathogens.
		• There are modified epidermal cells according to their functions:
		  • **Guard cells** – control the opening of the stoma
		  • **Root hair cells** – increase the surface area of the root for water and mineral salts absorption

Ground tissues	**Parenchyma tissues**	• **Parenchyma tissues** are simplest living cells and do not undergo differentiation. • They have the thinnest cell walls. • Parenchyma tissues are always in a turgid state providing support and maintaining the shape of herbaceous plants. • Involved in photosynthesis, help in the storage of starch and sugar, and involved in gaseous exchange. • Involved in the repair and regeneration of plant tissue as well as in the vascular system.
	Collenchyma tissues	• **Collenchyma tissues** are made of living cells which mature into cells that are flexible. • Have cell walls made of **pectin** and **hemicellulose**. • Their cell walls are thicker than the parenchyma tissues. • Provide mechanical support and elasticity to plants.
	Sclerenchyma tissues	• **Sclerenchyma tissues** consist of dead cells when they are matured. • Their cell walls are the thickest among the three ground tissues. • Provide support and mechanical strength to the parts of matured plants. These tissues also help in the transport of water and nutrients in plants.
Vascular tissues	**Xylem**	• **Xylem** is made up of dead cells without the **cytoplasm.** • The cell wall of xylem contains lignin. • Consists of xylem vessels that are elongated, hollow and connected to each other from its roots to the leaves. • This enables xylem to transport water and mineral salt to all parts of a plant.
	Phloem	• **Phloems** are made of companion cells and sieve tubes. • Made of living cells, which is the sieve tubes with the presence of cytoplasm. • The sieve tubes do not have any organelles such as nucleus and ribosome as they decompose at maturity stage. • Phloems consist of sieve tubes arranged from end to end forming elongated and continuous tube structures. • Phloems transport sugars produced from the photosynthesis from the leaves to storage organs such as roots, fruits and tubers.

1.1.1

Formative Practice 1.1

1. State an example of cell modified from epidermal cells.
2. Explain the differences of parenchyma, collenchyma and sclerenchyma tissues.
3. How is the structure of xylem adapted to its functions?

1.2 Meristematic Tissues and Growth

Have you observed the development of a plant from a seedling to an adult plant? (Photograph 1.2). Which part of the plant grows first? There are undifferentiated living tissues in plants which are responsible for plant growth. These tissues are known as **meristematic tissues.** Figure 1.4 shows the types of meristematic tissues.

MERISTEMATIC TISSUES

- Apical meristems
- Lateral meristems

Figure 1.4 Types of meristematic tissues

Apical meristem tissues are located at the tips of plant shoots and roots, whereas lateral meristem tissues consist of vascular cambium and cork cambium (Figure 1.5).

Photograph 1.2 The growth of seedlings

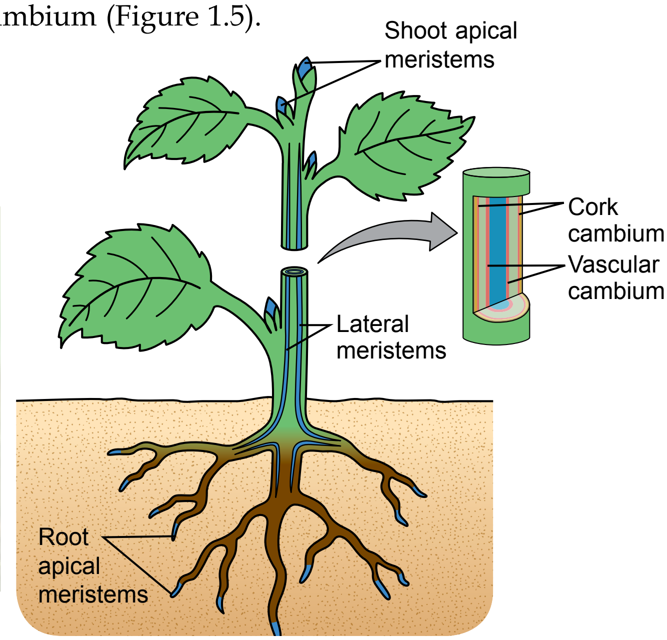
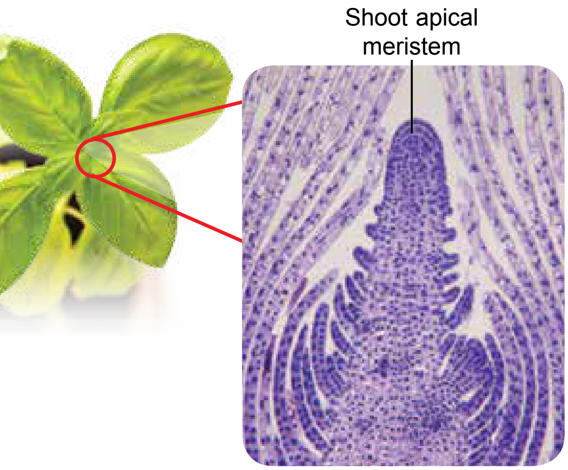


Figure 1.5 Apical meristems and lateral meristems

The changes in organisms which start from the zygote stage to an adult is known as **growth** and **development**. In Form 4, you have learnt about the growth in humans and animals. Can you state the definition of growth?

Zone of Cell Growth

The tips of shoots and roots can be divided into three zones of cell growth, which are the **zone of cell division**, the **zone of cell elongation** and the **zone of cell differentiation** (Figure 1.6 and Figure 1.7). The growth that happens in these zones is the **primary growth** for plants (Table 1.2).



Photograph 1.3
Micrograph of meristematic cells at the shoot tip

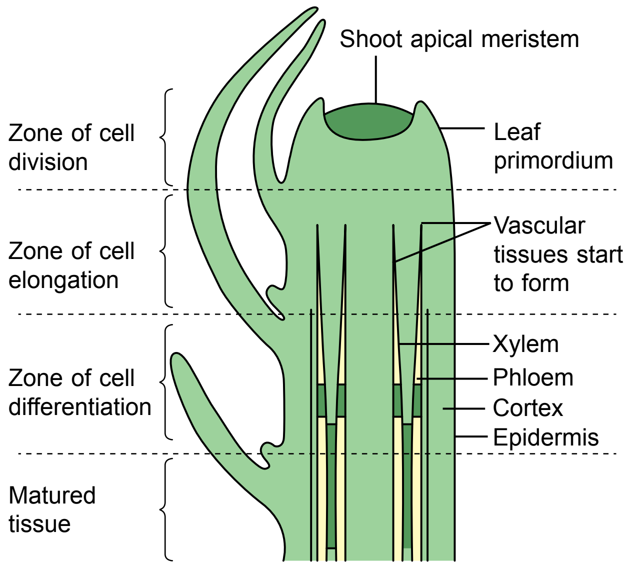
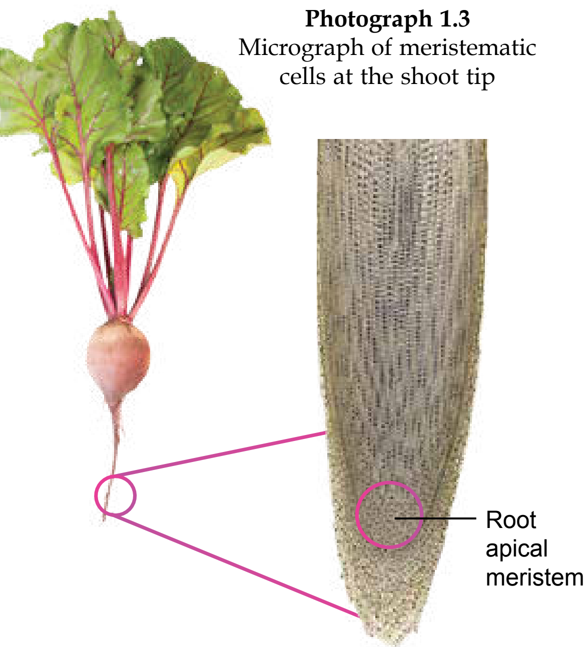


Figure 1.6 The zone of cell growth at the shoot tip



Photograph 1.4
Micrograph of meristematic cells at the root tip

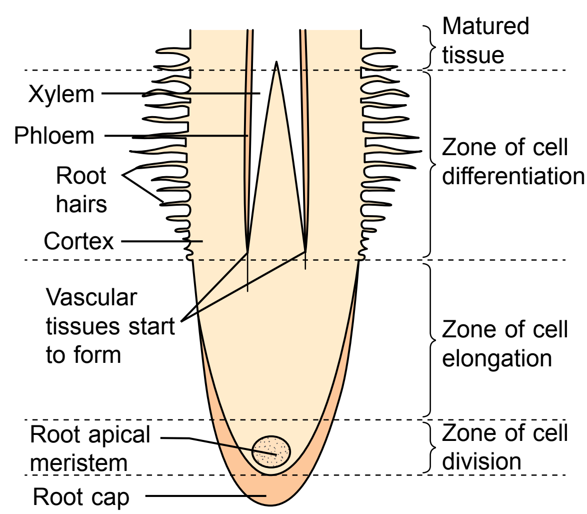


Figure 1.7 The zone of cell growth at the root tip

1.2.2

Table 1.2 The zones of cell growth

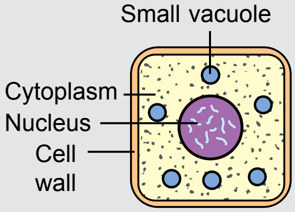
<table>
<tr><th>1. Zone of cell division</th><th>2. Zone of cell elongation</th><th>3. Zone of cell differentiation</th></tr>
<tr>
<td>• The zone of cell division takes place at the apical meristems which consists of actively dividing meristem cells through mitosis (Figure 1.8).
• The increase of the number of cells causes the elongation of the plant stem.
• When new cells are forming, the cells formed previously are pushed to the zone of cell elongation.


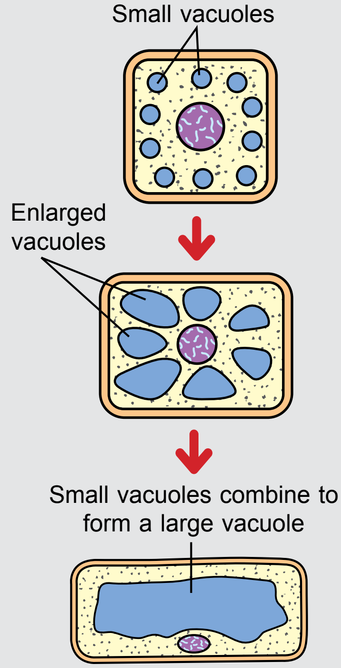
Figure 1.8
Meristem cell</td>
<td>• The zone of cell elongation consists of cells that are increasing in size.
• The increase in size happens through water diffusion by osmosis and the absorption of nutrients into the cells and stored in the vacuoles.
• Small vacuoles fuse to form a large vacuole. This process is known as vacuolation.
• The diffused water exerts pressure against the cell walls which pushes, elongates and widens the cells (Figure 1.9)


Figure 1.9 Cell elongation</td>
<td>• The zone of cell differentiation consists of differentiating cells that differentiate once they have reached their maximum size.
• Cells differentiate to form permanent tissues such as epidermis, cortex, xylem and phloem.
• The cells change their shapes and structures to become specialised cells with specific functions.
• For example, epidermal cells in leaves differentiate and form guard cells that control the opening of stoma. Other than that, epidermal cells in roots differentiate and form root hair cells.</td>
</tr>
</table>

Activity 1.1

Aim
To prepare microscope slides of zone of cell division, zone of cell elongation and zone of cell differentiation

Materials
Mung green beans, aceto-orcein stain, acetic acid, distilled water, ethanol

Apparatus
Knife, glass slide, cover slip, light microscope, dropper, mounting needle

Procedure
1. Soak the mung green beans overnight. Transfer the mung green beans into a cotton-filled container for three to five days to allow the growth of the radicle which will then form the root.
2. Cut the end of the roots about 10 mm and soak them in a mixed solution of 25% acetic acid and 75% ethanol for 30 seconds. This solution will kill the root cells but maintain their structures.
3. Using a knife, obtain a longitudinal section of a root cutting.
4. Wash the longitudinal section of the root cutting by using distilled water.
5. Place the cutting in a drop of distilled water on the glass slide and close it with the cover slip.
6. Carry out the staining technique using aceto-orcein stain for 30 seconds to 1 minute to stain the chromosomes.
7. Observe the slide using a microscope starting with the low power objective lens and followed by the high power objective lens.
8. Draw and label the cell division zone, cell elongation zone and cell differentiation zone observed. Record the power of magnification that have been used.

CAUTION
Be careful when using a knife.

Bio Exploration
Aceto-orcein stain can be replaced with aceto-carmine to stain the chromosomes so it can be seen clearly during observation of the mitotic phases.

Discussion
1. What are the zones that can be observed at the tip of a seedling radicle?
2. Describe the shapes and structures of the cells that can be observed in between the zones of the seedling radicle.

Bio Exploration

1.2.3

Types of Growth

There are two types of growth that occur in plants, namely **primary growth** and **secondary growth**.

Primary Growth

Primary growth is the growth that occurs after germination and it takes place in all plants to elongate their stems and roots.

This growth takes place in the **apical meristems** at the **shoot tips** and **root tips**. Primary growth starts when the meristem cells in the zone of cell division of apical meristems are actively dividing. This is followed by elongation and differentiation of the cells.

At the shoot tips, **leaf primordia** and **shoot primordia** will grow to form new leaves and shoots (Figure 1.10). This enables the plants to increase in height. At the root tips, the **root cap** will become exhausted when they penetrate the soil. This causes the cells of the root cap to be replaced by the meristem cells.

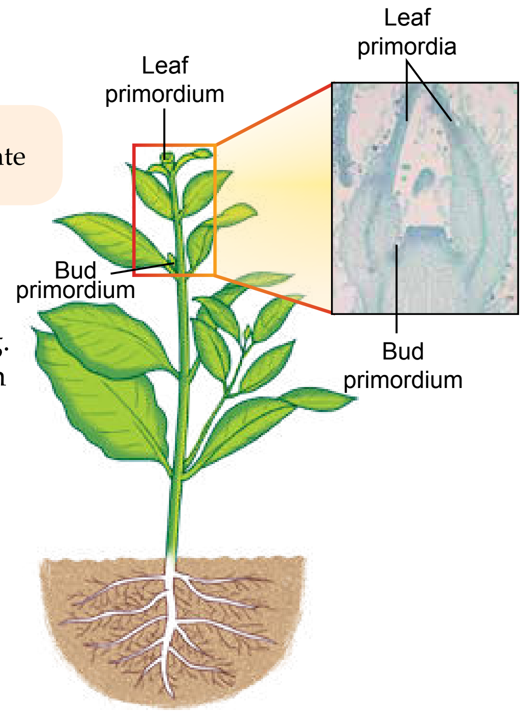


Figure 1.10
Primary growth at the shoot tips

Secondary Growth

Secondary growth occurs mainly in eudicots and a small number of monocots (shrub) to increase the circumference or diameter of plant stem and root (Figure 1.11).

Can you identify eudicots that go through primary growth only? For non-woody plants such as herbaceous plants, secondary growth does not happen. Secondary growth results from the division of lateral meristem cells located in the stem (Figure 1.13 and Figure 1.14) and root. **Lateral meristems** consist of **vascular cambium** and **cork cambium** (Figure 1.12).

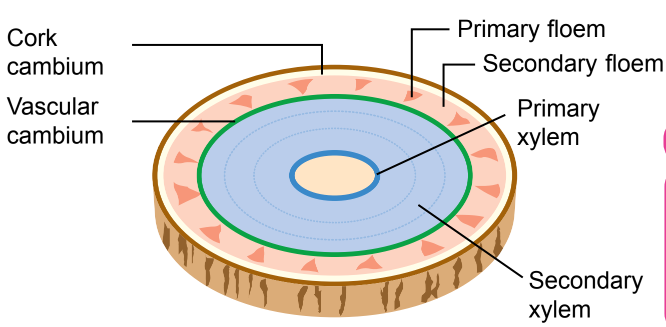


Figure 1.11 Cross section of eudicot stem that shows secondary growth

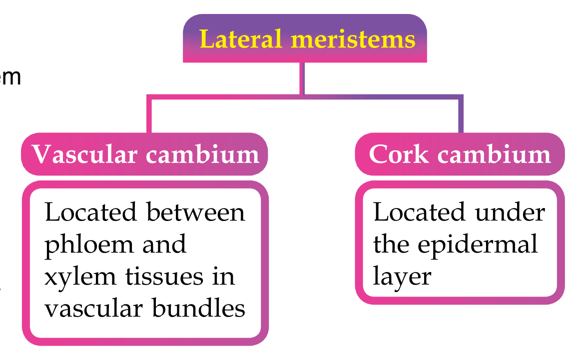


Figure 1.12 Types of lateral meristems

1.2.4

Secondary Growth at the Stem

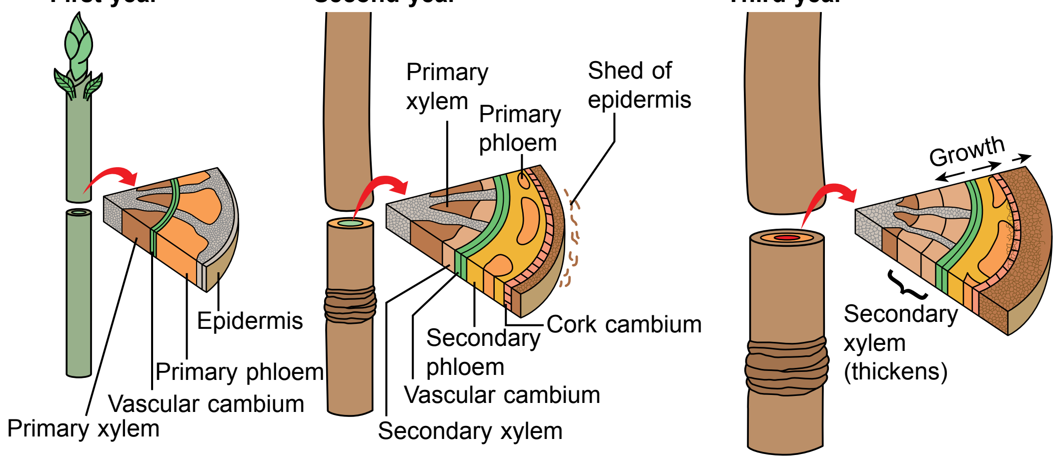
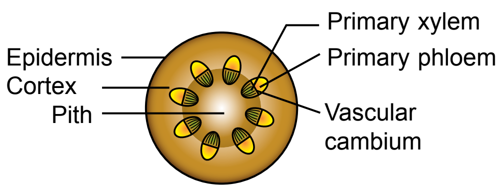
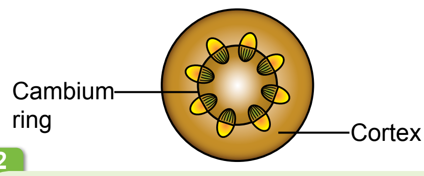


Figure 1.13 Cell divisions at vascular cambium and cork cambium during secondary growth



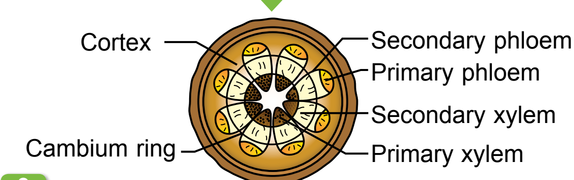
1

Secondary growth starts when the **vascular cambium** divides actively through mitosis.



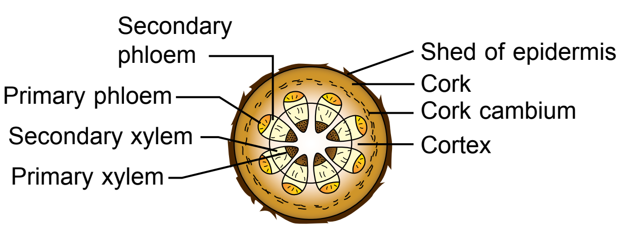
2

The cells in the cambium ring divide inwards to form **new xylem** and outwards to form **new phloem**. The new xylem tissues become **secondary xylem** and the new phloem tissues become **secondary phloem**.



3

- When undergoing secondary growth, primary xylem is pushed towards the pith whereas primary phloem is pushed towards the epidermis.
- As a result, the primary xylem tissues are compressed to form a stronger wood layer. This is because the walls of xylem are thickened with lignin.
- The thickening of lignin provides mechanical support to plants.



4

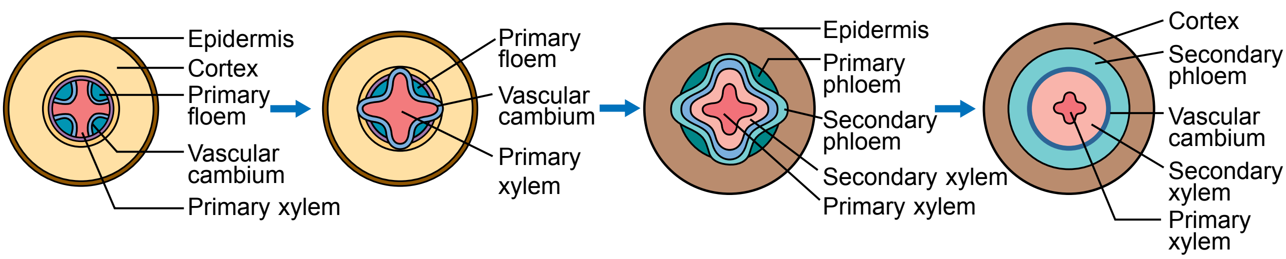
- When the secondary xylem layer is compressed, there is an addition to the circumference of the stem which causes the epidermis of the stem to stretch and crack.
- Cork cambium actively divides to form cork cells on the outer side and cortex on the inner side.
- The cork layer protects the stem from insect and pathogen attack when the epidermis is cracked.

Figure 1.14 Secondary growth at the stem

1.2.4

Secondary Growth at the Root

The root of plants also undergoes secondary growth in order to increase the **circumference of the root**. The secondary growth process at the root is the same as the secondary growth of a eudicot stem (Figure 1.15).



- **Vascular cambium** cells divide actively and combine to form a complete ring.
- The cells in the cambium ring divide inwards to form **secondary xylem** and outwards to form **secondary phloem**.

- Due to the vascular cambium activity, the root becomes thicker.
- The **cork cambium** located under the epidermis divides actively to form cork cells. The cork cells provide protection to the root tissues.

Figure 1.15 Secondary growth at the root

Bio Exploration

The age of plants living in temperate climate can be determined based on the annual growth rings in the stem. This is because secondary growth happens at different rates according to seasons. In spring, when there is enough water supply and sunlight, the secondary xylem formed is bigger and the wall is thinner. Therefore, the xylem tissues formed in this season are brighter in colour. The growth is unsuitable in summer, causing the formation of secondary xylem to be smaller, with thicker walls. Therefore, the xylem tissues that are formed are darker in colour (Photograph 1.5).

Photograph 1.5 Formation of secondary xylem in spring and summer

1.2.4

Secondary Growth of Monocots

Even though most monocots do not undergo secondary growth, some do, such as *Draceana* sp., *Aloe* sp. and *Agave* sp. (Photograph 1.6).

Photograph 1.6 Monocots that undergo secondary growth

The Necessity of Primary Growth and Secondary Growth

The necessity of primary growth:

- Allows maximum **elongation of plants** to absorb sunlight for photosynthesis
- Primary phloem can transport the products of **photosynthesis** from the leaves to other parts of the plants.
- Primary xylem can transport **water** and **mineral salts** from the soil via the roots to the leaves.
- Primary xylem provides **support** to herbaceous or young plants.

The necessity of secondary growth:

- Provides **stability** to plants by increasing the stem and root diameters to suit the height of plants
- Provides **mechanical support** to plants
- Produces more **xylem** and **phloem** tissues
- Produces xylem and phloem tissues continuously to replace **old** and **damaged** xylem and phloem tissues
- Produces **stronger** and **thicker bark** to provide protection to the plants from excessive water loss, physical injuries and pathogen infections
- Able to **live longer** by increasing the chances of seed production and reproduction

1.2.4

Activity 1.2

21st CENTURY SKILLS

21st CENTURY SKILLS FOLIO

Aim

To gather information on the necessity of primary and secondary growth

Procedure

1. Work in groups.
2. Gather information about the necessity of primary and secondary growth from a variety of media such as reference books, magazines, pamphlets and the internet.
3. Discuss and present the information that you have gathered in the form of a folio according to the following format:
   (a) Title
   (b) Introduction
   (c) Aim
   (d) Discussion encompassing the following aspects:
      (i) the necessity of primary growth in terms of height, support and transportation
      (ii) the need of secondary growth to increase support and transportation
      (iii) the importance of plants undergoing secondary growth economically
   (e) Photographs, figures, tables and relevant graphics
   (f) Conclusion
   (g) Source of reference

Activity 1.3

Aim

To gather information about the types of monocots that undergo anomalous secondary growth

Procedure

1. Work in groups.
2. Divide the areas in your school to a few small groups.
3. Each group has to identify two types of monocots that undergo anomalous secondary growth in their respective areas.
4. Identify the characteristics of the plants.
5. Obtain pictures of the identified plants.
6. Prepare a report about this field research.
7. Present the findings of your group.

1.2.5

Comparison between Primary Growth and Secondary Growth in Eudicots

The comparisons between primary growth and secondary growth in eudicots can be made based on the aspects shown in Table 1.3.

Table 1.3 Comparison between primary growth and secondary growth in eudicots

Similarities		
• Both growths can increase the size of the plants permanently.		
• Both growths occur in woody plants.		
• Both growths involve cell division by mitosis		
Differences		
Primary growth	**Aspect**	**Secondary growth**
Apical meristem	**Meristem tissue involved**	Lateral meristem (vascular cambium and cork cambium)
Occurs on stems and roots in younger regions of the plant	**Parts of the plant that undergo growth**	Occurs when primary growth has ceased on matured stems and roots
Growth occurs longitudinally	**Direction of growth**	Growth occurs radially
Increases the length of stems and roots of plant	**Growth effects**	Increases the thickness or circumference of stems and roots of plant
Epidermis, cortex and primary vascular tissues (primary xylem and primary phloem)	**Tissues and structures formed**	Bark, periderm (cork cambium and cork tissues), lenticels and secondary vascular tissues (secondary xylem and secondary phloem)
Do not have woody tissues	**Presence of woody tissues**	Have woody tissues
Thin	**Thickness of bark**	Thick
Absence of annual growth rings	**Presence of annual growth rings**	Presence of annual growth rings at the plant stem

1.2.6

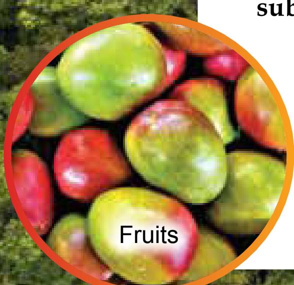
Bio Exploration

Flowering plants (Angiosperms) can be classified into monocotyledons and eudicotyledons. Both groups differ in terms of pollen structure, number of cotyledons, type of root, leaf venation and vascular bundle arrangement. Eudicotyledons are the largest group in flowering plants and consist of various species. Some eudicots can undergo secondary growth allowing them to grow tall and live for hundreds of years.

The Economic Importance of Plants that Have Undergone Secondary Growth

Plants that undergo secondary growth have high economic values because they can produce timber such as *Shorea* sp. (meranti) and *Balanocarpus* sp. (cengal).

- Plants that undergo secondary growth have strong and hard woods which are suitable to be used as structures for houseboats, furniture, fences, doors and others.
- The presence of annual rings makes furniture look attractive and they can be made as decorative items.
- The woods and barks of some plants such as *Hopea* sp. (merawan) and meranti can produce **resin** and **oil**. The substances can be commercialised as **varnish**, **adhesive substance**, **perfume** and **medicine**.
- Flowering plants can be made as decorative plants.
- Commercialised **fruits** such as mangoes and mangosteen, are products of plants that have undergone secondary growth and they are able to generate income as well as boost **economic growth**.



Photograph 1.7 The uses of plants that undergo secondary growth

ICT

Info

Example of Secondary Plants in Malaysia

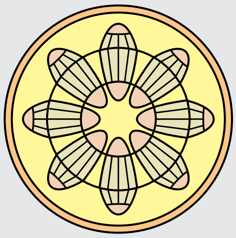
bukuteksksm.my/Biologi/T5/Ms16

ACTIVITY ZONE

Gather information about the types and uses of timbers in Malaysia. Present the information in the form of a brochure.

Formative Practice 1.2

1. Name the **three** zones of cell growth.
2. The figure below shows a cross-section of a plant stem that undergoes secondary growth.



(a) Label the primary xylem, primary phloem, secondary xylem and secondary phloem.
(b) Explain the formation of secondary xylem and secondary phloem.
3. Why is secondary growth important to plants?
4. Secondary growth supports primary growth.

Using your knowledge in biology, support the above statement.

1.3 Growth Curves

Types of Plants Based on Life Cycles

Plants can be classified based on their life cycles, which are **annual**, **biennial** and **perennial plants**.

Annual Plants

Annual plants are plants that have only one life cycle for a season or a year. These plants usually die after completing their biological cycle which starts from germination and ends with flowering or producing seeds. Examples of annual plants are **paddy**, **pumpkin** and **watermelon** plants (Photograph 1.8).

Photograph 1.8 Examples of annual plants

1.3.1

Biennial Plants

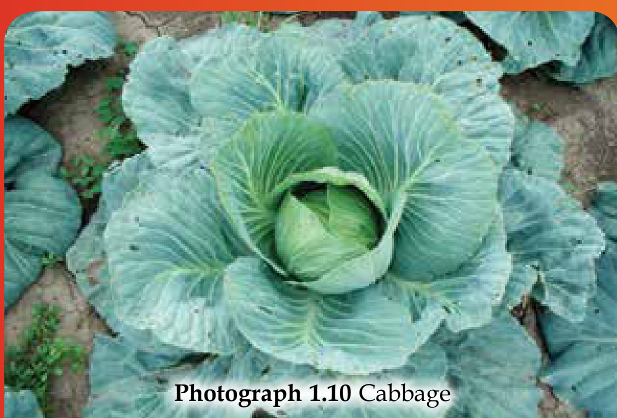
Biennial plants refer to plants which take two years with two seasons of growth to complete their life cycle. The first growth season is the **vegetative growth** which is the growth of roots, leaves and stem structures whereas the second growth season is **reproduction**. Most of the biennial plants grow in temperate regions.

After going through vegetative growth, these plants briefly stop the growth process during winter. During spring and summer, the growth continues as preparation for reproduction by flowering. The plants produce fruits and seeds and eventually the plants will die. Examples of biennial plants are **cabbage**, **carrot** and **silver cock's comb**.

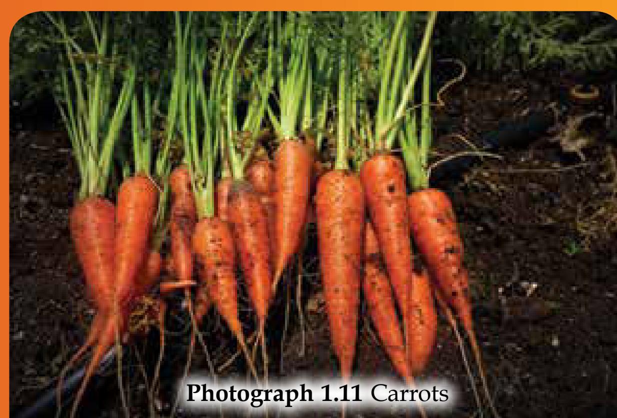
Photograph 1.9
Silver cock's comb plant

ACTIVITY ZONE

Identify the types of plants in your school area based on their life cycles. Obtain the pictures of the plants and record them in your science book.



Photograph 1.10 Cabbage



Photograph 1.11 Carrots

Perennial plants

Perennial plants refer to plants which live more than two years. These plants have longer lifespan depending on the species and conditions. Perennial plants can be classified into two categories, which are **woody perennial plants** and **herbaceous perennial plants**. Most of these plants are able to flower and bear fruits many times throughout their lives. These plants have structures that are adaptable to their surroundings and temperature change. Examples of perennial plants are **grass**, **hibiscus plant** and **mango plant.**

Photograph 1.12
Hibiscus plant

1.3.1

Growth Curve in Plants

In Form 4, you have learnt about the growth curve of humans and animals with exoskeleton. The growth curve of most organisms are sigmoid curve. What is the shape of the growth curve of plants?

The growth curve of annual plants

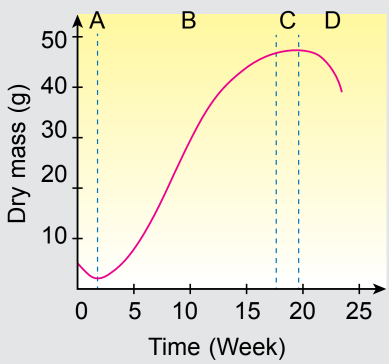


Figure 1.16

- The growth curve is a **sigmoid curve** (Figure 1.16).
- **Stage A: Decreasing dry mass**
  Food stored in the **cotyledon** is used for germination before the leaves emerge to carry out photosynthesis.
- **Stage B: Increasing dry mass**
  The rate of growth increases rapidly. This is because the plant has carried out photosynthesis.
- **Stage C: Constant dry mass**
  -The rate of growth is zero.
  -Plant is **matured** at this stage.
- **Stage D: Decreasing dry mass**
  Happens slowly because of aging, lower rate of photosynthesis, shedding of leaves and flowers and seed dispersal.

The growth curve of biennial plants

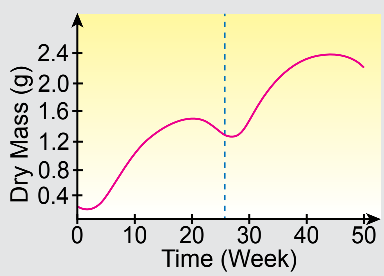


Figure 1.17

- The growth curve has **two sigmoid curves** which are combined (Figure 1.17).
- **First growth season:**
  -Plants produce leaves, photosynthesis takes place.
  -Food is stored in tubers.
- **Second growth season:**
  -The food stored is used to produce flowers and seeds

The growth curve of perennial plants

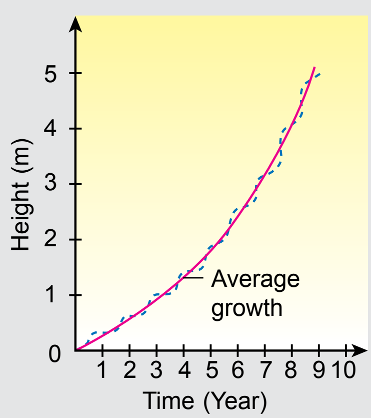


Figure 1.18

- The growth curve is a series of small **sigmoid curves** (Figure 1.18).
- Every year the growth curve is a **sigmoid** curve. Growth occurs throughout the lifespan of the plant.
- The rate of growth is **high** during spring and summer. High light intensity increases the rate of photosynthesis.
- The rate of growth **decreases** in winter.

1.3.2

EXPERIMENT

1.1 The Shape of Growth Curve in Plants

PRECAUTIONS

Ensure the plants obtain enough nutrients, water, air and light.

Bio Exploration

The scientific name of corn plant is *Zea mays*.

Problem Statement

What is the shape of the growth curve of a corn plant?

Aim

To investigate the growth curve of a corn plant.

Hypothesis

The growth curve of a corn plant is a sigmoid curve.

Variables

Manipulated variable: Number of days after planting
Responding variable: Dry mass of corn seeds
Constant variable: Type of corn seeds

Material: 30 corn seeds

Apparatus: Nursery box, electronic balance, oven

Procedure

1. Prepare 30 corn seeds that had been soaked for at least an hour. In a spacious area, prepare the nursery box.
2. Take three seeds at random.
3. Dry them in the oven at 100 °C for 5 minutes.
4. Weigh the dried seeds one at a time and record their dry mass readings.
5. Repeat steps 3 and 4 with the same three seeds until there are no changes in their dry mass readings.
6. Record their dry mass readings in the table of results (day '0'). Obtain the average dry mass reading for the three seeds.
7. Plant the remaining seeds at 30 cm intervals in the nursery box prepared.
8. Water the soil in the nursery box daily.
9. Retrieve and clean any three seedlings from the nursery box every three days.
10. Dry the three seedlings in the oven at 100 °C for 5 minutes and measure their dry mass.
11. Repeat step 10 until there are no changes in their dry mass readings and record the results in a table.
12. Repeat steps 9 to 11 by increasing the time in the oven 10 minutes at a time, for a maximum of 30 minutes, based on the size of the seedling, until day 21.
13. Plot a graph showing the dry mass of corn seedlings against time.

Results

Time (Day)	Dry mass of three seeds or seedlings (g)			Average dry mass of seeds or seedlings (g)
	Seed 1	Seed 2	Seed 3	
0				
3				

Discussion

1. What is the shape of the growth curve of the corn plant?
2. Explain the growth curve.

Conclusion

Is the hypothesis accepted? Suggest a suitable conclusion.

1.3.3

EXPERIMENT 1.2

The Effect of Sound Towards Growth in Plants

Aim
To design an experiment to study the effect of sounds towards growth in plants

Material: Five corn seedlings of the same type and size

Apparatus: Classical music, heavy metal music, ruler

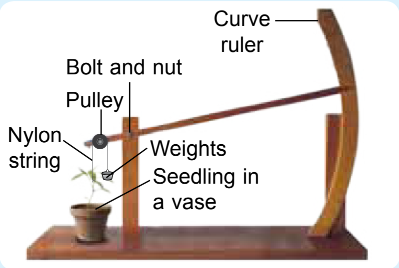
Procedure
1. Work in groups.
2. Each group needs to design an experiment to study the effect of sound towards the growth of corn plants.
3. Build a hypothesis and determine the variables for this experiment.
4. Plan and carry out the experiment by exposing the seedlings to different types of music.
5. Record and discuss the results of the experiment. Present the data in the form of a graph.
6. Write a report of the experiment and submit it to your teacher.

Activity 1.4 STEM

Aim
Design an auxanometer to measure the rate of plant elongation

Material
Seedling in a vase

Apparatus
Board, bolts and nuts, nylon strings, weights, curve ruler, pulley



Photograph 1.6 Auxanometer

Procedure
1. Work in groups.
2. Each group needs to design an auxanometer.
3. Measure the rate of plant elongation using the built auxanometer.
4. Record and discuss the results obtained. Present the data in the form of a graph.
5. Present the findings of your group.

Formative Practice 1.3

1. State the classification of plants based on their lifespan.
2. Based on your knowledge in biology, specify the types of plants that are able to survive in extreme surroundings. Discuss.
3. In general, the growth curves for three types of plants are a single sigmoid curve or a combination of a few sigmoid series. Why does the growth curve of perennial plants consist of a series of small sigmoid curves?

1.3.3

Memory Flashback

Organisation of Plant Tissues and Growth

- Organisation of tissues
  - Meristematic tissues
    - Apical meristematic tissues
    - Lateral meristematic tissues
  - Permanent tissues
    - Epidermal tissues
    - Ground tissues
      - Parenchyma tissues
      - Collenchyma tissues
      - Sclerenchyma tissues
    - Vascular tissues
      - Xylem tissues
      - Phloem tissues
- Meristematic tissues and growth
  - Meristematic tissues
    - Apical meristems
      - Shoot tips
      - Root tips
    - Lateral meristems
      - Vascular cambium
      - Cork cambium
  - Zone of cell growth
    - Zone of cell division
    - Zone of cell elongation
    - Zone of cell differentiation
  - Types of growth
    - Primary growth
    - Secondary growth
- Growth curve
  - Types of plants based on their life cycles
  - Growth curve
    - Annual plants
    - Biennial plants
    - Perennial plants

Interactive Bio 1

SELF-REFLECTION

Complete the following self-reflection to identify the important concepts that you have studied.

Important concepts	Very good	Try again
The types of plant tissues and their main functions		
The types and parts of tissues involved in growth		
The position of the zone of cell division, zone of cell elongation and zone of cell differentiation in shoots and roots		
The zone of cell division, the zone of cell elongation and the zone of cell differentiation in the seed radicle		
Primary growth and secondary growth		
The importance of primary growth and secondary growth		
The comparison between primary growth and secondary growth in eudicots		
The economic importance of plants that have undergone secondary growth		
The types of plants based on their life cycles		
Growth curve for annual, biennial and perennial plants		

Summative Practice 1

1. Figure 1 shows three examples of tissues which are found in plants.

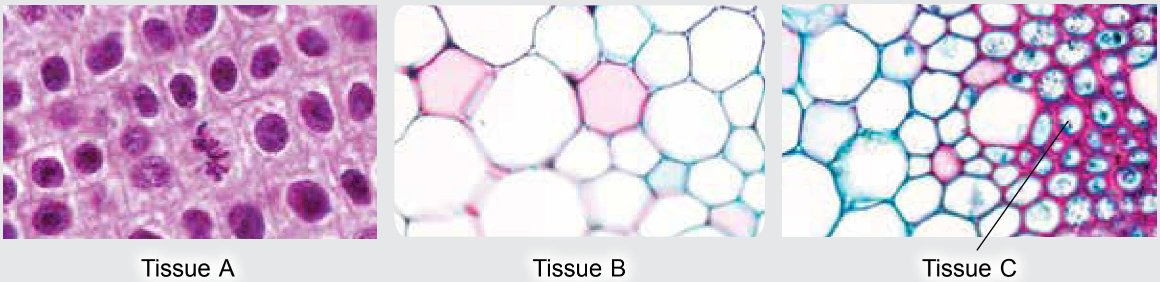


Figure 1

Identify tissue A, tissue B and tissue C. State **one** characteristic and function of each tissue.

2. Figure 2 shows a longitudinal cross-section of a eudicot shoot tip.

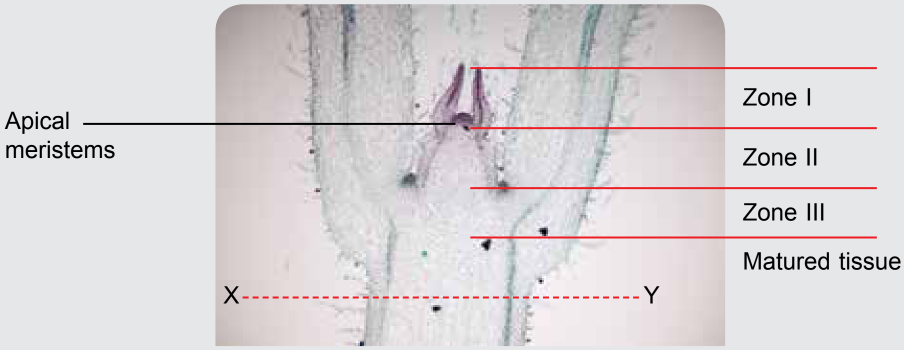


Figure 2

(a) Name Zone I, Zone II and Zone III.

(b) (i) Draw a cell to represent Zone I and Zone II.

(ii) State the differences between the cell in Zone I and cell in Zone II.

(c) Draw a cross-section of the shoot at XY.

(d) After a few years, the plant undergoes secondary growth. Draw a cross-section of the plant stem which has undergone the secondary growth.

3. Figure 3 shows a growth curve of a plant which lives in a temperate climate.

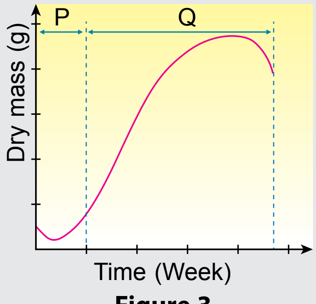


Figure 3

(a) Identify the type of plant and state an example of a plant that has the same growth curve in Figure 3.

(b) Why is there a difference in the shape of the growth curve in weeks P and Q?

(c) Figure 4 shows the stages of growth in a eudicot stem.

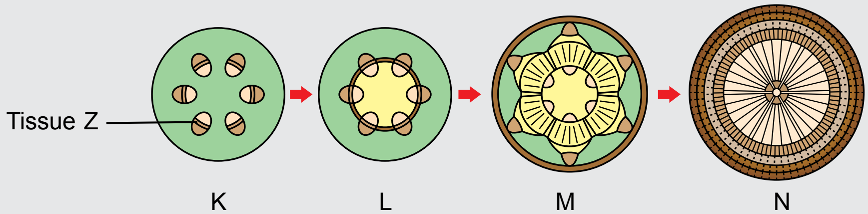


Figure 4

(i) Name tissue Z.
(ii) Explain the development of tissue Z from stage K to stage L.
(iii) Predict what would happen to the plant if tissue Z is not formed.

4. (a) Figure 5 shows a cross-section of a plant stem which lives in a temperate climate. The annual growth rings form a combination of dark and bright growth rings.

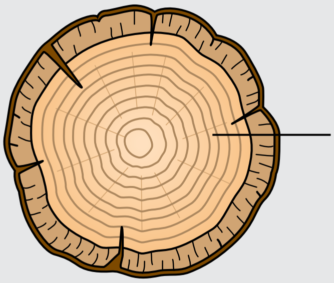


Figure 5

Estimate the age of the plant. Explain the formation of the annual growth rings.

(b) (i) Based on the statement below, what are the advantages of the plants that undergo secondary growth? Discuss the importance of secondary growth.

Eudicots such as mangosteen undergo primary growth to increase its height and followed by secondary growth to increase the diameter of its stem and roots. Monocots such as grass only undergo primary growth.

(ii) Why are there only a small number of monocots that undergo secondary growth? Explain.

5. The timber industry in Malaysia is the biggest contributor to the commodities sector, with an export income value of RM23.2 billion in 2017. However, the income in this sector recorded a decrease in 2018 because of the lack of raw materials. Among the initiatives carried out by the government to overcome this problem is by opening acacia forest plantations. In your opinion, why is the acacia plant chosen to resolve the problem?

21st Century Mind

6. The height of fruit trees need to be controlled so that they are not too tall. As a botanist, Mr. Lim suggests to his neighbour to trim the fruit trees in his orchard. Justify Mr. Lim's suggestion based on your knowledge in biology.

Chapter 2

Leaf Structure and Function

Chapter Exploration

- Structure of a Leaf
- Main Organ for Gaseous Exchange
- Main Organ for Transpiration
- Main Organ for Photosynthesis
- Compensation Point

Learning Standards

Do You Know?

- How are the external structures of a leaf and internal structures of a leaf lamina?
- What is the main organ for gaseous exchange in plants?
- What is the main organ for transpiration?
- What is the main organ for photosynthesis?
- What is meant by compensation point?

The Changes of Leaf Colour in Four-Season Countries

The colours of leaves depend on the pigment molecules contained in them. Examples of the pigments are chlorophyll, carotenoid and anthocyanin.

The chlorophyll pigment causes the leaf to appear green. In four-season countries, the leaves are green during summer because the light intensity is very high. During autumn and winter, some plants stop making chlorophylls. These chlorophylls are broken down into smaller molecules. Without chlorophyll, other pigments such as carotenoid and anthocyanin will be produced and causing the colours of the leaves to change into yellow and red.

Keywords

- Lamina
- Petiole
- Palisade mesopyhll
- Spongy mesophyll
- Transpiration
- Microbalance
- Herbarium
- Granum
- Thylakoid
- Stroma
- Photolysis
- Compensation point

2.1 Structure of a Leaf

A leaf is the main organ of a plant which carries out photosynthesis. The structure of a leaf can be divided into two parts, which are the **external structure** and the **internal structure**.

The External Structure of a Leaf

Commonly, the external structure of a green leaf consists of **lamina** and **petiole** (Photograph 2.1).

Photograph 2.1
The external structure of a leaf

Lamina

- Lamina is the flat, thin, smooth and green part of the leaf.
- Lamina is flat-shaped to provide a wide surface in order to expose the cells containing chloroplasts to the maximum amount of sunlight.
- Lamina is also thin to allow gases involved in photosynthesis to diffuse efficiently in the leaf.

Petiole

- Petiole is the leaf stalk that connects the lamina to the stem of the plant.
- The petiole stretches out into the lamina producing a network of middle veins to support the lamina.

ACTIVITY ZONE

Herbarium is a specimen collection from plants which are preserved through a certain method.

- Prepare a herbarium from various plants available in the area of your house.
- Complete with data such as taxonomy, morphology, ecology and geography of the plants.

Photograph 2.2
Herbarium specimen

Family	: Malvaceae
Scientific name	: *Hibiscus rosa-sinensis*
Common name	: Bunga raya
Collector	: Maisarah Jamalluddin
Sample number	: 14
Date	: 9/10/2020
Location	: Taman Mewah, Perak
Notes	: • The leaves are light-green. • Half of the leaves are jagged upwards. • The flowers stand out. • The number of flower is one and it is positioned at the end of a long stalk.

2.1.1

The Internal Structure of a Leaf Lamina

In most plants, the leaves grow without overlapping to enable them to receive optimum light to carry out photosynthesis. Such arrangement is called **leaf mosaic**. (Photograph 2.3). Let us study the cross-section of a leaf lamina (Figure 2.1) and the explanation of internal structures of a leaf lamina (Table 2.1).

Photograph 2.3
The arrangement of leaf mosaic

ACTIVITY ZONE

Draw and label the internal structure of a leaf.

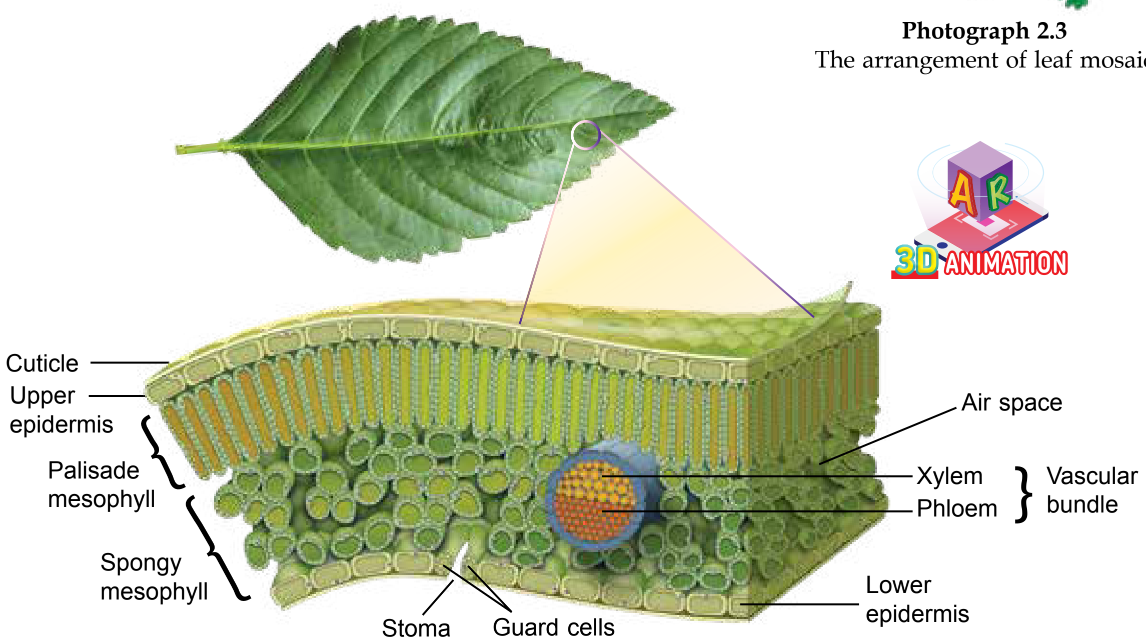


Figure 2.1 Cross-section of a leaf lamina

Table 2.1 The internal structures of leaf lamina

Structure	Explanation
Cuticle	• Cuticle is a **waxy**, **waterproof** and **transparent** layer which covers the upper and lower parts of the leaf epidermis. • The cuticle layer also reduces excessive loss of water through evaporation (transpiration). • The transparent cuticle allows sunlight to pass through it.
Upper epidermis	• Upper epidermis is located on the upper surface of the leaf which is under the cuticle layer. • This layer does not contain any chloroplasts and it is transparent so that light can pass through it.
Lower epidermis	• Lower epidermis is located at the lower surface of the leaf. • This layer consists of stomata. Each stoma is guarded by a pair of guard cells.

2.1.2

Palisade mesophyll	• Palisade mesophyll cells are arranged vertically and closely-packed to receive maximum light exposure. • These cells are the sites for photosynthesis. Therefore, they contain many **chloroplasts**.
Spongy mesophyll	• Spongy mesophyll cells are irregular-shaped that increases the internal surface area for gaseous exchange. • These cells are loosely arranged and they have many intercellular air spaces. • It can ease **carbon dioxide** and **water** absorption through the leaves to palisade mesophyll cells during photosynthesis. • Spongy mesophyll has less number of chloroplasts than palisade mesophyll.
Vascular bundle	Xylem • Xylem transports water and mineral salts absorbed from the roots to the leaf. • The walls of the xylem are **lignified** and thickened to provide mechanical support and strength to the plants. Phloem • Phloem transports **organic substances** produced during photosynthesis from the leaves to other parts of the plants.

Activity 2.1

Aim
To identify the cross-sections of monocot and eudicot leaves

Apparatus
Prepared slides of the cross-sections of monocot and eudicot leaves, light microscope

Procedure
1. Observe the prepared slides of the monocot leaf and eudicot leaf using a light microscope.
2. Identify the epidermis tissues, palisade mesophyll tissues, spongy mesophyll tissues, xylem tissues and phloem tissues.
3. Draw and label the cross-sections of the monocot and eudicot leaves as seen through the light microscope.

Discussion
1. Identify the differences between the structures of monocot and eudicot leaves.
2. Between the monocot and eudicot leaves, which has larger air spaces?

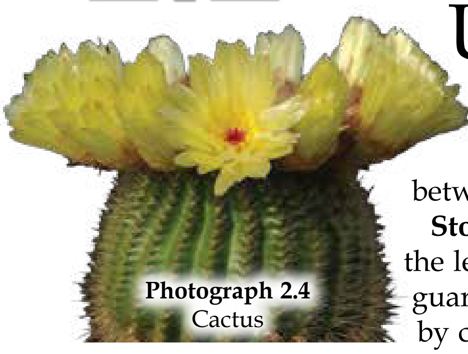
Formative Practice 2.1

1. Name **two** external structures of a leaf.
2. What is the importance of cuticle in leaves?
3. Name **five** internal structures of a leaf.
4. State the functions of xylem and phloem.
5. The layer of cuticle and upper epidermis is transparent. Justify.
6. Compare the layers of palisade mesophyll and spongy mesophyll.

2.1.2

2.2 Main Organ for Gaseous Exchange

The Necessity of Gaseous Exchange in Plants



Photograph 2.4 Cactus

Unlike animals that search for their own food, plants on the other hand synthesise their own food through photosynthesis. In order to carry out photosynthesis efficiently, plants need to exchange gases and absorb light. The exchange of oxygen and carbon dioxide between plants and the surroundings occurs through stomata. **Stomata** are the pores located on the lower epidermis of the leaf (Photograph 2.5). Each stoma is guarded by a pair of guard cells that controls the opening and closing of the stoma by changing their shapes. The guard cells contain chloroplasts to carry out photosynthesis.

Bio Exploration

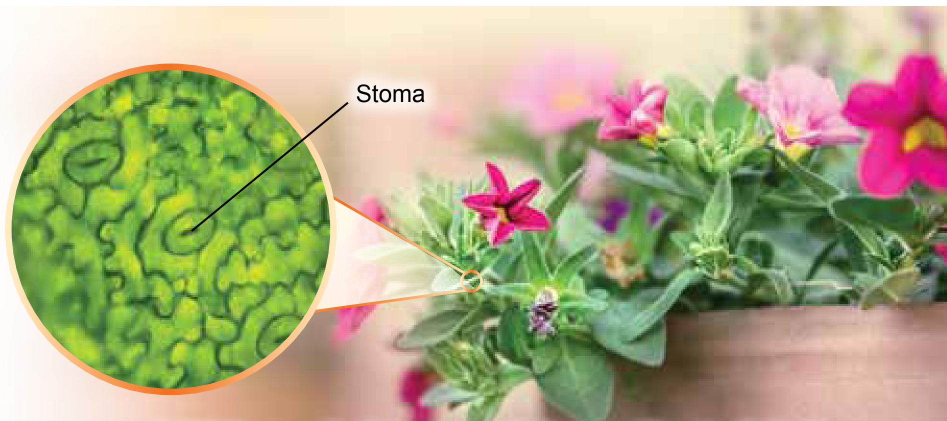
Cacti (Photograph 2.4) in the desert open their stomata only during the night for carbon dioxide. Colder temperature at night can reduce the loss of water.

ICT

Activity

Preparation of the microscope slide of guard cells.

http://bukuteksksm.my/Biology/F5/InquiryActivity.pdf



Photograph 2.5 Micrograph of stomata on the lower epidermis of a leaf

The Mechanism of Stomatal Opening and Closing

The mechanism of stomatal opening and closing depends on the conditions of the guard cells whether turgid or flaccid. The condition of the guard cells depends on the **potassium ion (K^+) uptake** by the cells or the **sucrose concentration** in the sap of the guard cells (Table 2.2).

Table 2.2 Stomatal opening and closing mechanism

Uptake of potassium ions by guard cells	Sucrose concentration in the guard cell sap
• The accumulation or elimination of potassium ion (K^+) in the guard cells changes the solute potential. • This increases or decreases the water potential in the guard cells. • Water is diffused out or into the guard cells through osmosis. This condition determines whether the guard cells are turgid or flaccid.	• During day time or in the presence of light, photosynthesis takes place and produces dissolved sugar (sucrose). • During night time or in the absence of light, sugar in the guard cells converts into starch.

2.2.1 2.2.2

The Opening of Stoma

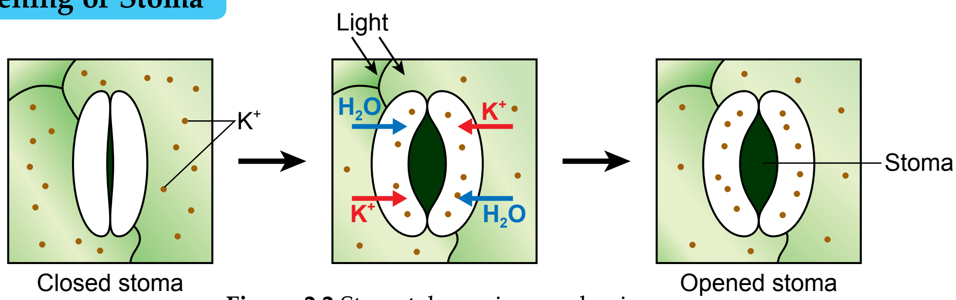


Figure 2.2 Stomatal opening mechanism

Uptake of potassium ions by guard cells

- The potassium ions enter the guard cells.
- The solute potential in the guard cells increases.
- The water potential in the guard cells decreases.
- The water molecules from the epidermal cells diffuse into the guard cells by osmosis.
- The guard cells become turgid and curve outwards.
- The stoma opens (Figure 2.2).

Sucrose concentration in the guard cell sap

- In the presence of light, photosynthesis occurs.
- The concentration of sucrose in the guard cells becomes high.
- The water potential in the guard cells decreases.
- The water molecules from the epidermal cells diffuse into the guard cells by osmosis.
- The guard cells become turgid and curve outwards.
- The stoma opens (Figure 2.2).

The Closing of Stoma

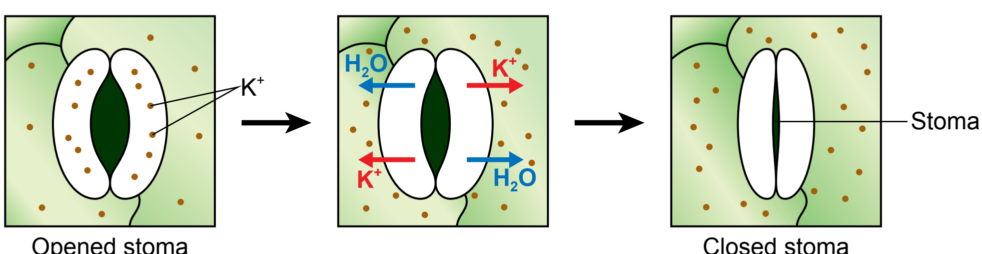


Figure 2.3 Stomatal closing mechanism

Uptake of potassium ions by guard cells

- The potassium ions move out from the guard cells.
- The solute potential in the guard cells decreases.
- The water potential in the guard cells increases.
- The water molecules diffuse out from the guard cells to the epidermal cells by osmosis.
- The guard cells become flaccid.
- The stoma closes (Figure 2.3).

Sucrose concentration in the guard cell sap

- In the absence of light, photosynthesis does not occur.
- The sucrose concentration in the guard cells becomes low.
- The water potential in the guard cells increases.
- The water molecules diffuse out from the guard cells to the epidermal cells by osmosis.
- The guard cells become flaccid.
- The stoma closes (Figure 2.3).

Activity 2.2

Aim
To design a model to relate the mechanism of stomatal opening and closing to uptake of potassium ions and changes in sucrose concentration

Materials: Balloons, thread

Apparatus: Y-tube

Procedure

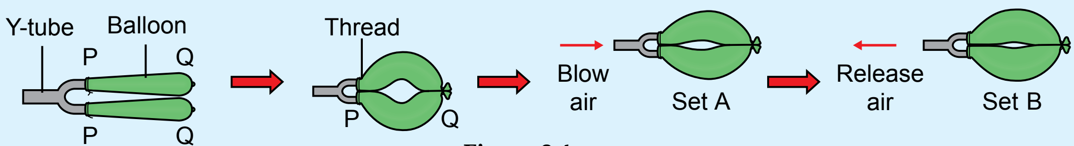


Figure 2.4

1. Insert the Y-tube into two balloons. Tie Ps neatly with thread (Figure 2.4).
2. Tie both Qs ends with a loose knot.
3. Blow through the end of the Y-tube slowly until there is a space in between both balloons (Set A).
4. Repeat steps 1 to 3 to obtain another set of apparatus (Set B).
5. Release a certain amount of air from Set B balloons until the balloons straighten.

Discussion
1. Name the plant structures that are represented by the balloons and the space between them.
2. What represents the potassium ions?
3. State the effect of the addition of air in the balloons and the space between them in Set A.
4. State the effect of releasing some air from the balloons in Set B.

EXPERIMENT 2.1 The Distribution of Stomata on the Upper and Lower Epidermis of Monocot and Eudicot Leaves

Problem Statement
Is the distribution of stomata in the upper and lower epidermis of monocot and eudicot leaves the same?

Aim
To conduct an experiment to compare stomatal distribution of upper and lower epidermis of monocot and eudicot leaves.

Hypothesis
The distribution of the stomata in the lower epidermis of the monocot and eudicot leaves are more packed as compared to the distribution of the stomata on the upper epidermis.

Variables
Manipulated variables: The part of epidermis layer and the type of leaves
Responding variable: The number of stoma
Constant variable: The leaves of plants

Materials
Balsam leaf, lily leaf

Apparatus
Colourless nail polish, magnifying glass, forceps, glass slides, cover slips, light microscope

2.2.2 2.2.3

EXPERIMENT

Procedure

1. Apply some colourless nail polish on the upper epidermis of a balsam leaf.
2. Let the nail polish dry. Peel off the nail polish layer from the surface of the leaf.
3. Drop a bit of water onto a glass slide and place the nail polish layer on the water droplets. Cover with a cover slip. Observe the presence of stomata and count the number of stoma using a light microscope with low power objective lens.
4. Repeat steps 1 to 3 for the lower epidermis of the balsam leaf.
5. Repeat steps 1 to 4 by replacing the balsam leaf with a lily leaf.

Results

Type of leaves	Part of epidermis layer	Number of stoma
Balsam leaf	Upper epidermis	
	Lower epidermis	
Lily leaf	Upper epidermis	
	Lower epidermis	

Discussion

1. Which epidermis has more stomata? Explain how this characteristic enables balsam plants to carry out photosynthesis at optimum rate.
2. Compare the shape of guard cells and the arrangements of stomata between the balsam plant (eudicot) and the lily plant (monocot).

Conclusion

Is the hypothesis accepted? Suggest a suitable conclusion.

Think Smart

What is the difference between the leaf cuticle of a plant in the desert and an aquatic plant?

ICT

Activity

Designing a microbalance

http://bukutekskssm.my/Biology/F5/STEMActivity.pdf

Photograph 2.6 Lotus

The Effect of Water Deficiency in Plants on Stomatal Opening and Closing

Water from plants is lost in the form of water vapour to the surroundings through the stomata. When stoma opens widely, the rate of water loss from the plants is high. The opening and closing of the stoma is dependent on the turgor pressure of the guard cells.

Fresh plants

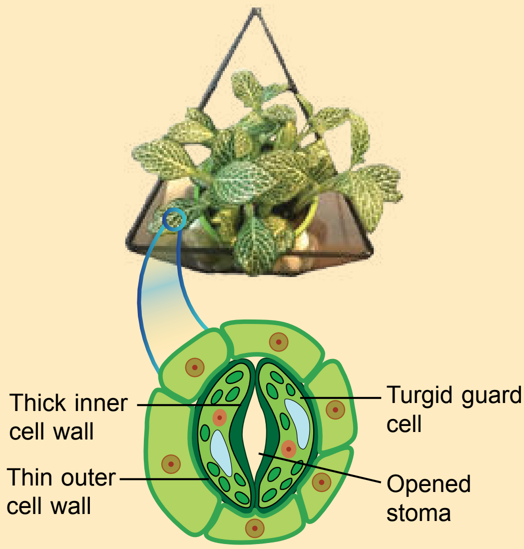


Figure 2.5 Opened stoma

- When the plant obtains enough water, the guard cells become turgid.
- The inner cell wall of the guard cells is thick and less elastic as compared to the outer cell wall.
- The thin and more elastic outer cell wall causes the guard cells to curve outwards and the stoma to open (Figure 2.5).

Wilted plants

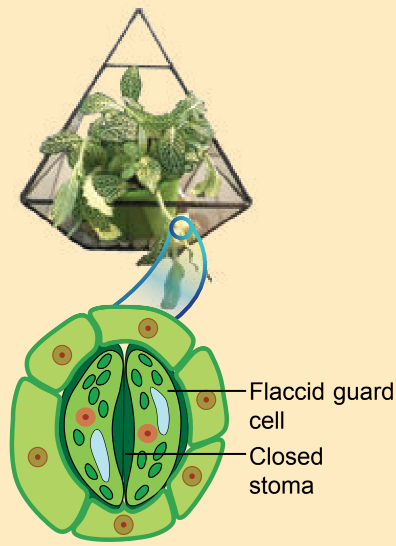


Figure 2.6 Closed stoma

- When the plant lacks water, the guard cells become flaccid.
- The thin and more elastic outer cell wall causes the guard cells to lose turgidity and the stoma to close (Figure 2.6).

Formative Practice 2.2

1. State the differences of gaseous exchange in plants during respiration and photosynthesis.
2. How does humidity in the surroundings affect the size of the stomatal opening?
3. The stomatal distribution on the lower leaf surface is more packed as compared to the upper leaf surface. Justify.
4. What is the importance of stomatal closure when the plant lacks water?

2.2.4

2.3 Main Organ for Transpiration

The Necessity of Transpiration in Plants

Transpiration is a process of water loss in the form of water vapour through evaporation from the plants to the atmosphere. Even though the transpiration process takes place through the stem and flower, 90% of water diffuses out through stomata pores in the leaves. Water diffuses into the root system by osmosis continuously (Figure 2.7).

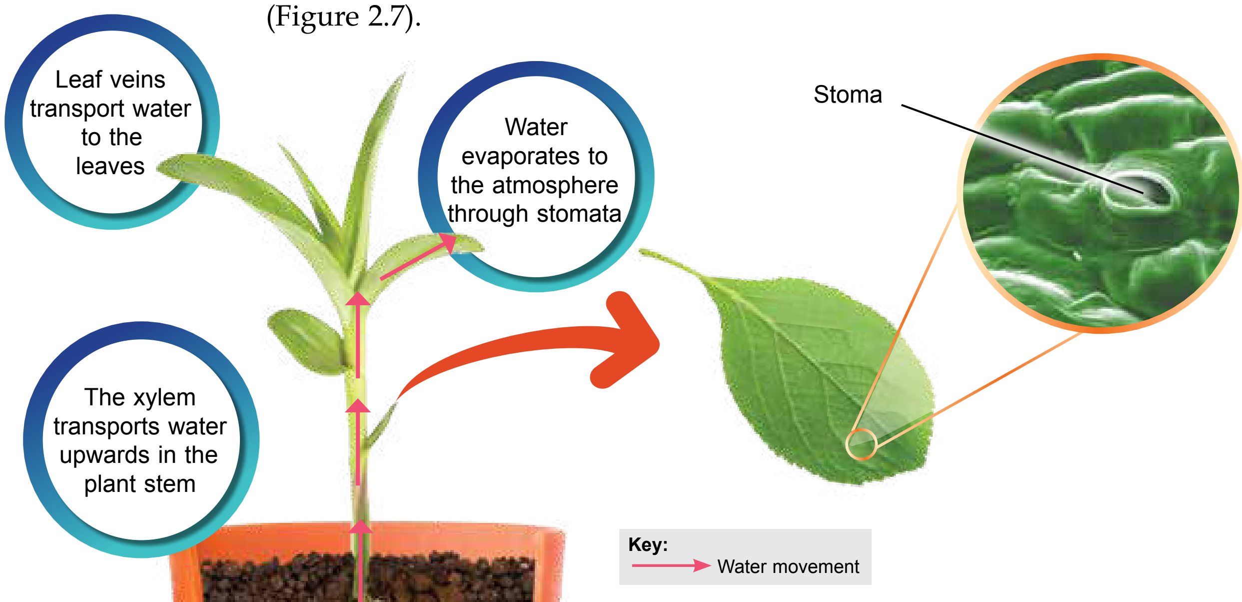


Figure 2.7 Path of water movement in plants

ACTIVITY ZONE

Prove that the stomata of a leaf are the main site of transpiration. You can follow the arrangement as shown in Figure 2.8.

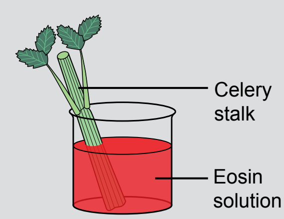


Figure 2.8 The arrangement to test the main organ in transpiration

Why is transpiration required in plants?

- Plant roots absorb water and mineral salts from soil.
- Water absorbs heat energy from leaves and evaporates as water vapour to give cooling effect.
- Produces a pulling force that moves the water and mineral salts continuously in the xylem vessels from the roots to all plant cells.

2.3.1

The Environmental Factors that Affect the Rate of Transpiration

The rate of transpiration is affected by various environmental factors (Figure 2.9 - Figure 2.12).

Is the rate of transpiration of plants in the desert and in the tropical rainforest different?

Does a polluted surrounding affect the rate of transpiration?

Light intensity

The higher the light intensity, the higher the rate of transpiration. If the light intensity increases, the rate of transpiration will increase until it becomes constant. The rate of transpiration is constant because the relative air humidity, temperature and air movement become the limiting factors.

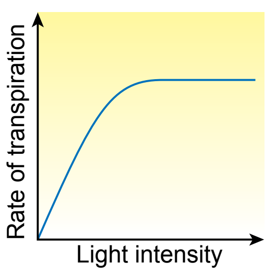


Figure 2.9

Relative air humidity

The lower relative air humidity of the surrounding atmosphere, the faster water vapour escapes from the stomata. Therefore, the rate of transpiration becomes higher.

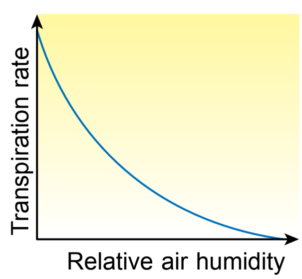


Figure 2.10

Temperature

An increase in temperature increases the kinetic energy of water molecules thus increasing the rate of transpiration.

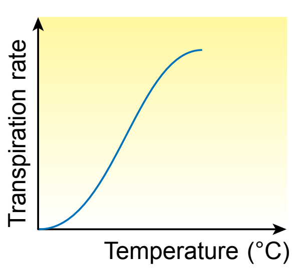


Figure 2.11

Air movement

The movement of air carries away water molecules that have been diffused out from the leaves. Hence, the faster the air movement, the faster the rate of transpiration.

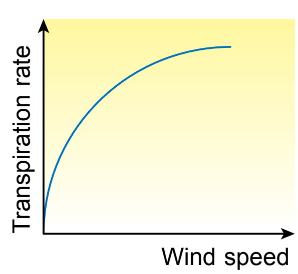


Figure 2.12

2.3.2

2.2 EXPERIMENT

The Effects of Environmental Factors on Rate of Transpiration Using a Potometer

Problem Statement
What are the effects of environmental factors on the rate of transpiration?

Aim
To study the effects of environmental factors on the rate of transpiration using a potometer

Hypotheses
(a) Transpiration rate is higher in the presence of wind.
(b) Transpiration rate is higher at a higher light intensity.
(c) Transpiration rate is higher at a higher temperature.
(d) Transpiration rate is higher at a lower relative air humidity.

Variables
Manipulated variable: Environmental factors
Responding variable: Rate of transpiration
Constant variable: Types of plants

Materials
Leafy twigs, water, petroleum jelly, plastic bag, tissue paper

Apparatus
Cork, beaker, stopwatch, ruler, electrical table fan, 100 W bulb, potometer (capillary tube, screw clip)

Procedure

Potometer is a device used to measure water intake by a leafy twig.

1. Prepare a potometer and ensure the connections are applied with petroleum jelly so that they are airtight.
2. Cut a leafy twig of a plant in water. Ensure the size of the stem is compatible with the cork covering the potometer.
3. Set the leafy twig to the potometer and make sure it is airtight (Figure 2.13).
4. Wipe all the leaves until they are dry using tissue papers.
5. Fill the potometer with water until it is full.
6. Trap a small air bubble at the base of the potometer to be used as an indicator.
7. Mark the initial position of the air bubble in the potometer as P.

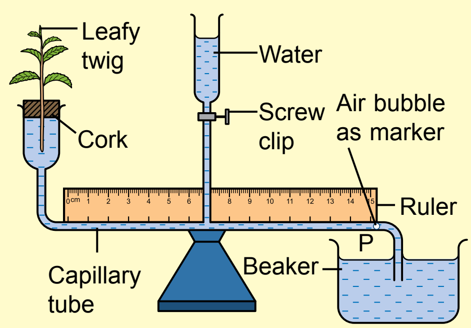


Figure 2.13 Set-up of potometer

8. Place the potometer in a room without fan circulation and followed by placing it in front of fan with speed 2.
9. After 10 minutes, measure the distance of the air bubble in the potometer using a ruler or a scale on the capillary tube of the potometer.
10. Repeat steps 1 to 8 by exposing the potometer set under the following surroundings:
    (a) High and low light intensities
    (In a dark room and under a 100 W bulb)
    (b) High and low temperatures
    (In a room with an air conditioner and in a room without air conditioner)

2.3.3

EXPERIMENT

(c) High and low relative air humidities
(Plant that is covered with a humid plastic bag and plant that not covered)

10. Calculate the rate of transpiration using the following formula:

$$\frac{\text{Distance travelled by air bubble (cm)}}{\text{Time (min)}}$$

Results

Surrounding factor		Distance travelled by air bubble in 10 minutes (cm)	Transpiration rate (cm/min)
(a) Air movement	Fast		
	Slow		
(b) Light intensity	High		
	Low		
(c) Temperature	High		
	Low		
(d) Relative air humidity	High		
	Low		

Discussion

1. Why does the leafy twig has to be cut in water?
2. What is shown by the distance travelled by the air bubble in the capillary tube of the potometer?
3. What are the effects of air movement, light intensity, temperature and relative air humidity towards the distance travelled by the air bubble in the capillary tube?
4. State the operational definition of transpiration.

Conclusion

Are the hypotheses accepted? Suggest a suitable conclusion.

Formative Practice 2.3

1. What is the meaning of transpiration? State the relationship between transpiration and stomata.
2. Other than higher temperature and faster air movement, light intensity also affects the rate of transpiration. Explain.
3. A plant X was submerged in flood for two days. When the water subsided, the leaves of plant X were covered with mud. How does this condition affect the rate of transpiration? Explain.

2.3.3

2.4 Main Organ for Photosynthesis

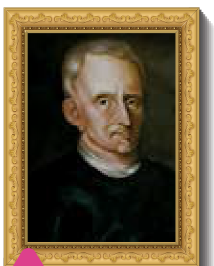
The Necessity of Photosynthesis in Plants

Plants are autotrophic organisms that produce their own food through photosynthesis. The product of photosynthesis, which is glucose, is used by other organisms to generate energy through oxidation of food. Energy is needed to carry out living processes such as growth and reproduction.

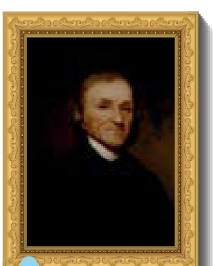
Brief History of Discovery of Photosynthesis

In 1640s, Jan-Baptista van Helmont carried out an experiment to test the idea that plants obtained their food from the soil.

In the year 1772, an experiment conducted by Joseph Priestly showed that plants released oxygen to the atmosphere.



Helmont's conclusion: The plant had grown by only being watered and not from the water of the soil.



Priestly's conclusion: Plants release oxygen.

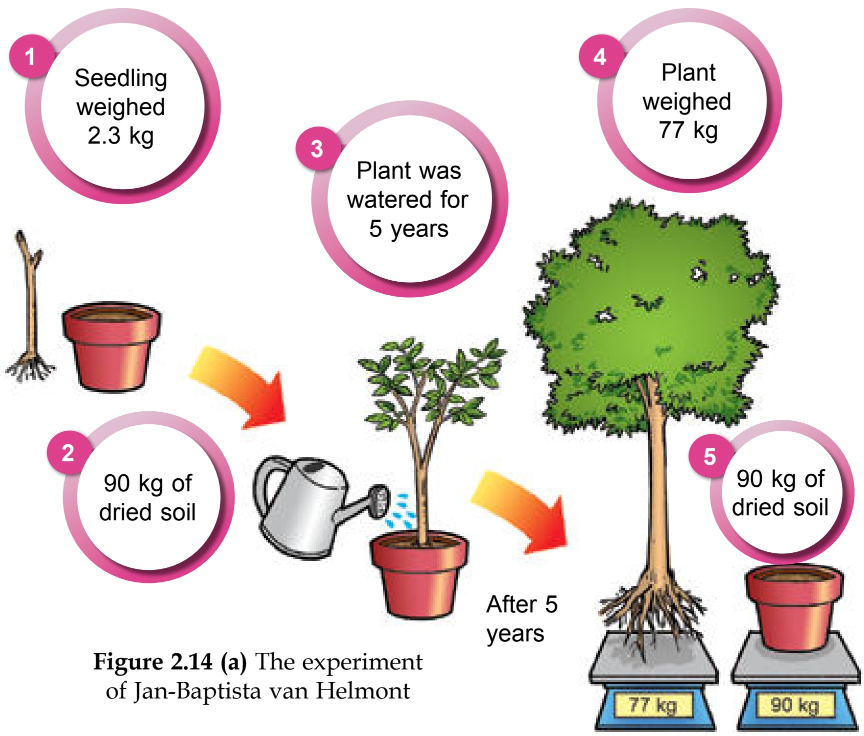


Figure 2.14 (a) The experiment of Jan-Baptista van Helmont

A rat was placed in an inverted glass jar. The rat died.

When a plant was placed inside an inverted glass jar with a rat, the rat lived.

Figure 2.14 (b) The experiment of Joseph Priestly

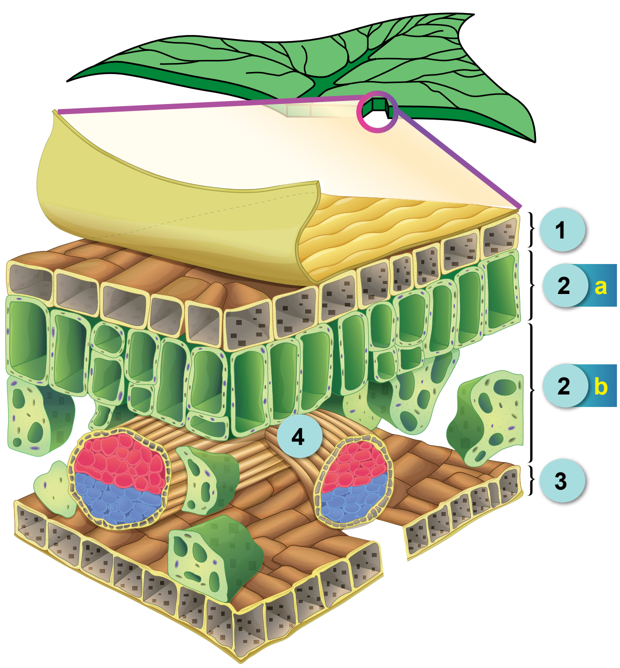
2.4.1

The Adaptation of the Internal Structure of a Leaf to Photosynthesis

Photosynthesis needs chlorophyll to absorb light energy from the sun, carbon dioxide from the atmosphere and water from the soil. Oxygen is released as a by-product. Besides the leaf being the main photosynthesis organ, young stem and other green parts of the plants are also able to carry out photosynthesis (Figure 2.15).

TERM ANALYSIS

Photosynthesis originated from the Greek words,
- **Photo** = light
- **Synthesis** = arranged together or producing



1 3 UPPER EPIDERMIS AND LOWER EPIDERMIS

- **Transparent waxy cuticle** on the upper and lower epidermis allows sunlight to penetrate the upper and lower epidermis into the palisade mesophyll.
- **Stomata** are present in the lower epidermis:
  - In the presence of light, stomata open and allow gaseous exchange to occur

2 a PALISADE MESOPHYLL

- Packed with **chloroplasts**:
  - Enables sunlight to be absorbed at a maximum rate
- Chloroplast contains chlorophyll
  - **Chlorophyll** absorbs **light energy** for photosynthesis

2 b SPONGY MESOPHYLL

- Contains a lesser amount of chloroplasts compared to palisade mesophyll
- Contains air spaces:
  - Allows efficient gaseous exchange during photosynthesis

4 VASCULAR BUNDLES

- **Xylem** – transports water and mineral salts absorbed from the root to the leaf
- **Phloem** – transports sucrose produced by photosynthesis from the leaf to all parts of the plant

Figure 2.15 The relation of internal leaf structure adaptation with photosynthesis

2.4.2

Chloroplast Structure

In Form Four, you were introduced to the chloroplast organelle in plant cells which functions as a site for photosynthesis. A chloroplast contains chlorophyll to absorb sunlight and converts it into chemical energy during photosynthesis. A chloroplast consists of **thylakoids**, **grana**, **stroma** and **lamellae** (Figure 2.16).

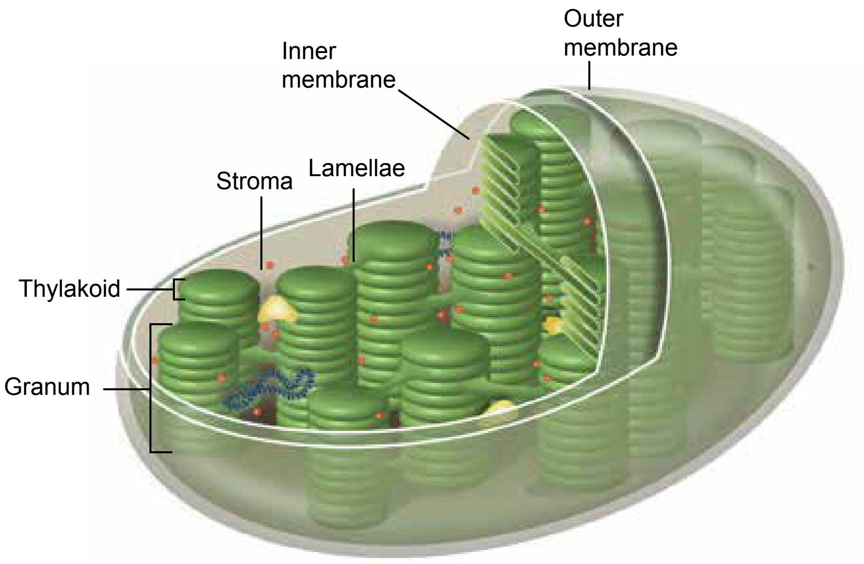


Figure 2.16 Chloroplast structure

THYLAKOID

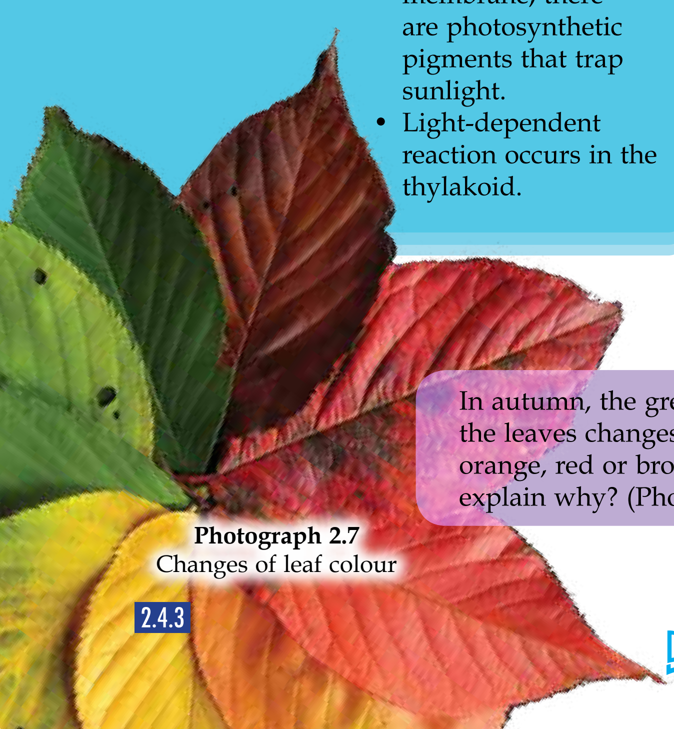
- Disc-shaped sacs containing chlorophyll.
- In thylakoid membrane, there are photosynthetic pigments that trap sunlight.
- Light-dependent reaction occurs in the thylakoid.

GRANUM

- A disc-shaped stack of thylakoids.
- This arrangement increases the surface area for optimal photosynthesis.

STROMA

- Colourless fluid surrounding **granum** in the chloroplast.
- Site for light-independent reaction to take place which produces glucose.



Photograph 2.7
Changes of leaf colour

In autumn, the green colour of the leaves changes to yellow, orange, red or brown. Can you explain why? (Photograph 2.7)

TERM ANALYSIS

Chlorophyll originates from the Greek words,
- ***Chloros*** = green
- ***Phyllos*** = leaf

How many types of photosynthetic pigments in leaves are involved to produce the green colour of a plant? Do you know that the **chromatography method** can be used to separate the photosynthetic pigments in leaves? Chromatography is a technique separating components of a mixture based on the differences in solubility of the components in certain solvents.

TERM ANALYSIS

Chromatogram:
Paper chromatography with the test result (separated components).

Activity 2.3

Aim
To carry out an investigation to separate photosynthetic pigments in a leaf using paper chromatography

Materials
Coleus plant leaves/ pandan leaves/ red spinach leaves, fine sand, 80% acetone, solvent (one part of aceton and nine parts of petroleum ether), skewer, filter paper, pencil

Apparatus
Glass container, ruler, mortar and pestle

Procedure
1. Pound two leaves of coleus plant/ pandan leaves/ red spinach leaves with 80% acetone and a little bit of fine sand using a mortar and pestle until a thick leaf extract is obtained.
2. Prepare a filter paper of size 3 cm × 15 cm.
3. Draw a line of 1.5 cm from the end of the filter paper horizontally using a pencil.
4. Transfer the leaf extract in the middle of the pencil line and let it dry.
5. Repeat step 4 ten times to get a thick extract on the filter paper.
6. Dip the end of filter paper in a glass container containing solvent at a height of 1 cm (Figure 2.17).
7. Let the filter paper dry for a while and observe the changes.
8. Mark the points of each pigment that can be seen on the chromatogram.

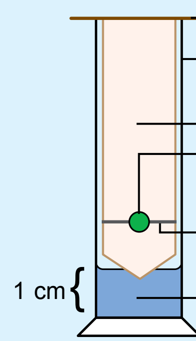


Figure 2.17 Set-up of paper chromatography

CAUTION
Ensure that solvent is not touching the droplet of leaf extract.

Discussion
1. What is the function of solvent in this activity?
2. Why is fine sand used to prepare the leaf extract?
3. How are the photosynthetic pigments in the leaves separated using the chromatography method?

Bio Exploration

Plant pigments can be determined by calculating the value of R_f. Table 2.3 shows the examples of plant pigments, R_f value and their colours.

$$R_f = \frac{\text{Distance travelled by pigment}}{\text{Distance travelled by solvent}}$$

Table 2.3 R_f values and the colour of plant pigments

Plant pigment	R_f value	Colour
Chlorophyll a	0.60	Blue/ greenish
Chlorophyll b	0.50	Green
Carotenoid	0.95	Orange
Xantophyll	0.35	Yellow
Pheophytin	0.70	Grey

2.4.3

Light-Dependent and Light-Independent Reactions in Photosynthesis

There are two main stages in photosynthesis, which are **light-dependent reaction** and **light-independent reaction** (Figure 2.18).

Photosynthesis

Light-dependent reactions (occurs in the thylakoids)

1. Photosynthetic pigments on the surface of the thylakoids absorb light energy.
2. Light energy excites electrons in chlorophyll pigments to a higher level.
3. The excited electrons from the chlorophyll go through a series of electron carriers. The energy from the electrons is used to generate energy in the form of ATP.
4. Eventually, these electrons are accepted by the last electron acceptor, which is the $NADP^+$. The $NADP^+$ then combines with H^+ from photolysis and forms NADPH which is a reducing agent.
5. Chlorophyll pigment attracts electrons from water via photolysis to become stable.
6. Photolysis is a process whereby water molecules are broken down to form hydrogen ions (H^+) and hydroxide ions (OH^-) in the presence of light energy and chlorophyll.
7. Hydroxide ions lose electrons and form oxygen and water.

Light-independent reactions (occurs in the stroma)

1. 5-carbon organic compounds fix carbon dioxide gases to form 6-carbon organic compounds.
2. NADPH and ATP from the light-dependent reaction reduces the organic compounds to glucose monomers.
3. Glucose monomers condensate to form starch molecules. Starch granules are stored in the stroma of chloroplasts.

The overall reaction for photosynthesis can be represented by the following chemical reaction:

$$\underset{\text{Water}}{12H_2O} + \underset{\text{Carbon dioxide}}{6CO_2} \xrightarrow[\text{Chlorophyll}]{\text{Light energy}} \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Oxygen}}{6O_2} + \underset{\text{Water}}{6H_2O}$$

Figure 2.18 The light-dependent reaction and the light-independent reaction

Bio Exploration

Nicotinamide adenine dinucleotide phosphate ($NADP^+$) is a coenzyme in cells that functions as a hydrogen carrier. In photosynthesis, $NADP^+$ is an oxidising agent which receives hydrogen ions in the light-dependent reaction, while NADPH is a reducing agent in the light-independent reaction.

2.4.4 2.4.5

Comparison between Light-Dependent and Light-Independent Reactions in Photosynthesis

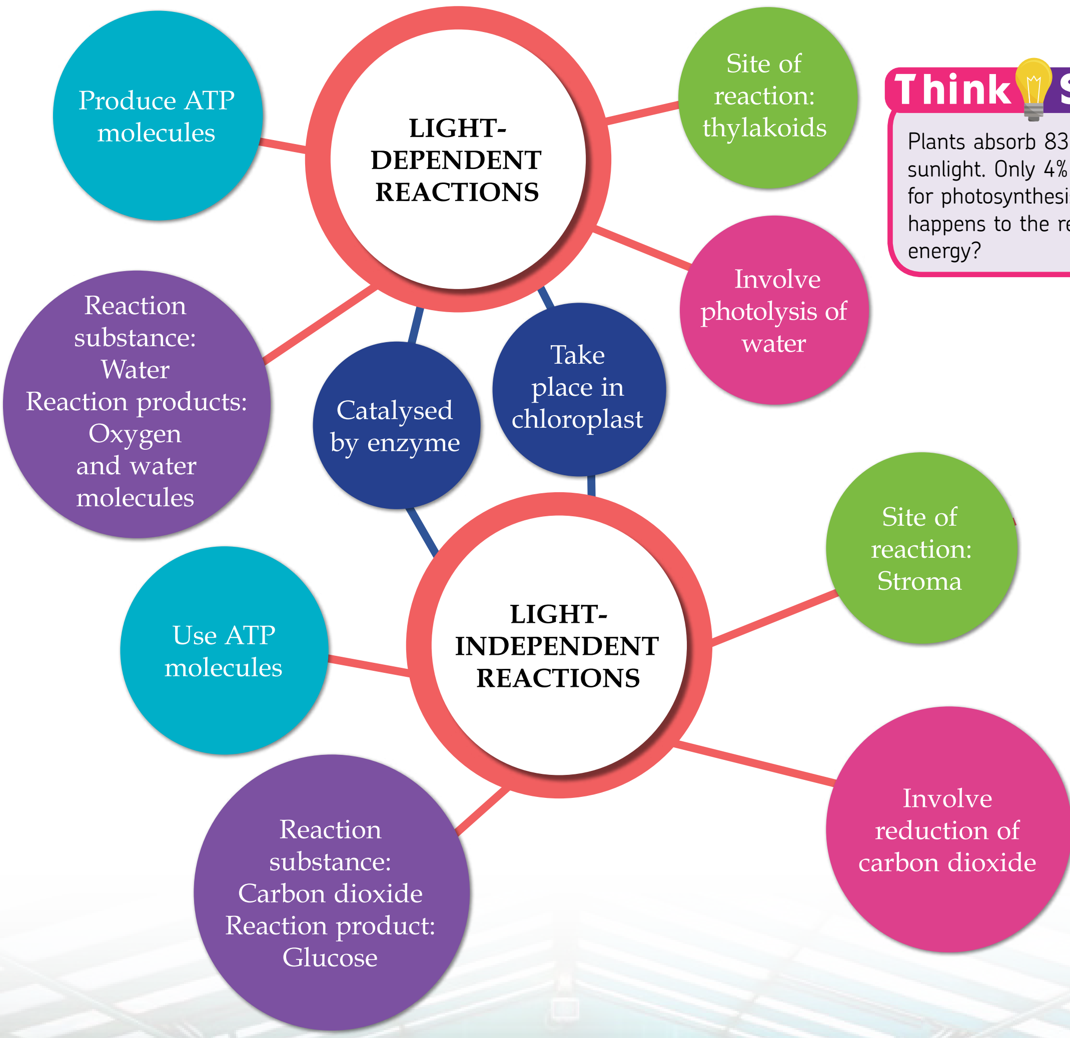


Figure 2.19 Comparison between light-dependent and light-independent reactions

Think Smart

Plants absorb 83% of sunlight. Only 4% is used for photosynthesis. What happens to the remaining energy?

ACTIVITY ZONE

1. Sketch a design of a greenhouse that can be used in a building.
2. Discuss:
   (a) The characteristics of a greenhouse that can help the growth of plants.
   (b) Besides light intensity, what are the other factors that affect the rate of photosynthesis?

Photograph 2.8 Greenhouse

2.4.6

Environmental Factors that Affect the Rate of Photosynthesis

Carbon Dioxide Concentration

The increase in carbon dioxide concentration increases the photosynthesis rate as long as there are no other **limiting factors** such as surrounding temperature and light intensity (Figure 2.20).

At P, photosynthesis rate is constant. As the concentration of carbon dioxide increases after P, the rate of photosynthesis remains unchanged. This is due to light intensity becoming the limiting factor.

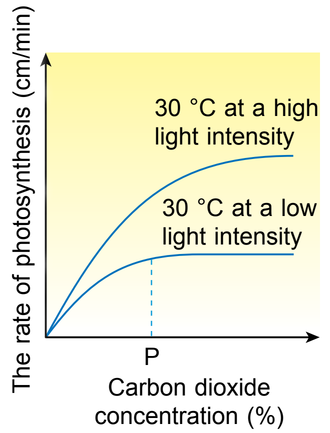


Figure 2.20
The relationship between the rate of photosynthesis and carbon dioxide concentration

Bio Exploration

Limiting factor is a factor that controls a biochemistry process and changes according to other variables. An increase in the limiting factor will increase the rate of a certain biochemistry process if the other factors are constant.

Light Intensity

Light is needed in the light-dependent reaction. If the concentration of carbon dioxide and temperature are constant, the rate of photosynthesis increases until it reaches its maximum point at noon.

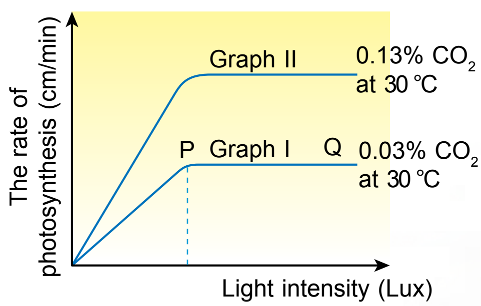
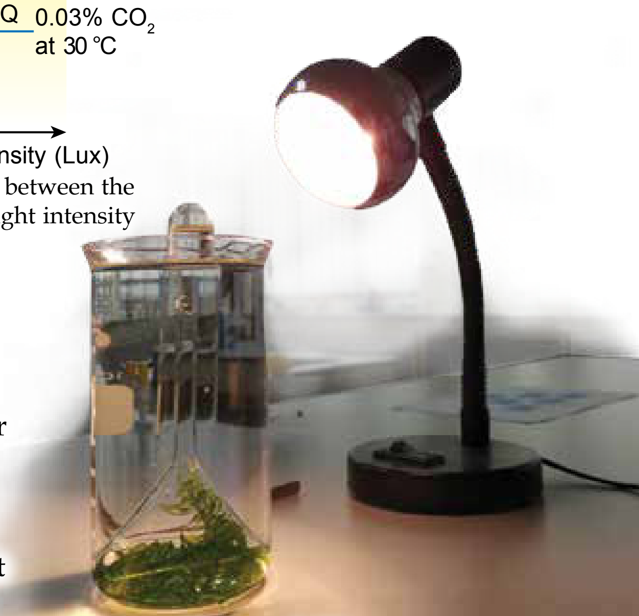


Figure 2.21 The relationship between the rate of photosynthesis and light intensity

Figure 2.21 (Graph I) shows that the rate of photosynthesis increases with the increase of light intensity until it reaches a light saturation point at P. After point P, the increase in light intensity (from P to Q) is no longer increases the rate of photosynthesis because it is limited by other factors such as temperature and carbon dioxide concentration.

Figure 2.21 (Graph II) shows when the concentration of carbon dioxide in the environment is increased to 0.13%, the rate of photosynthesis also increases.



Photograph 2.9
Light-dependent reaction

Temperature

The reactions in photosynthesis are catalysed by enzymes. Therefore, changes of surrounding temperature will affect enzyme activity and also the rate of photosynthesis. The optimum temperature is different for different plant species but in general, the optimum temperature is between **25°C** to **30°C**. A very high temperature denatures the enzymes and the process of photosynthesis is stopped (Figure 2.22).

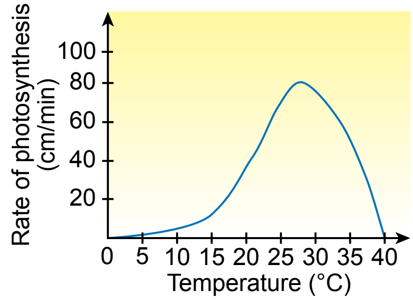


Figure 2.22
The relationship between the rate of photosynthesis and temperature

2.3 The Effects of Environmental Factors on the Rate of Photosynthesis

EXPERIMENT

Problem Statement
What are the effects of light intensity, temperature and concentration of carbon dioxide towards the rate of photosynthesis?

A Light Intensity

Aim
To investigate the effects of light intensity on the rate of photosynthesis

Hypothesis
The higher the light intensity, the higher the rate of photosynthesis.

Variables
Manipulated variable: The distance between the light source and *Hydrilla* sp.
Responding variable: The number of air bubbles released in 5 minutes
Constant variables: The type and size of *Hydrilla* sp., the concentration of sodium hydrogen carbonate, the voltage of the bulb

Materials
Hydrilla sp., 50 ml of distilled water, 0.2% of sodium hydrogen carbonate solution

Apparatus
Scissors, 60 W bulb, metre ruler, stopwatch, paper clips, boiling tube, measuring cylinder, retort stand and clamp, thermometer, beaker

Procedure
1. Attach a paper clip under the stem cutting of *Hydrilla* sp. and put them in the boiling tube containing 0.2% of sodium hydrogen carbonate solution (Figure 2.23).
2. Clamp the boiling tube vertically to the retort stand.
3. Light the 60 W bulb with a distance of 20 cm from the *Hydrilla* sp.
4. Count and record the number of air bubbles released in 5 minutes. Take three readings to obtain an average.
5. Replace the 0.2% of sodium hydrogen carbonate solution in the boiling tube with a new one.
6. Repeat steps 3 to 5 at different distances between the bulb and the *Hydrilla* sp. at 30 cm, 40 cm, 50 cm and 60 cm.
7. Record the results in a table.

2.4.7 2.4.8

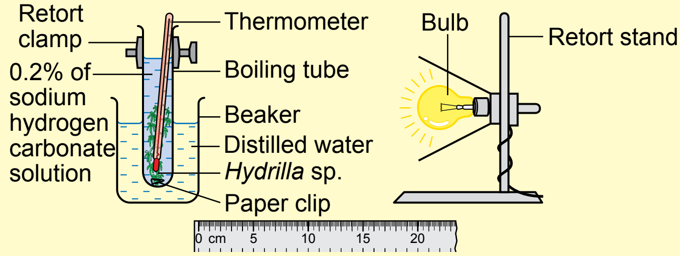


Figure 2.23 Set-up of apparatus

Results

Distance of the light source (cm)	Number of air bubbles released in 5 minutes			Average
	1	2	3	
20				
30				

B Temperature

Aim

To investigate the effects of temperature on the rate of photosynthesis

Hypothesis

The higher the temperature, the higher the rate of photosynthesis.

Variables

Manipulated variable: Temperature

Responding variable: The number of air bubbles released in 5 minutes

Constant variables: The distance between the light source and *Hydrilla* sp., the type and size of *Hydrilla* sp., the concentration of sodium hydrogen carbonate, the voltage of the bulb

Materials

Hydrilla sp., distilled water, ice cubes, 0.2% of sodium hydrogen carbonate solution

Apparatus

Scissors, 60 W bulb, meter ruler, stopwatch, paper clip, boiling tube, measuring cyclinder, retort stand and clamp, thermometer, beaker

Procedure

1. Repeat steps 1 to 2 as in Experiment A (Figure 2.24).
2. Light the 60 W bulb with a distance of 10 cm from the *Hydrilla* sp.
3. Prepare iced water with a temperature of 5 °C in the beaker.
4. Count and record the number of air bubbles released in 5 minutes. Take three readings to obtain an average.

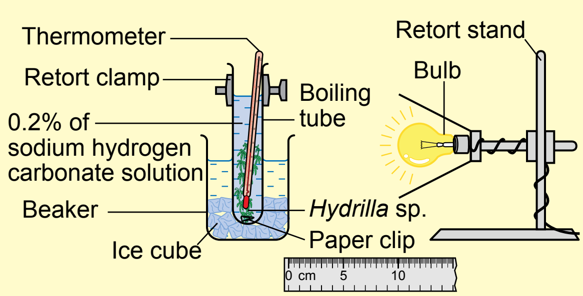


Figure 2.24 Set-up of apparatus

5. Change the 0.2% of sodium hydrogen carbonate solution in the boiling tube with a new one.
6. Repeat steps 3 to 5 for different water temperatures which are 15 °C, 25 °C, 35 °C, 45 °C, 55 °C, 65 °C and 75 °C.
7. Record the results in a table.

EXPERIMENT

Results

Temperature (°C)	Number of air bubbles released in 5 minutes			Average
	1	2	3	
5				
15				

C Carbon dioxide concentration

Aim: To investigate the effects of carbon dioxide concentration on the rate of photosynthesis

Hypothesis: The higher the carbon dioxide concentration, the higher the rate of photosynthesis.

Variables

Manipulated variable: The concentration of sodium hydrogen carbonate solution

Responding variable: The number of air bubbles released in 5 minutes

Constant variables: The distance of light source and *Hydrilla* sp., the type and size of *Hydrilla* sp., the voltage of the bulb

Materials

Hydrilla sp., distilled water, sodium hydrogen carbonate solutions (0.01 M, 0.02 M, 0.03 M, 0.04 M, 0.05 M, 0.06 M, 0.07 M, 0.08 M, 0.09 M, 0.10 M)

Apparatus

Scissors, 60 W bulb, metre ruler, stopwatch, paper clips, boiling tube, measuring cylinder, retort stand and clamp, thermometer, beaker

Procedure

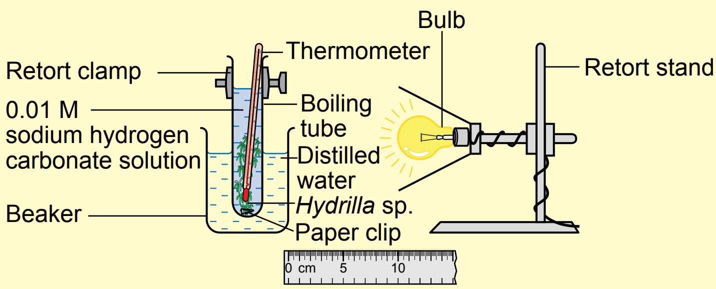


Figure 2.25 Set-up of apparatus

1. Attach a paper clip under the stem cutting of *Hydrilla* sp. and put them in the boiling tube (Figure 2.25).
2. Pour 5 ml of 0.01 M sodium hydrogen carbonate solution using a measuring cylinder into the boiling tube.
3. Clamp the boiling tube vertically to the retort stand.
4. Light the 60 W bulb at a distance of 10 cm from the *Hydrilla* sp.
5. Count and record the number of air bubbles released in 5 minutes. Take three readings to obtain an average.
6. Repeat steps 2 to 5 for the other concentrations of sodium hydrogen carbonate solution.
7. Record the results in a table.

Results

Concentration of sodium hydrogen carbonate solution (M)	Number of air bubbles released in 5 minutes			Average
	1	2	3	
0.01				
0.02				

2.4.8

EXPERIMENT

Discussion

1. Based on the recorded observations, plot the graphs of:
   (a) the number of air bubbles produced against the distance of light source and *Hydrilla* sp.
   (b) the number of air bubbles produced against the temperature
   (c) the number of air bubbles produced against the concentration of sodium hydrogen carbonate solution
2. Based on the plotted graphs, state the inferences that can be made about:
   (a) the effects of light intensity on the rate of photosynthesis.
   (b) the effects of temperature on the rate of photosynthesis.
   (c) the effects of concentration of sodium hydrogen carbonate solution.
3. Explain a method to handle all the variables in the Experiment A – C.
4. Why is the sodium hydrogen carbonate solution being used instead of distilled water in the experiments?

Conclusion

Are the hypotheses accepted? Suggest a suitable conclusion.

The Effect of Different Light Intensities and Light Colours on the Rate of Photosynthesis

ACTIVITY ZONE

Prepare a proposal to increase crop production based on the factors affecting the rate of photosynthesis in four-season countries.

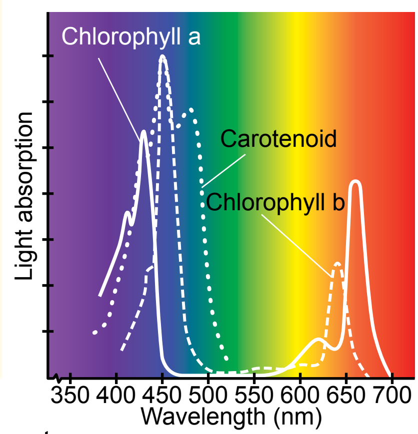


Figure 2.26
A graph of light absorption against wavelength

The rate of photosynthesis in plants is different throughout the day. Other than the light intensity factor, the rate of photosynthesis is also affected by the colour of light.

Light spectrum consists of seven colours in a certain sequence (violet, indigo, blue, green, yellow, orange and red). Each colour has a different wavelength. The rate of photosynthesis is the highest in red and blue light (Figure 2.26).

2.4.8 2.4.9

This is because all of the red light is absorbed by **chlorophyll**. The blue light is absorbed by **carotenoid** pigments before being transferred to the chlorophyll. These two lights have enough amount of energy to excite electrons in the light-dependent reaction.

Bio Exploration

Why is a leaf with chlorophyll seen as green in colour?

1. When light passes through the chlorophyll, most of the blue and red lights are absorbed, whereas the green colour is reflected.
2. Therefore, our eyes can only see the green colour on the leaf containing chlorophyll (Figure 2.27).

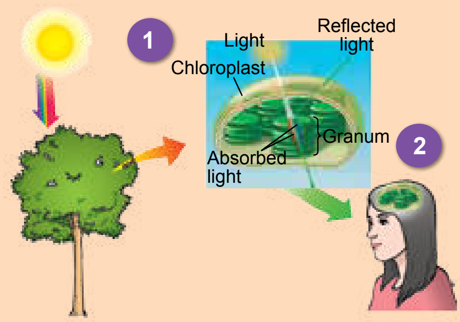


Figure 2.27 Interaction between light and chlorophyll

What is the best light colour for aquatic plants?

EXPERIMENT 2.4 The Best Light Colour for Aquatic Plants

Aim

To design an experiment to identify the best light colour to maximise the rate of photosynthesis in aquatic plants

Instruction

Design an experiment to identify the best light colour to maximise the rate of photosynthesis in aquatic plants.

2.4.9

Formative Practice 2.4

1. State **three** main factors affecting the rate of photosynthesis.
2. State the effects of different light intensities on the rate of photosynthesis.
3. Mr. Kumar has succeeded in planting a grape plant in a greenhouse in Cameron Highlands. List the equipment needed.
4. Light-independent reaction depends on the light-dependent reaction.

   Do you agree with this statement? Explain.

2.5 Compensation Point

Compensation point is the level of light intensity when the rate of respiration equals to the rate of photosynthesis.

Light Intensity and Attainment of Compensation Point

At the compensation point, the rate of photosynthesis is the same as the rate of respiration. Glucose produced in photosynthesis is used in the respiration of plants.

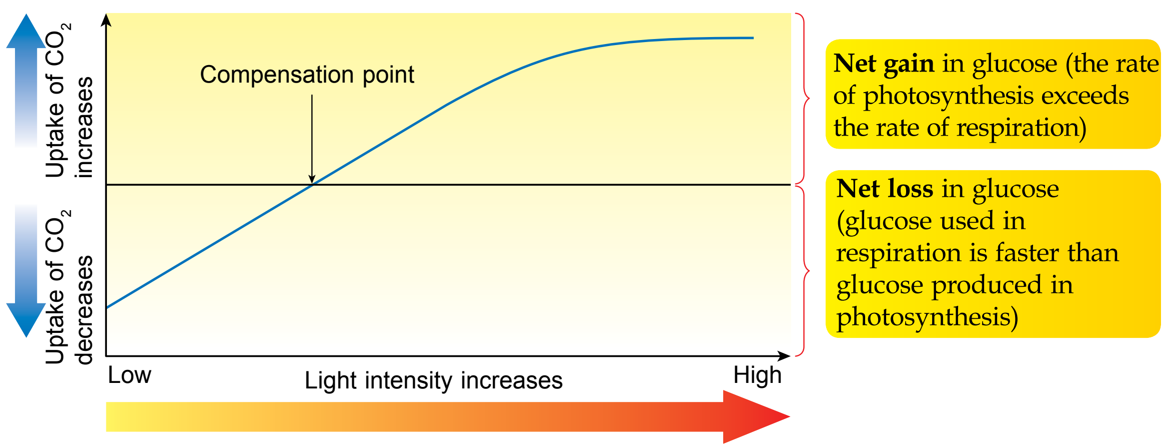


Figure 2.28 Light intensity and compensation point

When light intensity continues to increase beyond the compensation point, the rate of photosynthesis becomes faster compared to the rate of respiration. At this time, carbon dioxide needs to be absorbed from the atmosphere to compensate the rate of its usage in photosynthesis. Excessive oxygen is released into the atmosphere. At the same time, the rate of glucose production exceeds the rate of glucose usage, where the excess glucose is stored in the form of starch by the plants (Figure 2.28).

ACTIVITY ZONE

Carry out an investigation to confirm the prediction about the effects on plant growth if the rate of photosynthesis and rate of cellular respiration remain at its compensation point.

2.5.1 2.5.3

What would happen if the rate of respiration and the rate of photosynthesis remain the same at the compensation point? The products of photosynthesis will be fully used for the plant respiration. The rate of photosynthesis must exceed the rate of respiration every day to ensure the growth and production of flowers, seeds and fruits to occur. This enables the rate of glucose production to exceed the rate of glucose usage and the excess glucose can be used for growth and development processes in the plant. At the same time, the excess oxygen from the photosynthesis is then released into the atmosphere to support other organisms.

Think Smart

What is the difference between compensation point in plants exposed to light with plants under a shady place?

Comparison between Photosynthesis and Respiration in Plants

Both photosynthesis and respiration processes in plants have a few similarities and differences (Table 2.4).

Table 2.4 Comparison between photosynthesis and respiration

Similarities		
Both processes take place in living organisms		
Both processes involve the uptake and release of gases		
Differences		
Photosynthesis	**Aspect**	**Respiration**
Green plants and photosynthetic bacteria	**Organisms involved**	All living organisms
Happens in the cells containing chlorophyll	**Type of cells**	Happens in all cells
Anabolism process happens, which is the synthesis of glucose using carbon dioxide and water	**Type of metabolism**	Catabolism process happens, which is the breakdown of glucose to produce energy
Chloroplast	**Site**	Mitochondria
Carbon dioxide and water	**Reaction substances**	Oxygen and glucose
Glucose	**Products**	Energy
Oxygen and water	**By-products**	Carbon dioxide and water
Light energy is absorbed and converted into chemical energy	**Energy involvement**	Chemical energy is converted to ATP and heat energy is released
Needs light	**Light requirement**	Does not need light

Formative Practice 2.5

1. Give the definition of compensation point.
2. The compensation point of fern plants which grow on the rainforest floor happens at 10.00 am. In your opinion, at what time does a ficus plant which grows higher in the same forest achieve its compensation point?
3. At the compensation point, the rate of photosynthesis and cellular respiration is the same. State the effects on:
   (a) The production of glucose by plants
   (b) The release of oxygen into the atmosphere

2.5.2 2.5.4

Memory Flashback

Leaf Structure

- The external structure of a leaf
  - Lamina
  - Petiole
- The internal structure of a leaf lamina
  - Cuticle
  - Upper epidermis
  - Lower epidermis
  - Palisade mesophyll
  - Spongy mesophyll
  - Vascular bundles

Leaf Function

- Main organ for gaseous exchange
  - The necessity of gaseous exchange in plants
  - The mechanism of stomatal opening and closing
  - The effect of water deficiency in plants on stomatal opening and closing
- Main organ for transpiration
  - The necessity of transpiration
  - The environmental factors that affect the rate of transpiration
    - Temperature
    - Light intensity
    - Relative air humidity
    - Air movement
- Main organ for photosynthesis
  - The necessity of photosynthesis
  - The adaptation of the internal structure of a leaf to photosynthesis
  - Chloroplast structure
  - Light-dependent and light-independent reactions in photosynthesis
  - The environmental factors that affect the rate of photosynthesis
    - Light intensity
    - Temperature
    - Carbon dioxide concentration
- Compensation point
  - Definition of compensation point
  - Comparison between photosynthesis and respiration

Interactive Bio 2

SELF-REFLECTION

Complete the following self-reflection to identify the important concepts that you have studied.

Important concepts	Very good	Try again
The external structure of a leaf and the internal structure of a leaf lamina		
The necessity of gaseous exchange in plants		
The mechanism of stomatal opening and closing		
The effect of lack of water in plants on stomatal opening and closing		
The necessity of transpiration in plants		
The environmental factors that affect the rate of transpiration		
The necessity of photosynthesis in plants		
The relationship of the adaptation of the internal structure of a leaf to photosynthesis		
Chloroplast structure		
The relationship between the light-dependent and light-independent reactions		
Chemical equation to represent the process of photosynthesis		
The environmental factors that affect the rate of photosynthesis		
The effect of light intensity and colours of light on the rates of photosynthesis		
Compensation point		
The comparison between photosynthesis and cellular respiration in plant		

Summative Practice 2

1. (a) Petiole and lamina are external structures of a leaf. State the function of these two structures.
   (b) A leaf is a plant organ that is flat, thin and green in colour. Explain the importance of these characteristics on the function of a leaf.

2. Other than chlorophyll pigment, plants also have carotenoids, which are yellow, orange and red pigments that can absorb light energy from the sun to carry out photosynthesis. Explain the differences of chlorophyll and carotenoids involvement in photosynthesis.

3. A group of students carry out an experiment to investigate the distribution of stomata on mint and thyme leaves. Thyme plants have less number of leaves than mint plants. Table 1 shows the results of the experiment.

Table 1

Leaf sample	Estimated mass loss (%)	
	Mint	**Thyme**
Sample A Petroleum jelly layer on lower epidermis and upper epidermis	13	12
Sample B Petroleum jelly layer on lower epidermis	35	19
Sample C Petroleum jelly layer on upper epidermis	43	29

   (a) For mint leaf, which sample loses water the most? Explain.
   (b) For thyme leaf, which sample has the highest distribution of stoma? Explain.
   (c) Explain the differences of both leaves based on the results of the experiment.
   (d) Based on the results of the experiment, which plant can adapt to a hot and dry surrounding condition? Give a reason for your answer.

4. Figure 1.1 and Figure 1.2 show the average of stomata size in two different types of plants in a 24-hour duration. One of the plants is placed in a humid surrounding whereas another plant is placed in a hot and dry surrounding.

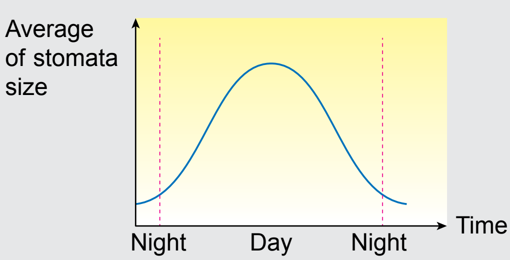


Figure 1.1

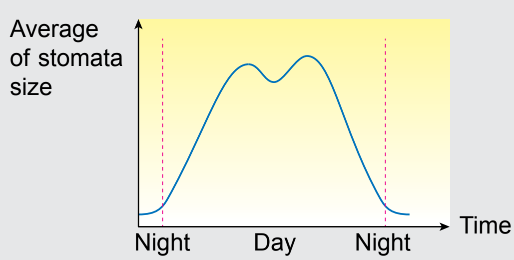


Figure 1.2

(a) Which graph shows the plant that has been placed in a hot and dry surrounding?

(b) Explain your answer in 4(a).

(c) Why is the average of stomata size at night smaller than day time?

(d) Predict **two** characteristics of the plant structures which have been placed in a hot and dry surrounding in order to continue living.

5. (a) Name **two** types of reactions in photosynthesis.
(b) In which reaction is chlorophyll needed? Explain.

6. Aizat keeps a few fish in an aquarium which is decorated with plastic aquatic plants. However, those fish die because there is no electrical supply. Suggest **one** way for Aizat to overcome the problem.

7. (a) What is meant by compensation point?
(b) How does the compensation point affect the production and usage of oxygen and carbon dioxide?

8. Temperate crops are high in demand in Malaysia. Other than being imported from overseas, these crops are also planted domestically in higher regions such as Cameron Highlands. If controllable surroundings can be established, these crops can also be planted in lower regions in Malaysia.

(a) What kind of technology exists in Malaysia that enables these crops to be planted in lower regions with controllable surroundings?

(b) In your opinion, what are the challenges to the farmers who will be using this technology?

(c) Suggest **one** technology that can be used by the farmers to face the challenges.

21st Century Mind

9. In the monsoon season, frequent rain causes the air to become saturated with water vapour. In your opinion, does this condition affect the mineral supply in plants? Explain.

10. Long-day plants such as pea plants need more than 12 hours of light to produce flowers. Suggest **one** best way that can be used by farmers in four-season countries to plant in autumn. Explain.

Chapter 3

Nutrition in Plants

Chapter Exploration

- Main Inorganic Nutrients
- Organ for Water and Mineral Salts Uptake
- Diversity in Plant Nutrition

Learning Standards

Do You Know?

- What are the examples of macronutrients and micronutrients that are required by plants?
- Why do crops need to be fertilised?
- Can plants be infected with diseases?
- Why do the roots act as an organ for water and mineral absorption?
- How is the *Rafflesia* sp. able to live without leaves?

Organic Compost Fertilisers

Did you know that excess leftover food can be recycled to produce organic fertilisers? Compost is a type of fertiliser produced from the decomposition process of leftover substances such as crop leftovers, kitchen leftovers, plant excretory substances and animal faeces which are decomposed by microorganisms. How is the organic compost fertiliser made?

Leftover substances, together with bacteria, are placed in a container with aeration to speed up the decomposition process. Dry leftover substances are layered with wet leftover substances alternately. Water is sprinkled on every layer. The leftover substances are stirred every two days until compost is formed. The compost is usually done after being kept for a few months.

Figure 3.1 Leftover substances for composting

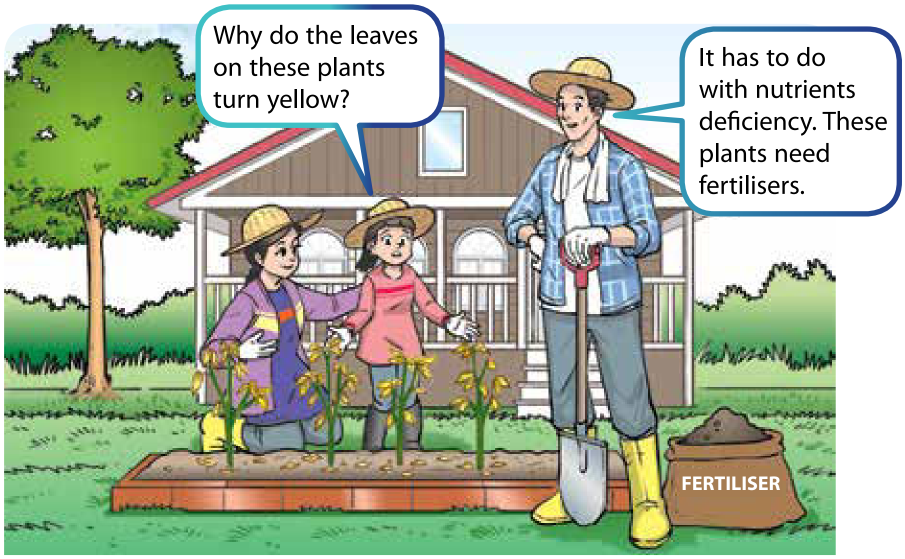
The practice of producing compost fertilisers at home can save many landfill sites. In addition, the cost of buying chemical fertilisers can also be reduced (Figure 3.1).

Keywords

- Chlorosis
- Culture solution
- Macronutrients
- Micronutrients
- Nutrition
- Nutrients
- Root hair
- Parasitic plants
- Epiphytic plants
- Carnivorous plants

3.1 Main Inorganic Nutrients

Like other living things, plants need nutrients to grow well and produce high quality yields. Plants need inorganic nutrients to produce organic compounds such as carbohydrates and proteins. What are the inorganic nutrients required by plants?



Macronutrients and Micronutrients Required by Plants

These nutrients can be divided according to quantities required by plants, which are **macronutrients** and **micronutrients** (Figure 3.2).

MAIN INORGANIC NUTRIENTS

Macronutrients

- Carbon (C)
- Calcium (Ca)
- Hydrogen (H)
- Magnesium (Mg)
- Oxygen (O)
- Phosphorus (P)
- Nitrogen (N)
- Sulphur (S)
- Potassium (K)

Micronutrients

- Chlorine (Cl)
- Zinc (Zn)
- Iron (Fe)
- Copper (Cu)
- Manganese (Mn)
- Nickel (Ni)
- Boron (B)
- Molybdenum (Mo)

Figure 3.2 Main inorganic nutrients

3.1.1

Three main macronutrients, which are **carbon**, **hydrogen** and **oxygen**, can be obtained easily from air and water from the soil. These nutrients make up most of the dry mass of plants. Therefore, the lack of these nutrients is rarely experienced by plants. The remaining nutrients are taken in the form of mineral salts which are dissolved in the soil through fertilisation.

The Necessity of Macronutrients in Plants

Every nutrient has its own function in order to ensure that plants complete their life cycle and achieve optimum growth and development. The lack of one or more macronutrients can cause bad effects on the health and growth of plants. Table 3.1 shows the functions and effects of macronutrient deficiency.

Table 3.1 The functions and effects of macronutrient deficiency

Macronutrients	Functions	Effects of Deficiency
Carbon (C) Oxygen (O) Hydrogen (H)	• Important components in carbon cycle and oxygen cycle • Components in all organic compounds of plants and important components in synthesis of sugar	• Photosynthesis will not take place • Less oxygen released by plants • Stunted growth which can cause death because there is no glucose
Nitrogen (N)	• Gives the green colour to plants through the formation of chlorophyll • Main components of proteins, nucleic acids and enzymes in photosynthesis and respiration	• Leaves undergo chlorosis (yellowing of the leaves) (Photograph 3.1) mainly on matured leaves • Underlying leaves fall off • Protein synthesis disrupted • Stunted growth
Potassium (K)	• Important in protein synthesis and carbohydrate metabolism • As cofactors for some enzymes • Maintains plant turgidity	• Protein synthesis disrupted • Edges of leaves become yellowish (Photograph 3.2) • Premature death of plants
Calcium (Ca)	• Main component of middle lamella, cell wall and spindle fibres during cell division	• Stunted growth • Leaves become distorted and lobed • Parts between leaf veins become yellowish
Magnesium (Mg)	• Main component of the structure of chlorophyll molecule • Activates some plant enzymes • Involved in carbohydrate metabolism	• Parts between matured leaf veins become yellowish • Red spots on leaf surfaces • Lobed leaves
Phosphorus (P)	• Synthesises nucleic acids, adenosine triphosphate (ATP) and phospholipids in plasma membrane • Act as coenzymes in photosynthesis and respiration	• Unhealthy root growth • Formation of dark green and dull coloured leaves • Red or purple spots appear on older leaves
Sulphur (S)	• Components of a few amino acids • One of vitamin B constituents and a few types of coenzymes	• Leaves or the whole plant turns yellow

3.1.2

Photograph 3.1 The leaves of *Ficus benjamina* plant undergo chlorosis due to lack of nitrogen

Photograph 3.2 The leaves of *Cyrtostachys renda* (red pinang palm) caused by lack of potassium

The Necessity of Micronutrients in Plants

Table 3.2 shows the functions and effects of micronutrients deficiency.

Table 3.2 The functions and effects of micronutrients deficiency

Micronutrients	Functions	Effects of Deficiency
Chlorine (Cl)	• Important in the equilibrium of osmotic pressure in cells and photosynthesis reaction	• Plants wilt • Slower root growth • Leaves undergo chlorosis • Lesser fruit production
Iron (Fe)	• Acts as a cofactor in chlorophyll synthesis • Important in the growth of young plants	• Young leaves become yellowish
Manganese (Mn)	• Activates photosynthetic enzymes • Important for cell respiration and nitrogen metabolism	• Network of dark green leaf veins with a background of light green • Light brown or grey spots in between leaf veins
Boron (B)	• Helps the roots in calcium ion uptake and sucrose translocation • Involves in carbohydrate metabolism and helps in germination of pollen	• Death of terminal buds and abnormal growth • Leaves become thicker, rolled up and fragile
Zinc (Zn)	• Important in leaf formation • Synthesis of auxin (growth hormone) • As a cofactor in carbohydrate metabolism	• Leaf surfaces become spotted with chlorosis parts • Stunted growth
Copper (Cu)	• Involves in nitrogen metabolism and photosynthesis • Important for growth, reproduction and flower formation	• Death of young shoot apex • Brown spots on terminal leaves • Plants become stunted
Nickel (Ni)	• A component of plant enzymes involved in the breakdown of urea to become ammonia which can be used by plants	• Stunted growth • Reduces crop production • Burnt effect at the end of leaves due to urea accumulation
Molybdenum (Mo)	• Involves in nitrogen fixation and nitrate reduction during protein synthesis	• Chlorosis in between matured leaf veins • Leaf colour becomes pale green • Reduces crop production

3.1.2

A culture solution is used to study the importance of nutrients for plant growth. A culture solution known as **Knop's solution**, contains all nutrients including trace elements needed by healthy plants. A complete culture solution was prepared by a chemist named Wilhelm Knop in 1859. Table 3.3 shows the composition of a complete Knop's culture solution.

Table 3.3 The composition of a complete Knop's culture solution

Complete Knop's culture solution	
Calcium nitrate, $Ca(NO_3)_2$	0.8 g
Potassium nitrate, KNO_3	0.2 g
Potassium dihydrogen phosphate, KH_2PO_4	0.2 g
Magnesium sulphate, $MgSO_4$	0.2 g
Iron(III) phosphate, $FePO_4$	Trace
Distilled water	1000 cm^3

History Corner

Julius Sachs and Wilhelm Knop were the botanists who carried out experiments to determine the role of macronutrients in plant growth.

EXPERIMENT 3.1

The Effects of Nitrogen: Phosphorus: Potassium Ratios on Plant Growth

Problem Statement: What are the effects of nitrogen: phosphorus: potassium (N:P:K) ratio on the growth of corn seedlings?

Aim: To investigate the effects of identified nitrogen: phosphorus: potassium (N:P:K) ratio on the growth of corn seedlings

Hypothesis: Corn seedlings undergo healthy growth in Knop's solution with the ratio of nitrogen: phosphorus: potassium (N:P:K)

Variables

Manipulated variable: Nitrogen, phosphorus and potassium ratio

Responding variable: Growth of corn seedlings

Constant variable: Volume of solution

Materials: Corn seedlings (*Zea mays*), calcium nitrate, $Ca(NO_3)_2$, potassium nitrate, KNO_3, potassium dihydrogen phosphate, KH_2PO_4, magnesium sulphate, $MgSO_4$, iron(III) phosphate, $FePO_4$, distilled water, cotton, black paper, calcium chloride, potassium chloride, calcium phosphate, iron(III) oxide, sodium nitrate

Appparatus: Culture bottles, L-shaped delivery tubes, corks, air pumps

Procedure

1. Prepare five culture bottles with A, B, C, D and E labels.
2. Fill the culture bottles A, B, C, D and E with solution as shown in Table 3.4.
3. Select five corn seedlings of the same size and put each one of them into the culture bottles by inserting the stem through the hole on the cork. Make sure the roots of the seedlings are immersed in the solution.

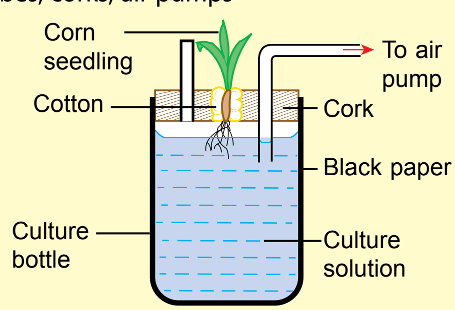


Figure 3.3 Set-up of apparatus

3.1.2

EXPERIMENT

4. Cover all the culture bottles with black paper to avoid the growth of green algae.
5. Connect the culture bottles to an air pump to ensure the roots receive oxygen supply.
6. Replace the culture solution in each bottle with a new solution every week.
7. Place the apparatus in a well-lit place.
8. Observe and record the growth of corn seedlings in terms of leaf colour, plant height, root length and stem strength after four weeks.

Table 3.4

Culture bottle	Components of culture solution					
	Calcium nitrate (0.8 g)	Potassium nitrate (0.2 g)	Potassium dihydrogen phosphate (0.2 g)	Magnesium sulphate (0.2 g)	Iron(III) phosphate (Trace)	Distilled water (1000 ml)
A (Complete culture solution)	✓	✓	✓	✓	✓	✓
B (control)	✗	✗	✗	✗	✗	✓
C (without nitrogen)	Replaced with calcium chloride	Replaced with potassium chloride	✓	✓	✓	✓
D (without phosphorus)	✓	✓	Replaced with potassium chloride	✓	Replaced with iron(III) oxide	✓
E (without potassium)	✓	Replaced with sodium nitrate	Replaced with calcium phosphate	✓	✓	✓

Observation

Culture bottle	Nutrient deficiency	Observation
A		
B		
C		
D		
E		

Discussion

1. State **two** precautionary steps to be taken during apparatus and material preparation. Justify.
2. Which culture bottle has grown a healthy corn seedling?
3. How does the ratio of nitrogen: phosphorus: potassium (N:P:K) affect the growth of corn seedlings?

Conclusion

Is the hypothesis accepted? Suggest a suitable conclusion.

Formative Practice 3.1

1. How are macronutrients different from micronutrients?
2. State **three** nutrients which can cause chlorosis if there is a lack of any of these nutrients.
3. Corn plants are very sensitive to nutrient deficiency. How does the NPK (nitrogen, phosphorus and potassium) fertiliser stimulate healthy growth of corn plants?
4. Roots and leaves are the medium to transport nutrients in plants. With your knowledge in biology, support this statement.

3.2 Organ for Water and Mineral Salts Uptake

Why is the root the most important organ for plants? As you have learnt in Chapter 1, roots are involved directly in plant growth. Usually, roots are located under the soil surface. This is because roots grow towards the centre of the earth and watery areas. The internal and external structures of roots are adapted to their functions (Figure 3.4 and Table 3.5). There are two main functions of roots:

- Provide support and strength to anchor the plant in the soil
- Absorb water and mineral salts from the soil and transport them to the stem and leaves

The Root Structure for Water and Mineral Salts Uptake

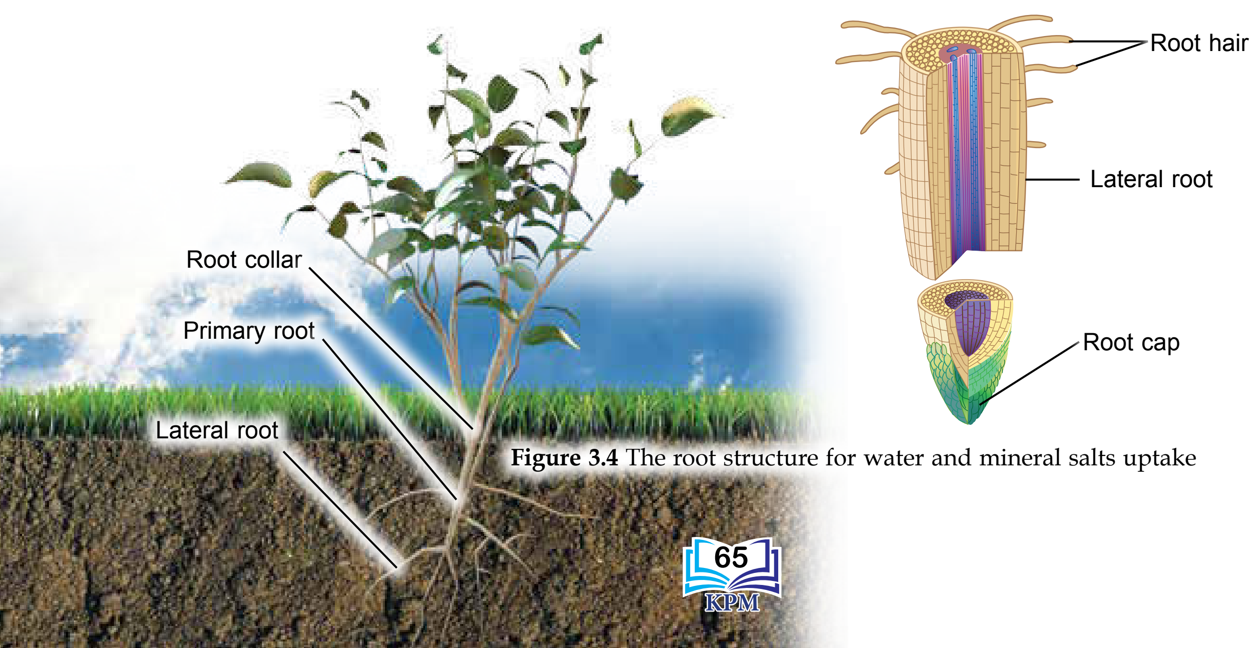


Figure 3.4 The root structure for water and mineral salts uptake

3.2.1

Table 3.5 The structure of roots and their functions

Structures	Functions
Root collar	• Part of the root connected to the base of the plant stem
Root hairs	• Adapted from epidermal cells of the roots • Increases the total surface area of the roots to increase the uptake of water and mineral salts
Root cap	• Located at the tip of the root • Protects the root from damage when going through the soil

Root Adaptations for Water and Mineral Salts Uptake

Figure 3.5 shows the internal structure of roots whereas Table 3.6 shows the functions of internal structures of roots.

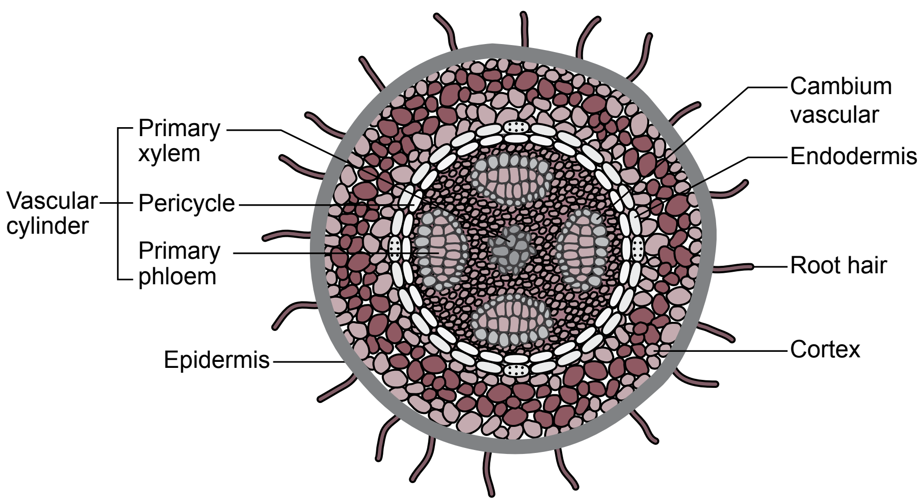


Figure 3.5 The internal structures of roots

Table 3.6 The functions of the internal structures of roots

Structures	Functions
Epidermis	• Epidermal cells are closely arranged. • Thin cell walls and water-permeable cell membranes facilitate water movement in the roots. • There are epidermal cells which form root hairs by elongating towards lateral sides from the outer walls. • Root hair cells are not layered with cuticle to allow water absorption. • The root hair cells also have big vacuoles to store water and mineral salts to increase water absorption.
Cortex	• Cortex is located under the epidermal layer. • Has thin cell walls, facilitating water movement in the roots. • The cells are loosely arranged to facilitate gaseous exchange. • Most of the cortex consists of parenchyma cells.

Endodermis	• Separating layer between cortex and vascular cylinder. • Endodermal cells are closely arranged and one cell thick. • Most of the endodermal cells have suberin or lignin thickening at the walls which form Casparian strips. • Endodermis allows water and mineral salts absorbed from the soil to enter the vascular cylinder, but not air bubbles.
Vascular cylinder	• Vascular cylinder is the root core that consists of xylem and phloem tissues surrounded by one cell thick pericycle cell tissues. • Pericycle is involved in secondary growth and the formation of lateral roots. • Usually, xylem and phloem tissues are arranged in a star-shaped pattern. • Xylem tissue transports water and mineral salts, whereas phloem tissue transports organic substances such as sucrose and plant hormone.

Activity 3.1

Aim

To observe prepared slides of cross-sections of monocot and eudicot roots

Apparatus

Light microscope, prepared slides of cross-sections of *Zea mays* (corn plant) root and *Tilia* sp. (lime tree) root

Procedure

1. Observe the prepared slides of cross-sections of *Zea mays* and *Tilia* sp. roots using a light microscope with low power objective lens and then with high power objective lens.
2. Identify root hair cells, epidermis, cortex, endodermis, pericycle, xylem and phloem.
3. Draw the cross-sections of *Zea mays* and *Tilia* sp. roots. Record the power of magnification used.

Discussion

1. What tissues form the cortex? How can these tissues be identified?
2. How are the xylem and phloem tissues arranged in the roots of a monocot and eudicot?
3. Based on your knowledge in biology, why is the arrangement of xylem and phloem tissues different in monocot and eudicot roots?

Formative Practice 3.2

1. What tissues form the root?
2. Explain the adaptations of root epidermal cells to carry out their functions in the absorption of water and mineral salts.
3. Compare monocot and eudicot roots in terms of cortex tissues, endodermis tissues and Casparian strip.

3.2.2

3.3 Diversity in Plant Nutrition

Nutrition is a process of organisms obtaining energy and nutrients from food for growth, maintenance and repair of damaged tissues. **Parasitic, epiphytic** and **carnivorous** plants have different adaptations to obtain nutrients.

Nutritional Adaptations of Plants

Parasitic plants

- **Parasitic plants** live by growing on other plants which are the hosts.
- The roots of this plant absorb organic substances, minerals and water from the host by penetrating the stem up to the vascular bundles of the host.
- This causes the parasitic plant to grow faster and flourish, whereas the host is malnourished, dried and will eventually die.

Example of parasitic plant

Rafflesia sp.

Epiphytic plants

- **Epiphytic plants** are green plants which live on other plants which are the hosts.
- Epiphytic plants receive more sunlight for photosynthesis by living on taller hosts.
- These plants synthesise their own food.
- Epiphytes do not harm the host because the roots of epiphytes can absorb nutrients accumulated in the gaps of the plant's stem.
- Most epiphytes have swollen stems that are able to store a lot of water.

Examples of epiphyte plants

Asplenium nidus (Bird's nest fern)

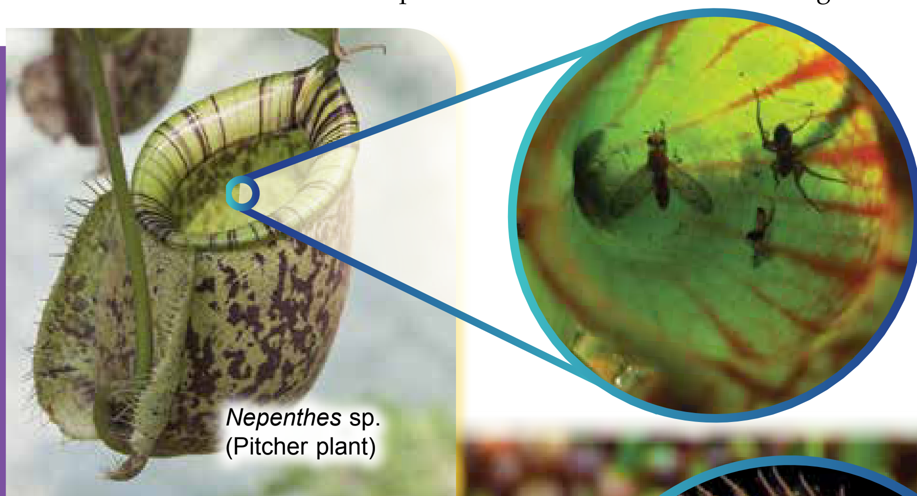
Bulbophyllum sp. (Orchids)

3.3.1

Carnivorous plants

- **Carnivorous plants** are able to synthesise their own food by carrying out photosynthesis.
- Carnivorous plants secrete nectar and they have cups to trap their prey, typically insects.
- The prey are then slowly digested by digestive enzymes.
- The trapped animals can supply nitrogen to the plants. Nitrogen is important for growth. This is because carnivorous plants live in soil which lacks nitrogen sources.

Examples of carnivorous plants


Nepenthes sp.
(Pitcher plant)


Dionaea muscipula
(Venus fly trap)

Activity 3.2

Aim
To investigate the effects of habitat change on the growth of carnivorous, parasitic and epiphytic plants

Materials
Pitcher plant, Indian willow plant, bird's nest fern

Apparatus
Vases containing soil

Procedure
1. Get a healthy pitcher plant, Indian willow plant and bird's nest fern.
2. Plant each of them inside vases containing soil.
3. Make sure each plant is provided with enough light, water and fertiliser.
4. Observe and record the growth of each plant on every week for a month.

Discussion
1. Which of the three plants can adapt to habitat change?
2. Based on your observation, what happened to the Indian willow plant after one week? Justify.

Bio Exploration

Riftia pachyptila (giant tube worm) lives on the floor of the ocean in the dark zone near hydrothermal vent. The hydrothermal vent produces water rich in chemical substances and minerals. The dark zone is a very deep zone in the sea where no light is able to reach. This worm does not depend on sunlight as its source of energy. Instead, it depends on bacteria living in its body. Hydrogen sulfide in the hydrothermal vent is oxidised by the bacteria into food and energy for the giant tube worm.

Photograph 3.4 *Riftia pachyptila*

Formative Practice 3.3

1. State the nutritional habits of the following plants:
   (a) *Cuscuta* sp. (dodders)
   (b) *Hypnum* sp. (moss)
   (c) *Bulbophyllum* sp. (orchid)
   (d) *Uticularia* sp. (golden floating bladderwort)
2. Differentiate between the nutritional adaptations of parasitic plants and epiphytic plants.
3. Predict what would happen to the growth of the bird's nest fern if it is exposed to direct sunlight.

Memory Flashback

NUTRITION IN PLANTS

- Main inorganic nutrients
  - Macronutrients
    - Carbon (C)
    - Oxygen(O)
    - Hydrogen (H)
    - Nitrogen (N)
    - Potassium (K)
    - Calcium (Ca)
    - Magnesium (Mg)
    - Phosphorus (P)
    - Sulphur (S)
  - Micronutrients
    - Chlorine (Cl)
    - Iron (Fe)
    - Manganese (Mn)
    - Boron (B)
    - Zinc (Zn)
    - Copper (Cu)
    - Nickel (Ni)
    - Molybdenum (Mo)
- Organ for water and mineral salts uptake
  - External structures of roots
    - Root collar
    - Primary root
    - Lateral root
    - Root hair
    - Root cap
  - Internal structures of roots
    - Epidermis
    - Cortex
    - Endodermis
    - Vascular cylinder
  - Importance
- Diversity in plant nutrition
  - Carnivorous plants example:
    - Pitcher plant
    - Venus fly trap
  - Parasitic plants example:
    - Rafflesia
  - Epiphytic plants example:
    - Bird's nest fern
    - Orchid plant

Interactive Bio 3

SELF-REFLECTION

Complete the following self-reflection to identify the important concepts that you have studied.

Important concepts	Very good	Try again
Macronutrients and micronutrients needed by plants		
The importance of macronutrients and micronutrients in plants		
Uptake of water and mineral salts		
Nutritional adaptations of plants		

Summative Practice 3

1. A farmer uses NPK fertiliser for his chili crops. NPK fertiliser contains nitrogen, phosphorus and potassium elements which are important nutrients for crop growth and also contains micronutrients needed by plants.

(a) In your opinion, what are the micronutrients contained in the fertiliser?

(b) Explain the functions of nitrogen, phosphorus and potassium elements towards chili plants.

(c) After using the fertiliser several times, the farmer found that the leaves of the chili plants were turning darker green and the plant stem was becoming weaker.

(i) What caused these plants to undergo such abnormal situation?

(ii) Suggest **one** solution to overcome the situation.

2. Mrs. Rodiah uses a vase, brick shards, charcoal shards, and coconut fibres to grow an epiphytic orchid plant. The orchid plant is placed at a corner in her house.

(a) What is meant by epiphytic orchid plant?

(b) Why does Mrs. Rodiah use coconut fibres to plant the orchid?

(c) In your opinion, what is the main factor that needs to be considered by Mrs. Rodiah before placing the orchid plant at the corner? Explain.

(d) Why does Mrs. Rodiah not plant the orchid directly into the ground? Give suitable reasons.

3. Mr. Ali uses a technique shown in Photograph 1 for his herb plants. He uses wicks immersed in a nutrient solution to fulfil the needs of his plants.

Photograph 1

(a) What is the technique used by Mr. Ali?
(b) State **four** basic needs of plants to ensure Mr. Ali's plants grow well and healthily.
(c) Justify the usage of wicks in the technique used by Mr. Ali.
(d) Explain the root adaptations that enable the plants to obtain enough nutrients.

4. Photograph 2.1 and Photograph 2.2 show two types of plants which can be found in a tropical rainforest ecosystem. Both of these plants carry out different modes of nutritions. The plant in Photograph 2.1 can produce their own food by photosynthesis whereas the plant in Photograph 2.2 depends on other plants for nutrition.

Photograph 2.1

Photograph 2.2

(a) State the role of the plant in Photograph 2.1 in a tropical rainforest ecosystem.
(b) Explain the importance of the plant in Photograph 2.2 in a tropical rainforest ecosystem.
(c) Explain the differences of nutritional adaptations of both plants.

21st Century Mind

5. Studies show that organic crops contain more nutrients as compared to normal crops but there are studies that show there is no difference in nutrient content for both crops. As an agricultural officer, justify this information.

Chapter 4

Transport in Plants

Chapter Exploration

- Vascular Tissues
- Transport of Water and Mineral Salts
- Translocation
- Phytoremediation

Learning Standards

Do You Know?

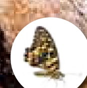
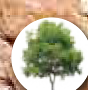
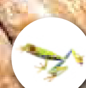
- What is the role of the vascular tissues in plants?
- How are water and mineral salts transported to all parts of the plant?
- What is the translocation pathway in plants?
- How do phytoremediation plants control water and soil pollution?

The Wonders of Transport in Plants

Do you know that the *Sequoia sempervirens* is the tallest tree in the world? Every day, this tree can absorb 1 000 kg of water from the soil and transport it to the stem and leaves up to a height of 100 m. How is water transported in plants?

Like humans, plants also have an effective transportation system to absorb, transfer, store and utilise water. This system consists of a network of channels which are formed from vascular bundles.

This water and nutrient transportation pathway is similar to the vascular system which transports blood to all parts of the human body. Xylem tissues in this system start from the roots, and they are connected to the stems, branches, twigs and leaves. Phloem tissues, on the other hand, transport nutrients and sugars which are produced by the leaves to other parts of the plant such as the stem and roots to be used in cell respiration and as storage.

Keywords

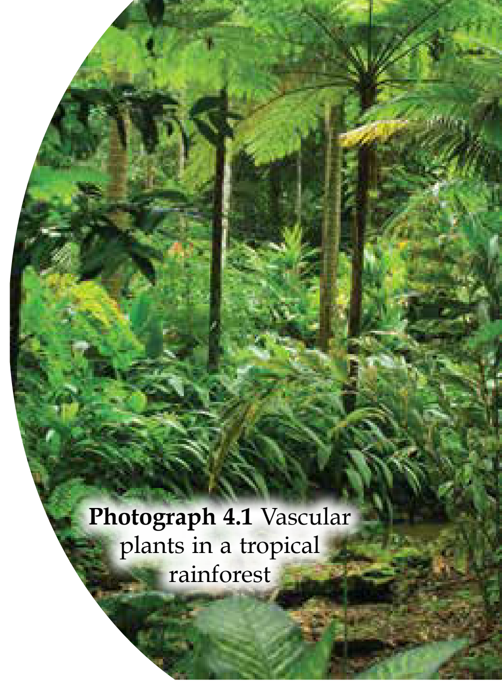
- Xylem vessel
- Sieve tube
- Companion cell
- Tracheid
- Adhesion force
- Cohesion force
- Root pressure
- Capillary action
- Guttation
- Translocation
- Phytoremediation

4.1 Vascular Tissues

The Necessity of Transport in Plants

You have learnt about transport in humans and animals in Form Four. Do plants have the same transport system like humans and animals? Why do plants need a transport system as well? (Photograph 4.1).

Plants are multicellular organisms which are formed from cells that need water and nutrients. The large and tall size of the plants creates a total surface area that is insufficient for the plant to absorb its basic needs from the surroundings. In order to overcome this problem, plants have **vascular tissues** to transport water, mineral salts and nutrients to all the cells.



Photograph 4.1 Vascular plants in a tropical rainforest

Vascular tissues

- **Xylem**: Transports water and mineral salts absorbed by the roots to the stems and leaves
- **Phloem**: Transports organic compounds which are synthesised by the leaves through photosynthesis to the stems and roots

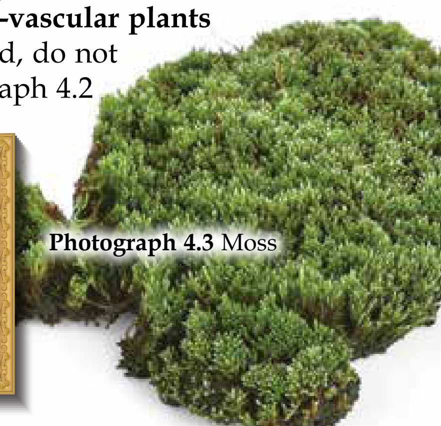
Figure 4.1 Vascular tissues

Plants which have a transport system are known as **vascular plants** (Figure 4.1). **Non-vascular plants** like alga and moss on the other hand, do not have any transport system (Photograph 4.2 and Photograph 4.3).

Bio Exploration

Macrocystis pyrifera is a brown macro alga which can grow up to 60 m high in the sea. This alga does not have any transport system (Photograph 4.2).

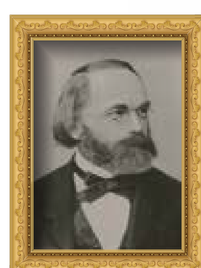
Photograph 4.2 *Macrocystis pyrifera*



Photograph 4.3 Moss

History Corner

In 1858, Carl Nageli who was a botanist had introduced the names xylem and phloem as tissues in the plant transport system (Photograph 4.4).



Photograph 4.4 Carl Nageli

Structural Adaptations of Xylem Vessels and Tracheids to Transport Water and Mineral Salts

Other than transporting water and mineral salts absorbed by the roots to the stems and leaves, xylem is also responsible to provide **mechanical support** to the plant. How does the structure of xylem adapt to its function? (Figure 4.2 and Figure 4.3).

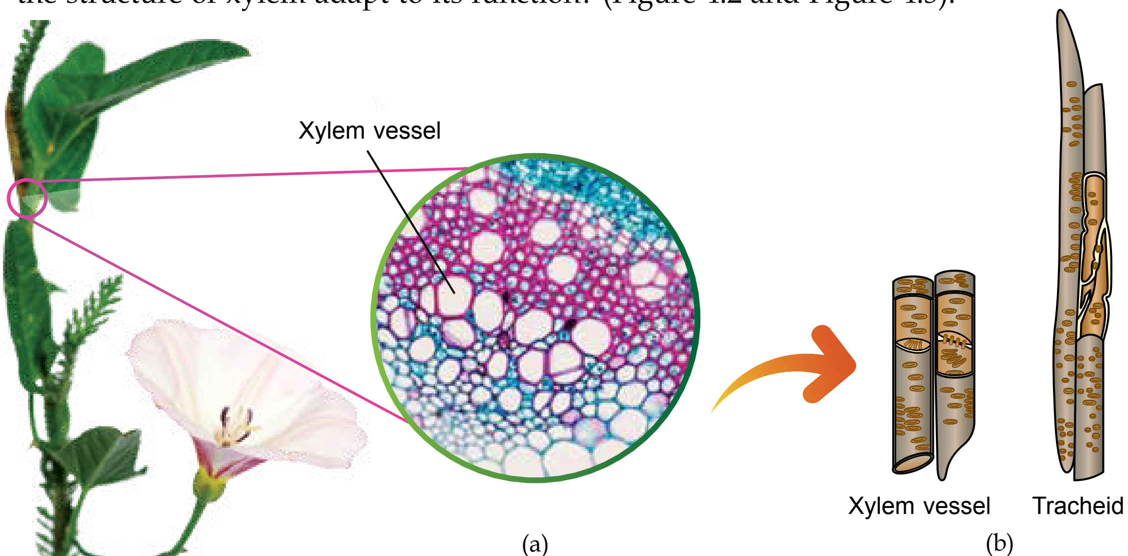


Figure 4.2 **(a)** Micrograph of a cross-section of the stem **(b)** structure of xylem vessel and tracheid

Xylem vessel

- Xylem vessel consists of dead cells at maturity which do not have cytoplasm.
- These cells are arranged longitudinally from end to end to form a continuous tube to allow water flow from the roots to the leaves.
- The walls of the xylem vessel have uneven **lignin thickening** to:
  - ➢ Give strength to xylem vessels to prevent them collapsing due to the tension force and pressure changes when water moves through it
  - ➢ Prevent the plant from being bent

Tracheid

- The cell wall of **tracheid** also has lignin thickening and pits to allow water movement to adjacent cells.

Figure 4.3 The functions of xylem and tracheid structures

4.1.2

Activity 4.1

Aim

To observe the structure of xylem in a longitudinal cross-section of a celery stalk

Materials: Celery stalk, red dye, distilled water

Apparatus: 250 ml beaker, sharp knife, cover slip, glass slide, light microscope, dropper

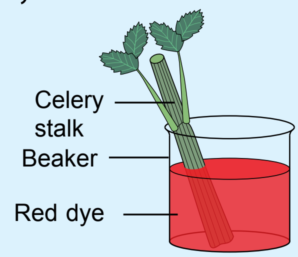


Figure 4.4 Set-up of apparatus

Procedure

1. Pour 150 ml of distilled water into a 250 ml beaker and put in 5 drops of red dye. Stir until the colour of the solution is mixed.
2. Soak a celery stalk into the beaker and let it remain there for an hour (Figure 4.4).
3. After an hour, rinse the colouring of the celery stalk by using distilled water.
4. Cut a thin layer of the stalk horizontally.
5. Place it on a glass slide which has a drop of distilled water.
6. Cover the slide with a cover slip and observe it under a light microscope by a low-power objective lens and followed by a high-power objective lens.
7. Sketch a figure to show the distribution of colouring in the celery stalk.

Discussion

1. Name the coloured tissue.
2. How does a herbaceous plant which has no woody tissues gets its support from xylem tissues? Explain.

Structural Adaptations of Sieve Tubes and Companion Cells to the Transport of Organic Substances

Phloem tissues transport and distribute dissolved organic compounds such as sucrose, amino acids and plant hormones to all parts of the plant. Unlike xylem, phloem is a living cell because it has cytoplasm (Figure 4.5).

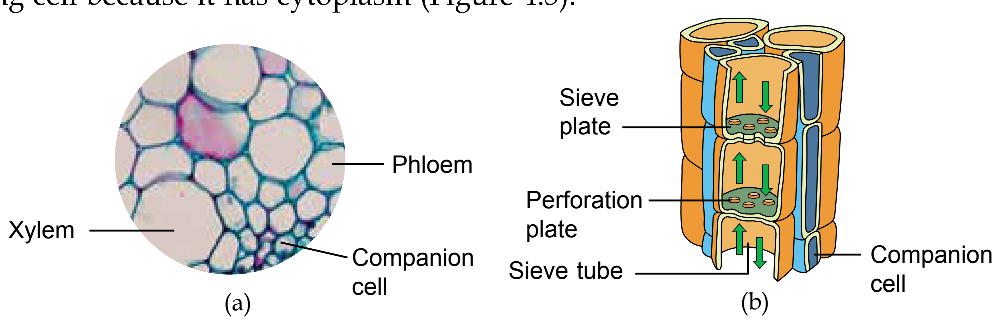


Figure 4.5 (a) Micrograph of a cross-section of a stem and **(b)** phloem structure

How do sieve tubes and companion cells adapt to their functions?
- Sieve tubes do not have nuclei, ribosomes or vacuoles. This allows sucrose molecules to pass through sieve tubes easily.
- On both ends of the sieve tube, there is a sieve plate that has pores through which organic compounds can flow from one sieve tube to the next.
- Companion cells contain mitochondria to provide energy in the form of ATP to transport sucrose from the leaf to the sieve tube through active transport.

Formative Practice 4.1

1. Do all plants need a transport system? Explain.
2. A tree is attacked by a type of bacteria which damages its xylem vessels. Predict the effects to the tree.
3. Transport of organic compounds such as sucrose by active transport along the sieve tubes needs a lot of energy. How does this process happen even though the sieve tubes have very few mitochondria?

4.2 Transport of Water and Mineral Salts

Water is very important to the growth of plants because water helps to move mineral salts from the soil to the stems and leaves. Other than that, water also helps in giving turgidity to plant cells so that the plant remains fresh.

Have you ever thought of how water is moved through the xylem to the plant stems which can reach up to hundreds of metres high? The water and mineral salts movement from the soil to the leaves are helped by **transpirational pull**, **capillary action** and **root pressure** (Figure 4.6).

ACTIVITY ZONE

Build a model of the vascular tissue system of plants using the following materials:
- Long ruler
- Scissors
- Cellophane tape
- Rubber band
- Cardboard tubes of toilet paper rolls
- Wooden stick
- Drinking straw (big and small in size)

Photograph 4.5 Example of a model

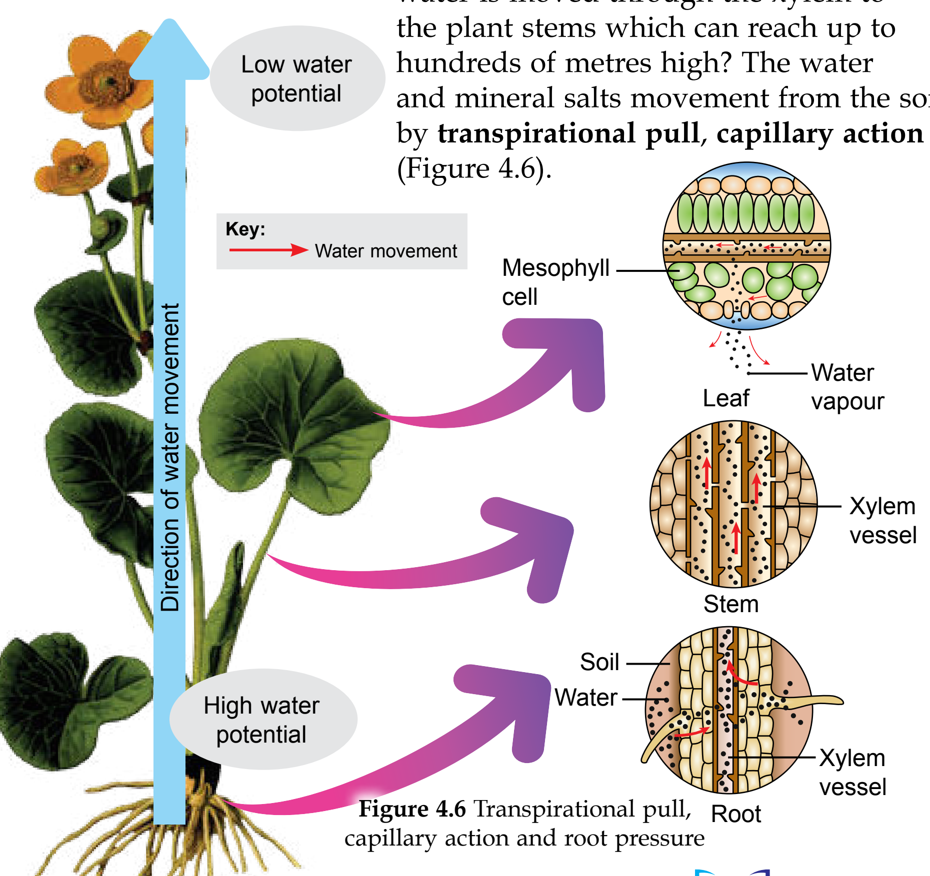


Figure 4.6 Transpirational pull, capillary action and root pressure

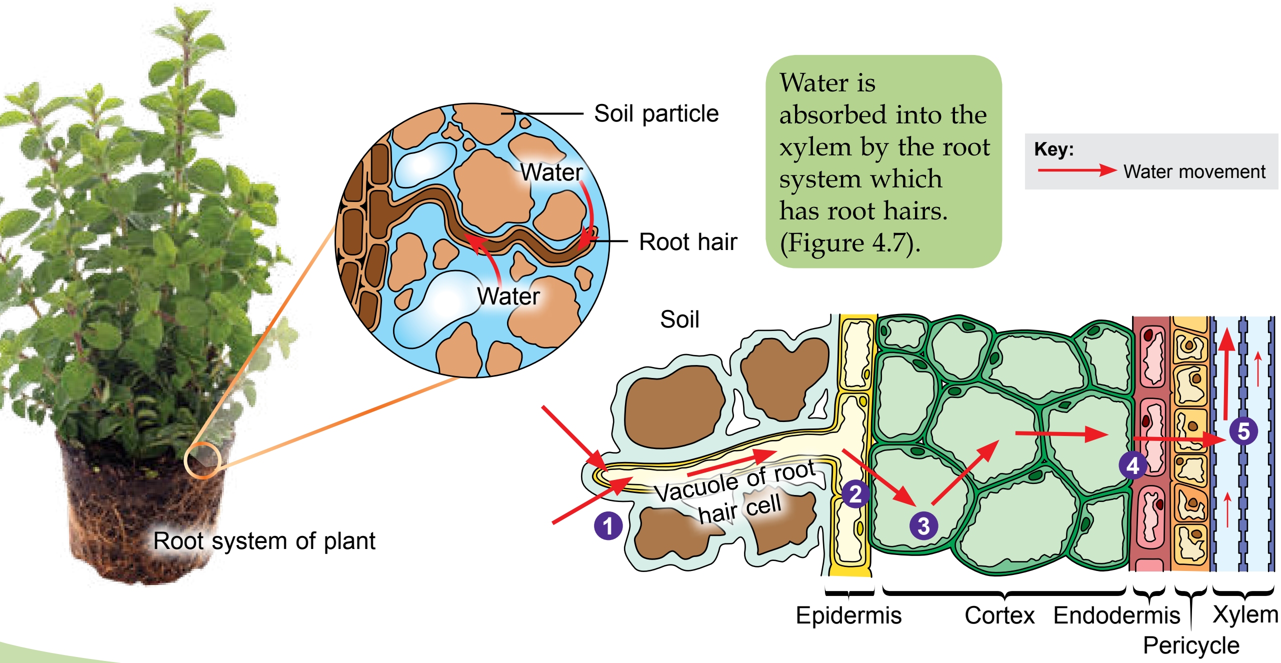
Transpirational pull
Produced when water that is evaporated from the **stoma,** pulls water from the **leaves**.

Capillary action
Capillary action is produced from **adhesion force** and **cohesion force** of water molecules which moves water upwards in the **stem against gravity.**

Root pressure
Moves water from the soil into the xylem vessels of the **root** via osmosis.

4.2.1

How Does Water Move from the Soil to the Xylem Vessel?



1
The water potential in the **root hair cells** is lower compared to water in the soil. This is because the mineral ions are actively pumped by the root hair cells into the **vacuole**, causing the cell sap of the root hair to have **low water potential** compared to the soil.

2
Water from the soil diffuses into the root hair cells and **epidermal cells** via **osmosis**.

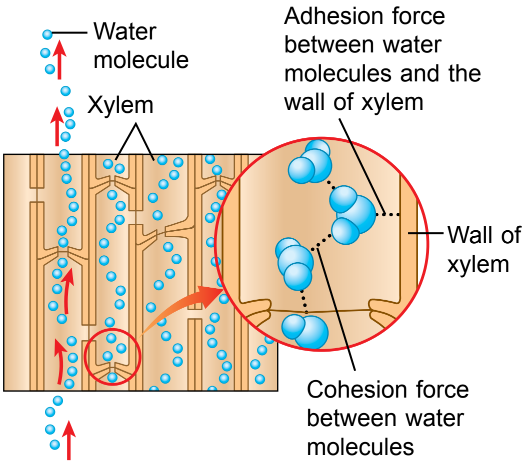
3
The high water potential in the root hair cells causes the water to diffuse from the root hair cells into the cortex via osmosis.

4
This condition causes osmosis to continuously occur throughout the **cortex**, **endodermis** and **pericycle** layers.

5
This causes root pressure to push water into the **xylem vessels** of the root and then into the xylem vessels of the stem.

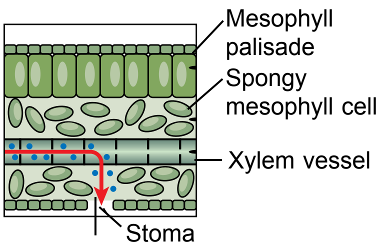
Figure 4.7 Water movement from the soil to the xylem vessel

How does Water Move in the Xylem Vessels?



(a) Water movement in the xylem vessels of stem

- For tall plants, root pressure cannot transport water to the leaves, especially the shoots.
- Therefore, the movement of water molecule in the xylem vessel is also helped by the **capillary action of xylem** produced by **adhesion** and **cohesion forces** and also **transpirational pull**.
- Adhesion and cohesion forces produce a pulling force which continuously moves water in the **xylem vessel**.



Water vapour released to the surrounding by transpiration

(b) Water movement in the xylem vessel of the leaves

Key: Water movement

- When transpiration process happens, water diffuse out as water vapour from the spaces between the cells to the surroundings through opened stoma.
- **Spongy mesophyll cells** lose water and they have **low water potential** towards adjacent cells.
- Water molecules diffuse from neighbouring cells via spongy mesophyll cells by **osmosis**.
- This movement produces a force called **transpirational pull** that pulls water molecules in the xylem vessel of the leaves to the outside of the leaves.

Figure 4.8 Water movement in xylem vessel of stem and leaf

Bio Exploration

Water movement from the root cells to the xylem happens in two ways:
- simplast pathway – water moves through cytoplasm and plasmodesmata
- apoplast pathway – water moves through the spaces between cellulose fibres at the cell wall

Because the cell walls in the endodermis layer have Casparian strips which are not permeable to water, water cannot move through the apoplast pathway but through simplast pathway.

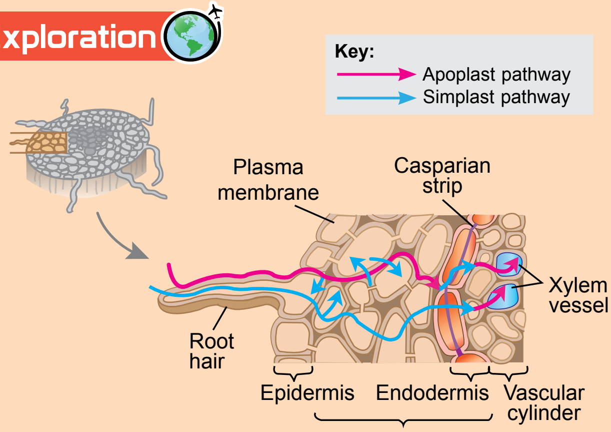


Figure 4.9 Simplast and apoplast pathways

4.2.1

EXPERIMENT

4.1 The Effect of Root Pressure on Water Transport

Problem Statement
What are the effects of root pressure towards water transport?

Aim
To investigate the effects of root pressure towards water transport

Hypothesis
Root pressure helps in moving water from the soil to the shoots.

Materials
Fresh balsam plant in a vase, petroleum jelly, soil

Apparatus
Knife, rubber tube, retort stand and clamp, marker pen, water manometer

Procedure

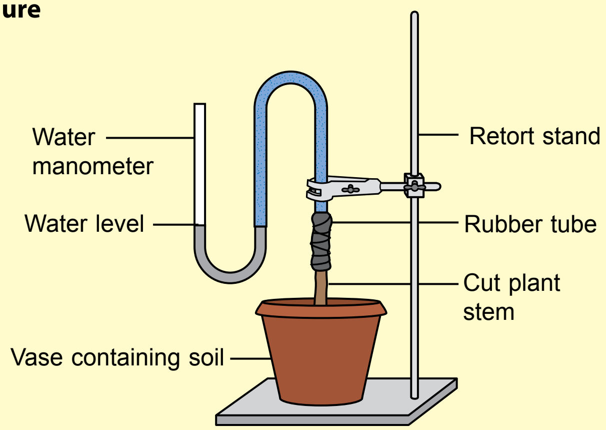


Figure 4.10 Set-up of apparatus

PRECAUTIONS

1. Soil in the vase needs to have enough minerals.
2. Leave the apparatus (Figure 4.10) in a cold and damp area.

1. Water the balsam plant in the vase and keep it overnight.
2. The next morning, cut the stem of the balsam plant 5 cm from the soil surface.
3. Using a rubber tube, connect the end of the cut stem with a manometer. Make sure the connection is neat.
4. Apply some petroleum jelly to the connected parts to ensure the connection is airtight.
5. Mark the initial water level at the arm of the manometer.
6. Leave the apparatus for about 30 minutes.
7. Observe the water level in the arm of the manometer.

Discussion
1. What is the purpose of watering the soil before the experiment is carried out?
2. Compare the water potential of root cells with the water potential of the soil.
3. What is the effect of the difference in the water potential of the root cells and the water potential in the soil?
4. Why is root pressure needed in plants?

Conclusion
Is the hypothesis accepted? Suggest a suitable conclusion.

4.2.1

EXPERIMENT 4.2

The Effect of Transpirational Pull on Water Transport

Problem statement
What is the effect of transpirational pull on water transport?

Aim
To investigate the effect of transpirational pull on water transport

Hypothesis
Transpirational pull moves water from roots to leaves.

Materials
A plant with leaves and roots, water, cooking oil, petroleum jelly

Apparatus
A bottle with an opening at the edge, side tube, cork, marker pen

Procedure

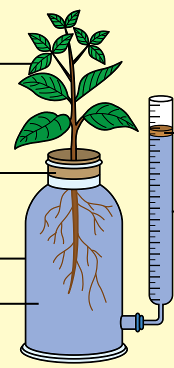


Figure 4.11 Set-up of apparatus

1. Connect the bottle to a side tube as in Figure 4.11.
2. Fill the bottle with water.
3. Put a few drops of cooking oil on the water surface inside the side tube.
4. Carefully, put in the plant stem with the roots through the hole of the cork.
5. Apply petroleum jelly at the connection of the plant stem and the cork to ensure it is airtight.
6. Cover the mouth of the bottle using a cork with the roots of the plant fully immersed in water. Then, apply the petroleum jelly at the connection to ensure it is airtight.
7. Mark the initial water level in the side tube using a marker pen.
8. Put the apparatus under the sunlight for about 30 minutes.
9. Observe the changes of the water level in the side tube.

Discussion
1. State the need of putting cooking oil on the water surface in the side tube.
2. What is the inference that can be made from this experiment?
3. If the experiment is repeated by reducing the number of leaf lamina of the plant, predict the observation that can be made regarding the water level in the side tube. Explain your answer.

Conclusion
Is the hypothesis accepted? Suggest a suitable conclusion.

4.2.1

Activity 4.2 STEM

Aim

To produce multi-coloured flowers by applying the concept of water transport in the xylem and sell the products in school

Materials

Fresh white rose flowers, fabric dyes of red, yellow, green and blue

Apparatus

Knife, 50 ml measuring cylinder

Procedure

1. Work in groups.
2. Produce a variety of coloured flowers by applying the concept of water transport in the xylem vessel. You can use the above mentioned apparatus and materials.
3. Sell your group's product in your school (Photograph 4.6).

Photograph 4.6 Variety of coloured flowers

Discussion

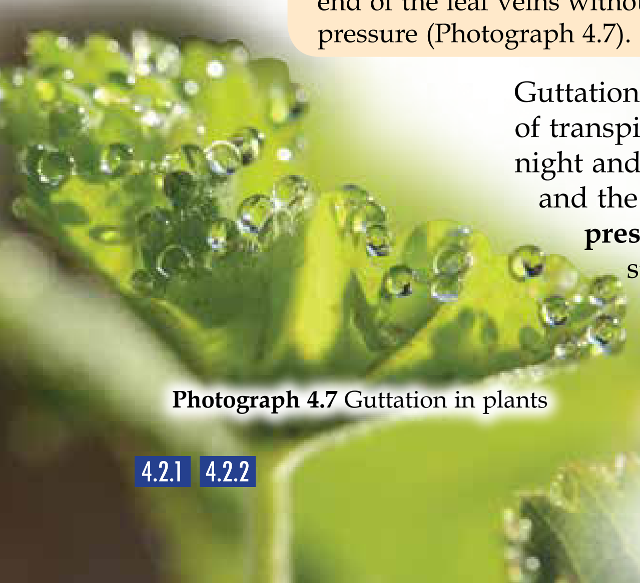
1. Why are white rose flowers used?
2. State the vascular tissue involved in flower colouration.
3. These flowers with a variety of colours wilt faster compared to the original flowers if they are left in a vase containing water. Why?

Guttation in Plants

Guttation is a secretion of water droplets through a special structure at the end of the leaf veins without involving the stomata caused by a high root pressure (Photograph 4.7).

Guttation occurs when the root pressure and the rate of transpiration is low. This condition usually occurs at night and early morning when the air humidity is high and the surrounding temperature is low. The **root pressure** formed pushes water to the leaves and stems of the plant.

Can you compare between guttation and transpiration? (Table 4.1).



Photograph 4.7 Guttation in plants

Comparison between Guttation and Transpiration

Table 4.1 The comparison between guttation and transpiration

Guttation	Transpiration
	
Similarities	
• Both processes occur through the leaf.	
• Both processes cause permanent water loss from the plant.	
Differences	
Guttation happens at night and early morning.	Transpiration happens on hot and windy days.
Guttation only happens in herbaceous plants.	Transpiration happens in all plants.
Water is released in the form of water droplets.	Water is released as water vapour.
Water is released through a special structure at the end of the leaf veins.	Water is released through stomata.
Guttation happens when root pressure is high.	Transpiration is controlled by the stomatal opening and closing.
Guttation releases water that is rich in minerals.	Transpiration releases pure water.

The Condition of Plants that Do Not Undergo Transpiration and Guttation

Effects towards plants that do not undergo guttation

- Without guttation, effective root pressure cannot be maintained. Therefore, water absorption by root hair cells is disrupted in a surrounding with high relative humidity.
- Without guttation, plant waste substances cannot be eliminated.
- If guttation does not occur, the leaf vein pressure becomes high and causes the leaf vein to burst. This leads to the leaves being exposed to pathogen and eventually fall.

Effects towards plants that do not undergo transpiration

- Without transpiration, optimum temperature of plants cannot be maintained. Increase in temperature can denature enzymes and disrupt biochemical processes such as photosynthesis and respiration.
- Without transpiration, mineral ions such as potassium ions cannot be transported from the roots to the leaves for photosynthesis.
- Without transpiration, water transport throughout the plants will be disrupted and causing the plants to wilt.
- Plants can die in the long run.

4.2.3 4.2.4

Activity 4.3

21st CENTURY SKILLS

21st CENTURY SKILLS INDIVIDUAL PRESENTATION

Aim
To use mind map to compare and contrast between guttation and transpiration

Procedure
1. Work in groups.
2. Watch a video about guttation and transpiration by scanning the QR code at the side.
3. Note down important points and build a mind map to compare and contrast between guttation and transpiration on a mahjong paper.
4. Present your mind map in class.

ICT

Video

Guttation and transpiration
http://bukuteksksssm.my/Biology/F5/TranspirationandGuttation.mp4

Formative Practice 4.2

1. State the factors involved in the water and mineral salts pathway from soil to leaves.
2. Give the definition of guttation and state its importance.
3. What is the difference between guttation and transpiration?
4. On a hot and windy condition, water absorption by the roots and water transport in the xylem becomes faster.

   Do you agree with the statement? Justify.

4.3 Translocation

Photograph 4.8 Aphids suck liquid from phloem

You have learnt about transport system in the human body and animals in Form Four. How is the transport system in plants which transports substances required by the cells to all parts that need them? What is the process involved?

Definition of Translocation

Translocation is a process of transporting organic substances such as sucrose, amino acids and hormones in the phloem from the leaves to other parts of the plant such as the roots and stem.

Bio Exploration

Pesticides such as aphids suck sap from the phloem of plant stems. If the sap collected is analysed, it is found to contain sucrose and amino acids. This shows that translocation happens in the phloem (Photograph 4.8).

4.2.3 4.3.1 4.3.2

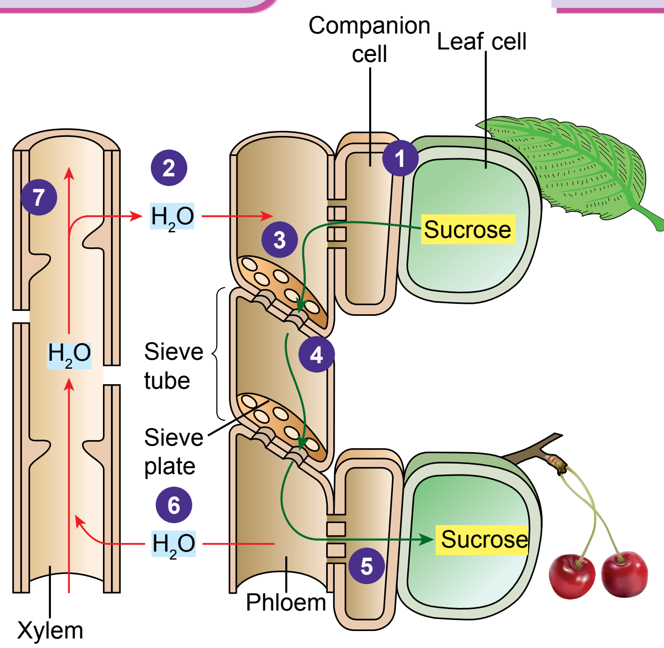
The Necessity of Translocation in Plants

Translocation helps in transporting photosynthetic products from the leaves to other parts of the plant that need them for growth and respiration such as roots, fruits, tip of shoots or developing flowers. Other than that, translocation also transports excess photosynthetic products to other parts of the plants such as rhizomes, tubers and bulbs (Figure 4.12).

Pathways of Translocation in Plants

7 **Transpiration** pulls water along the xylem vessel against the direction of gravitational pull.

1 **Sucrose** is actively transported into the sieve tube.



6 The high water potential in the phloem causes the water to diffuse in order for it to return into the xylem by osmosis.

2 The transport of sucrose into the sieve tube through the companion cell from the leaf cells reduces the water potential in the sieve tube. This causes water to diffuse from the xylem into the sieve tube via osmosis.

5 The phloem sap (sucrose) is transported from the sieve tube to other parts such as stems, roots, shoots, fruits and tubers by active transport.

4 The increase in the hydrostatic pressure causes the phloem sap to be pushed along the sieve tube to other organs of the plant.

3 The water diffusion increases the **hydrostatic pressure** in the sieve tube.

TERM ANALYSIS

Translocation originates from Greek words,
- **Trans** = crossing
- **Locus** = site or place

Key:
- Water movement (red arrow)
- Sucrose movement (green arrow)

Figure 4.12 Translocation pathway in plants

4.3.3

EXPERIMENT

4.3 The Role of Phloem Tissue in the Transport of Organic Substances

Problem statement
What is the role of phloem tissues in the transport of organic substances?

Aim
To investigate the role of phloem tissues in the transport of organic substances

Hypothesis
The upper part of the removed ring bark from a plant stem becomes swollen and the lower part of the removed ring bark shrinks after a few weeks.

Variables

Manipulated variable
The part of the removed ring bark

Responding variable
The condition of the upper part and lower part of the removed ring bark from a plant stem

Constant variable
Hibiscus plant

Materials
Hibiscus plant, petroleum jelly

Apparatus
Ruler, knife

Procedure
1. Cut and remove a ring-shaped part of woody bark from a branch of a hibiscus flower (Figure 4.13).
2. Apply petroleum jelly at the ring part
3. Water the plant every day and leave it for three weeks.
4. Record your observation into the table of result below.

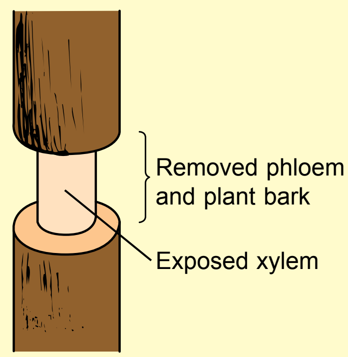


Figure 4.13 Removal of part of plant bark

Result

Observation	Beginning of the experiment	After three weeks
(a) Upper part of the ring		
(b) Lower part of the ring		

Discussion
1. What is the purpose of:
   (a) Ringing the plant stem?
   (b) Applying petroleum jelly to the exposed part?
2. What are the structures removed when the branch is ringed?
3. Predict what will happen to the hibiscus plant after six months.

Conclusion
Is the hypothesis accepted? Suggest a suitable conclusion.

4.3.3

Formative Practice 4.3

1. State the definition of translocation.
2. What is the role of translocation in plants?
3. How does translocation occur from the leaves to the roots? Explain.
4. Compare sucrose concentration in a leaf cell and sieve tube. What is the effect of the difference?
5. How does translocation affect a plant's yield?

4.4 Phytoremediation

The environment and human health can be affected if waste water from domestic, agricultural, breeding and industrial activities is not treated. Water supply will be filled with heavy metals and pollutants. The need of management and waste water treatment is important in order to overcome the lack of clean water, issue of water pollution and increasing cost of water treatment.

To overcome these problems, phytoremediation method is one of the alternatives in waste water treatment by eliminating heavy metals and also trapping harmful nutrients and microorganisms. Phytoremediation treatment uses aquatic plants that can absorb heavy metals and nutrients contained in waste water.

TERM ANALYSIS

Phytoremediation originates from the words
Phyton = plant
Remediate = repair

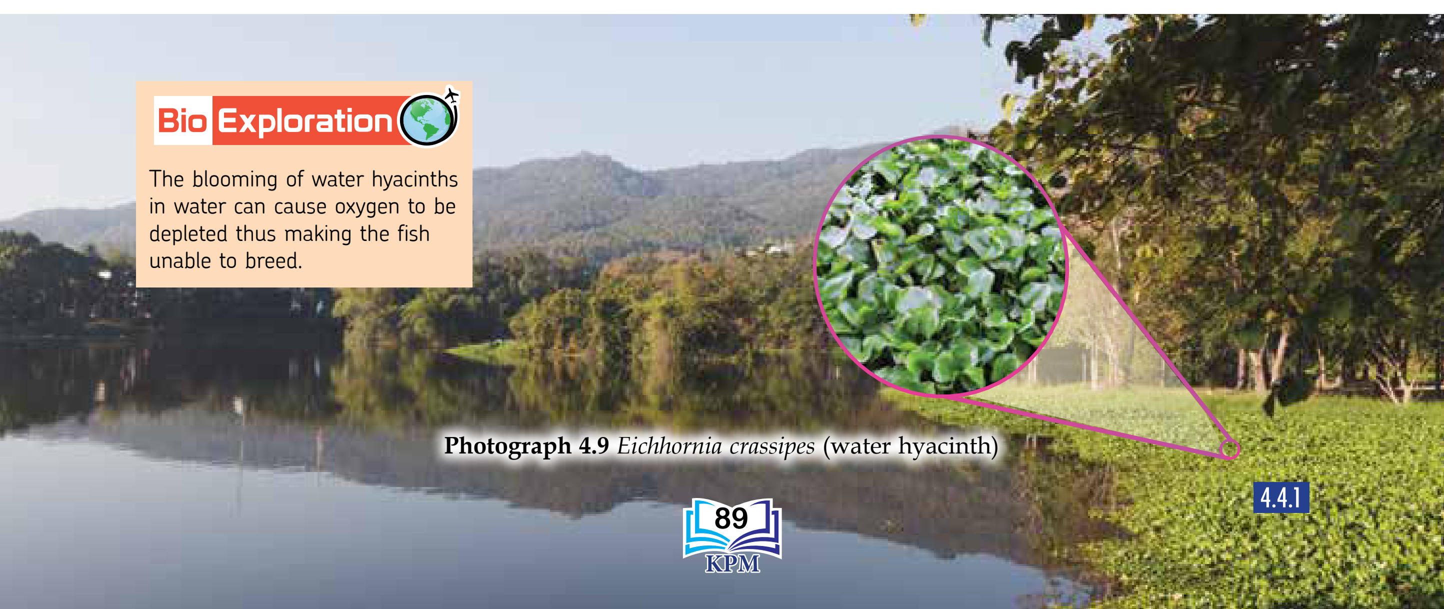
Definition of Phytoremediation

Phytoremediation is one of the treatment methods which uses plants for the purpose of degradation, extraction or elimination of pollute substances from soil and water.

Among the examples of plants used for phytoremediation is *Eichhornia crassipes* (water hyacinth). This plant has long roots which can accumulate heavy metals such as copper and lead in water (Photograph 4.9). What are other examples of phytoremediation uses in our daily life?

Bio Exploration

The blooming of water hyacinths in water can cause oxygen to be depleted thus making the fish unable to breed.



Photograph 4.9 *Eichhornia crassipes* (water hyacinth)

4.4.1

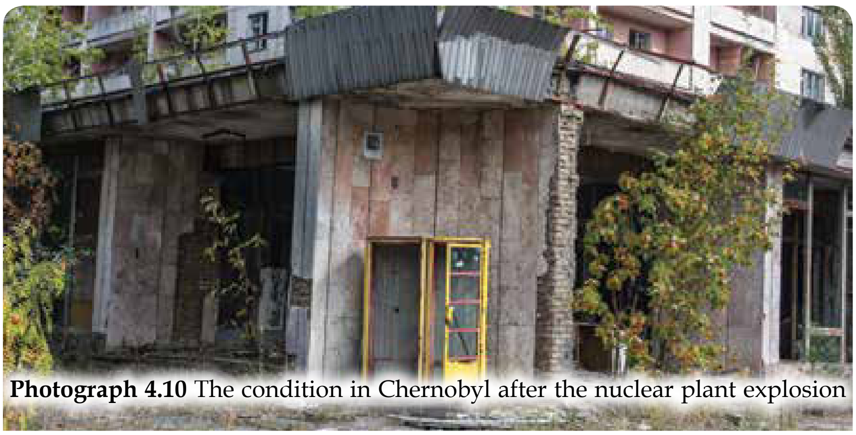
The Uses of Phytoremediation in Life

On 26th April 1986, the fourth reactor of the nuclear power plant in Chernobyl, Russia exploded during a safety test. Smoke filled with radioactive substances flew as far as 2334 km. (Photograph 4.10).

1

Sunflowers (Photograph 4.11) are used for **remediation of soil** polluted by the explosion of the **nuclear plant** in **Chernobyl, Russia.**

Sunflower acts as a **hyperaccumulator** which can eliminate heavy metals such as **zinc**, **chromium, copper**, **lead** and **nickel** and also radioactive substances such as **caesium** and **strontium**.



Photograph 4.10 The condition in Chernobyl after the nuclear plant explosion

Photograph 4.11 Sunflower plants

2

There are aquatic plants that are suitable to **treat waste water** in a waste plant (Photograph 4.12) through the phytoremediation method. For example, *Pistia stratiotes* (water lettuce plant) (Photograph 4.13), which has a fast growth rate, can accumulate heavy metals and absorb nutrients in the waste plant.

Photograph 4.12 Waste water plant

Photograph 4.13 Water lettuce

3

The roots of ground water spinach (Photograph 4.14) are able to absorb mercury from the soil whereas the roots of river water spinach are able to absorb heavy metals such as cadmium from the water.

Photograph 4.14 Water spinach

4.4.2

EXPERIMENT

4.4 The Effectiveness of Phytoremediation Plants in Controlling Water Pollution

Problem statement
Are phytoremediation plants effective in controlling water pollution?

Aim
To study the effectiveness of phytoremediation plants in controlling water pollution

Hypothesis
The roots of common water hyacinth can absorb ammonia found in lake water.

Variables
Manipulated variable: The presence of water hyacinths
Responding variable: Reading of ammonia at the end of the experiment
Constant variable: Volume of lake water

Materials: *Eichhornia crassipes* (water hyacinths), 10 litre of lake water, 100 ml of 10% ammonium chloride solution, tap water, ammonia test kit

Apparatus: Two glass containers with a 5 litre capacity

Procedure

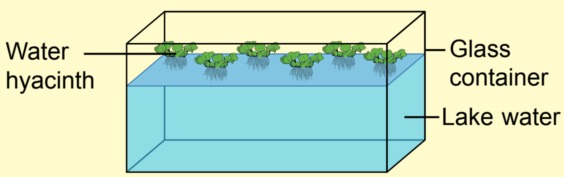


Figure 4.14 Apparatus set-up for phytoremediation

Bio Exploration
Ammonia test kits can be obtained from aquaculture stores or aquarium stores.

1. Remove dirt and mud from the water hyacinths.
2. Fill the two glass containers with 5 litres of lake water and label them A and B.
3. Insert 50 ml of 10% ammonium chloride solution into each container.
4. Record the initial reading of ammonia in both containers using the ammonia test kit.
5. Put six water hyacinths from step 1 into container A (Figure 4.14).
6. Leave both glass containers at room temperature.
7. Record the final reading of ammonia in containers A and B after seven days using the ammonia test kit.
8. Record the reading of ammonia in a table.

Result

Glass container	Reading of ammonia in the lake water	
	Beginning of the experiment	End of the experiment
A		
B		

Discussion
1. Why must the common water hyacinths be washed first (step 1)?
2. Name another plant that can absorb ammonia from water.
3. What is the effect of ammonia towards the aquatic ecosystem?

Conclusion
Is the hypothesis accepted? Suggest a suitable conclusion.

4.4.3

EXPERIMENT

4.5 The Effectiveness of Phytoremediation Plants in Controlling Soil Pollution

Problem statement

Are phytoremediation plants effective in controlling soil pollution?

Aim

To study the effectiveness of phytoremediation plants in controlling soil contamination

Hypothesis

The roots of water spinach can absorb nutrients such as ammonia in soil.

Variables

Manipulated variable: The presence of water spinach

Responding variable: Reading of ammonia in the soil at the end of the experiment

Constant variable: Mass of black soil

Materials: Water spinach, 5 kg of food wastes, 50 ml of 2 M potassium chloride solution, plastic container, 5 kg of black soil, distilled water, ammonia test kit

Apparatus: 100 ml beaker, oven

Procedure

1. Flatten a thin layer of 5 kg of black soil on a plastic sheet and dry it by using an oven.
2. Put 2.5 kg of black soil in a plastic container and label it as container A.
3. Put the remaining 2.5 kg of black soil in another plastic container and label it as container B.
4. Determine the ammonia content of the soil in containers A and B:
   (a) Put 7 g of black soil from containers A and B in different conical flasks.
   (b) Mix 50 ml of 2 M potassium chloride solution into two different conical flasks and shake them.
   (c) Filter the mixture into a 100 ml beaker.
   (d) Put 20 ml of distilled water into the filtrate.
   (e) Determine the concentration of ammonia in the filtrate using an ammonia test kit.
5. Mix 2.5 kg of food waste with soil mixture in container A so that the mixture is even.
6. Repeat step 5 for the soil mixture in container B.
7. Transfer 20 water spinach stalks into container A while container B is left without a water spinach plant as a control set.
8. Place containers A and B in a warm but sheltered area.
9. Put equal amount of water everyday into containers A and B for two weeks.
10. After two weeks, repeat step 4 to test for ammonia content in containers A and B.
11. Record the final readings of ammonia in a table.

Result

Glass container	Reading of ammonia in the soil	
	Beginning of the experiment	End of the experiment
A		
B		

Discussion

1. Why must the soil sample be dried before the experiment begins?
2. What is the significance of using water spinach in this experiment?

Conclusion

Is the hypothesis accepted? Suggest a suitable conclusion.

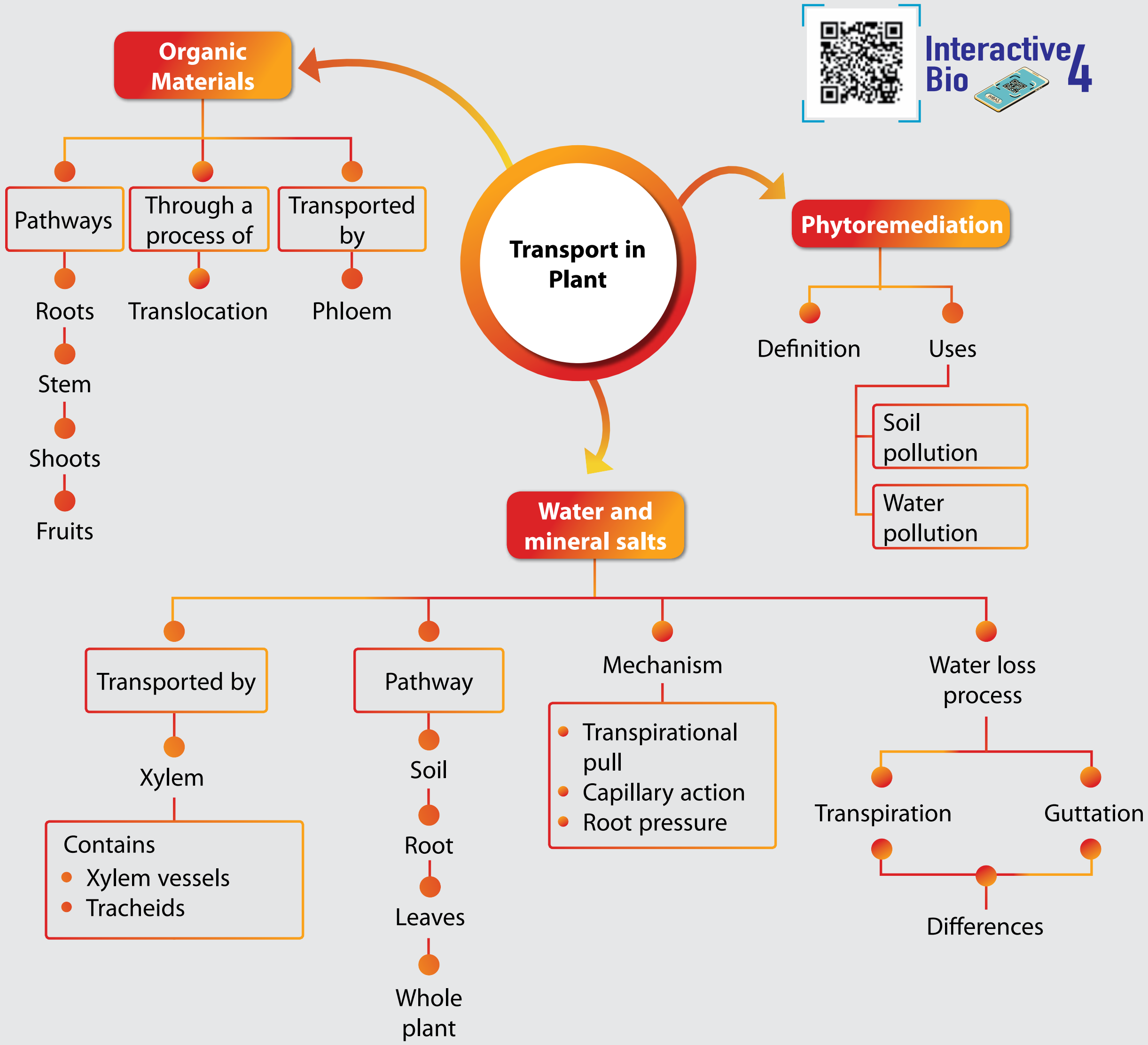
4.4.3

Formative Practice 4.4

1. What does phytoremediation mean?
2. Name **two** uses of phytoremediation in daily life.

Memory Flashback

Interactive Bio 4



SELF-REFLECTION

Complete the following self-reflection to identify the important concepts that you have studied.

Important concepts	Very good	Try again
The necessity of transport in plants		
Structural adaptations of xylem vessels and tracheids to transport water and mineral salts		
Structural adaptations of sieve tubes and companion cells to the transport of organic substances		
Factors involved in the pathways of water and mineral salts from the soil to the leaves, including transpirational pull, capillary action and root pressure		
Guttation in plants		
Comparison between guttation and transpiration in plants		
Condition of plants that do not undergo transpiration and guttation		
The definition of translocation		
The necessity of translocation in plants		
The pathways of translocation in plants		
The definition of phytoremediation		
The uses of phytoremediation in life		
The effectiveness of phytoremediation plants in controlling water and soil pollution		

Summative Practice 4

1. (a) Are xylem vessels living or dead structures? Give a reason for your answer.
(b) What is the main function of the xylem vessel? State **three** structural adaptations of the xylem vessels and their functions.
(c) How are the adaptations in the roots of plants similar to the adaptations of the small intestines in humans for nutrient absorption? Explain.
(d) Systemic pesticides could be absorbed and carried throughout the whole plant. Does spraying pesticides systematically onto leaves kill insects such as aphids that primarily feed on the shoots of plants? Explain.

2. Photosynthesis product such as sucrose is transported by the phloem through translocation from the leaves to other parts of the plants such as the seeds, fruit, roots and tubers.
   (a) Describe the pathway of sucrose molecules as it is transported from the leaves to other part of the plant such as the fruit.
   (b) Plan an experiment using aphid to prove that the translocation of sucrose and amino acids occur in the phloem.

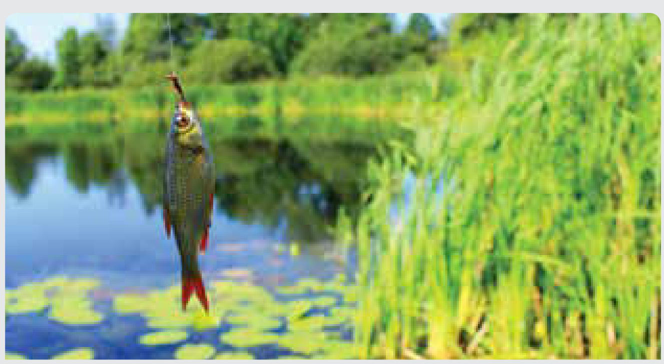
3. Photograph 1 shows the aftermath of the nuclear plant explosion in Chernobyl, Russia, in 1986.

Photograph1 Chernobyl nuclear plant in Russia

   (a) One of the methods used to treat the soil after the explosion is by removing pollutants through plants. What is the method called?
   (b) Suggest **one** type of plant that can be used for the method mentioned in 3(a).
   (c) Mr. Sani is a modern farmer who farms near to an industrial area. Mr. Sani digs a trench to provide irrigation water for his plants. He also plants common water hyacinths in the trench. Justify Mr. Sani's actions.

21st Century Mind

4. Photograph 2 shows Lake A, an artificial lake that is located near a market. More than 3000 fish from various species were released into this lake to propagate fishing activities. When the fish were matured enough to be caught, the lake was found to contain high amounts of lead. Imagine you work as a chemical engineer for the city council of that area, suggest one method to solve this problem. Plan an experiment to test the effectiveness of your method.



Photograph 2 Lake A

Chapter 5

Response in Plants

Chapter Exploration

- Types of Responses
- Phytohormone
- Application of Phytohormones in Agriculture

Learning Standards

Do You Know?

- Are responses of plants similar to responses in humans and animals?
- What stimulates a plant to respond to its surroundings?
- What is a phytohormone?
- How can a phytohormone be commercialised?

Effective Microorganism (EM) Technology

Effective Microorganisms (EM) are mixed cultures of anaerobic microorganisms that are used in the agricultural and livestock industries to increase quality and yield production.

Yeast is one of the many microorganisms present in an EM mix. Yeast produces hormones and enzymes which act as bioactive substances to increase the cell division activities in plant and root cells. Apart from that, yeast also increases the rate of photosynthesis in plants, stimulating more production of flowers and fruits.

Keywords

- Auxin
- Ethylene
- Photonasty
- Phototropism
- Phytohormone
- Geotropism
- Nastic movement
- Tropism movement
- Hydrotropism
- Chemotropism
- Nyctinasty
- Seismonasty
- Cytokinin
- Thermonasty
- Thigmotropism

5.1 Types of Responses

Responding towards stimuli is a characteristic of organisms to ensure survival. Plants, like humans and animals can adapt to their surroundings. How do plants respond to changes in surrounding? What stimulate plants to respond? (Figure 5.1).

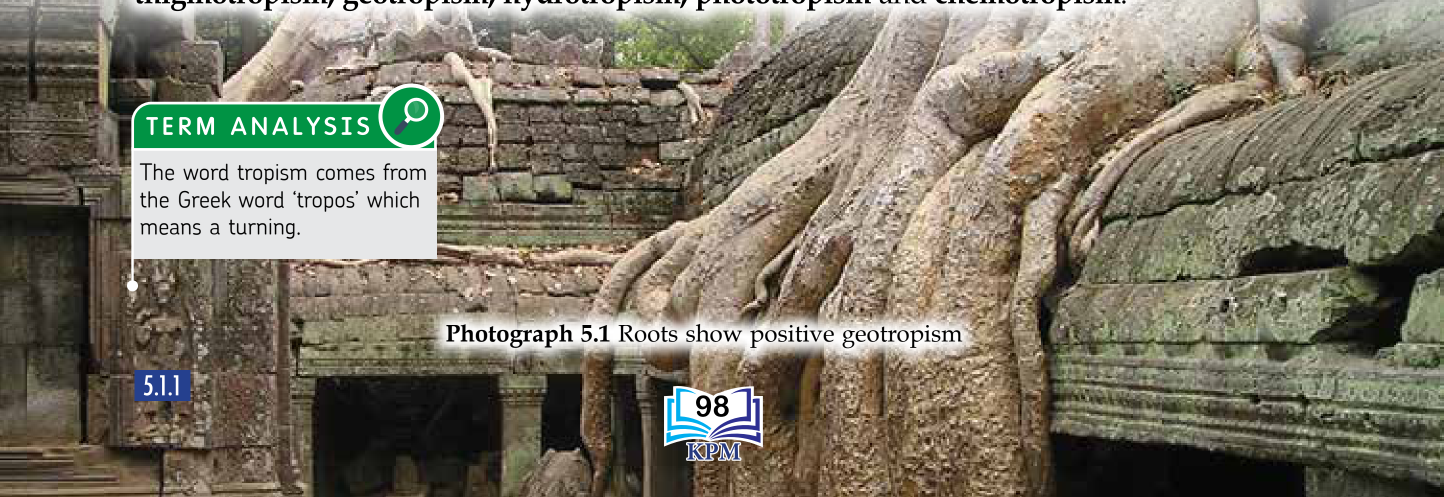
Figure 5.1 Plant response

You have learnt about plant responses in Form 3. Can you state the types of responses in plants? Normally, plants respond to surrounding stimuli are known as growth responses. There are two types of responses, **tropism** responses and **nastic** responses.

Types of Plant Responses

Tropism Responses

Tropism responses are the responses of certain parts of a plant such as **roots** and **shoots** that respond towards or away from a stimulus. Can you explain the root response in Photograph 5.1 below? There are several types of tropism in plants, which are **thigmotropism, geotropism, hydrotropism, phototropism** and **chemotropism**.



TERM ANALYSIS

The word tropism comes from the Greek word 'tropos' which means a turning.

Photograph 5.1 Roots show positive geotropism

5.1.1

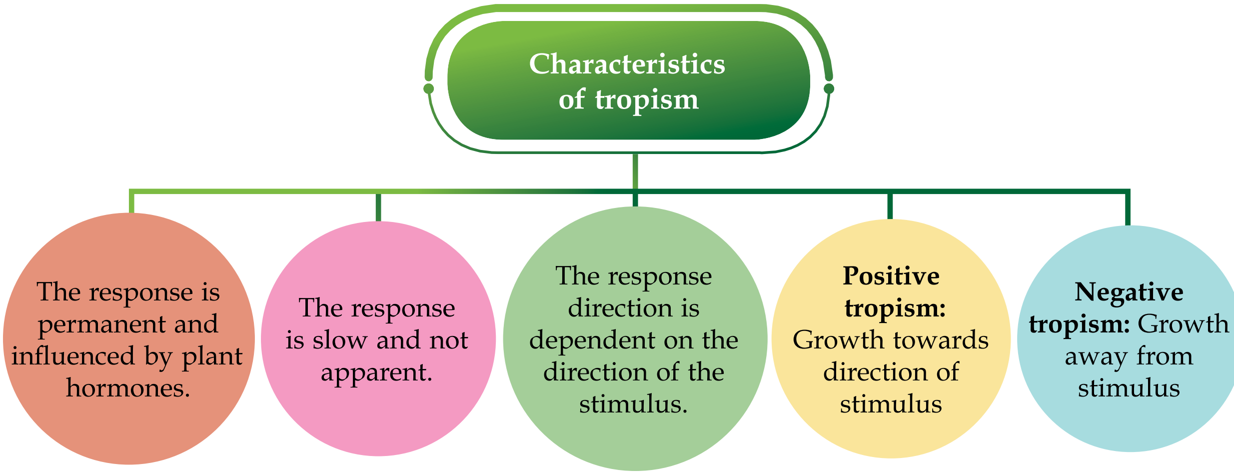


Figure 5.2 Characteristics of tropism in plants.

Types of Tropism

Thigmotropism

Thigmotropism is the plant response to **touch**.

Tendrils exhibit positive thigmotropism by coiling or wrapping around an object such as a wooden stake for support (Photograph 5.2).

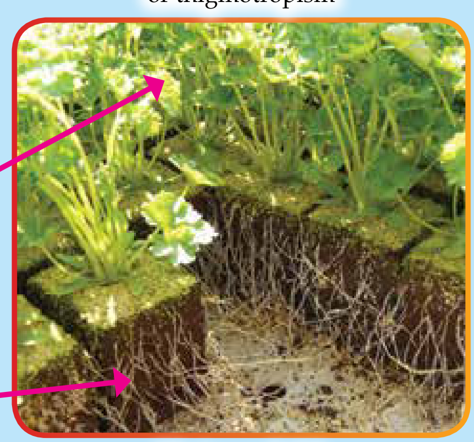
Photograph 5.2 An example of thigmotropism

Geotropism

Geotropism is the plant response to **gravity** (Photograph 5.3).

Shoots show negative geotropism.

Roots show positive geotropism.



Photograph 5.3
An example of geotropism

5.1.1

Hydrotropism

Hydrotropism is the plant response to **water.**

Roots show positive hydrotropism because they grow towards water (Photograph 5.4).

Photograph 5.4 An example of hydrotropism

Phototropism

Phototropism is the plant response to **light**.

Shoots show positive phototropism because they grow towards light (Photograph 5.5).

Photograph 5.5
An example of phototropism

Chemotropism

Chemotropism is the plant response to **chemical** (Photograph 5.6).

Roots show positive chemotropism when they grow towards mineral salts.

Roots show negative chemotropism when they grow away from chemical substances such as poison.

Photograph 5.6 An example of chemotropism

5.1.1

Nastic Responses

Nastic responses include **photonasty, seismonasty, nyctinasty, thermonasty** and **thigmonasty**.

Characteristics of nastic responses

- Not all nastic responses are growth responses.
- This response is quicker and more apparent compared to tropism response.
- Some nastic responses are intended for survival.

Figure 5.3 Characteristics of nastic responses

Types of Nastic Responses

Photonasty

Typically, flower petals engage in photonasty as a response to light. Have you ever seen Japanese roses open early in the morning? (Photograph 5.7).

Photograph 5.7 Japanese roses

Seismonasty

Seismonasty is a plant response that occurs due to a mechanical stimulus such as **shock, touch, wind** and **raindrops**. Seismonasty responses can be seen on **leaves, stigma** and **stamens**. What occurs in a mimosa plant when it is touched? (Photograph 5.8).

Photograph 5.8 Mimosa plant

5.1.1

Nyctinasty

Photograph 5.9 *Leucaena leucocephala* (River tamarind)

Nyctinasty is a circadian rhythm that responds towards the onset of darkness. Normally, the leaves of legume plants such as the river tamarind closes its leaves at night and unfurls them during daytime (Photograph 5.9).

Thermonasty

Thermonasty is the plant response towards changes in the surrounding temperatures. For example, tulips open when there is an increase in temperature and close when the temperature drops (Photograph 5.10).

Photograph 5.10 Tulips

Thigmonasty

Thigmonasty is the plant response towards vibration. This response can be seen in carnivorous plants such as the Venus flytrap. The exerted stimulus causes it to clamp its leaves shut and trap the insect inside it (Photograph 5.11).

Photograph 5.11 Venus flytrap

ACTIVITY ZONE

Compare tropism and nastic responses in plants using a mind map.

Formative Practice 5.1

1. State the definition of tropism.
2. List **three** types of tropism.
3. Justify phototropism in plants.
4. Danish discovered that the mimosa leaves fold up when a flame from a lighter was held close to its leaves. Explain this observation.

5.1.1

5.2 Phytohormone

What regulate responses in plants? Plants do not have a system like the nervous and endocrine systems in humans and animals to regulate their daily activities. This is the reason why responses in plants can only be seen clearly after a period of time.

ACTIVITY ZONE

Do a research about history of phytohormone and present the findings of your group.

Phytohormones or plant hormones are chemical substances that stimulate and coordinate responses in plants, at low concentrations. Generally, phytohormones are synthesised in a certain plant organ and transported to a target organ through the phloem.

The Functions of Phytohormones

Table 5.1 Types of phytohormones and their functions

Types of phytohormone	Functions
Auxin	• Functional in phototropism and geotropism • Stimulates development of the apical dominance in shoots and roots • Stimulates growth and elongation in root and shoot cells • Stimulates development of adventitious roots at the end of stem cuttings • Stimulates cell division in cambium during secondary growth • Inhibits abscission of fruits and young leaves • Inhibits growth of lateral buds
Gibberellin	• Stimulates growth and elongation in the stem cell • Stimulates development of leaves, flowers and fruits • Stimulates development and germination of seeds • Causes growth of flowers in dwarf plants • Inhibits development of roots
Cytokinin	• Stimulates division and elongation of root and stem cells when auxin is present • Stimulates seed germination • Inhibits development of apical dominance • Delays leaf senescence • Stimulates growth of lateral buds
Abscisic acid	• Inhibits growth of plants • Stimulates abscission of mature fruits, leaves and flowers • Induces seed dormancy • Induces stomatal closing during drought season • Inhibits growth of buds and seed germination
Ethylene	• Stimulates ripening in fruits • Stimulates senescence process in plants • Stimulates abscission of leaves and fruits

5.2.2

Effects of Auxin on Growth Response

Plants respond to stimulus in the form of growth. This growth response is controlled by the **auxin**. What are the effects of auxin on growth response? Let's study the following experiment about the effects of auxin on the coleoptiles of plants as shown in Figure 5.4.

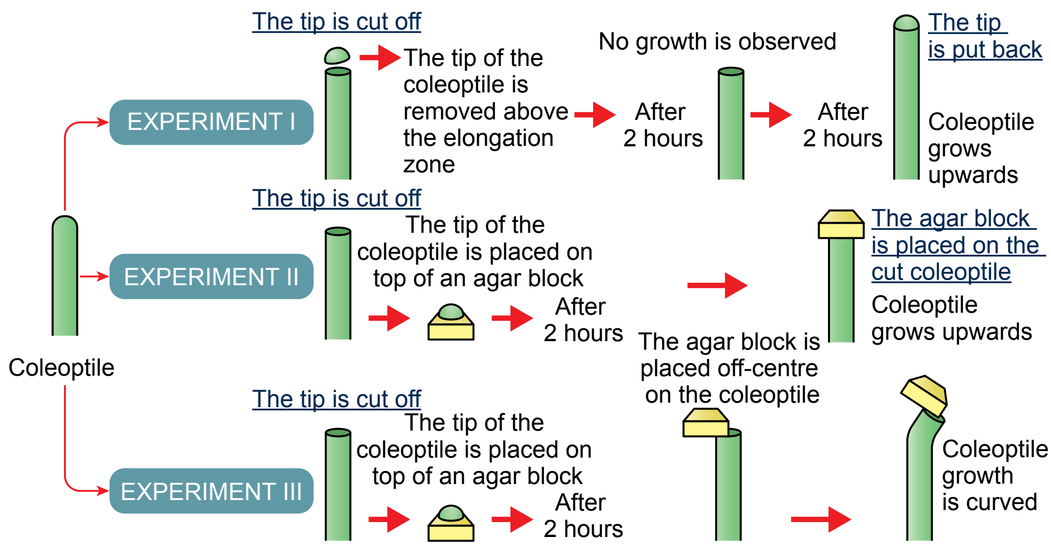


Figure 5.4 An experiment to study the effects of auxin on coleoptile growth at the shoot tip

What is the inference that can be made based on the observations from the experiment above? This experiment shows that auxin which has been synthesised at the coleptile tips stimulate cell elongation. Auxin distribution influences the direction of the shoot growth. Uniform distribution of auxin causes the coleptile to grow upwards. The area which receives more auxin will grow faster and cause coleptiles to curve to the side that receives less or none of the auxin.

Tropism is closely related to auxin distribution. External stimuli such as light and gravity influences the auxin distribution in plants. Auxin produces different effects to the cells in the shoots and the cells in the roots. High auxin concentrations stimulates cell elongation in the shoots but also inhibits cell elongation in the roots (Figure 5.5).

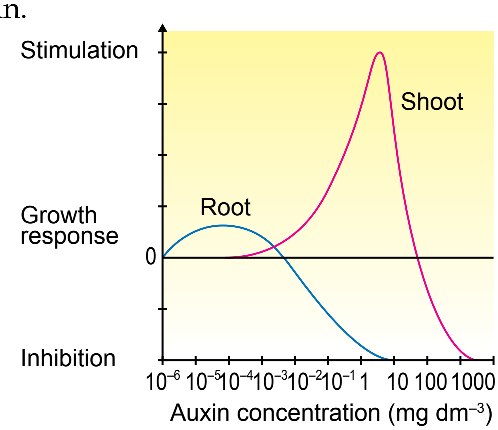


Figure 5.5 Graph of effect of auxin concentration towards elongation of shoot and root

5.2.3

The Roles of Auxins in Plant Responses

The Role of Auxin in Phototropism

The response direction of shoot tip depends on the direction of the light stimulus. The distribution of auxins in the shoots is uniform if the shoots are exposed to the light from all directions. This causes the shoots to grow upwards. When the shoots are exposed to the light from only one direction, the auxin will move away from the light. The auxin concentration is higher on the shaded side. The concentration of auxin becomes uneven on the shoots. The cells in the shaded side elongate more than the cells in the bright side. As a result, the shoots bend towards the light. The shoots show positive phototropism. Figure 5.6 shows the role of auxin in the coleoptile tips on plant response based on phototropism.

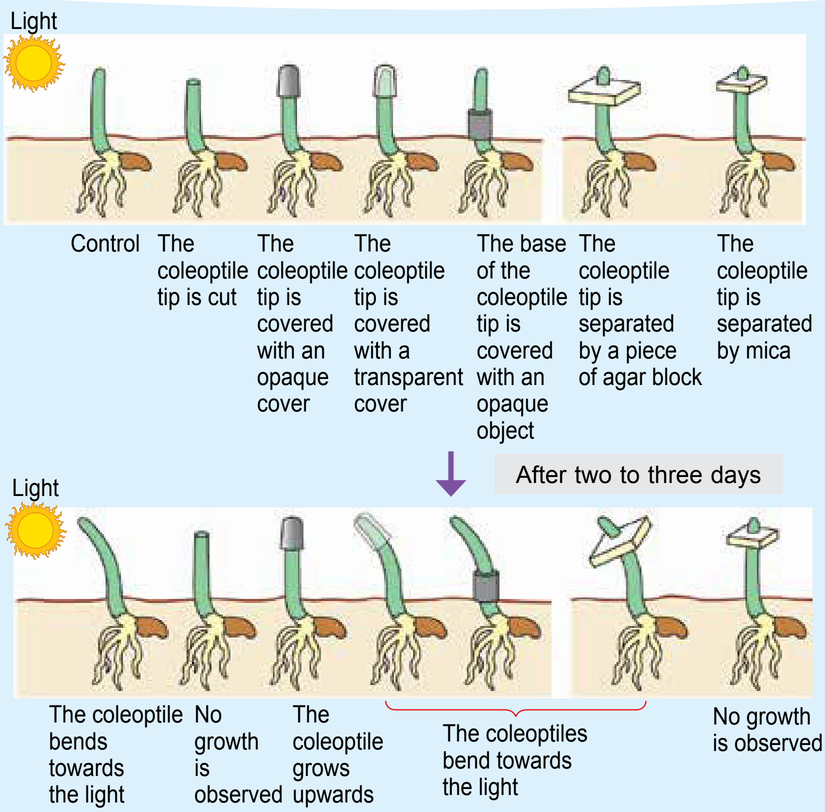


Figure 5.6 The role of auxin in the coleoptile tips on plant response based on phototropism

The Role of Auxin in Geotropism

Auxin also controls plant response to gravity. Seeds germinate horizontally in the soil. Due to the pull of gravity, auxin pools at the bottom side of the tips and roots. Roots grow downwards following the pull of gravity and exhibiting **positive geotropism**. Meanwhile shoots grow upwards against the pull of gravity, exhibiting **negative geotropism**. Figure 5.7 shows the role of auxin on geotropism at the tips of shoots and roots.

5.2.4

Bio Exploration

Uneven auxin distribution in tendrils allow tendrils to coil or wrap around an object. This response is known as thigmotropism.

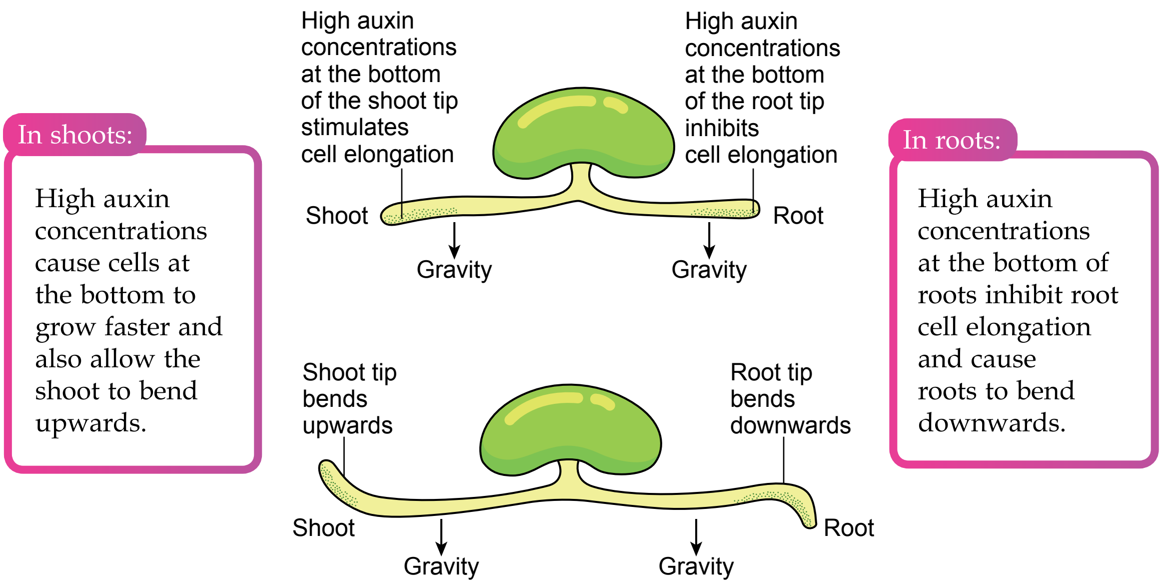


Figure 5.7 The role of auxin in shoot tips and root tips on plant growth response based on geotropism

EXPERIMENT 5.1 Responses of Radicles and Seedlings towards Gravity

Aim

To design an experiment to study the responses of radicles and seedlings towards gravity

Procedure

1. Work in groups.
2. Design an experiment to study the responses of radicle and plumule of a seedling towards gravitational pull.
3. Write a complete report that includes:

(a) Problem statement	(d) Variables	(g) Observation
(b) Aim	(e) Material and apparatus	(h) Discussion
(c) Hypothesis	(f) Procedure	(i) Conclusion

Formative Practice 5.2

1. Name **three** examples of phytohormones and state their functions.
2. How does auxin control shoot phototropism in the dark?
3. Mr. Farid who sells apples at a supermarket usually separates apples that are too ripe from those that are ripe. Justify his action.

5.3 Application of Phytohormones in Agriculture

Phytohormones are important chemicals that are directly involved in the development of flowers, fruits, stems and roots. Phytohormones can exist naturally or be synthesised in the laboratory. There are phytohormones that can be extracted for multiple purposes in agriculture. Figure 5.8 shows the application of phytohormones in the field of agriculture.

Auxin

- Encourages growth in crops
- Promotes root growth (asexual reproduction) on woody plant stems for horticultural crops
- Produces fruit without seeds via parthenocarpy
- Used as weed killer
- Induces dormancy in potatoes during storage or distribution
- Promotes growth of low-lying and lush plants

Gibberellin

- Treats mutated dwarf plants to grow to normal heights
- Promotes rapid elongation of flower stems
- Used to produce larger grapes
- Promotes germination of seeds such as salad, oats and tobacco during low temperatures and low light intensity

Cytokinin

- Tissue culture technique - promote division and differentiation of cells
- Tissue culture technique - used together with auxin to form plant organs such as roots and stems
- Used to delay leaf senescence in newly cut flowers

Abscisic acid

- Inhibits germination and growth

Ethylene

- Used commercially to promote maturation of fruit quickly and evenly
- Promotes simultaneous flowering in plants in the field

Bio Exploration

Bananas on trees are wrapped with waterproof straw sacks to speed up the ripening process using the ethylene gas that is trapped in the sacks.

Figure 5.8 Application of phytohormones in the field of agriculture

5.3.1

EXPERIMENT

5.2 Effects of Presence of a Phytohormone on Fruit Ripening

Problem statement
What are the effects of ethylene towards tomatoes?

Aim
To compare the effects of fruit ripening based on the presence or absence of ethylene

Hypothesis
Tomatoes ripen faster in the presence of ethylene.

Variable
Manipulated variable: Presence of ethylene
Responding variable: Ripening of tomatoes
Constant variables: Type of fruits, temperature

Materials: Paper bags, ripe banana, unripe tomatoes

PRECAUTIONS
Avoid using plastic bags as trapped moisture could lead to faster fruit spoilage.

Procedure
1. Prepare two paper bags and label them A and B.
2. Note the colour and condition of the tomatoes before placing them in the paper bags.
3. Fill the paper bags with the following:
   (a) Paper bag A: One unripe tomato
   (b) Paper bag B: One unripe tomato and one ripe banana
4. Seal the bags.
5. After 12 hours, observe and compare the changes in colours and conditions of the tomatoes in both bags.
6. Record your observations in the table below.

Results

Paper bag	Colour of tomatoes		Condition of tomatoes (hard/ soft)	
	At the beginning of the experiment	At the end of the experiment	At the beginning of the experiment	At the end of the experiment
A				
B				

Discussion
1. Which tomato ripens faster? Explain.
2. What is the purpose of the ripe banana in the experiment?
3. Explain the effects of ethylene gas on the tomatoes.

Conclusion
Is the hypothesis accepted? Suggest a suitable conclusion.

Formative Practice 5.3

1. State **one** application for each of these phytohormones in the field of agriculture.
   (a) Gibberellin
   (b) Cytokinin
   (c) Auxin

2. Based on the statement below, what is hormone X? Explain the role of hormone X when the surrounding temperature increases.

   > With hormone X, plants can retain their water content.

Memory Flashback

RESPONSE IN PLANTS

- Types of responses
  - Tropism
    - Thigmotropism
    - Geotropism
    - Hydrotropism
    - Phototropism
    - Chemotropism
  - Nastic
    - Photonasty
    - Seismonasty
    - Nyctinasty
    - Thermonasty
    - Thigmonasty
- Phytohormone
  - Definition of phytohormones
  - Types and functions
    - Auxin
    - Gibberellin
    - Cytokinin
    - Abscisic acid
    - Ethylene
  - Roles of auxins in responses
    - Phototropism
    - Geotropism
  - Application of phytohormones in agriculture

Interactive Bio 5

SELF-REFLECTION

Complete the following self-reflection to identify the important concepts that you have studied.

Important concepts	Very good	Try again
Types of plant responses, tropism and nastic		
Phytohormones and functions		
Effects of auxin on growth response		
Roles of auxin in phototropism and geotropism		
Application of phytohormones in agriculture		
Effect of fruit ripening in the presence of phytohormone (ethylene)		

Summative Practice 5

1. Figure 1 shows an experiment to study the response of the shoot tip and root tip of a seedling towards sunlight.

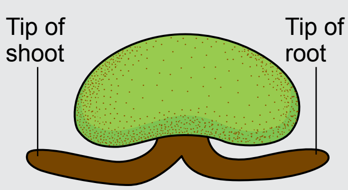


Figure 1

(a) Identify the response shown by the shoot tip and root tip towards light.

(b) On Figure 1, draw what is observed on the tips of shoot and root after several days of exposure towards light.

(c) Explain how the shoot tip can show the response drawn in 1(b).

(d) Using a plant tissue culture technique, a seed can produce many new shoots. These shoots are separated from the parent plant and moved to the new medium containing a full culture solution and particular phytohormone. In your opinion, how does the phytohormone stimulates the growth of the shoots into seedlings?

2. Figure 2 shows a technique to produce seedless fruits without pollination. This technique requires the use of phytohormone X.

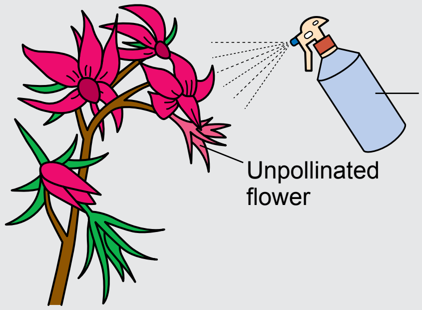


Figure 2

(a) Name this technique.

(b) Name **two** types of fruits that can be produced using the technique named in 2(a).

(c) Based on Figure 2, explain the technique you have mentioned in 2(a).

(d) Is fruit produced by using this technique beneficial for consumers? Explain your answer.

3. Ethylene is a phytohormone that exists in the form of gas, is odourless and invisible. Phytohormones control the ripening of plants.

(a) Mrs. Faridah placed an unripe key lime fruit together with a ripe banana in a closed container at room temperature.

(i) Justify Mrs. Faridah's decision to put both fruits in the same closed container.

(ii) Predict what would happen to the key lime. Explain your answer.

(iii) What will happen to the key lime fruit if the container is placed in the fridge? Explain your answer.

(b) Suggest a method that can be used on fruits bound for export to delay ripening during transport. Justify your suggestion.

21st Century Mind

4. Photograph 1 shows insect pollination in your fruit orchard. You find your yield to be contaminated by high concentrations of insecticide. As a farmer, explain how you can overcome this issue and the steps you can take to increase the quality of fruits in your orchard.

Photograph 1

Chapter 6

Sexual Reproduction in Flowering Plants

Chapter Exploration

- Structure of a Flower
- Development of Pollen Grains and Embryo Sac
- Pollination and Fertilisation
- Development of Seeds and Fruits
- Importance of Seeds for Survival

Learning Standards

Do You Know?

- What is the structure of a flower?
- How does the development of pollen grains and embryo sac occur?
- What is the importance of double fertilisation for the survival of flowering plants?
- Why are seeds important for plant survival?

Puya raimondii

Puya raimondii known as Queen of the Andes, is a species from the Bromeliad family which has been found growing in the highlands of Peru and Bolivia at an altitude of 3960 metres (Photograph 6.1). Its flower cluster emerges after the plant is aged between 80 to 150 years old.

The plant resembles a pineapple covered with sharp thorns. Every flower is white, with an estimated width of 5 cm. Besides, this plant has a bright orange anther to attract the pollinating agent, that is, the sunbird. Uniquely, this plant will die after producing flowers and seeds for reproduction.

Photograph 6.1
Puya raimondii plant

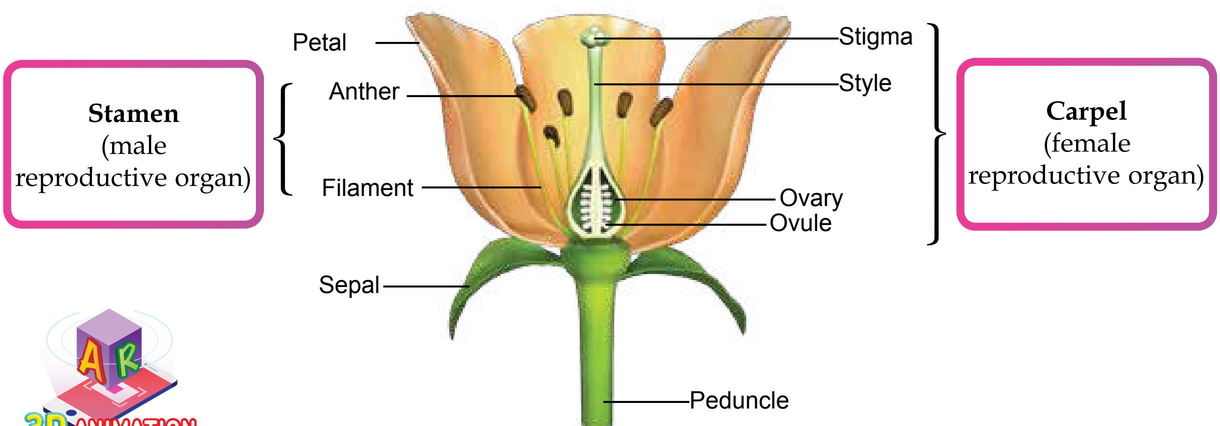
Keywords

- Petal
- Carpel
- Tetrad
- Microspore
- Megaspore
- Embryo sac
- Integument
- Funicle
- Nucellus
- Endosperm
- Dormant

6.1 Structure of a Flower

In general, flowers are the most distinctive organs in the angiosperms. The beauty and scent of flowers which have evolved, not only attract animals and insects, but also play a role in ensuring the survival of species. The flowers contain the plant reproductive structures.

Flowers contain both **male** and **female reproductive organs**. Besides, flowers also have structures called **peduncles, sepals** and **petals** (Figure 6.1).



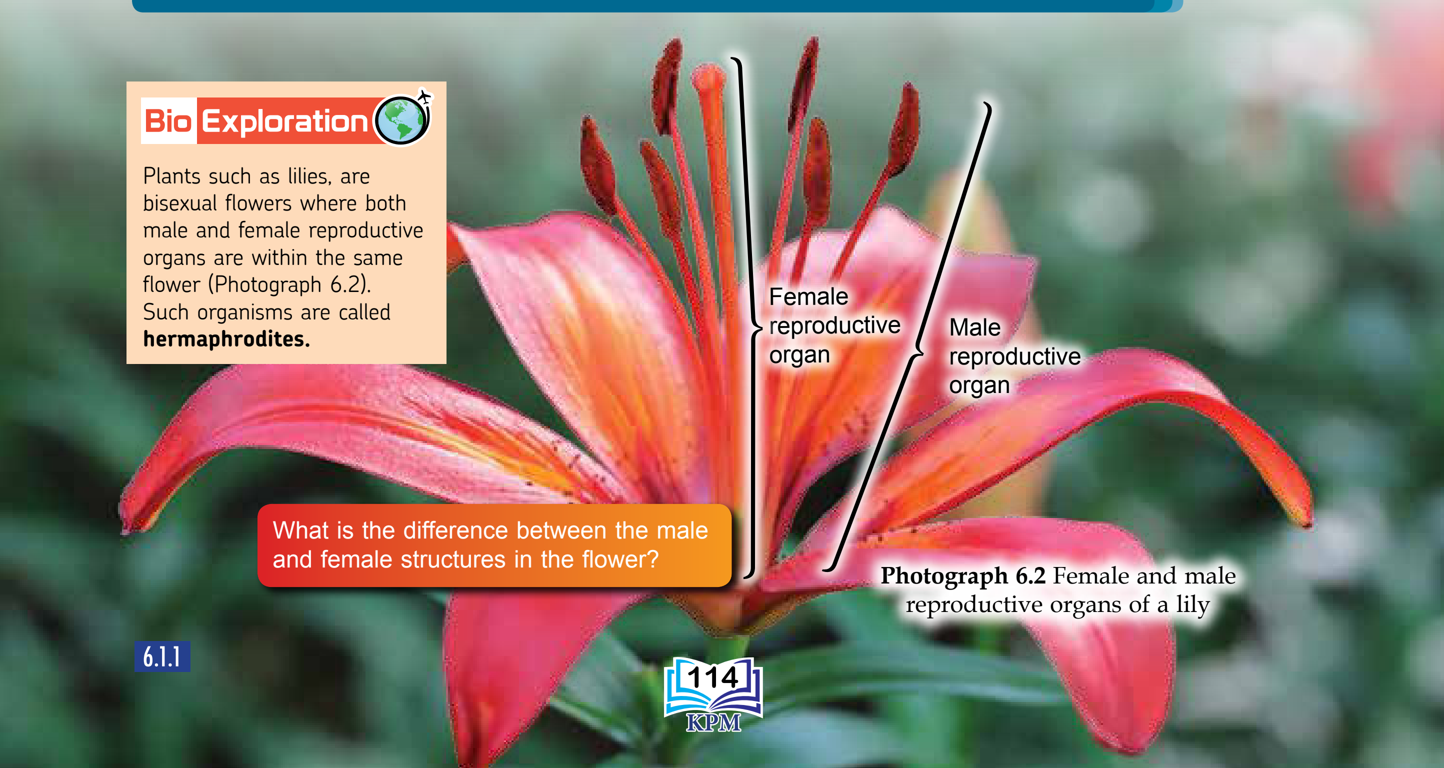
3D ANIMATION

Figure 6.1 Longitudinal section of a flower

Comparison between Male and Female Structures in a Flower

Bio Exploration

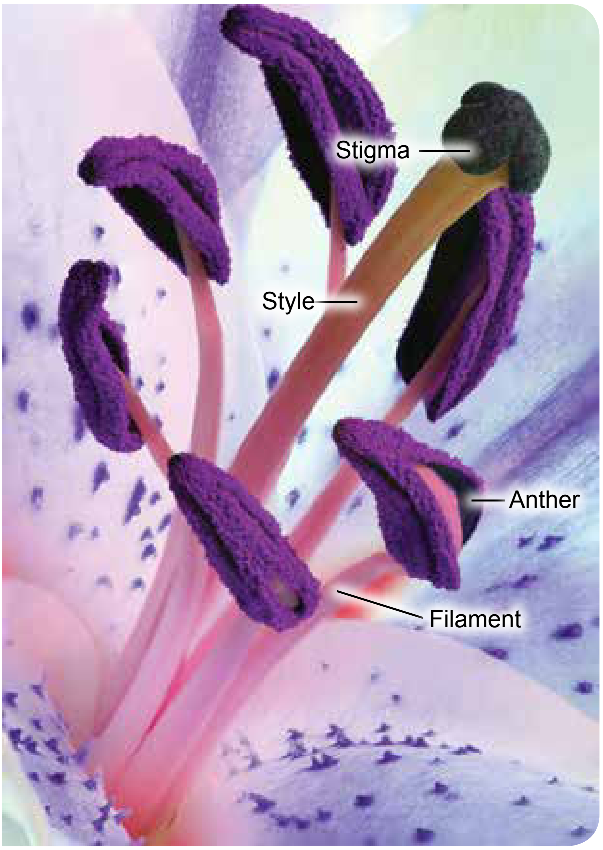
Plants such as lilies, are bisexual flowers where both male and female reproductive organs are within the same flower (Photograph 6.2). Such organisms are called **hermaphrodites.**



What is the difference between the male and female structures in the flower?

Photograph 6.2 Female and male reproductive organs of a lily

6.1.1



Photograph 6.3 Male and female flower parts

Table 6.2 Comparison between the male and female flower parts

Similarities	
Both produce gametes	
Both are located at the flower's organ	
Differences	
Male flower part	**Female flower part**
Consists of stamen	Consists of carpel
Has filament and anther	Has stigma, style and ovary
Produces pollen grains	Produces embryo sac
Projecting out from the base of the ovary	Located in the middle part of the flower

Bio Exploration

The number of stamens in a flower varies according to species. The rosary pea has a single stamen. The saguaro cactus in the Sonoran Desert, Arizona has the highest number of stamens, that is, 3482 stamens in a single flower.

Activity 6.1

Aim

To dissect a flower, draw and label the structures and state their functions

Material: *Hibiscus* sp.

Apparatus: Scalpel, magnifying glass

PRECAUTIONS

Be careful when using a scalpel.

Procedure

1. Prepare a fresh and large hibiscus.
2. Identify sepal, petal, stamen, carpel and peduncle.
3. Carefully cut the flower longitudinally from the peduncle to the stigma using a scalpel.
4. Identify and observe the internal structures such as the stigma, style and ovary using the magnifying glass.
5. Draw the longitudinal section of the flower and label the structures, which are the sepal, petal, anther, filament, stigma, style and ovary.

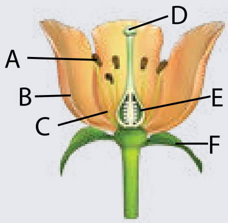
Discussion

1. Name the
   (a) male reproductive organ
   (b) female reproductive organ
2. State **one** feature of the petal. How is this feature related to its function?
3. Explain the position of stamens in a hibiscus flower. What is the importance of the position?

6.1.2

Formative Practice 6.1

1. The diagram below shows the structure of a flower.



(a) Label parts A - F.
(b) State the function of parts A - F.

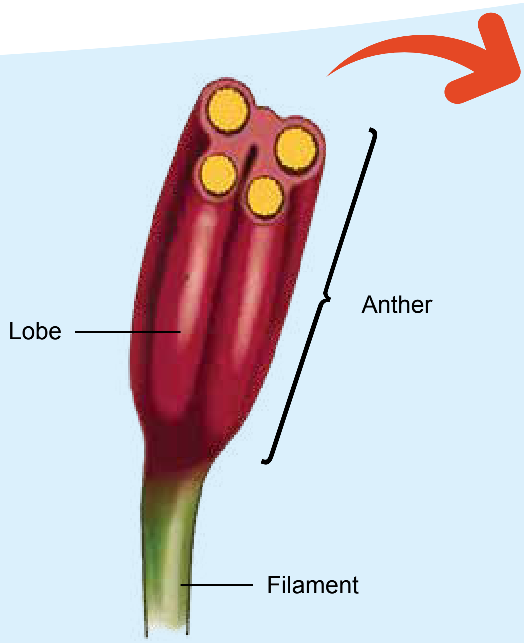
2. Why are stamens and carpels known as the reproductive organs of flowering plants?

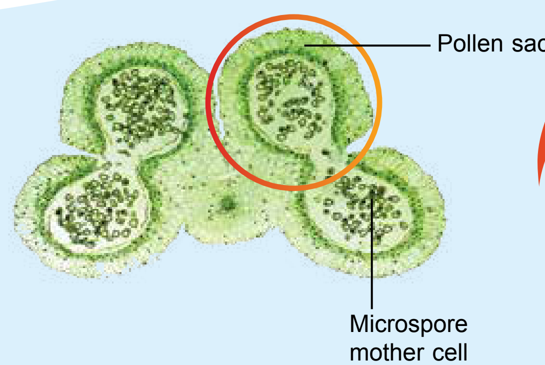
3. Compare male and female reproductive organs of flowers in terms of their:
(a) Names
(b) Structures that form them
(c) Functions

6.2 Development of Pollen Grains and Embryo Sac

The Formation of Pollen Grains in an Anther

The part of a flower that produces pollen grains is the **anther.** How are pollen grains produced? Figure 6.3 shows the development of pollen grains.





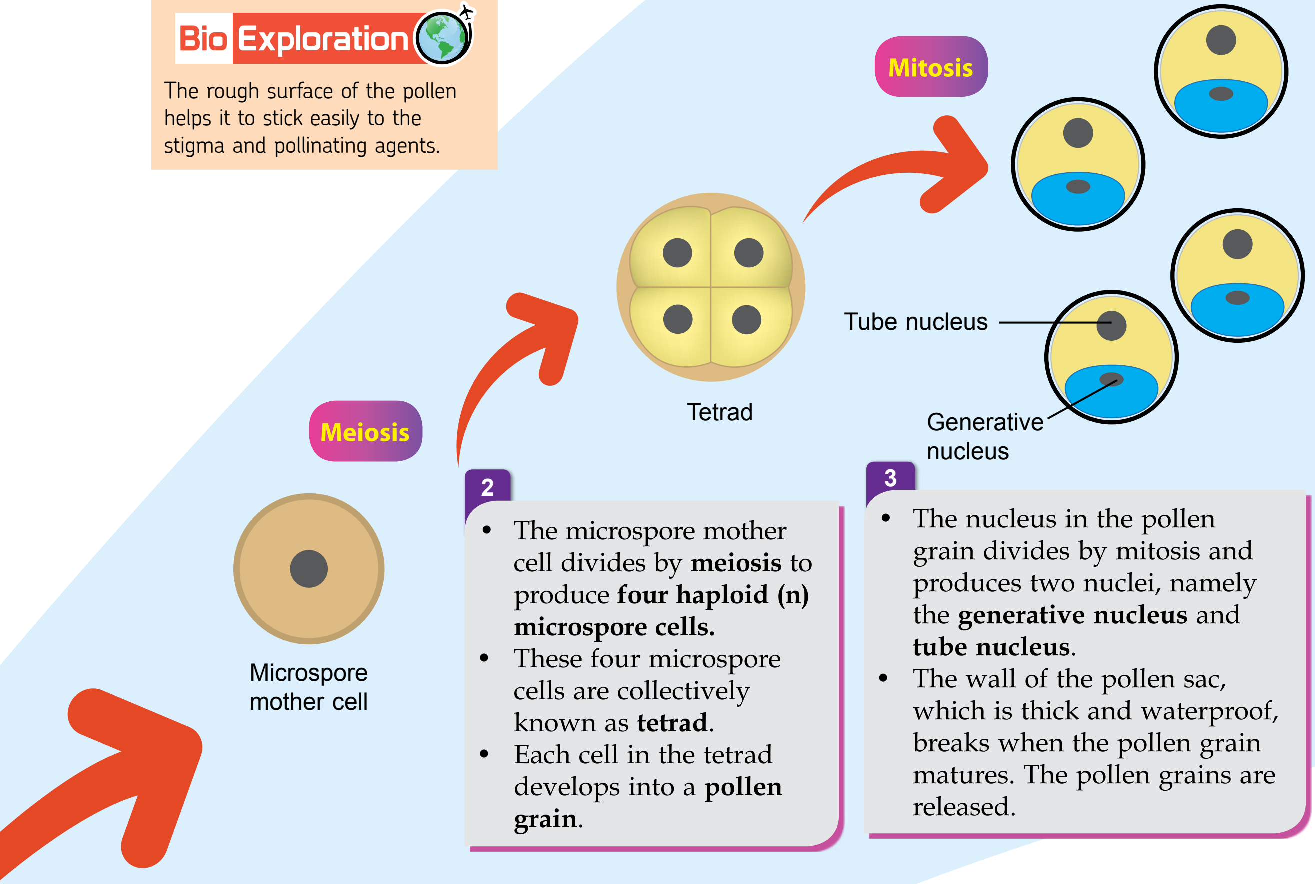
1

- During the development of anther, a group of tissues grows inside each **lobe** to form **four pollen sacs**.
- In each pollen sac, there are hundreds of pollen mother cells, called **microspore mother cells** which are **diploid (2n)**.

6.2.1

Bio Exploration

The rough surface of the pollen helps it to stick easily to the stigma and pollinating agents.



2

- The microspore mother cell divides by **meiosis** to produce **four haploid (n) microspore cells.**
- These four microspore cells are collectively known as **tetrad**.
- Each cell in the tetrad develops into a **pollen grain**.

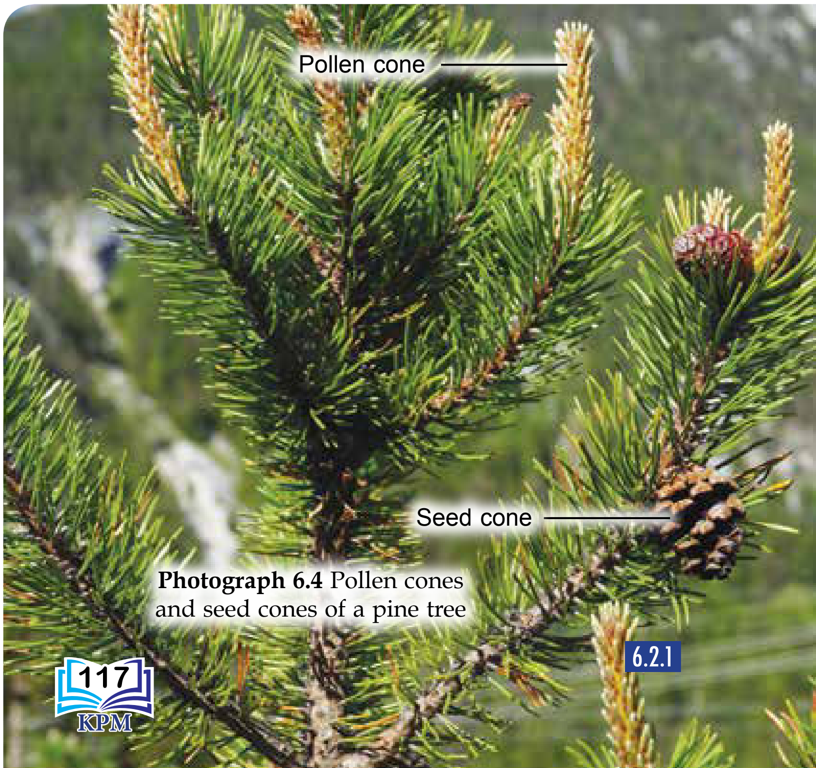
3

- The nucleus in the pollen grain divides by mitosis and produces two nuclei, namely the **generative nucleus** and **tube nucleus**.
- The wall of the pollen sac, which is thick and waterproof, breaks when the pollen grain matures. The pollen grains are released.

Figure 6.3 Development of the pollen grain

Bio Exploration

Plants of the gymnosperm phylum, such as the pines and fir do not have flowers. However, these plants produce pollens through structures called cones. There are two types of cones, namely the pollen cone, which is the male reproductive part and the seed cone, which is the female reproductive part. The seed cone is larger than the pollen cone. The pollen cone has scale-like structures that produce pollen grains. Normally, both pollen cones and seed cones are produced on the same tree (Photograph 6.4).



Photograph 6.4 Pollen cones and seed cones of a pine tree

6.2.1

Activity 6.2

Aim

To prepare and observe the slide as well as describe the shape of pollen grains of various plants through a light microscope

Materials

Anthers of various types of flowers, 3% sucrose solution

Apparatus

Forceps, light microscope, cavity glass slide, cover slip, dropper

Procedure

PRECAUTIONS

Nail polish can be applied to the sides of the cover slip to prevent the slide from moving.

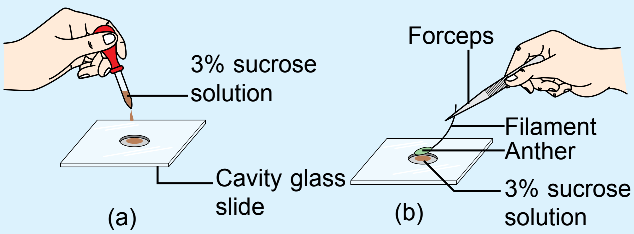


Figure 6.4 Set-up of a pollen grain slide

1. Add a few drops of 3% sucrose solution to the cavity glass slide (Figure 6.4 (a)).
2. Obtain some pollen grains from a mature anther by using the forceps. Drop the pollen grains onto the 3% sucrose solution (Figure 6.4 (b)).
3. Place the cover slip over the cavity on the slide and leave it aside for 3 minutes.
4. Observe the slide under the light microscope using low power objective lens.
5. Repeat steps 1 to 5 using pollen grains from different plants.
6. Draw a diagram of the observed structure of the pollen grains.

Discussion

1. Why does this activity use
   (a) cavity glass slides?
   (b) 3% sucrose solution?
2. Based on your sketch, state the name of the plant, the features of the pollens and the importance of these features.

Bio Exploration

Wind, animals and insects are pollinating agents that help in transferring pollen. Small, smooth and light pollens are transferred by wind. Examples of wind-pollinated flowers are corn, grass and paddy. Pollens that are carried by animals and insects are rough and sticky. Examples of animal-pollinated flowers and insect-pollinated flowers are rambutan, durian, papaya, rose, sunflower and hibiscus (Photograph 6.5).

(a) (b)

Photograph 6.5
(a) Example of insect-pollinated flower and **(b)** example of wind-pollinated flower

The Formation of Embryo Sac in an Ovule

Ovules are structures of a flower formed inside the carpel. Ovules develop from a layer of tissues inside the ovary. A single ovary may contain one or more ovules (Figure 6.5). The ovule attaches to the ovary wall through a stalk called the **funicle**. The area of attachment of the funicle to the ovary is called the **placenta**. The placenta supplies nutrients to the ovule through the funicle. A mass of tissues inside the ovary develops forming a lump called **nucellus**. The nucellus consists of parenchyma tissue.

The nucellus tissue develops into two layers called the **integument**. At the end of the integument, there is a little opening, called the **micropyle** which allows the entry of air and water into the seed during germination. One of the nucellus cells is the **megaspore mother cell** or also known as the **embryo sac mother cell** which will develop to form an embryo sac (Figure 6.6).

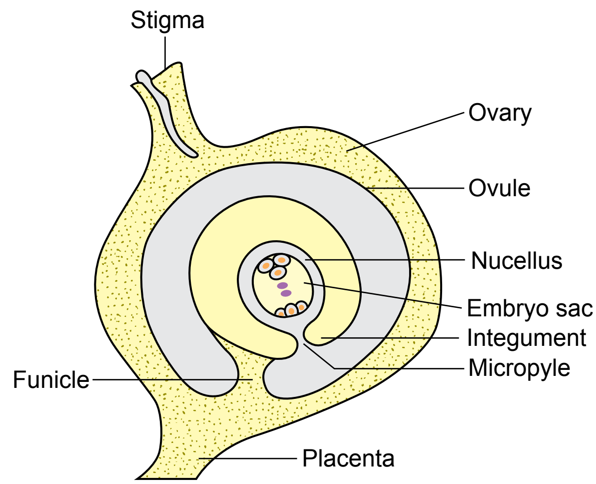
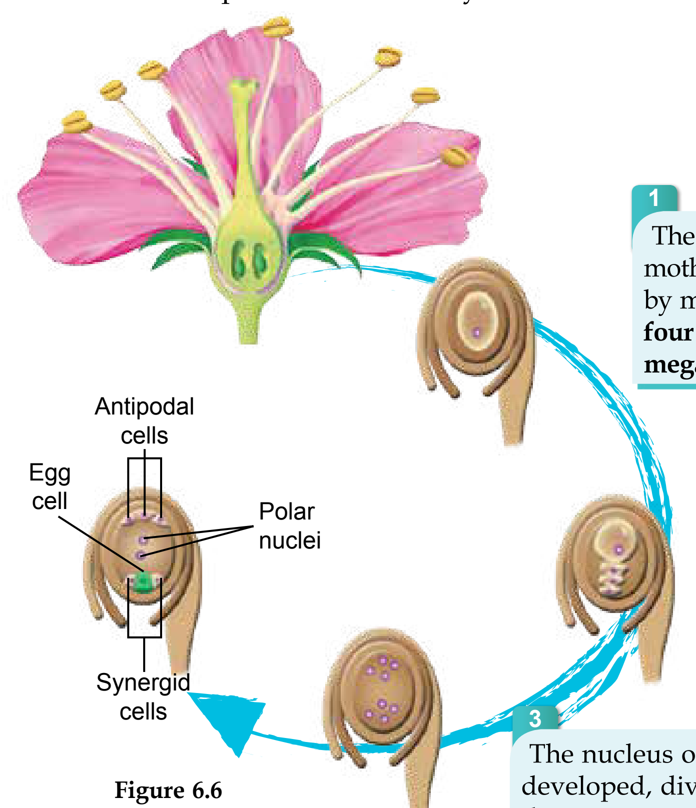


Figure 6.5 Structure of a mature ovule



1
The megaspore mother cell (2n) divides by meiosis to produce **four haploid (n) megaspore cells**.

2
Three of the megaspore cells degenerate and only **one megaspore cell** develops.

3
The nucleus of the cell that has developed, divides mitotically three times to produce a cell with **eight nuclei**.

4
- Three nuclei move to one end of the embryo sac to form **three antipodal cells**.
- Another three nuclei move to the opposite end of the embryo sac and form **two synergid cells** and one **egg cell**.
- Two nuclei in the centre of the embryo sac form the **polar nuclei**.

Figure 6.6 Development of the embryo sac

6.2.2

Activity 6.3

21st CENTURY SKILLS: THREE STRAY ONE STAY

Aim

To construct a mind map that shows the stages in the formation of pollen grains and embryo sac

Materials

Mahjong paper, marker pens of various colours

Procedure

1. Work in groups.
2. Construct a mind map on the mahjong paper to show the formation of:
   (a) Pollen grains from microspore mother cell
   (b) Embryo sac from megaspore mother cell
3. Display your work on the laboratory table.
4. Conduct the presentation using Three Stray One Stay method.

Formative Practice 6.2

1. Name the cell that differentiates to form:
   (a) Pollen grains in the anther
   (b) Embryo sac in the ovary
2. In the formation of pollen grains, the nucleus in the pollen will divide by mitosis to form two nuclei. Justify.
3. What is the importance of meiosis in the formation of pollen grains and cells of the embryo sac?
4. After the formation of embryo sac is completed, this cell contains eight nuclei. Name the nuclei.

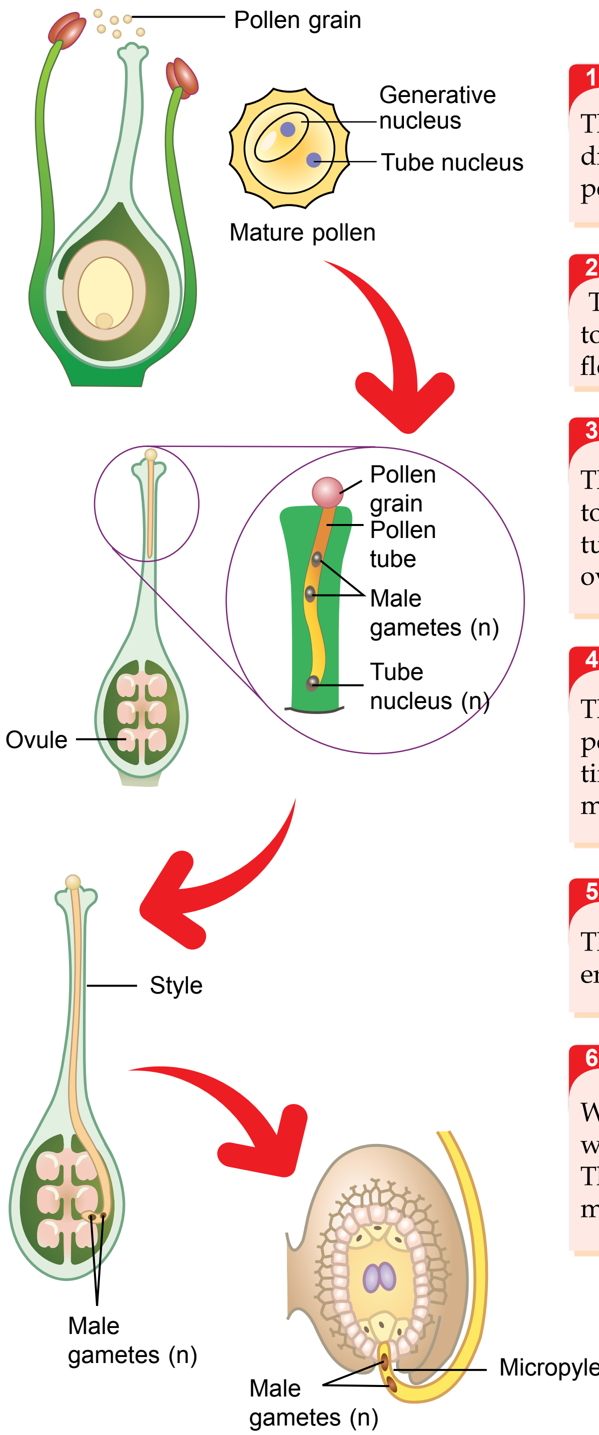
6.3 Pollination and Fertilisation

The process in which pollen grains are transferred from the anther to the stigma is known as **pollination**. This process is assisted by pollinating agents such as **insects, mammals, birds, water** or **wind** (Photograph 6.6). The presence of pollen grains on the stigma triggers the **process of fertilisation**.

Photograph 6.6 Pollination assisted by bees

6.2.2

Figure 6.7 shows the formation of pollen tube and male gametes.



1 The wall of anther from mature pollen will dry, shrink dan split. Pollen grains in the pollen sac are released.

2 The released pollen grains are transferred to the stigma of the same flower or different flowers by pollinating agent.

3 The pollen grains that have been transferred to the stigma will germinate and form a pollen tube. The pollen tube grows down towards the ovule through the style.

4 The generative nucleus will move along the pollen tube towards the ovule. At the same time, the generative nucleus will divide by mitosis to form two male gametes (n).

5 The end of the pollen tube will secrete an enzyme to digest the tissues of the style.

6 When it reaches the embryo sac, the pollen tube will penetrate the ovule through the micropyle. The tube nucleus will degenerate and both male gametes enter the embryo sac.

Figure 6.7 Formation of pollen tube and male gametes

6.3.2

Activity 6.4

Aim

To carry out an activity to observe the germination of pollen grains and formation of pollen tubes in a sugar solution under a light microscope

Materials: 10% sucrose solution, distilled water, acetocarmine stain solution, fresh flowers such as balsam, hibiscus or allamanda, filter paper

Apparatus: Cavity glass slides, cover slip, forceps, mounting needle, dropper, light microscope

Procedure

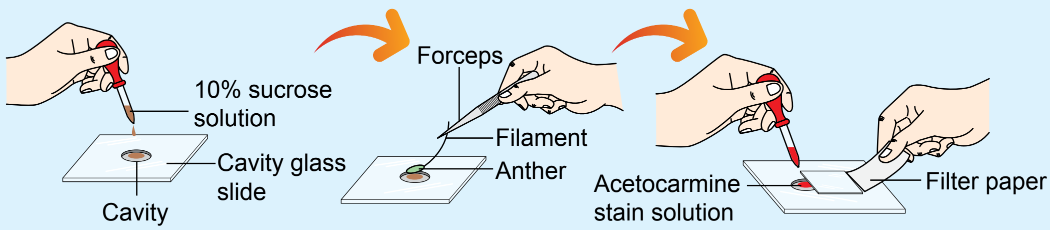


Figure 6.8 Set-up of apparatus to observe the germination of pollen grains

1. Prepare a clean cavity glass slide. Using a dropper, place two drops of 10% sucrose solution onto the surface of the slide.
2. Take a fresh flower with anther that has many pollen grains.
(Note: Pollen grains are the powdery substances on the anther)
3. Dip the anther into the drops of 10% sucrose solution that has been placed in the cavity of the slide.
4. Cover the specimen with the cover slip gently using the mounting needle to prevent the formation of air bubbles.
5. Observe the slide under the light microscope using low power objective lens to obtain the preliminary observation on the shape of the pollen grain.
6. Sketch your observation.
7. Leave the slide in a dark place at room temperature for 20 minutes.
8. Once again observe the slide under the light microscope using low power objective lens to observe the pollen grain that has germinated and formed a pollen tube.
9. Place a drop of acetocarmine stain solution on one end of the cover slip on the slide. By placing a filter paper at the opposite end, let the stain solution diffuse across the cover slip to stain the specimen underneath.
10. Once again using the slide that has been stained under the light microscope, observe the tube nucleus and generative nucleus in the pollen tube.
11. Draw and label a diagram to show the pollen grain before and after the formation of the pollen tube.

Discussion

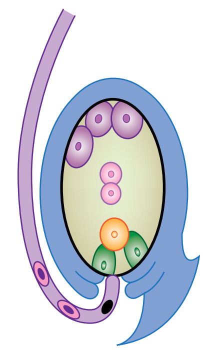
1. What is the need to use fresh flowers in this experiment?
2. Describe the specific shape and characteristics of the pollen grain you observed under the microscope.
3. A group of students did not follow the correct procedure. They did not use the 10% sucrose solution, instead they used distilled water. Predict the result obtained by them.
4. Another group of students forgot to stain the specimen by using the acetocarmine stain solution. State the problems they may have.

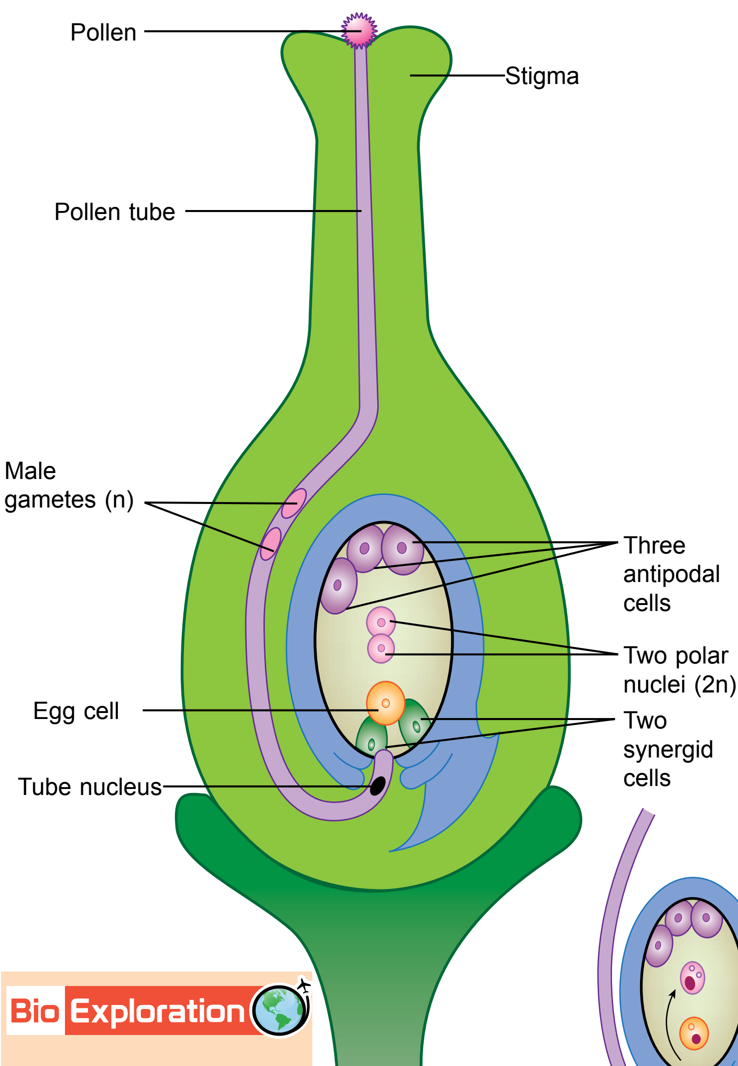
6.3.3

Double Fertilisation in the Formation of Diploid Zygote and Triploid Nucleus

Double fertilisation involves two male gametes, in which the first male gamete fertilises the egg cell to form a diploid zygote whereas the second male gamete fuses with polar nuclei to form a triploid endosperm tissue.

As discussed previously, the generative nucleus undergoes mitosis in the pollen tube to produce two male gametes which are haploids. Thus, both male gametes will enter the embryo sac for fertilisation (Figure 6.9).





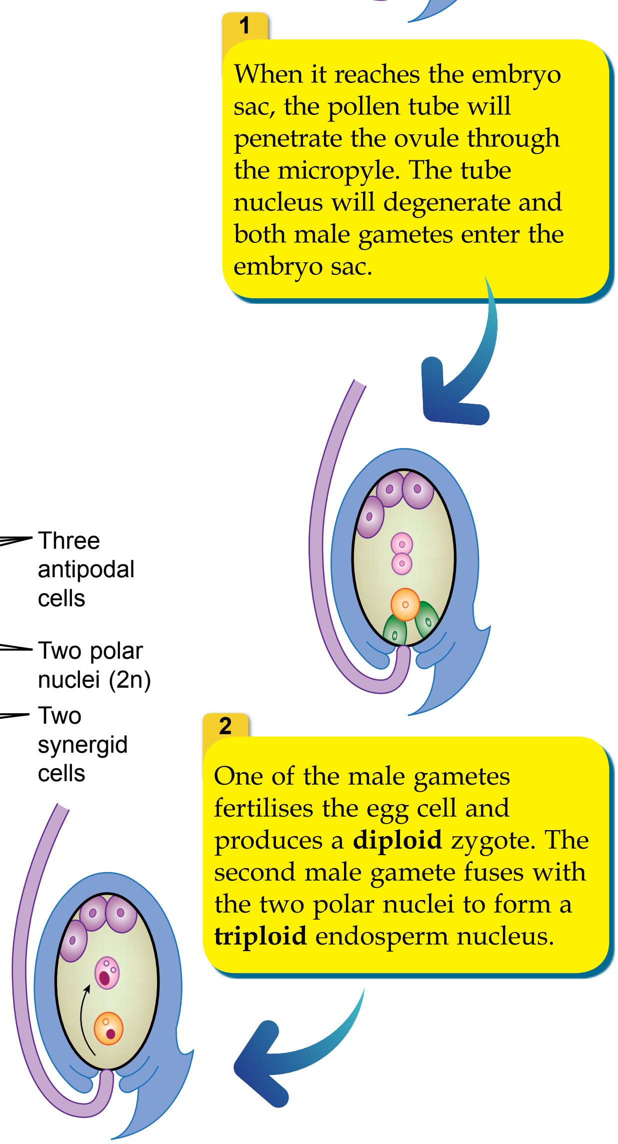


Figure 6.9 Double fertilisation in flowering plants

Bio Exploration

Starch obtained from grains such as wheat, rice, barley and corn is the endosperm tissue formed from double fertilisation.

6.3.3

Importance of Double Fertilisation for the Survival of Flowering Plants

1. The fusion of one of the male gametes with the egg cell produces a **zygote**.
   (a) Genetic information is passed down from one generation to the next.
   (b) Restores **haploid** condition in gametes with the formation of the diploid zygote.
2. The fusion of another male gamete with **two polar nuclei** produces **endosperm tissue**.
   (a) This tissue is used for the development of an embryo for the survival of plant species.
   (b) In eudicots such as legumes, mangoes and mustard, the endosperm is fully utilised by the embryo to develop before the seed matures.
   (c) In most monocots such as coconut, wheat, barley and corn, only a part of the endosperm is utilised for the development of an embryo. Some of them are stored in the cotyledon to be utilised during the germination of the seed. The **endosperm tissue** enables the embryo to survive in the seed for a long time if conditions are not favourable for germination to occur.

Activity 6.5

21st CENTURY SKILLS

21st CENTURY SKILLS MIND MAP

Aim
Explain double fertilisation by using a mind map.

Material
Manila card, mahjong paper, coloured pencils

Procedure
1. Work in groups.
2. Construct a mind map on a mahjong paper. The mind map should include:
   (a) The formation of two male gametes from the generative nucleus
   (b) The formation of triploid endosperm nucleus
   (c) The formation of zygote
3. Present your mind map to the class.

Formative Practice 6.3

1. What is meant by pollination?
2. Pollination is very important to ensure that reproduction in flowering plants occurs successfully. Explain.
3. During the formation of pollen grain, the microspore mother cell divides by meiosis and produces tetrad. State the features of the tetrad and the importance of such features.
4. The generative nucleus divides by mitosis in the pollen tube. State the importance of this process.
5. The megaspore cell contains eight nuclei. How does this occur?
6. State the role of double fertilisation in ensuring the survival of flowering plants.

6.3.4

Photograph 6.6 Development of tomato seeds and fruits after fertilisation .

6.4 Development of Seeds and Fruits

Double Fertilisation and Development of Seeds and Fruits

After double fertilisation occurs, the triploid endosperm nucleus divides by mitosis and form the endosperm tissue. The endosperm tissue is the food storing tissue which surrounds and supplies nutrients to the embryo.

The zygote divides by mitosis to form two cells, a larger cell and a smaller cell. The larger cell develops into a **suspensor** that anchors the embryo to the wall of the embryo sac. The smaller cell will become an embryo that consists of **plumule, radicle** and **cotyledon** (Figure 6.10).

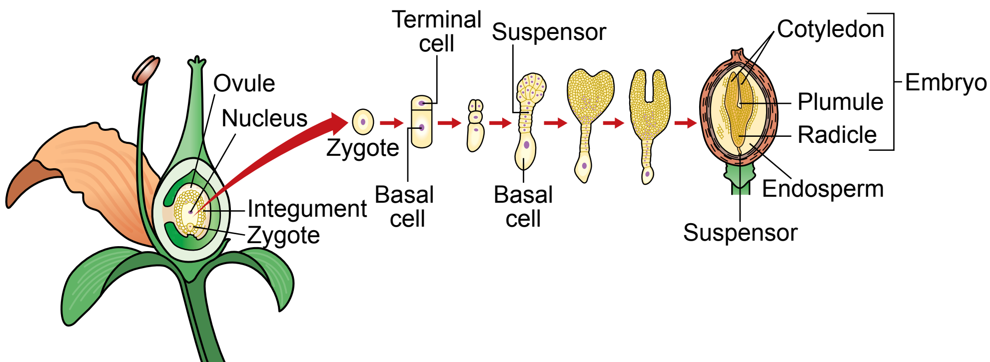


Figure 6.10 Development of an embryo

The **ovule** develops to become the **seed** in the fruit. The integument becomes two layers of seed coat that serves to protect the embryo. During the development of ovule and seed, the **ovary** develops into a **fruit**. Other flower parts such as the stigma and style degenerate and leave a scar on the ovary wall (Figure 6.11 and Photograph 6.6). The ovary wall becomes the pericarp of the fruit which consists of the **exocarp**, **mesocarp** and **endocarp**.

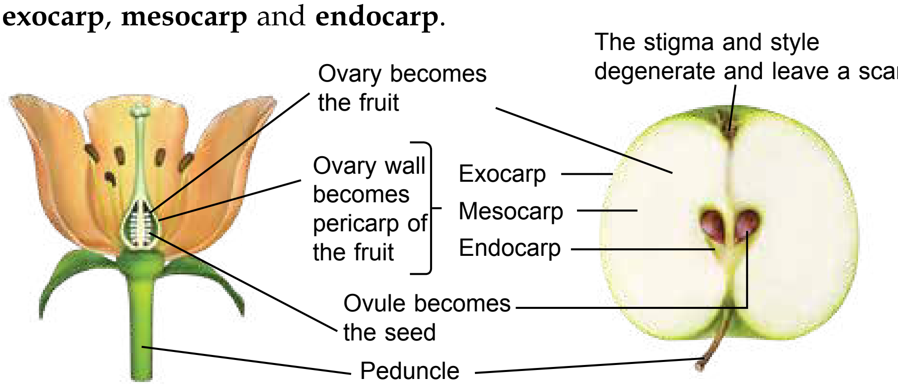


Figure 6.11 Development of the ovary into a fruit after fertilisation

6.4.1

Activity 6.6

Aim
To observe the structure of a fruit and relate it to the structure of the flower

Material
Papaya, female flower of papaya

Apparatus
Sharp knife, magnifying glass, dissecting tray

PRECAUTIONS
Be careful when using a knife.

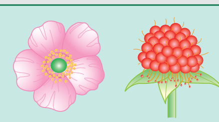
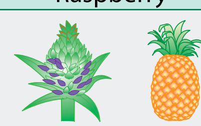
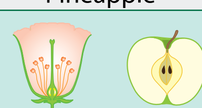
Procedure
1. Make a longitudinal cut in the papaya flower by using a sharp knife.
2. Place the cut papaya flower on the surgical tray.
3. Identify the parts of the papaya flower such as ovary, ovary wall, ovule and peduncle by using a magnifying glass.
4. Repeat steps 1 to 3 for the papaya fruit.
5. Identify the fruit parts which correspond to the parts inside the flower.
6. Draw the longitudinal section of the flower and fruit and label the parts such as the ovary, ovary wall, ovule, fruit pericarp, seed, and peduncle.

Discussion
1. Name the structure that forms the:
   (a) Fruit (b) Seed
2. Name the parts of the fruit that can be eaten.

Activity 6.7

Aim
To collect specimens to study the types of fruits

Procedure
1. Work in groups.
2. Study the information below about the types of fruits.

Types of fruits	Examples
Simple fruit The fruit develops from a single carpel or several carpels fused together in a single flower.	 Peas
Aggregate fruit The fruit develops from numerous carpels in a single flower.	 Raspberry
Multiple fruit The fruit develops from carpels of a cluster of flowers.	 Pineapple
Accessories fruit The fruit develops from a tissue that is not in the ovary but from some tissues near the carpel.	 Apple

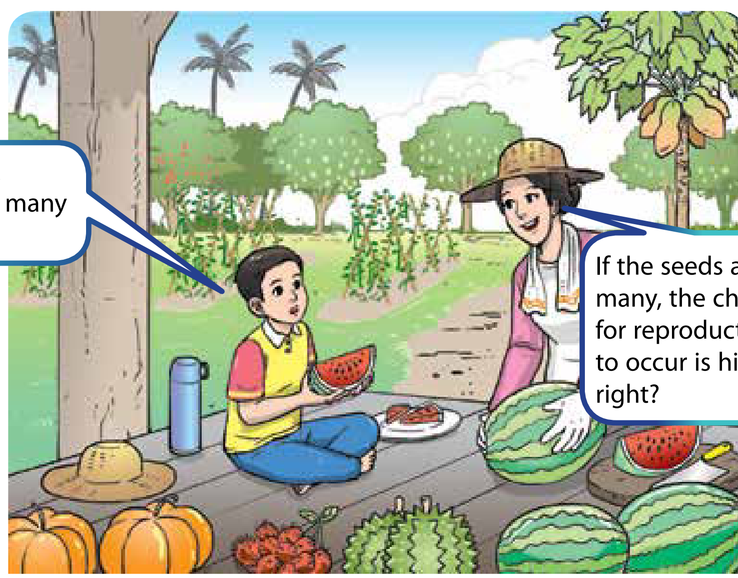
3. Based on the above information, give an example of each type of fruit.

4. Study the fruits and identify:
   (a) The number of fruits in each stalk
   (b) The size of the fruit
   (c) The number of flowers that forms it
5. Present the findings of your group.

Formative Practice 6.4

1. After fertilisation occurs between the male gamete and the egg cell, the zygote produced undergoes mitosis forming two cells. Explain.
2. State the structure of the seed which enables it to be stored for a long time before it germinates.
3. What is the function of the suspensor in the development of seeds?
4. What is the difference between the plumule and radicle which are structures forming an embryo in a seed?
5. The exocarp is said to protect fruits from spoiling. Justify.

6.5 Importance of Seeds for Survival



Think Smart

What are human actions that aid in the dispersal of seeds?

6.5.1

Seeds are the structures used to replant most angiosperms to maintain the survival of plant species. Seeds have specific features to increase the chances of reproduction. (Figure 6.12).

Importance of seeds for plant survival

- Seeds contain embryo that germinate to form seedlings.
- Inside the seeds, the endosperm tissue or cotyledon is the source of nutrients to supply energy when germination occurs.
- Seeds are enclosed by the testa which is strong and water impermeable to prevent the seeds from spoiling.
- Seeds can form a dormant structure which enables the seeds to be stored for a long time.
- Seeds have special features such as light, have spongy tissue, strong and do not spoil easily. Features like these are important so that the seeds are easily dispersed to another place to avoid competition.

Figure 6.12 Importance of seeds for plant survival

Formative Practice 6.5

1. Why are seeds important to ensure that plant species are not extinct?
2. Explain the following statements.
   (a) There are cotyledons inside a seed
   (b) Some plants have a very large number of seeds
3. Why does asexual reproduction produce crops of lesser quality compared to sexual reproduction through seeds?

Memory Flashback

SEXUAL REPRODUCTION IN FLOWERING PLANTS

- Structure of a flower
  - Male reproduction organ (stamen)
    - Anther
    - Filament
  - Female reproduction organ (carpel)
    - Stigma
    - Style
    - Ovary
- Development of pollen grains in the anther
  - Microspore mother cell
  - meiosis
  - 4 microspore cells
  - Nucleus undergoes mitosis
  - Pollen grain with 2 nuclei
- Development of embryo sac in the ovule
  - Megaspore mother cell
  - meiosis
  - 4 megaspore cells (3 develop, 1 degenerates)
  - Nucleus undergoes mitosis three times
  - Embryo sac cell with 8 nuclei
- Pollination and fertilisation
  - Pollination
  - Development of pollen tube
  - Double fertilisation
- Development of seeds and fruits
  - Relation of structure of seeds to ovules
  - Relation of structure of fruits to ovaries
- Importance of seeds for survival

Interactive Bio 6

SELF-REFLECTION

Complete the following self-reflection to identify the important concepts that you have studied.

Important concepts	Very good	Try again
Structure of a flower		
Comparison between male structure and female structure		
Formation of pollen in the anther		
Formation of embryo sac in the ovule		
Pollination		
Formation of pollen tube and male gametes		
Double fertilisation in the formation of diploid zygote and triploid nucleus		
The importance of double fertilisation in the survival of flowering plants		
Double fertilisation with the development of seeds and fruits		
Relation of structure of seeds to ovules		
Relation of the structure of fruits to ovaries		
The importance of the seeds for plant survival		

Summative Practice 6

1. The stigma secretes a sugary solution called nectar. What is the importance of the solution?
2. The formation of pollen grains involves the division of cells by meiosis and mitosis. State the importance of both processes.
3. In some species, the petals are not included in the reproductive structure of the flower, but they are very important in ensuring that reproduction occurs. Why?
4. Flower X is pollinated by insects. State the position of the anther and stigma of the flower. Explain your answer.

5. *Lalang* produces dull-coloured flowers without nectar. However, it is very easy for this plant to reproduce. Explain.

6. Mr. Suresh is a farmer who grows long beans. Mr. Suresh often lets the fruits from some of the trees to mature and dries them to make seeds. Suggest **one** way to store the seeds so that they last longer.

7. A tree has produced two flowers. However, the tree was attacked by a type of fungus that damaged the structure of its stigma. This has disrupted the division of the generative nucleus in the style. In your opinion, can this tree produce fruits and seeds? Explain.

8. Figure 1 shows the conversation between Salina and Liza.

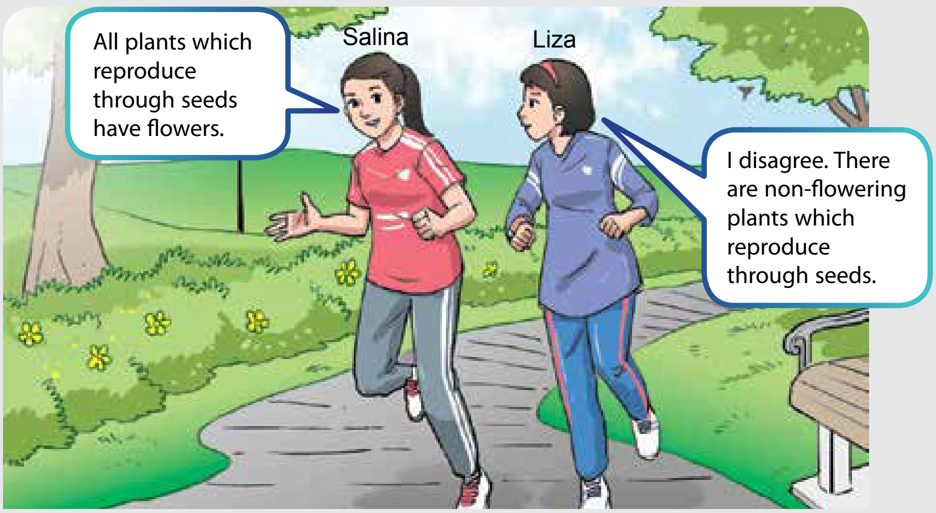


Figure 1

Do you support the opinion of Salina or Liza? Explain.

21st Century Mind

9. Mr. Samad has been cultivating strawberries in the lowland area. He does the cultivation in a greenhouse to ensure his crops thrive so that the temperature can be lowered from 25 °C to 18 °C. Unfortunately, the strawberry trees bear very few fruits. According to an agricultural officer who came for a visit, the pollination process by insects rarely occurs in the greenhouse. What are the suggestions that can be given to Mr. Samad to overcome the problem?

Chapter 7

Adaptations of Plants in Different Habitats

Chapter Exploration

- Adaptations of Plants

Learning Standards

Do You Know?

- Why do plants need to adapt themselves to the environment?
- What are the problems faced by plants that live in the desert?
- What are the adaptive features of plants that live on land and in the water?
- How can plants adapt themselves to the changes in their habitats?

The Uniqueness of Terrarium

Terrarium is the name of a transparent glass container to keep small plants or terrestrial animals. Terrarium is a combination of two words, namely 'terra' and 'rium'. 'Terra' means plant, while 'rium' means glass container.

This glass container is often decorated with pebbles, charcoal, soil, succulent plants, cacti and moss as its main medium. Terrarium creates an ecosystem as similar as possible to the environment or natural habitat. The glass is closed to prevent loss of moisture. Therefore, terrarium requires minimum maintenance due to the existence of the natural water cycle (Photograph 7.1).

Photograph 7.1 Terrarium

Keywords

- Adaptation
- Halophyte
- Hydrophyte
- Lenticel
- Mesophyte
- Xerophyte
- Aerenchyma tissue
- Pneumatophore

7.1 Adaptations of Plants

Adaptation is the adjustment of an organism to the environment. All organisms adapt. Animals and plants have unique structures and shapes to adapt to the environment to ensure the survival of the species. For a plant, this adaptation can be observed in the shape of its leaves, roots, and stem, to adjust itself to live in its habitat. Photograph 7.2 shows examples of plants that live in different habitats. Can you explain the adaptation of the plant in its habitat?

Photograph 7.2 Some examples of plants adapting to different habitats

Classifications of Plants based on Habitats

Try to list some unique features of plants that can be observed around you. Why do the plants you named need those characteristics? Plants in different habitats have different adaptations. Therefore, plants can be classified into **mesophytes, hydrophytes, halophytes,** and **xerophytes** (Figure 7.1).

ACTIVITY ZONE

Collect information about plant classification based on their adaptations in habitats.

7.1.1

Classification of Plants based on Habitats

Halophytes
- Plants that live in swampy habitats at the river mouth, the meeting point of fresh water and seawater. This swampy area is rich in salt content.
- Example: Mangrove tree

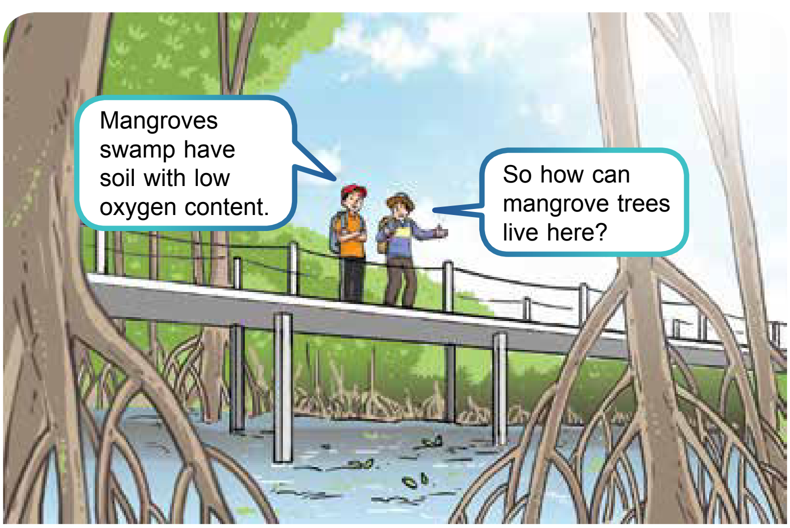
Hydrophytes
- Plants that live in aquatic habitats, either on the water surface or submerged in the water.
- Examples: Lotus and *Elodea* sp.

Mesophytes
- Plants that live in a habitat that is not too dry nor too wet with an adequate supply of water.
- Most plants are mesophytes.
- Example: Mango tree, hibiscus plant and rubber tree

Xerophytes
- Plants that live in a habitat that is hot and dry with a minimum presence of water, that is, a place with very high temperatures such as the desert.
- Example: Cactus and date palm

Figure 7.1 Classification of plants based on habitats

Adaptive Features of Hydrophytes, Halophytes and Xerophytes



7.1.1 7.1.2

Adaptive Features of Halophytes

Halophytes are plants that can live in a habitat with high **concentration of salt** and low **oxygen content**. Mangrove trees are an example of **halophytes**. Mangrove trees that live here have specific adaptive features to adapt to the environmental conditions. This area is also exposed to high **intensity of light** (Figure 7.2).

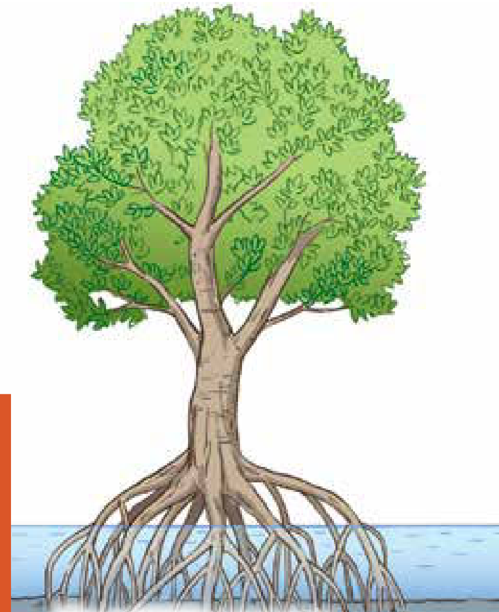


Figure 7.2 Mangrove tree

Leaves

- Leaves with thick cuticle and sunken stomata can reduce the rate of transpiration.
- Succulent leaves can store water.
- Leaves with a special structure known as hydatode eliminate excess salt.
- Old leaves can store salt and fall off when the concentration of salt stored is too high.

Roots

- The root system that branches widely and exists in various shapes and sizes:
  - ➢ Provides support for the plants to continue living in the soft and muddy soils.
  - ➢ Prevents plants from being uprooted due to strong wind.
- The root system of mangrove trees also produces hundreds of breathing roots that grow vertically upwards above the surface of the soil, called **pneumatophores**.
- There are many pores on this root which are called **lenticels** to enable the exchange of gases with the atmosphere.
- The cell sap of mangrove roots has a higher salt content than sea water. Hence, the cell sap of the roots does not lose water by osmosis. Instead, the mangrove trees receive water and mineral salts from the seawater entering their roots.

Adaptive Features of Hydrophytes

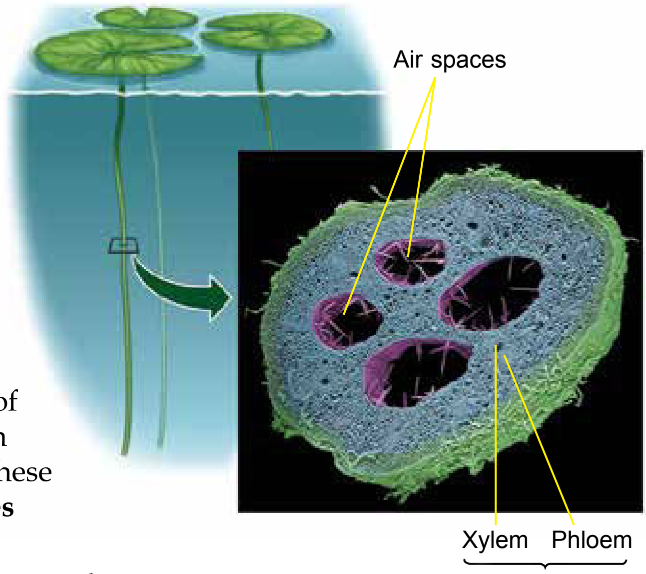
Hydrophytes (Photograph 7.3) refer to plants that can adapt to their wet habitat, whether by floating on the water surface or sinking in the water. Therefore, most hydrophytes have fibrous roots that provide a large surface area and trap air bubbles to enable the hydrophytes to be more stable and lighter. The adaptation of the roots enables them to float or stay upright in the water as well as the buoyant force exerted by the surrounding water.

Eichhornia sp. *Hydrilla* sp. *Elodea* sp.

Photograph 7.3 Some examples of hydrophytes

7.1.2

Floating plants such as the lotus are plants that grow by floating on the water surface with the roots not anchored to the bottom of the lake. The leaves which are broad, thin, and flat help these plants absorb maximum sunlight for photosynthesis. Most of the stomata are distributed on the upper epidermis of the leaves. The upper epidermis of the leaves is also covered by a waxy, waterproof cuticle to ensure the stomata are always open. The stem of these plants consists of light tissues with plenty of air spaces between the cells. These tissues are known as **aerenchyma tissues** (Photograph 7.4).



Photograph 7.4 Aerenchyma tissues in a lotus

Submerged plants such as *Elodea* sp., are plants that grow completely inside the water. These plants have leaves that are thin and small to increase the total surface area per volume and to increase the diffusion rate of water, mineral salts and dissolved gases directly into the plants through the epidermis. The submerged plants do not have stomata and waxy cuticle on the leaves. Their stems which are small and hollow help these plants float upright in the water and help to reduce water flow resistance.

Adaptive Features of Xerophytes

In contrast to hydrophytes, the xerophytes live in the desert, an area that receives very little rainfall. However, xerophytes can overcome this problem of extreme dryness. This adaptive ability is what will determine the survival of xerophytes.

The roots of xerophytes (Photograph 7.5) grow widely and can penetrate deep into the soil to absorb water and mineral salts. The absorbed water is stored in the roots, stems and leaves. Besides, the stem of the cactus carries out photosynthesis. The cactus has small leaves and thick waxy cuticles on its stem and leaves. There are also leaves modified into thorns. This feature reduces the total surface area exposed to the sun thus reducing water loss. The presence


Photograph 7.5 Roots of a cactus

Bio Exploration

Plants in the Arctic are also classified as xerophytes. This is because the plants in the Arctic cannot absorb water when the ground is frozen.

7.1.2

of thorns can also help the cactus to get water supply by collecting dew. The dew will drop on the ground and is absorbed by the roots. Besides, the thorns can also prevent the plant from being eaten by animals. The stomata in the cactus are embedded to reduce water evaporation from the leaves.

Activity 7.1

Aim

To conduct visits to the botanical gardens/ herbal gardens/ agricultural parks to observe the adaptive features of plants in different habitats

Photograph 7.6 Perlis Herbal Forest

Photograph 7.7 Agriculture Heritage Park, Putrajaya

Procedure

1. The teacher and students conduct visits to the botanical gardens/ herbal gardens/ agricultural parks.
2. Work in groups.
3. Collect information on the types of plants based on their habitats.
4. Then, observe and record the adaptive features of the plants living in their habitat.
5. Take photos of the plants and adaptation structures of the plants studied.
6. Prepare a report in the form of a folio about your visit according to the following format:
   (a) Title
   (b) Aim
   (c) Content
   (d) Conclusion

Formative Practice 7.1

1. Halophytes are plants that live in swamps. Explain two adaptive features of these plants to increase the rate of photosynthesis.
2. A group of students studied a tree. Based on their observations for several weeks, the leaves were found to be growing fast on the tree and provide shade to its stem. Additionally, there are thorns on the leaves and stem of the tree. Its roots grow close to the surface of the ground and some of them grow deep into the soil. In your opinion, what type of plant is this? Support your answer with biological facts.

7.1.2

Memory Flashback

Interactive Bio 7

ADAPTATION OF PLANTS IN HABITATS

Adaptations of plants

- Classification of plants based on habitats
  - Mesophyte
  - Hydrophyte
  - Halophyte
  - Xerophyte
- Adaptive features of hydrophytes, halophytes and xerophytes
  - Uptake of water and mineral salts
  - Gaseous exchange
  - Support
  - Photosynthesis

SELF-REFLECTION

Complete the following self-reflection to identify the important concepts that you have studied.

Important concepts	Very good	Try again
Classification of plants based on habitats, namely mesophytes, hydrophytes, halophytes and xerophytes		
Adaptive features of hydrophytes, halophytes and xerophytes in terms of uptake of water and mineral salts, gaseous exchange, support and photosynthesis		

Summative Practice 7

1. Figure 1 shows a mangrove swamp ecosystem which has experienced adverse effects because of the water pollution.

Figure 1

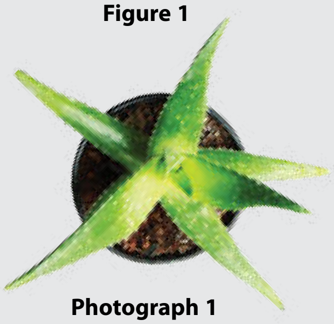
   (a) State the plant classification for mangrove swamps based on their habitat.

   (b) State the problems faced by the plants in the mangrove swamp and explain the adaptive features to overcome the problems.

   (c) Oil spills have adverse effects on the growth of mangrove trees. Predict what will happen to the mangrove trees. Explain your answer.

   (d) In your opinion, can mangrove trees live in a freshwater habitat? Give reasons for your answer.

2. Photograph 1 shows an *Aloe vera* plant in a pot.



Photograph 1

   (a) State **two** features that you can observe on the *Aloe vera* plant.

   (b) From the features you stated in question 2(a), identify the type of this plant based on its habitat.

   (c) Explain the adaptive features that enable *Aloe vera* plant to thrive in its habitat.

   (d) If you live in a cold climate country, what is the action that you can take on the *Aloe vera* plant in Photograph 1 to ensure it survives?

21st Century Mind

3. A hotel located near the beach intends to build a landscape with a combination of elements such as plants, structures and rocks. As a landscape architect, consider examples of plants which are suitable to be grown close to the beach and justify the selection of the plants.

Theme 2

Ecosystem and the Environmental Sustainability

This theme aims to provide an understanding of biodiversity, ecosystem and environmental sustainability.

The theme also covers studies related to biodiversity, population ecology, practices in preservation, conservation and restoration of ecosystems in addition to emphasis on green technology.

- How are organisms classified and named?
- What is the importance of the mangrove to human beings?
- What are the threats of climate change to humans and environment?
- How can the use of green technology help in environmental sustainability?

Chapter 8

Biodiversity

Chapter Exploration

- Classification System and Naming of Organisms
- Biodiversity
- Microorganisms and Viruses

Learning Standards

Do You Know?

- How are organisms named and categorised?
- What is meant by biodiversity?
- Why are viruses different from other microorganisms?

Panthera tigris jacksoni

Malaysia is very fortunate to have one of the world's only six existing tiger subspecies which is called the Malayan tiger or scientifically known as *Panthera tigris jacksoni*, that can only be found in Peninsular Malaysia.

Tiger is a protected species under the Wildlife Conservation Act 2010 (Act 716) and is included in the International Union for Conservation of Nature (IUCN) Red List of Threatened Species.

Unfortunately, the tiger population has been dwindling since a century ago. To prevent this species from going extinct, the Department of Wildlife and National Parks (PERHILITAN) has initiated the Save Our Malayan Tigers campaign. Under this initiative, 24-hour surveillance has been carried out in the tiger's natural habitat to protect it from traps laid by poachers.

Keywords

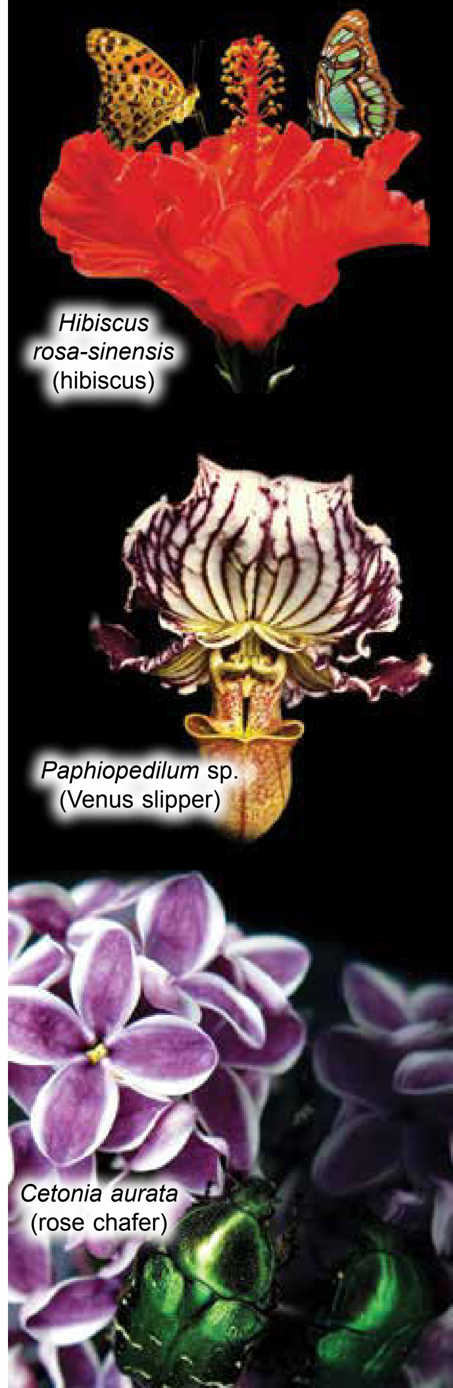
- Biodiversity
- Prokaryote
- Eukaryote
- Binomial nomenclature system
- Dichotomous key
- Phylogenetic tree
- Microorganism
- Pathogen

8.1 Classification System and Naming of Organisms

The Necessity of Classification System and Naming of Organisms

In Form 2, you have learnt briefly about biodiversity. Biodiversity is the variety of living organisms such as microorganisms, animals and plants that interact with one another. View Photograph 8.1. How are these organisms categorised and named?

Taxonomy is a field in biology which involves the classification, identification and naming of organisms in an organised manner (Figure 8.1). Taxonomy strives to manage information and data which has been collected using a systematic and methodical approach to elucidate the scientific community.



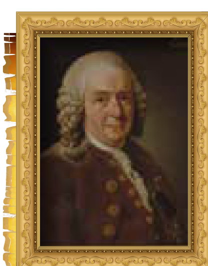
Photograph 8.1

Taxonomic Classification System

- **Classification**
  Organisms are categorised based on physical features in a **taxonomic hierarchy system.**
- **Identification**
  Organisms are identified using **dichotomous keys.**
- **Naming**
  Organisms are named using a **binomial nomenclature system.**

Figure 8.1 Taxonomic classification system

Why is the classification and naming of organisms important? All organisms need to be scientifically classified based on defining features in a systematic manner, in order to facilitate studies and discussions among scientists at an international level.


Photograph 8.2

History Corner

Carolus Linnaeus (Photograph 8.2) is known as the father of taxonomy. He had created a system to name and classify organisms which is in use even to this day.

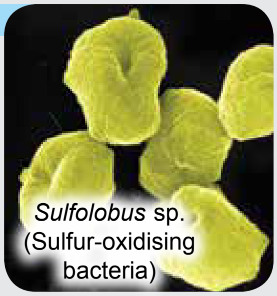
8.1.1

Classification of Organisms

All organisms in the world can be categorised into **six kingdoms** which are **Archaebacteria, Eubacteria, Protista, Fungi, Plantae** and **Animalia**. The organisms are classified based on **types of cells, number of cells** and **types of nutrition** (Figure 8.2).

Archaebacteria

- Prokaryote
- Unicellular organism
- Autotroph or heterotroph



Sulfolobus sp. (Sulfur-oxidising bacteria)

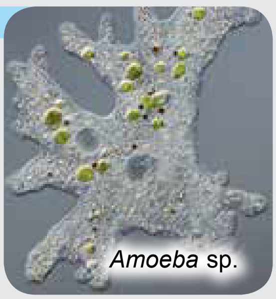
Eubacteria

- Prokaryote
- Unicellular organism
- Autotroph or heterotroph

Salmonella sp.

Protista

- Eukaryote
- Unicellular or multicellular organism
- Autotroph or heterotroph



Amoeba sp.

Fungi

- Eukaryote
- Unicellular or multicellular organism
- Heterotroph

Mycena haematopus (mushroom)

Plantae

- Eukaryote
- Multicellular organism
- Autotroph

Coleus blumei (coleus)

Animalia

- Eukaryote
- Unicellular or multicellular organism
- Heterotroph

Alcedo atthis (common kingfisher)

Figure 8.2 The six kingdoms

TERM ANALYSIS

• Prokaryote: A type of cell which lacks a membrane-bound nucleus and membrane-enclosed organelles	• Eukaryote: Has a nucleus and membrane-enclosed organelles
• Unicellular: Single-celled	• Multicellular: More than one cell
• Heterotroph: An organism that cannot synthesise its own food but obtains food molecules by eating other organisms	• Autotroph: An organism that can synthesise its own food from organic materials by using light energy or chemical energy

8.1.2

The Main Features of Organisms in Each Kingdom

Archaebacteria

- Is a **prokaryote** organism
- Is a **unicellular** organism
- Are **primitive bacteria**
- Has cell walls with no **peptidoglycan**
- Lives in very hot, acidic, salty or anaerobic environments
- Can be divided into three groups based on their habitats:
  - **Methanogen:** Obligate anaerobic bacteria are found in swamps and the digestive tract of ruminants and humans. Produces methane as a metabolic byproduct.
  - **Halophile:** Found in places with extremely high salt concentration, such as the Dead Sea.
  - **Thermophile:** Bacteria that can withstand high temperatures and flourishes at an optimum temperature of 60 °C to 80 °C. Found in hot springs and highly acidic locations like the Yellowstone National Park in the U.S.
- Examples: *Sulfolobus sp.* (sulfur-oxidising bacteria) and *Halobacterium salinarum*

Halobacterium salinarum

Photograph 8.3 Archaebacteria

Eubacteria

- Is a **prokaryote** organism
- Is a **unicellular** organism, usually form colonies
- Also known as **"true" bacteria**
- Has cell walls made up of **peptidoglycan.** Peptidoglycan is also known as **murein** which is a polymer made up of sugars and amino acids.
- The cytoplasm of the eubacteria contains **ribosome** and **plasmids** but has none of the membrane-enclosed organelles like the mitochondria, endoplasmic reticulum and others.
- Bacteria are classified according to their shape.
- Examples: *Streptococcus pneumoniae* and *Vibrio cholerae*

Streptococcus pneumoniae

Vibrio cholerae

Photograph 8.4 Eubacteria

History Corner

Robert Whittaker (1969) introduced five kingdoms, namely Monera, Protista, Fungi, Plantae and Animalia. However, developments in the study of biomolecules found differences in RNA between bacteria and archaebacteria. Carl Woese (1990) proposed the six kingdom system by breaking down the Monera kingdom to bacteria and archaebacteria.

Bio Exploration

Blue-green algae, Cyanobacteria (Photograph 8.5) contains chloroplast and can undergo photosynthesis.

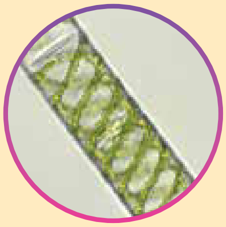
Photograph 8.5 Cyanobacteria

8.1.2 8.1.3

Protista

- Is a **eukaryote** organism
- Can either be a **unicellular** or a **multicellular** organism
- Can either be a **heterotroph** or an **autotroph** or **both**
- Has a simple cell organisation without specialised tissue
- The cells contain a nucleus that is bound by a nuclear membrane as well as other membrane-bound organelles.
- Protists are divided into three groups: protozoa, algae and slime mould.
- Examples of protozoa: *Euglena* sp., *Amoeba* sp. and *Paramecium* sp.
- Examples of algae: *Chlamydomonas* sp. and *Spirogyra* sp.
- Examples of slime mould: *Physarum polycephalum*

Chlamydomonas sp.

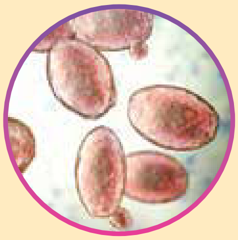


Spirogyra sp.

Photograph 8.6 Protista

Fungi

- Is a **eukaryote** organism
- Can either be a **unicellular** or a **multicellular** organism
- They are also **heterotrophs** (saprophytes or parasites)
- Their cell wall is made up of **chitin**
- The body is made up of a thread-like network of hyphae called the **mycelium**
- Examples: *Saccharomyces cerevisiae* (yeast) and *Agaricus* sp. (mushroom)



Saccharomyces cerevisiae

Agaricus sp.

Photograph 8.7 Fungi

Plantae

- Is a **eukaryote** organism
- Includes all **multicellular** plants
- Can synthesise own food via photosynthesis (photoautotroph) because they have chlorophyll
- Can undergo **sexual** or **asexual reproduction**
- Examples: Seedless plants (ferns) and plants with seeds (all flowering plants)

Photograph 8.8 *Bougainvillea* sp.

Animalia

- A **eukaryote** organism
- Involves all **multicellular** animals
- **Heterotrophs**
- Most animals can move
- Most animals reproduce **sexually**
- Examples: Invertebrate (starfish) and vertebrate (elephant)

Elephas maximus

Asterias sp.

Photograph 8.9 Animalia

8.1.2 8.1.3

Activity 8.1

THINK-PAIR-SHARE

Aim
To collect information and present the main characteristics of organisms from each kingdom

Procedure
1. Work in pairs.
2. Collect information about the main characteristics of organisms from all six kingdoms.
3. Copy this table onto a large piece of paper and complete it.

Kingdom	Number of cells	Structure of cell wall	Presence of chlorophyll	Presence of nucleus	Example of organisms
Archaebacteria					
Eubacteria					
Protista	Unicellular and multicellular				
Fungi		Chitin cell wall	No chlorophyll	Present	
Plantae					
Animalia					

4. Present your table in the class.

Taxonomy Hierarchy

The hierarchy system used in taxonomy is the **Linnaeus hierarchy system**. The Linnaeus hierarchy system classifies organisms according to hierarchy, starting from species to domain. The orders of the hierarchy are domain, kingdom, phylum, class, order, family, genus and species.

Domain is the highest taxonomic rank of organisms in the hierarchical biological classification system. Each **kingdom** is divided into smaller groups called **phylum**. Organisms in the same phylum have mutual characteristics. Organisms in a particular phylum are different from organisms from different phylum. Phylum is further divided into **class**, while class is divided into **order**. By using the same method, order is divided into **family**, family is divided into **genus** and genus is divided into **species**. A species is the smallest group used to classify organisms. Organisms of the same species are capable of interbreeding among themselves to produce viable fertile offsprings. This classification order is known as the **taxonomy hierarchy** (Figure 8.3).

MALAYSIAN SCIENTIST

Research Fellow from Forest Research Institute Malaysia (FRIM), Dr. Saw Leng Guan (Photograph 8.10) received the prestigious Royal Botanic Garden Edinburgh (RBGE) award in 2016. RBGE is an internationally renowned research institute which is known for their study of plants, diversity and conservation efforts worldwide. Dr. Saw Leng Guan is a taxonomist who has greatly contributed to the biodiversity research in Malaysia for over 30 years.

Photograph 8.10

8.1.3 8.1.4

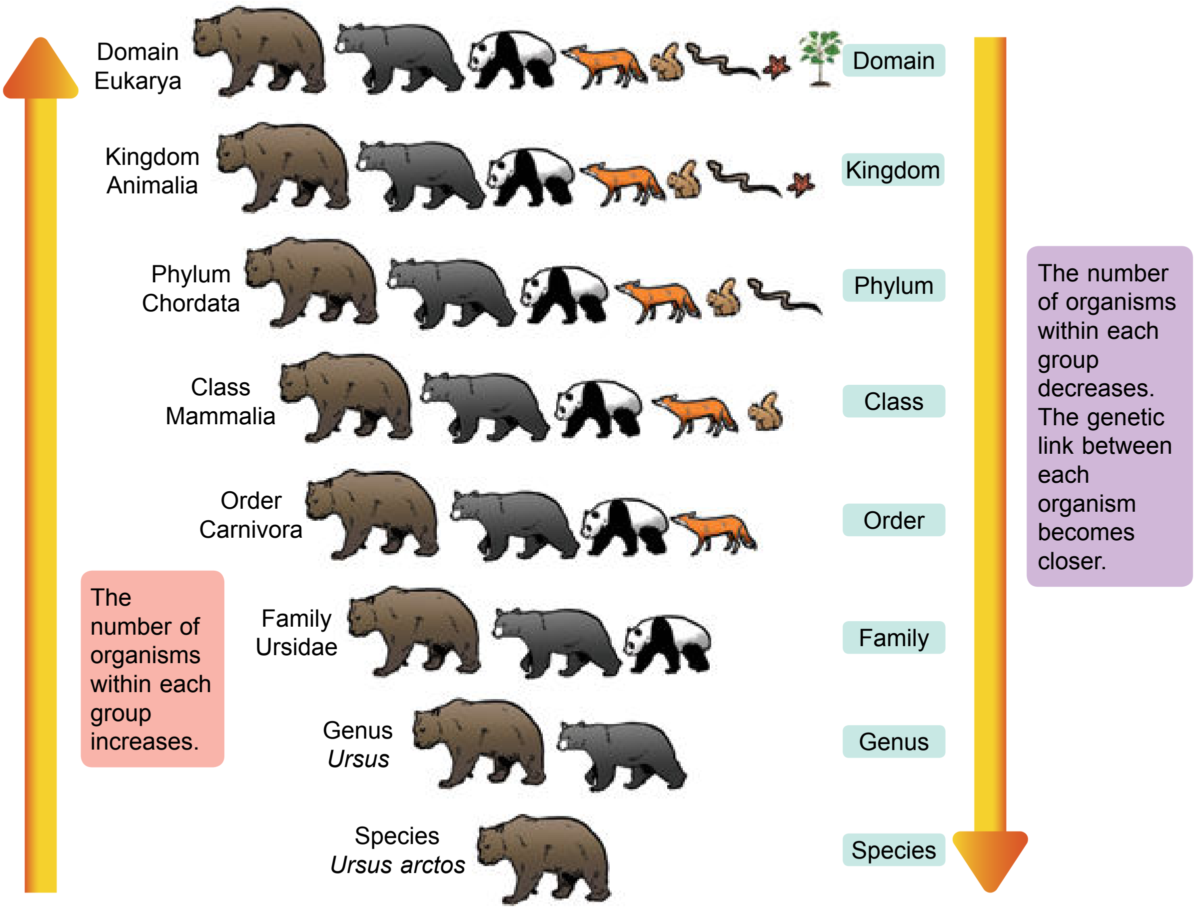


Figure 8.3 Taxonomy hierarchy

Binomial Nomenclature System

The formal system of naming organisms practised today is called the **Linnaeus binomial system**. How do you write the scientific name of an organism?

1. Each scientific name consists of two words: the first word is the name of the **genus**, the second word is the name of the **species**.
2. The first letter of the genus is capitalised while the name of the species is not.
3. All scientific names must be printed in italics. If handwritten, the two names must be underlined separately (Table 8.1 and 8.2).

Photography 8.11
Alcedo atthis

Table 8.1 How to write scientific names

Common name	Genus name	Species name	Scientific name (Handwritten)	Scientific name (Printed)
Common kingfisher	*Alcedo*	*atthis*	<u>Alcedo</u> <u>atthis</u>	*Alcedo atthis*

8.1.4

Table 8.2 How to write scientific names of a few organisms

Common name	Scientific name	
	Handwritten	Printed
Green paddy frog	Rana erythraea	*Rana erythraea*
Paddy	Oryza sativa	*Oryza sativa*
Sacred lotus	Nelumbo nucifera	*Nelumbo nucifera*
Common sunflower	Helianthus annuus	*Helianthus annuus*

The scientific name given to all organisms is accepted and used worldwide. Each given name usually provides an idea of the organisms traits, the state of their habitat, their country of origin or to honour the researchers that had studied them. For example, in the scientific name for the pea plant, *Pisum sativum* L., the L refers to Linnaeus, the first person who named the plant.

Innovation in Malaysia

Malaysian Agricultural Research and Development Institute (MARDI) has produced new orchid hybrids across multiple orchid genus. One particular species, *Dendrobium maharia* was later renamed as *Dendrobium Datin Seri Jeanne*, after the wife of the Prime Minister of Malaysia at the time, Tun Abdullah bin Haji Ahmad Badawi (Photograph 8.12).

Photograph 8.12

ACTIVITY ZONE

Observe the plants in your school environment. Identify the common names of the plant and identify their scientific names based on the binomial nomenclature system. You can scan this QR Code to find the scientific names of plants found in Malaysia.

ICT

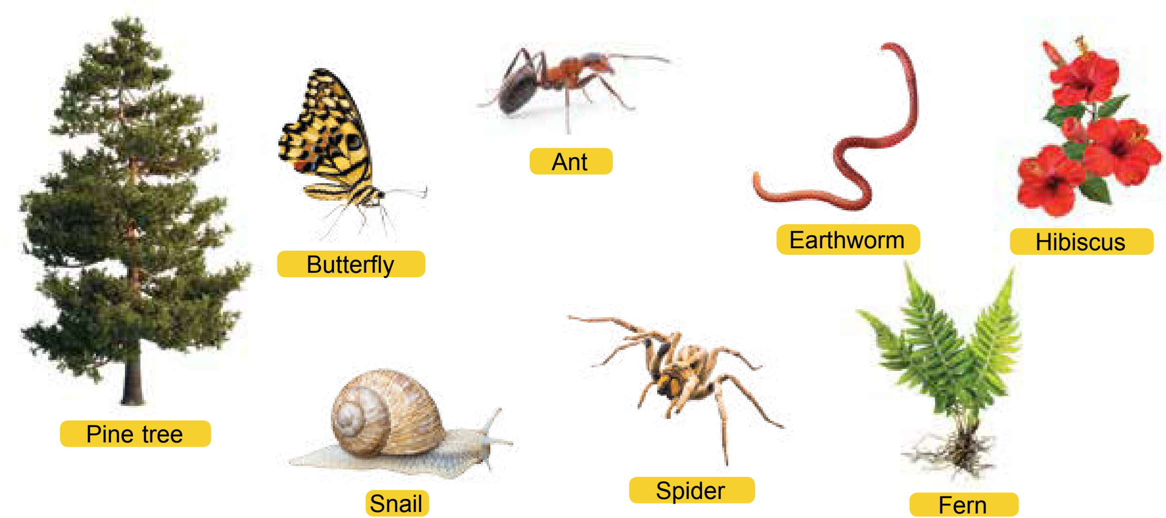
Info

Biodiversity in Malaysia

bukutekskssm.my/Biologi/T5/Ms150

Dichotomous Key

A dichotomous key is a tool used by taxonomists to identify organisms based on similarities and differences. One of the ways to build a dichotomous key, covered in Form 2, is by using a **series of couplets**. Each couplet is made up of two statements about the organism's traits or its grouping (Figure 8.4).



		Dichotomous key
1a	Animals	Go to 2
1b	Plants	Go to 6
2a	Has legs	Go to 3
2b	Does not have legs	Go to 5
3a	Three pairs of legs	Go to 4
3b	More than three pairs of legs	**Spider**
4a	Has wings	**Butterfly**
4b	Does not have wings	**Ant**
5a	Has shell	**Snail**
5b	Does not have shell	**Earthworm**
6a	Has seeds	Go to 7
6b	Does not have seeds	**Fern**
7a	Flowering plant	**Hibiscus**
7b	Non-flowering plant	**Pine tree**

Figure 8.4 A sample of a dichotomous key

A dichotomous key is specific to an identification process. When identifying other organisms, a different set of dichotomous key is used. The traits chosen must be based on obvious and observable features. Overlapping traits must be avoided. Do you know that there is another way to produce a dichotomous key for identifying organisms? Let's look at Figure 8.5.

8.1.5

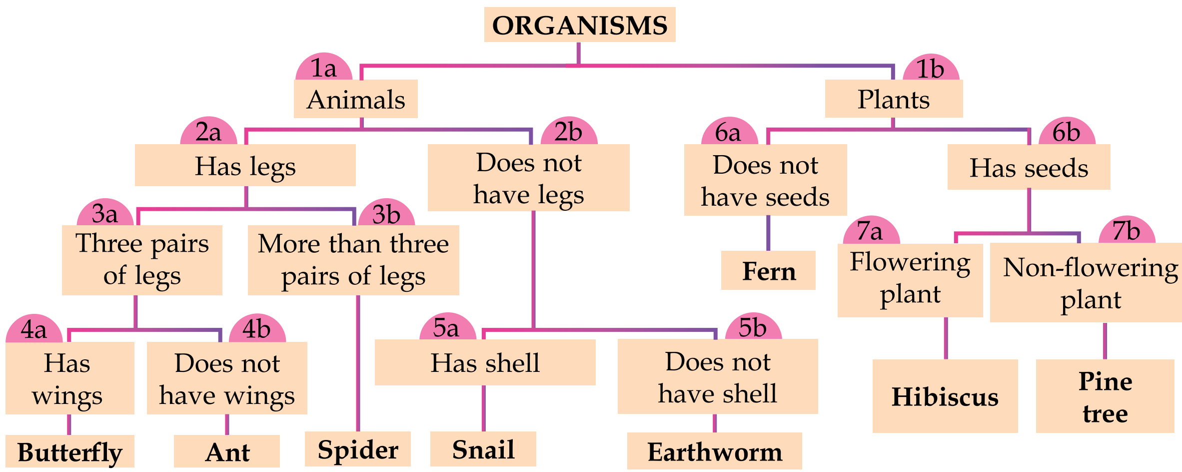


Figure 8.5 Spider dichotomous key

Formative Practice 8.1

1. State **two** characteristics of organisms from the kingdom Fungi.
2. How is an organism classified based on the taxonomy hierarchy?
3. Who introduced the binomial nomenclature system?
4. How is an organism named based on the binomial nomenclature system?

8.2 Biodiversity

Concept of Biodiversity

Biodiversity can be divided into three types: **genetic diversity, species diversity** and **ecosystem diversity** (Table 8.3).

Table 8.3 Types of biodiversity

Genetic diversity	Species diversity	Ecosystem diversity
• **Genetic diversity** refers to the genes variation of an individual within a population and the genes variation between different populations of the same species. Differences in genes are due to individual isolation and adaptation to different environments. • No two individuals of the same species are identical. • Example: The huge variety in gene combination allows for genetic variation in plants such as paddy. There are many varieties of cultivated rice all over the world.	• **Species diversity** refers to the variation and variability of organisms on Earth. • Species diversity includes the total number of species in a community (species richness) and the species distribution in a community (species evenness). • Example: Tropical rainforests have large species diversities. There are 5-10 million of insect species while there can be more than two million species of flowering plants.	• **Ecosystem diversity** refers to the biotic community and ecological process in ecosystems on the land, in the sea and other aquatic environments. • Example: There are ecosystems rich with biodiversity that can be found in the ocean, in the desert or even in the swamp.

Activity 8.2

Aim
To conduct a field study at a botanical garden or an agricultural site and do a presentation on the *in situ* species diversity

Procedure
1. Work in groups.
2. Teachers are to conduct a visit to a botanical garden or an agricultural site for the students.
3. In a group, identify the species diversity that is in the area.
4. Take photos of the identified species and use the photos as reference for the naming of the species.
5. Prepare a folio about species diversity in one week.
6. Present your folio in class.

Phylogenetic Tree

Phylogeny means the evolutionary history of a species or a group of organisms that are genetically linked. A phylogenetic tree is a diagram that represents hypotheses on evolutionary relationships among a group of organisms. Phylogenetic classification is the classification system that shows the evolutionary relationship and history of the studied organism. Phylogenetic classification is now used in many modern classification systems.

In phylogenetic classification, classification is done using a **homologous structure**. A homologous structure refers to a structure (body parts or body anatomy) that can be observed across multiple organisms which share the same ancestor even though the function of the structure may differ from one organism to another. Figure 8.6 shows the limbs of four animals, namely human, cat, whale and bat, which share the same bone structure but differ greatly in size and length.

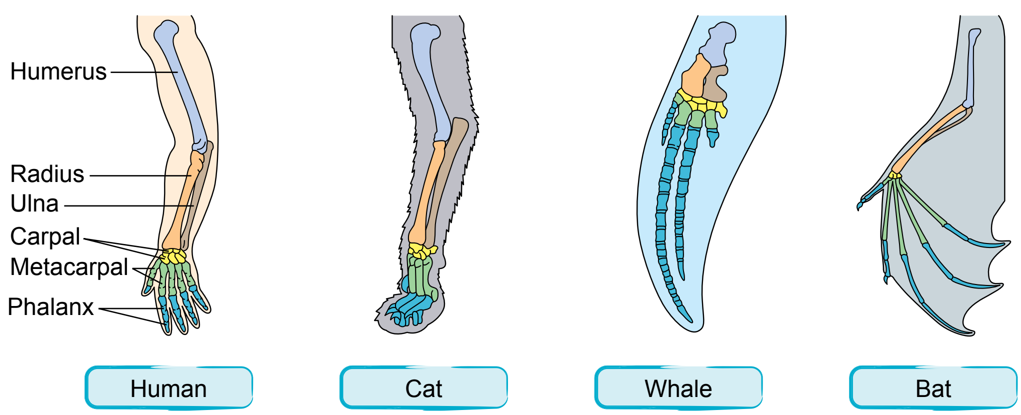
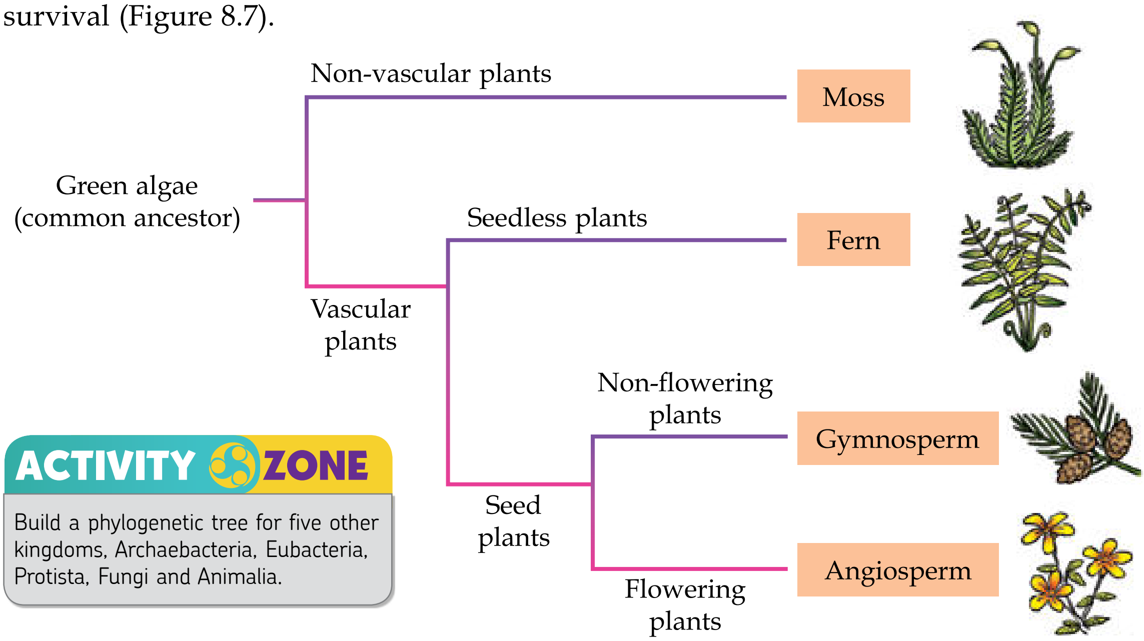


Figure 8.6 Homologous structures in multiple organisms

Despite the differences in function, it is clear that the limbs of the four animals originate from one common ancestor. The evolutionary relationship and history between different types of species can be depicted via a phylogenetic tree. The branches in a phylogenetic tree show how a species or a group of organisms diverge from the same ancestor.

8.2.1 8.2.2

Evidence suggests that land plants evolved from green algae. First land plants originated from non-vascular plants such as mosses, followed by seedless vascular plants such as ferns. Vascular plants then advance into gymnosperms and angiosperms, which are vascular plants with seed. Examples of gymnosperms and angiosperms are conifers and flowering plants respectively. Angiosperms are considered as the most successful plants since their seeds are enclosed inside the fruits to ensure species survival (Figure 8.7).



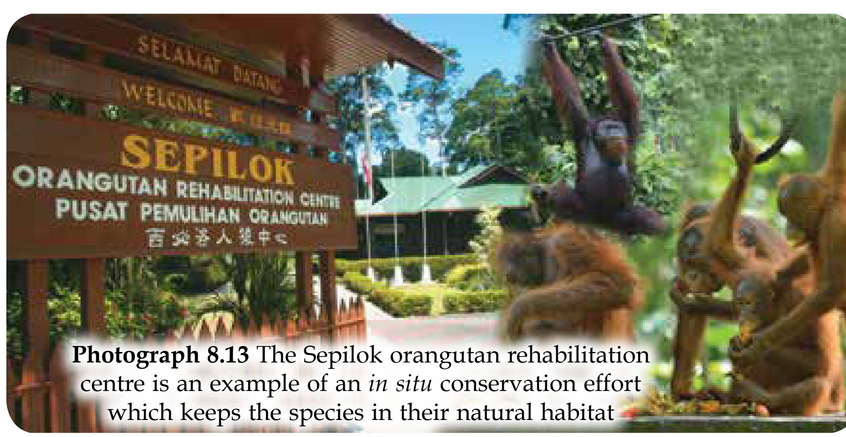
ACTIVITY ZONE

Build a phylogenetic tree for five other kingdoms, Archaebacteria, Eubacteria, Protista, Fungi and Animalia.

Figure 8.7 Phylogenetic tree of land plant

The Importance of Biodiversity on the Environment and Humans

In Form 2, you have learnt the importance of biodiversity as sources of food, medicine and education. Biodiversity also maintains a balance in nature, for both recreation and scientific research. Hence, every individual, organisations and the government must play their roles in preserving and conserving biodiversity. Can you state the measures taken in Malaysia for ***in situ* conservation** and ***ex situ* conservation**? *In situ* conservation maintains species in their natural habitat such as in the National Park and permanent forest reserves (Photograph 8.13). *Ex situ* conservation is efforts to conserve species found outside of their natural habitats such as in zoos and botanical gardens.



Photograph 8.13 The Sepilok orangutan rehabilitation centre is an example of an *in situ* conservation effort which keeps the species in their natural habitat

Activity 8.3

21st CENTURY SKILLS

THREE STRAY ONE STAY

Aim

To discuss the effects of a threat to biodiversity towards the environment and humans

Procedure

1. Work in groups.
2. Find information from various sources about the following issues:
   (a) Deforestation
   (b) Illegal hunting
   (c) Water pollution
   (d) Tourism and its exploitation of biodiversity
3. Discuss the effects of the issues towards the environment and humans.
4. Conduct your presentation using the three stray one stay method in the class.

Formative Practice 8.2

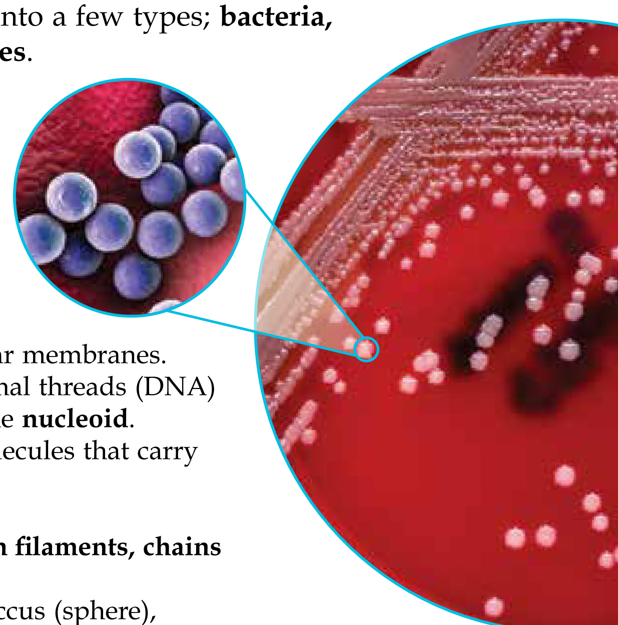
1. Explain ecosystem diversity, species diversity and genetic diversity.
2. Why do biologists use phylogenetic trees?
3. What is your role in preserving and conserving biodiversity in Malaysia?
4. State **two** importances of biodiversity towards humans.

8.3 Microorganisms and Viruses

Microorganisms are microscopic organisms that cannot be seen by the naked eye. These organisms can only be observed under the microscope. Most microorganisms are unicellular. Microorganisms can be divided into a few types; **bacteria, protozoa, algae, fungi** and **viruses**.

The Main Characteristics of Microorganisms and Viruses

Bacteria



Photograph 8.14
Staphylococcus aureus

Main characteristics of bacteria:

- **Bacteria** do not have nucleus due to the lack of nuclear membranes. Their genetic materials exist in the form of chromosomal threads (DNA) free-floating inside the cytoplasm. This is known as the **nucleoid**. Some bacteria have **plasmid**, which is small DNA molecules that carry extra genes (Figure 8.8).
- Bacteria range from **1 to 10 μm** long.
- Bacteria can exist as **a single cell, a diploid** (a pair), **in filaments, chains** or **clusters**.
- Bacteria can exist in a few basic shapes such as the coccus (sphere), vibrio (comma), bacillus (rod/cylinder) and spirillum (spiral) (Figure 8.9).
- Examples of bacteria include *Lactobacillus* sp., *Streptococcus* sp. and *Staphylococcus aureus* (Photograph 8.14).

8.2.3 8.3.1

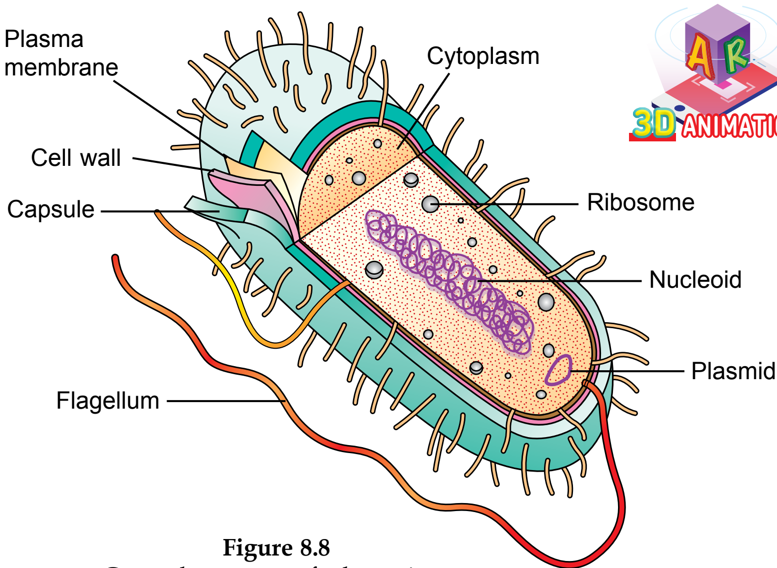


Figure 8.8
General structure of a bacterium

Figure 8.9 Shapes of bacteria

Protozoa

Main characteristics of protozoa:
- **Protozoa** are animal-like **unicellular** microorganisms.
- Protozoa move around using **pseudopodia** (false feet), **cilia** or **flagellum** (Figure 8.10).
- Protozoa are usually found in aquatic habitats (Photograph 8.15).
- Protozoa are **heterotrophs** or **autotrophs**. *Euglena* sp. is an autotrophic protozoa with chloroplasts that can undergo photosynthesis.
- Protozoa can be free-living or parasitic.

Bio & Application

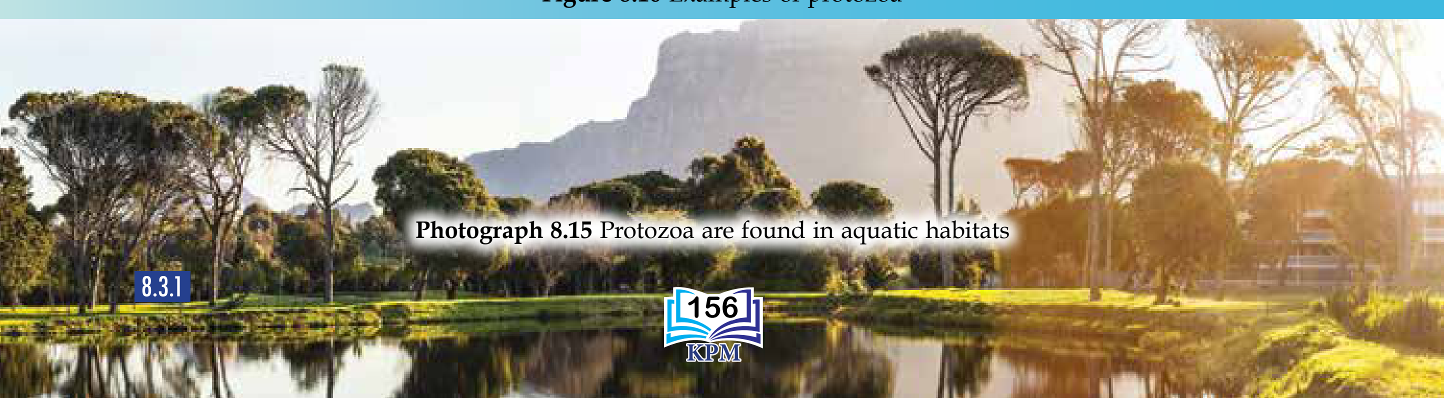
Acanthamoeba sp. is found in tap water. This organism can damage eye cornea. Thus, we are advised to not use tap water to clean contact lenses. It is safer to use sterile cleansing solutions.

Amoeba sp. moves by using pseudopodia

Paramecium sp. moves by using cilia

Euglena sp. moves by using a flagellum

Figure 8.10 Examples of protozoa



Photograph 8.15 Protozoa are found in aquatic habitats

8.3.1

Algae

Main characteristics of algae:
- Consist of unicellular microorganisms like *Chlamydomonas* sp. and multicellular organisms such as the brown algae, *Fucus* sp. (Photograph 8.16).
- Some algae have **flagellum** to move in water.
- Like plants, algae have chloroplasts and are therefore **autotrophs**. However, algae do not have leaves, stems, or roots like plants do.
- Algae live in ponds, lakes and ocean.

Chlamydomonas sp.

Fucus sp.

Photograph 8.16 Examples of algae

Fungi

Main characteristics of fungi:
- Fungi do not contain chlorophyll, thus fungi are **heterotrophs,** either **parasites** or **saprophytes**.
- Fungi do not contain roots, stems and leaves.
- Fungi have cell walls created by chitin.
- Fungi exist in the form of **mycelium**, which is made up of a network of threads called the **hyphae**.
- Fungi are unicellular microorganisms (*Saccharomyces cerevisiae* (yeast)) or multicellular microorganisms (*Mucor* sp.) (Figure 8.11 and 8.12).
- Fungi are found in dark or moist places and on decomposing or dead organisms.

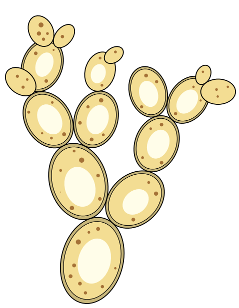


Figure 8.11
Saccharomyces cerevisiae structure

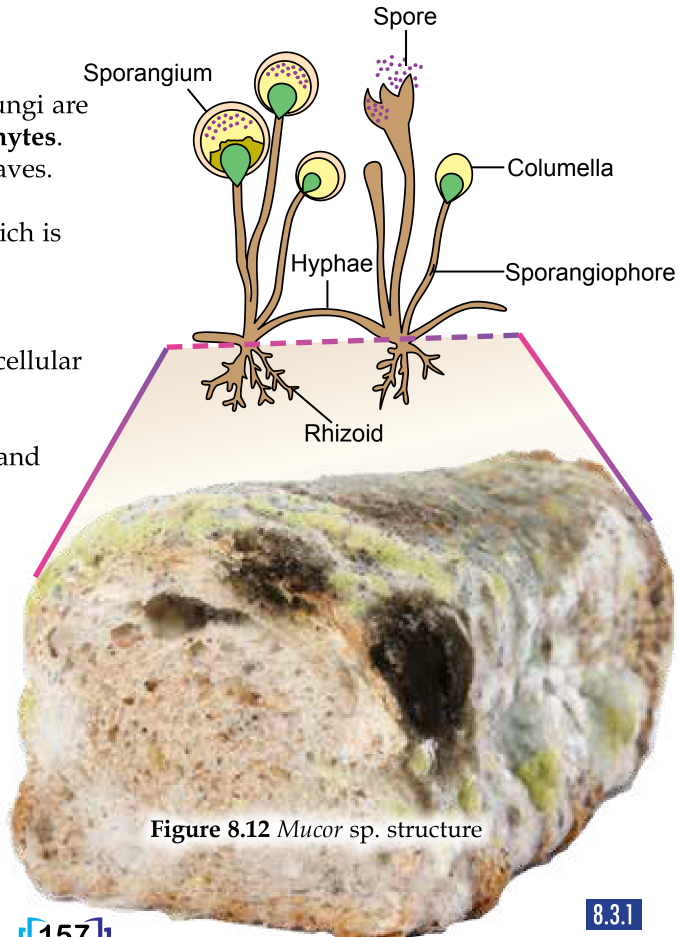
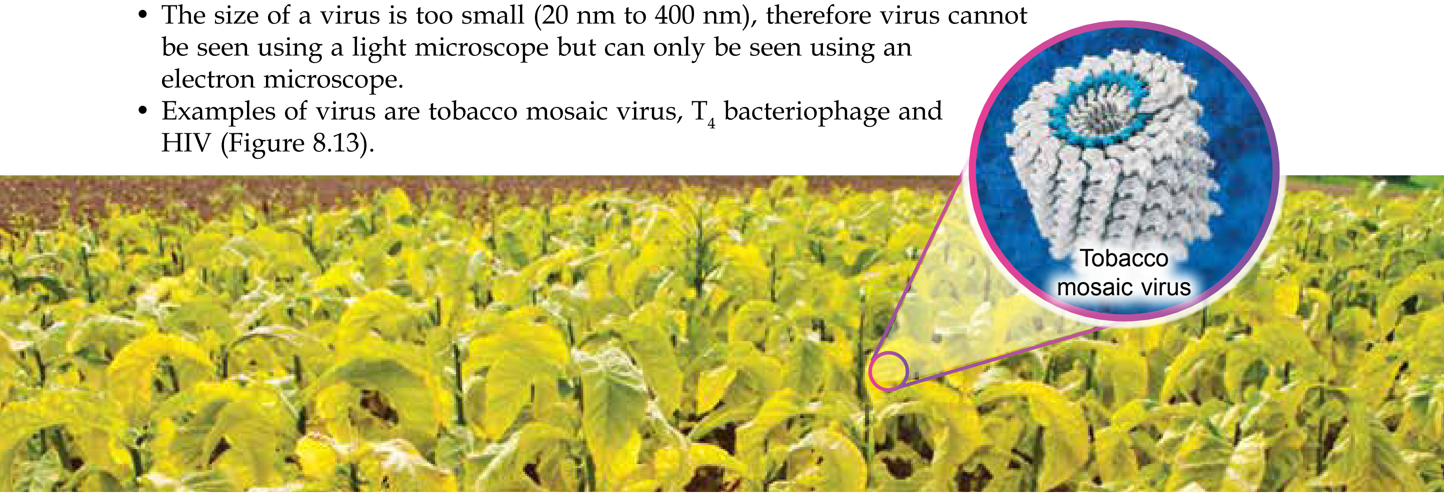


Figure 8.12 *Mucor* sp. structure

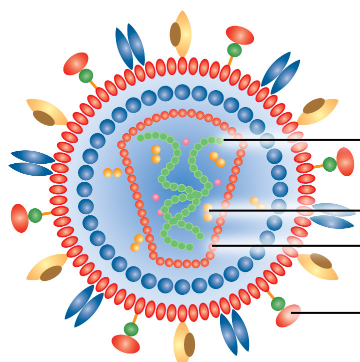
8.3.1

Viruses

Main characteristics of viruses:
- Viruses are not included in any of the kingdoms because they are not cellular organisms.
- The virus does not carry out any life process outside of a cell. Nonetheless, viruses reproduce using living cells by injecting their genetic materials into host cells.
- Viruses are made up of nucleic acid (DNA or RNA) and capsids made from protein.
- The size of a virus is too small (20 nm to 400 nm), therefore virus cannot be seen using a light microscope but can only be seen using an electron microscope.
- Examples of virus are tobacco mosaic virus, T_4 bacteriophage and HIV (Figure 8.13).



T_4 bacteriophage



Human Immunodeficiency Virus (HIV)

Figure 8.13 Examples of viruses

Activity 8.4

21st CENTURY SKILLS — DEBATE

Aim
To debate the status of a virus as a non-living thing

Procedure
1. Assign one student as a chairman and three students as the panels.
2. Conduct a forum to debate the status of a virus as a non-living thing.
3. Other students may remain as part of the audience and jot down important points from the debate.
4. Prepare a report using the following format:
   (a) Title (b) Aim (c) Content (d) Conclusion

8.3.1

The Role of Microorganisms in the Nitrogen Cycle

Plants require nitrogen to synthesise protein in plant tissues and this nitrogen is obtained from the soil in the form of **ammonium ions (NH_4^+)** and **nitrate ions (NO_3^-)**. How can the nitrogen gas from the atmosphere be converted into a form that can be used by plants? Let's study the nitrogen cycle in Figure 8.14.

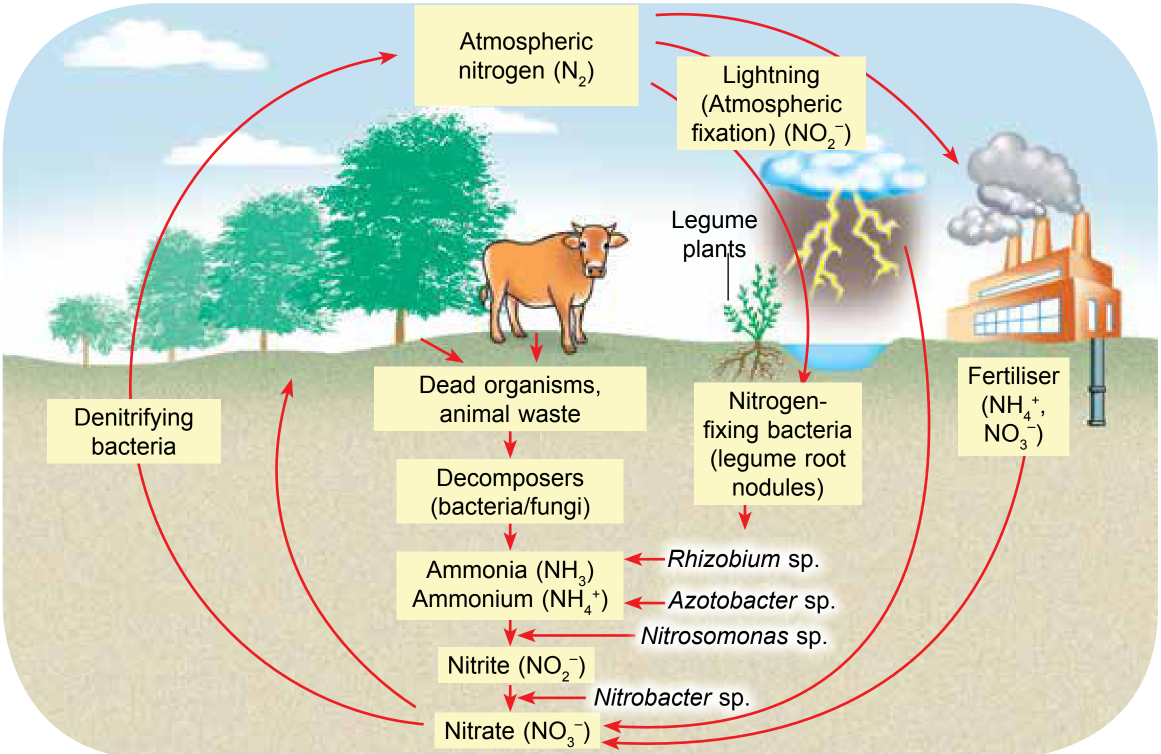


Figure 8.14 Nitrogen cycle

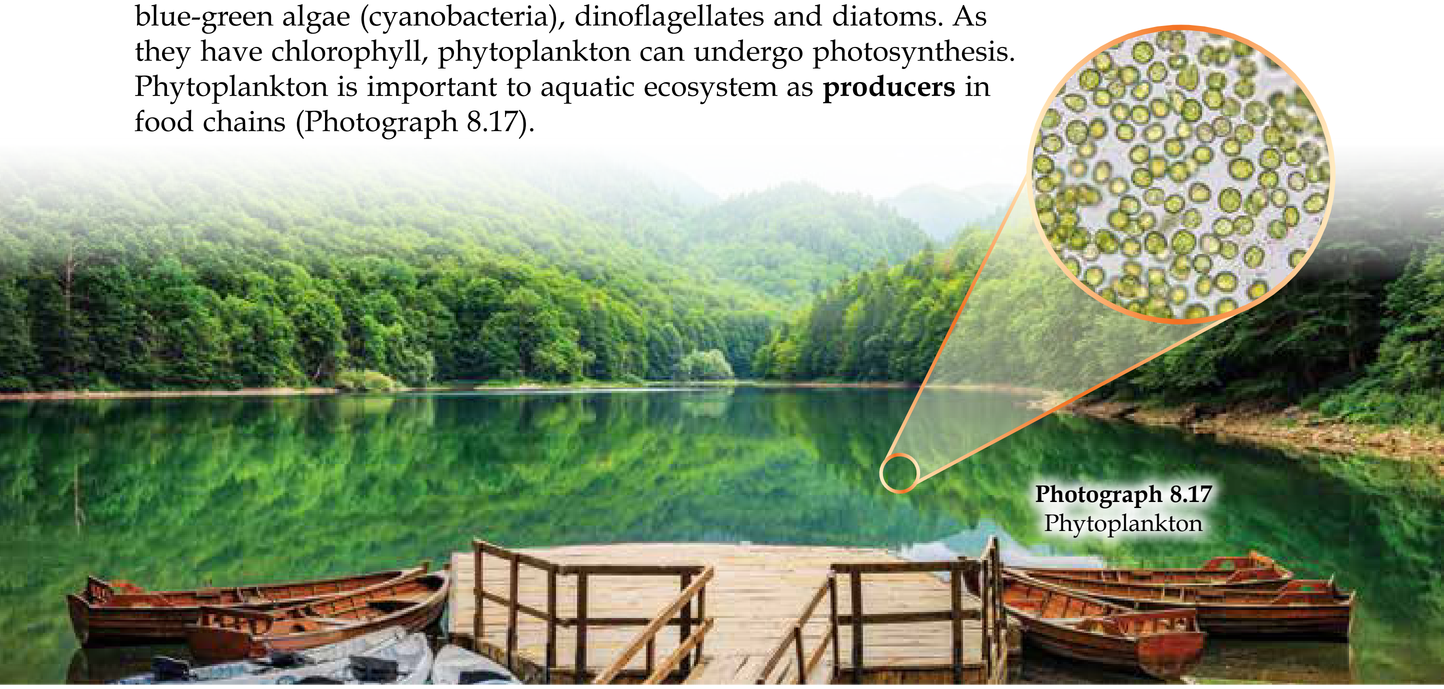
- Nitrogen-fixing bacteria that live in the root nodules of legumes like *Rhizobium* sp. and free-living nitrogen-fixing bacteria in the soil such as *Azotobacter* sp. fixes the nitrogen from the atmosphere and changes it to **ammonium ions (NH_4^+)** via the nitrogen-fixing process.
- Lightning in a thunderstorm oxidises nitrogen to nitrogen dioxide (NO_2) which dissolves in rainwater to form nitrous acid and nitric acid. Both form nitrate salts in the soil.
- Industrial fertilisers provide ammonium fertilisers and nitrates in the soil.
- When plants and animals die, decomposition is carried out by decomposers such as bacteria and saprophytic fungi. Protein in body tissue will be broken down into ammonium ions (NH_4^+) via ammonification.
- Ammonium ions are converted into **nitrite ions** (NO_2^-) via nitrification by the nitrifying bacteria *Nitrosomonas* sp.
- Nitrite ions will be converted to **nitrate ions** (NO_3^-) by the nitrifying bacteria, *Nitrobacter* sp.
- The nitrates will then be absorbed by plant roots and used to synthesise proteins. When the plants are eaten by animals, nitrogen gets transferred to the animal's tissue.
- Denitrifying bacteria convert nitrates in the soil into nitrogen gas through the **denitrification process.**

8.3.2

The Role of Microorganisms

Microorganisms as producers

Microorganisms like **phytoplankton** are usually found floating on the surface of the oceans, ponds or lakes. For instance, green algae, blue-green algae (cyanobacteria), dinoflagellates and diatoms. As they have chlorophyll, phytoplankton can undergo photosynthesis. Phytoplankton is important to aquatic ecosystem as **producers** in food chains (Photograph 8.17).



Photograph 8.17
Phytoplankton

Microorganisms as decomposers

Saprophytic fungi and **saprophytic bacteria** are important microorganisms that decompose organic materials from dead organisms. Saprophytic fungi and bacteria are known as **decomposers**. Decomposers break down complex organic materials such as animal wastes, carcasses and rotting trees (Photograph 8.18) into simple compounds such as ammonium. Decomposers secrete digestive enzymes into the decaying organic materials, then absorb the products of the digestive process. The products of this process contain important elements required by plants such as **carbon, nitrogen** and **sulphur** which are returned to the soil. These materials are then absorbed by plants.

Photograph 8.18
Fungi on a rotting tree trunk

8.3.3

Microorganisms as parasites

In a **parasitic** relationship, the parasite benefits from the relationship while the host is harmed or sometimes die from the negative effects caused by the parasite. Parasites will continue to benefit for as long as this interaction continues. Hence, most parasites try not to kill their hosts. One of the examples of parasitic microorganisms is *Plasmodium* sp. (Photograph 8.19), a protozoa that lives inside the female *Anopheles* mosquito (Photograph 8.20) and transmits malaria to anyone who is bitten by the mosquito when the parasite is transferred into the blood circulation system of the person.

Photograph 8.19 *Plasmodium* sp.

Photograph 8.20 Female mosquito *Anopheles* sp.

Microorganism as symbionts

A **symbiont** is an organism which has a close relationship with another organism (known as the host). There are two types of symbionts, **ectosymbionts** (Photograph 8.21) and **endosymbionts** (Photograph 8.22).

Symbiont

Ectosymbiont
- Lives outside the host cells.
- Example: Ectomycorrhiza, a fungi which lives around plant roots.

Endosymbiont
- Lives inside the host cells.
- Example: Protozoa *Trichonympha* sp. which lives in the alimentary canals of termites.

Photograph 8.21 Ectomycorrhiza

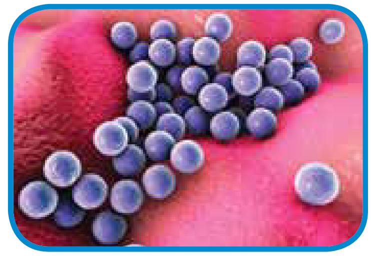
Photograph 8.22 *Trichonympha* sp. in termites

8.3.3

Definition of Pathogens and Vectors

Pathogens


Photograph 8.23
Vibrio cholerae


Photograph 8.24
Staphylococcus aureus

A **pathogen** is an organism which causes diseases. For example, viruses, bacteria, protozoa and fungi.

In Form 2, you have learnt about the pathogens that cause **infectious disease**. An infection is caused when a pathogen such as a virus, bacteria or any other microorganism enters the body, divides and multiplies. The disease caused by pathogens will occur when the cells inside the body are damage. This is caused by the infection and the infected person shows the symptoms.

Innovation in Malaysia

In Malaysia, scientists are now using *Wolbachia*, a type of bacteria in the fight against dengue. The bacteria is injected into the eggs of *Aedes aegypti* mosquitoes to curb the growth of the dengue virus in mosquitoes, thereby stopping the spread of dengue.

Activity 8.5

21st CENTURY SKILLS — GALLERY WALK

Aim
To collect and present information on diseases spread by pathogens

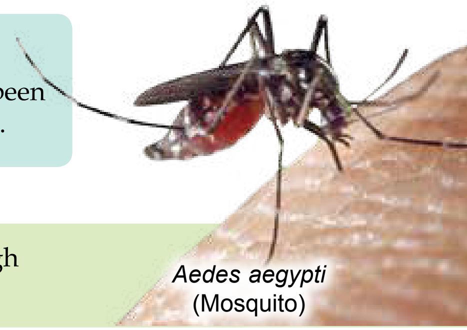
Procedure
1. Work in groups.
2. Collect information about diseases caused by pathogens:
   (a) Virus (example: *Human papillomavirus*)
   (b) Bacteria (example: *Salmonella* sp.)
   (c) Protozoa (example: *Plasmodium* sp.)
   (d) Fungi (example: *Tinea* sp.)
3. Design a poster about the diseases based on your creativity.
4. Display your poster in the class.
5. Then, do a Gallery Walk activity in the class.

Vectors

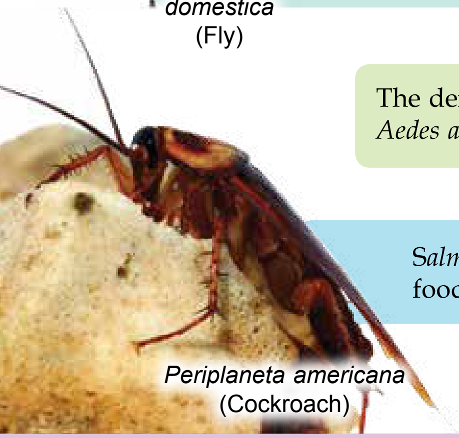
Some pathogens are caused by other organisms such as mosquitoes and flies. These organisms are known as **vectors**.

Vectors are organisms which transmit pathogens and cause certain diseases.

The bacteria *Vibrio cholerae* is spread amongst humans through flies. When a person consumes food that has been contaminated by *Vibrio cholerae*, they might get cholera.



The dengue virus is transmitted to humans through *Aedes aegypti* mosquito bites.



Salmonella typhi bacteria are transmitted to humans through food and water that has been contaminated by cockroaches.

Figure 8.15 Example of disease vectors

Activity 8.6 STEM

Aim
To design an environment-friendly trap or deterrent for vectors

Procedure
1. In a group, study the following statement:

   Old derelict buildings are breeding grounds for rats. This pest spreads infectious diseases and destroys the property of surrounding residents. To solve this problem, an environment-friendly and effective trap is needed to capture and release the rats in another area.

2. Design an effective and environment-friendly trap to remove the rats safely.
3. Test the prototype or model you have built. Improve on any weaknesses found.
4. Present the prototype or model in the class.
5. Prepare a full report.

The Effects of Pathogens on Human Health

Pathogens disrupt the immunity system in many ways. Viruses or bacteria cause sickness when they disturb cell functions or cause cell damage. Some pathogens release toxins that could lead to paralysis or destroy metabolic activities in the body.

8.3.4 8.3.5

Table 8.4 Symptoms of disease caused by pathogens

Pathogen	Example of disease	Symptoms of disease
Virus	Hepatitis B	• Inflammation (hepatic cirrhosis) • Swollen chest • Skin and eyes sclera become yellowish • May cause fatalities
Bacteria	Tuberculosis	• Loss of weight • Coughing blood • Shortness of breath
Protozoa	Dysentery	• Stomach ache • Diarrhoea • Vomit
Fungi	Tinea versicolour	• Whitish or pinkish patches on the skin

Formative Practice 8.3

1. Why are viruses not classified into one of the six kingdoms?
2. Why don't parasites kill their hosts?
3. What is the meaning of symbiont? Explain the types of symbionts.
4. State the meaning of pathogens. Give **three** examples of pathogens and their vectors.

Memory Flashback

Interactive Bio 8

BIODIVERSITY

- Classification and Naming
  - Taxonomy hierarchy
    - Levels
      - Domain
      - Kingdom
      - Phylum
      - Class
      - Order
      - Family
      - Genus
      - Species
  - Linnaeus binomial nomenclature system
  - Dichotomous key
- Biodiversity
  - Diversity of
    - Genetic
    - Species
    - Ecosystem
  - Importance
  - Phylogenetic tree
- Microorganisms and viruses
  - Bacteria
  - Protozoa
  - Algae
  - Fungi
  - Viruses
  - Role of microorganisms
    - Nitrogen cycle
    - Producer
    - Decomposer
    - Symbiont
    - Parasite
  - Pathogens and vectors
  - The effects of pathogens on human health

SELF-REFLECTION

Complete the following self-reflection to identify the important concepts that you have studied.

Important concepts	Very good	Try again
The necessity of a classification system and the naming of organisms		
Hierarchical classification of organisms in the six kingdoms: (a) Archaebacteria (b) Eubacteria (c) Protista (d) Fungi (e) Plantae (f) Animalia		
Main features of organisms in each kingdom		
The naming of organisms according to the binomial nomenclature system		
Dichotomous keys to classify organisms		
Biodiversity concepts based on diversities of: (a) Genetic (b) Species (c) Ecosystem		
The meaning of phylogenetic tree		
The importance of biodiversity to the environment and humans		
Main characteristics of microorganisms and viruses: (a) Bacteria (b) Protozoa (c) Algae (d) Fungi (e) Virus		
The role of microorganisms in/as: (a) The nitrogen cycle (b) A producer (c) A decomposer (d) A symbiont (e) A parasite		
Define pathogens and vectors		
The effect of pathogens on human health		

Summative Practice 8

1. The taxonomy hierarchy for a domestic cat (Photograph 1) is shown in Table 1.

Table 1

Level	Taxon
Kingdom	Animalia
Phylum	Chordata
Class	Mamalia
Order	Carnivora
Family	Felidae
Genus	*Felis*
Species	*catus*

Photograph 1

(a) Based on Table 1, what is the scientific name of the domestic cat?
(b) Using your answer in 1(a), explain the binomial nomenclature system which was introduced by Carolus Linnaeus.

2. Nadine found two amphibious species in a forest as shown in Photograph 2. Both of these amphibians have similar morphologies. How can Nadine determine if these two specimens are of the same species or different species?

Photograph 2

3. Photograph 3 shows a type of fungus on a tree trunk.
(a) Fungi were previously known as a plant. However, the fungus is now considered to be closer to the animals than to plants. Why are fungi classified into a separate kingdom and not into Plantae or Animalia?

(b) Predict what would happen in our environment if there are no fungi.

Photograph 3

4. Write a creative essay entitled "Who am I?" with an organism in mind. List characteristics about the organism in your essay.

5. Describe how nitrogen in the atmosphere can become a part of the animal and plant tissues, then return to the atmosphere in the form of nitrogen gas.

6. You have been given a task to classify the organisms found in the herbaceous garden in your school. Describe the method you will use for this task.

7. Suggest **one** way to produce a chemical poison that can be used to kill termites without harming other beneficial insects.

8. Read the statement below.

   All organisms depend on one another for species survival. When a species becomes extinct, other species will also be affected by the loss. Species extinction also leaves bad consequences on human life.

   Based on this statement, discuss the steps that can be taken to preserve and conserve biodiversity in Malaysia.

21st Century Mind

9. You are given a plot of land and are advised to plant the plants in Photograph 4. Explain how you will use the plants to keep your plot of land fertile.

Photograph 4

Chapter 9

Ecosystem

Chapter Exploration

- Community and Ecosystem
- Population Ecology

Learning Standards

Do You Know?

- How are the community and ecosystem established?
- What is the niche of a butterfly in its surroundings?
- How does light intensity affect the distribution of plants in a forest?
- What is meant by population ecology?
- What is the difference between population size and population density?

Tasik Chini Biosphere Reserve

Tasik Chini is a natural national treasure which should be appreciated, protected and marvelled at. In 2009, Tasik Chini has been awarded the biosphere reserve status by UNESCO. Currently, there are 651 sites of biosphere reserve located in 120 countries around the world.

It is important to maintain this biosphere reserve status to help in promoting Tasik Chini as a main destination for eco-tourism in Malaysia. In addition, the status can improve greater social awareness towards efforts in nature preservation and conservation at Tasik Chini.

The lake has been gazetted as a biosphere reserve site because of the rich diversity of its flora and fauna. Tasik Chini has 138 flora species, 300 non-aquatic life species, 144 freshwater species and 304 fauna species.

Keywords

- Niche
- Biotic
- Abiotic
- Altitude
- Aspect
- Topography
- Microclimate
- Autotroph
- Heterotroph
- Photoautotroph
- Chemoautotroph
- Ecological pyramid
- Colonisation
- Succession
- Pioneer species

9.1 Community and Ecosystem

Organisms do not just interact with each other but they also interact with non-living things to create a balanced system known as ecosystem (Figure 9.1). Let us understand a few important terms in this chapter.

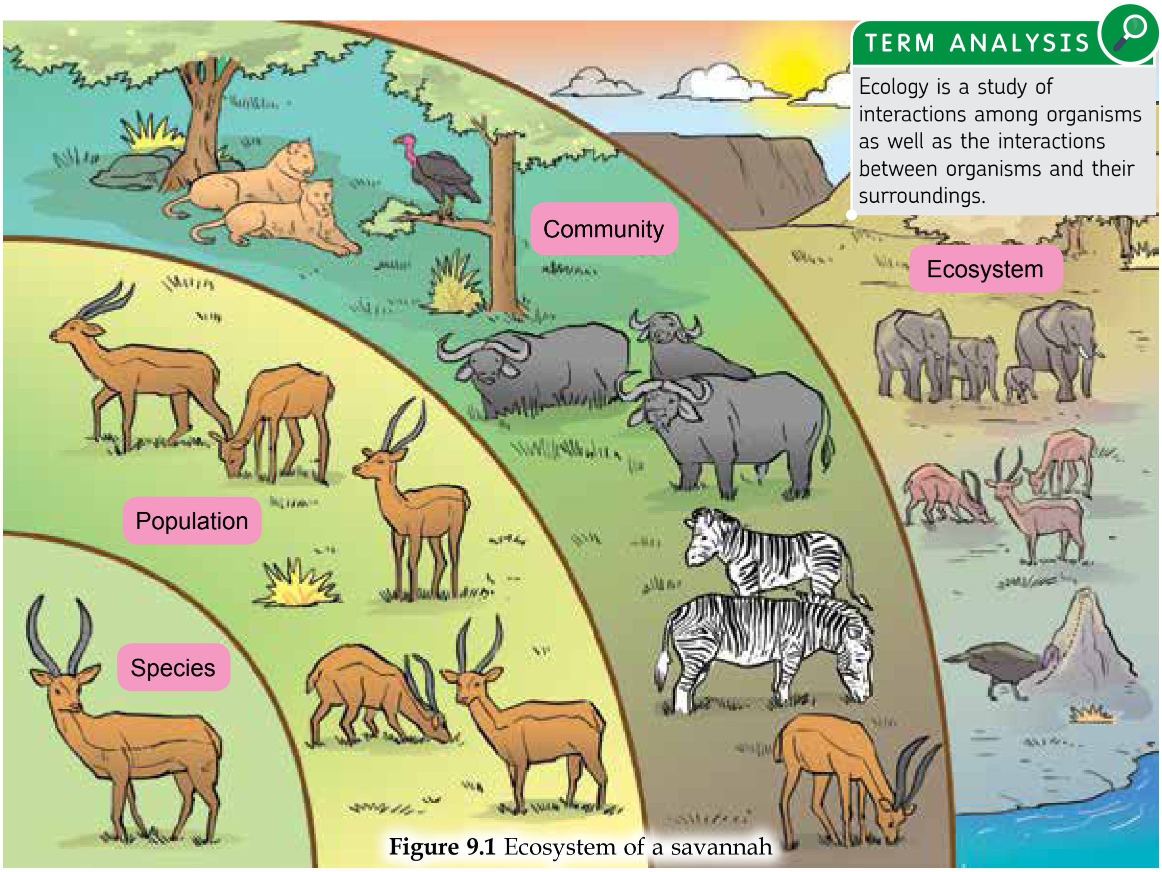


Figure 9.1 Ecosystem of a savannah

TERM ANALYSIS

Ecology is a study of interactions among organisms as well as the interactions between organisms and their surroundings.

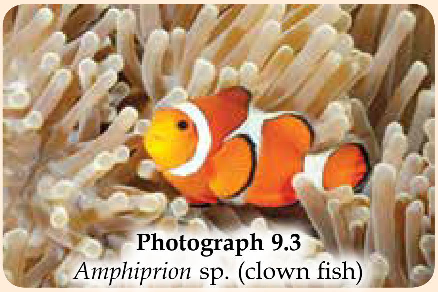
1 **Habitat** is the natural surrounding or the living place of an organism (Photograph 9.1 and Photograph 9.2).


Photograph 9.1 Habitat of birds in a forest


Photograph 9.2 Habitat of a frog in a pond

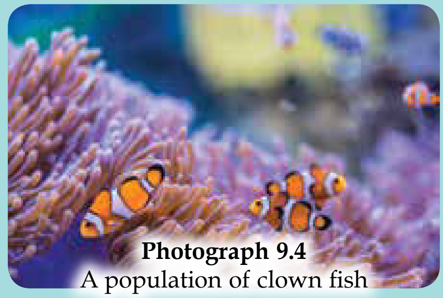
9.1.1

2 A **species** is a group of similar organisms, able to interbreed and produce offsprings (Photograph 9.3).



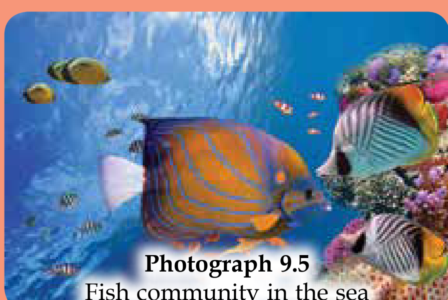
Photograph 9.3
Amphiprion sp. (clown fish)

3 A **population** is a group of organisms of the same species which live in the same habitat (Photograph 9.4).



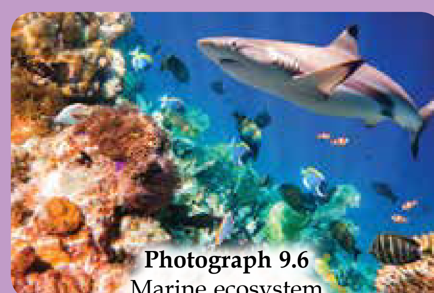
Photograph 9.4
A population of clown fish

4 A **community** is the populations of all organisms from different species living in the same habitat whilst interacting with each other (Photograph 9.5).



Photograph 9.5
Fish community in the sea

5 An **ecosystem** is a few communities that live together in a habitat and interact with each other including non-living components (abiotic) such as water, air and soil. (Photograph 9.6).



Photograph 9.6
Marine ecosystem

6 A **niche** is the role of an organism in an ecosystem which includes its behaviour and interactions with **biotic** and **abiotic components** in the surrounding of its habitat (Figure 9.2).

Niche
- **Ecological niche**: The role of a species in its surroundings.
- **Species niche**: The way in which a species interacts with biotic and abiotic components within its surroundings.

Figure 9.2 Ecological niche and species niche

Bio Exploration

The niche of an organism can vary according to the morphological change of an organism. For example, the life cycle of a butterfly has a metamorphosis that consists of different niches at each stage of its life.

9.1.1

Biotic and Abiotic Components in an Ecosystem

An ecosystem consists of two main components, which are **biotic components** and **abiotic components** (Figure 9.3). Biotic components refer to all organisms in an ecosystem which interact with other organisms. Abiotic components are all the non-living elements including their physical and chemical characteristics that can affect an organism in an ecosystem.

ECOSYSTEM

- Biotic components
  - Producers
  - Consumers
  - Decomposers
- Abiotic components
  - pH value
  - Temperature
  - Light intensity
  - Topography
  - Microclimate
  - Air humidity

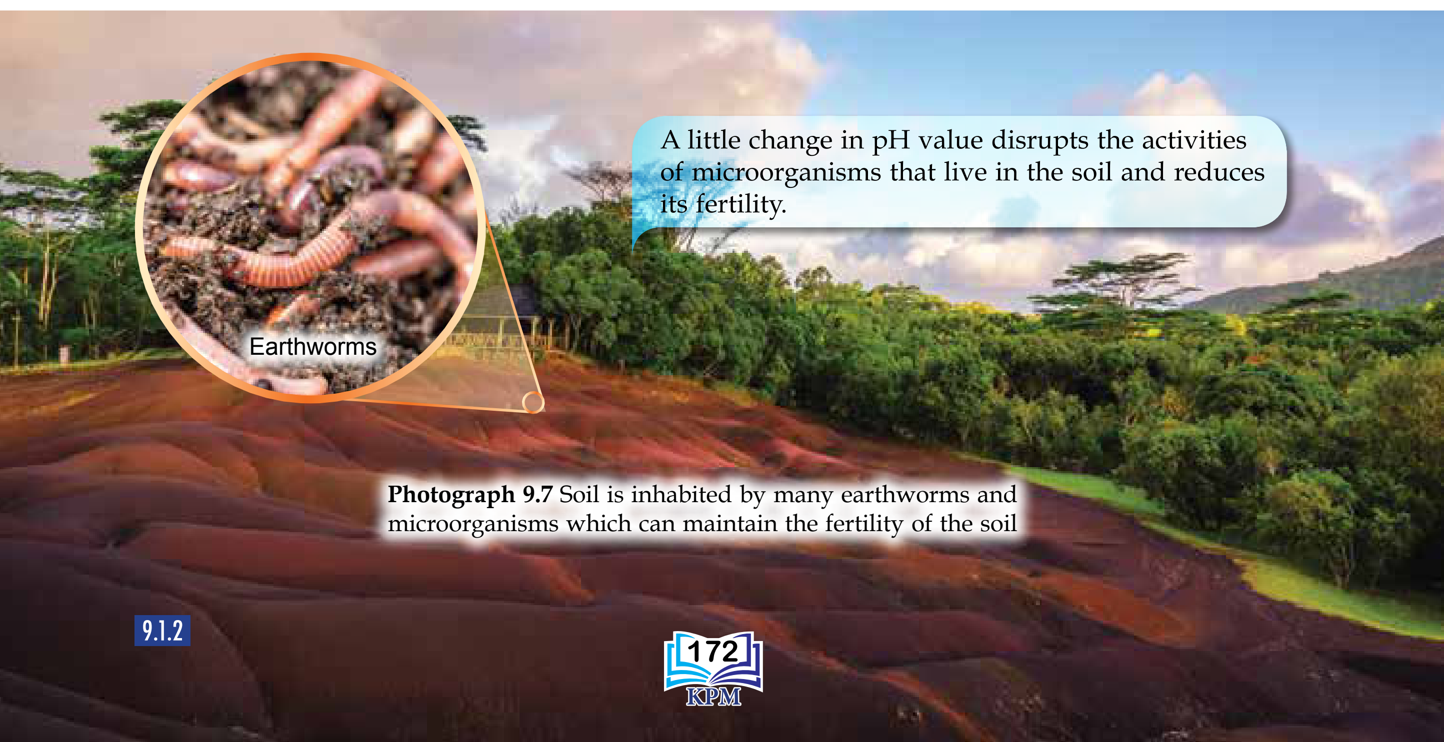
Figure 9.3 Main components of an ecosystem

> **ACTIVITY ZONE**
>
> Identify the biotic and abiotic components in a field or a pond around your school.

Abiotic Components

pH Value

- **pH value** of soil strongly influences the distribution of living organisms in a habitat. Most organisms are capable of living adequately in a condition in which the pH value is either **neutral** or almost neutral.
- Soil is a habitat for hundred millions of worms and microorganisms such as bacteria, fungi and protozoa (Photograph 9.7).



Photograph 9.7 Soil is inhabited by many earthworms and microorganisms which can maintain the fertility of the soil

9.1.2

Temperature

- Surrounding **temperature** affects the physiological activities of plants and animals.
- A little change in temperature causes a reduction in the metabolic rate of organisms as all the enzymes that catalyse physiological responses are sensitive towards temperature changes.
- Although most organisms can live within the temperature range of **20 °C to 40 °C**, there are also organisms which can live in extreme temperatures.
- Polar bears can live in Tundra, a habitat with a temperature of **–14 °C** whereas foxes can live in the desert where the temperature can reach up to **45 °C** during the day (Photograph 9.8).

Photograph 9.8 Examples of animals that live in areas with extreme temperature

Light Intensity

- **Light intensity** and duration of sunlight received by a certain region can strongly influence the distribution of organisms especially for plants that carry out photosynthesis.
- Taller plants in tropical rainforests that are exposed to high light intensity form a canopy providing low light intensity underneath.
- Only small plants such as ferns can grow under the canopy (Photograph 9.9).
- Coniferous forests in regions with temperate climate have lower density of plants due to low light intensity.
- Plants in coniferous forests are shorter as well as smaller in size (Photograph 9.10).

Photograph 9.9 Tropical rainforest

Photograph 9.10 Coniferous forest

Topography

- **Topography** is the physical characteristics on the surface of the Earth which include **altitude, gradient** and **aspect** (Figure 9.4).
- Topography determines **humidity, temperature** and **light intensity** in an ecosystem.

Altitude

- The higher the **altitude**, the lower the relative humidity, atmospheric pressure and oxygen content.
- Plants at different levels of altitudes are different in types, sizes and density.
- For example, pine trees that grow at higher altitudes are smaller in size compared to *meranti* trees which can be found in tropical rainforest.

Gradient

- **Steeper** mountain slopes are easily eroded due to swift water movement.
- The soil layer becomes thinner and drier.
- This area has less growth of plants except for some short, thorny shrubs with small and pointed leaves.

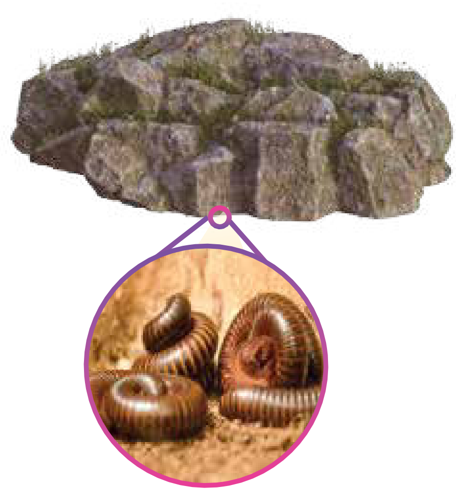
Aspect

- **Aspect** refers to the direction in which wind blows and the rays of sunlight.
- A mountain slope which faces the sea has denser plants compared to the one facing towards the land.
- This slope also gains more rainfall distribution.
- The slope that receives more sunlight is denser with plants.

Figure 9.4 Topography factors

Microclimate

- **Microclimate** refers to the climate condition of a small area which is different from the surrounding area.
- Microclimate can take place under the rocks (Photograph 9.11), or beneath the shades of bigger plants of the forest canopy.
- Microclimate depends on **temperature, humidity, light intensity, heat balance, atmospheric pressure**, **water evaporation** and **ability of soil** to retain water around an area in order to maintain humidity.



Photograph 9.11 Microclimate under a rock that has become a habitat for millipedes

9.1.2

Air Humidity

- **Air humidity** is the quantity of water vapour in the air which affects the distribution of organisms in a habitat.
- There are more organisms occupying areas of high humidity than in dry areas.
- Low air humidity increases water loss in a stoma through transpiration.
- This situation enhances the absorption of water and mineral salts from the soil.
- Transpiration also provides a cooling effect, therefore plants can maintain optimum temperature for enzyme action.

Photograph 9.12 A rhinoceros which has an affinity towards humidity, wallows in water

Bio Exploration

A rhinoceros has a big body and as a consequence, the ratio of its total surface area per volume is small. Therefore, the rate of heat released from the skin is low. On hot days, the rhinoceros often wallow in muddy water (Photograph 9.12). When the mud dries up, it forms a layer which protects the skin of the rhinoceros from the heat of the sun.

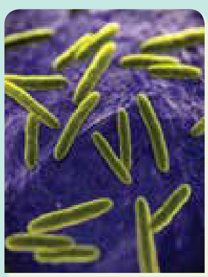
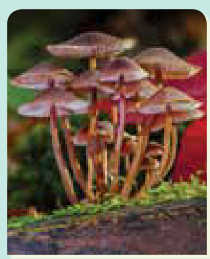
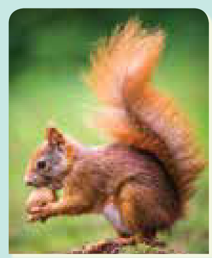
Autotrophic and Heterotrophic Nutrition

Nutrition is a way for an organism to obtain nutrients and energy from the food for its life processes (Photograph 9.13). There are two types of nutrition which are **autotrophic** and **heterotrophic**. Do you still remember about the nutrition in plants which you have learnt in Chapter 3? Table 9.1 shows the classification of organisms based on their nutritional habits.

Photograph 9.13 Chicks gain nutrients and energy from the worms they eat

9.1.2 9.1.3

Table 9.1 Classification of organisms according to their nutrition

Autotrophic		Heterotrophic		
Photoautotrophic	**Chemoautotrophic**	**Saprotrophic**	**Holozoic**	**Parasitic**
• Photoautotroph refers to an organism that synthesises complex organic compounds from carbon dioxide together with light energy. • Photoautotrophs synthesise their own food via the process of photosynthesis. • Example:  **Photograph 9.14** Green plants	• Chemoautotrophs include a few types of bacteria which synthesise organic compounds without using light. • Chemoautotrophs gain energy from the oxidation of inorganic substances such as hydrogen sulphide and ammonia through chemosynthesis. • Example:  **Photograph 9.15** *Nitrobacter* sp.	• Saprotrophs are saprophytic organisms which gain their nutrients from dead and decaying organic substances. • Digestion occurs outside the body of an organism before the nutrients are absorbed into its body. • Example:  **Photograph 9.16** Fungi	• An organism that survives by eating solid organic substances which are then digested and absorbed into the body. • Most animals including human beings are holozoic. • Example:  **Photograph 9.17** A squirrel	• Parasites are organisms that absorb nutrients from the hosts. For example, fleas and tapeworms get nutrients from their human hosts. • Example:  **Photograph 9.18** A flea

TERM ANALYSIS

- Autotroph
  Auto = self
  Trophos = eater
- Heterotroph
  Heteros = others
  Trophos = eater

Think Smart

Give one example of a plant that is classified as a holozoic heterotroph.

Biotic Components According to Trophic Levels

Biotic components are the organisms that need energy to carry out life processes. Have you ever thought of where you get your energy from? Humans and animals gain energy by feeding on other organisms including photosynthetic plants. In fact, the main source of energy for all organisms comes from the **sun**. There are three groups in biotic components which consist of **producers, consumers** and **decomposers** (Figure 9.5).

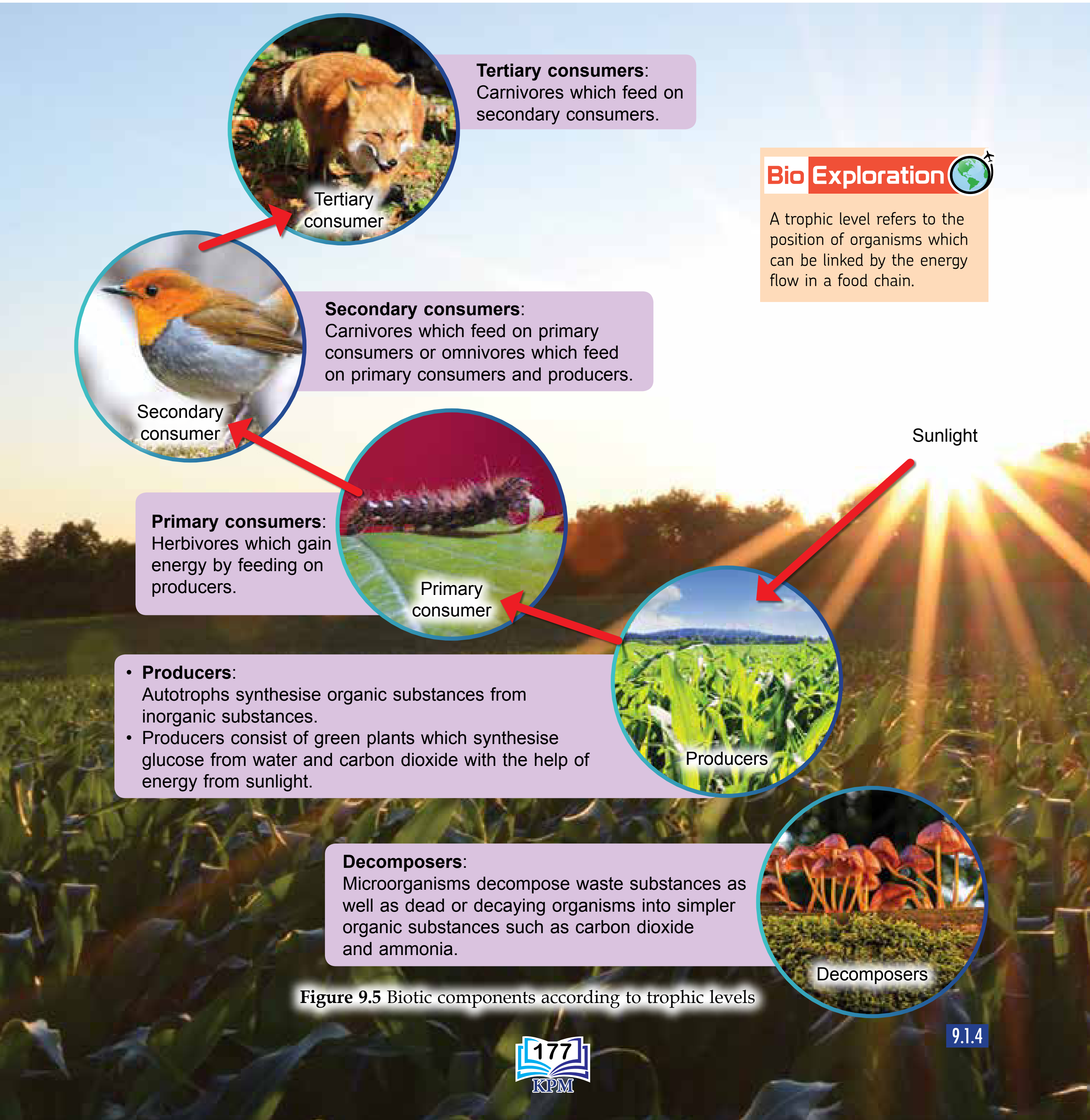


Figure 9.5 Biotic components according to trophic levels

Bio Exploration

A trophic level refers to the position of organisms which can be linked by the energy flow in a food chain.

Energy Flow in the Food Chain

Organisms in an ecosystem interact with each other in the form of a feeding relationship which can be shown in the **food chain.** A food chain is the sequence of energy transfer from one trophic level to another trophic level, beginning with the producers.

In a food chain:
- It starts with the **producer** and ends with either a **secondary consumer** or a **tertiary consumer** (Figure 9.6).
- Organisms feed on organisms from the previous trophic level.
- Energy is transferred from the consumed organisms to the feeding organisms.
- Energy is transferred between trophic levels when an organism eats other organisms from which it gains its energy. This energy is transferred to the organism after it has digested and assimilated the food to form new substances in the body.

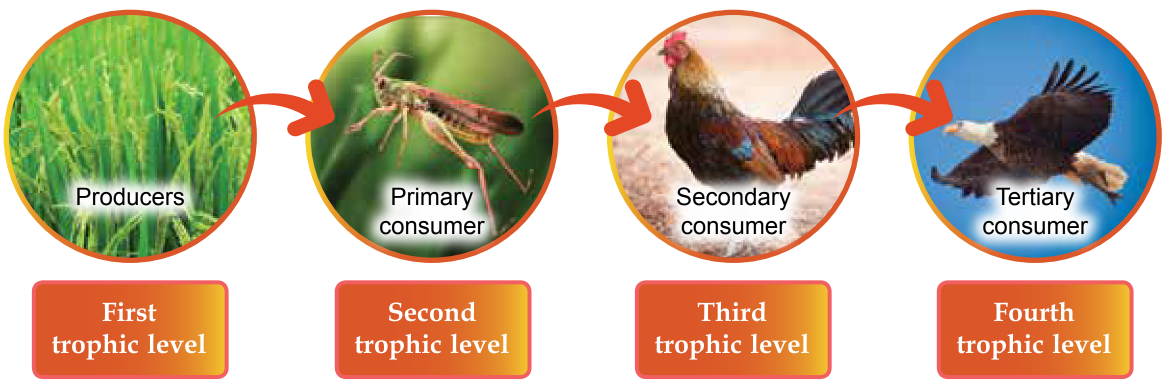


Figure 9.6 Trophic levels in the food chain

However, in natural conditions, most of the animals feed on more than one type of organisms. For example, birds eat caterpillars as well as grasshoppers and paddies. Thus, birds form a few food chains and occupy different trophic levels. A bird can be placed at the second trophic level as a primary consumer by feeding on paddy. However, the same bird can also exist at the third trophic level as a secondary consumer when feeding on grasshoppers. These are the circumstances that results in several food chains to be interconnected to form a **food web**.

In a food web:
- It shows the feeding relationships in a community.
- It consists of several food chains (Figure 9.7).
- Organisms in all food chains rely on each other in feeding aspects.
- It starts with photosynthetic producers which convert light energy from the sun into chemical energy in the form of food stored in organs such as roots, fruits, stems or leaves.

9.1.5

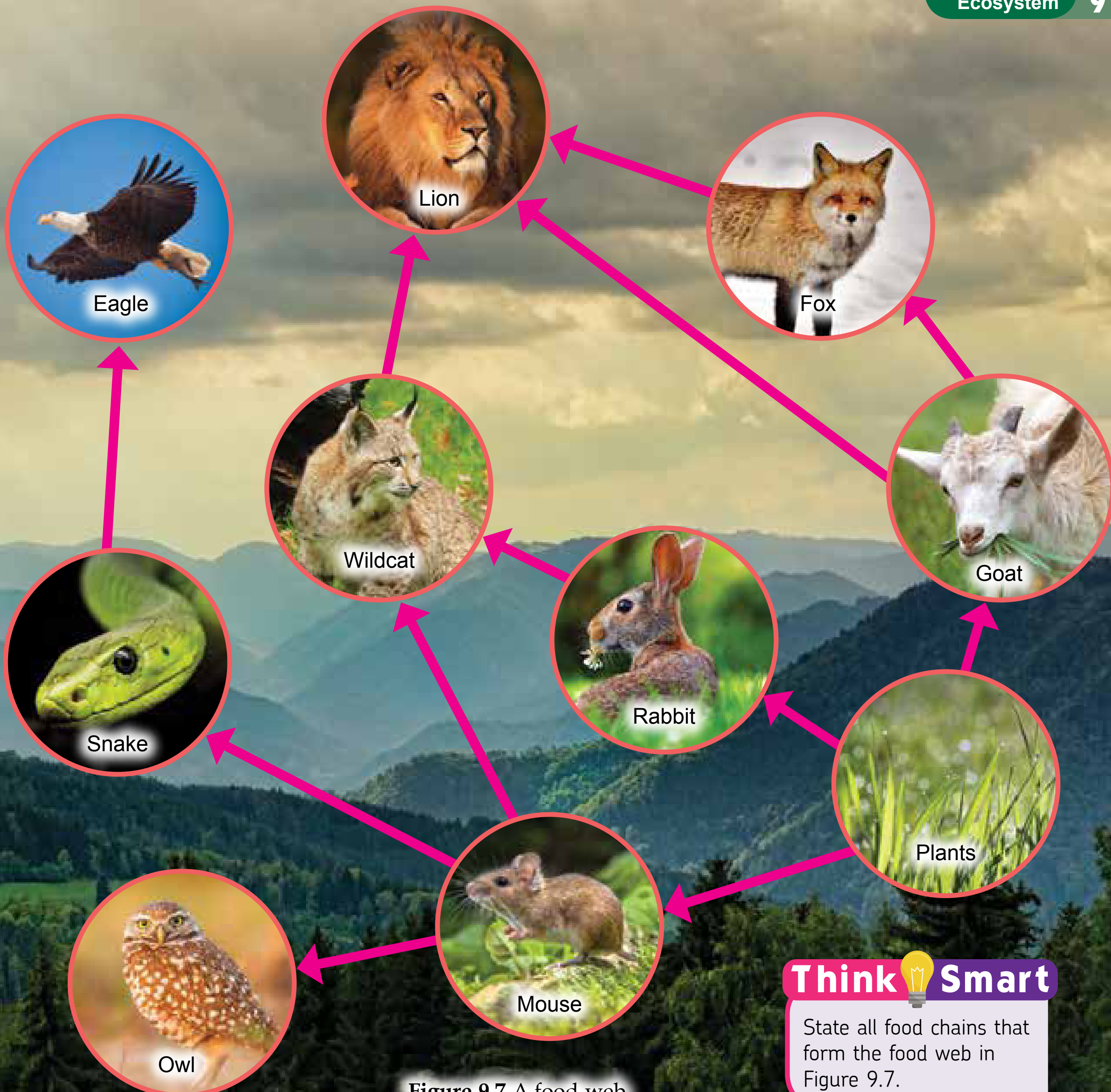


Figure 9.7 A food web

Think Smart

State all food chains that form the food web in Figure 9.7.

Activity 9.1 21st CENTURY SKILLS — THINK-PAIR-SHARE

Aim

To construct food chains as well as a food web for biotic components in the school field or pond

Procedure

1. Work in pairs.
2. Identify an ecosystem in your school area.
3. List the biotic components which are present in that ecosystem.
4. Construct a few food chains to show the interactions between the organisms.
5. Combine the constructed food chains to produce a food web to show all the interactions that happen in the ecosystem.
6. Present your findings.

9.1.5

Ecological Pyramids

Food chains and food webs show the feeding relationships among organisms. Energy transfer occurs when an organism feeds on another organism. In a feeding interaction, when a trophic level increases, the **number of individuals, biomass** and **total energy** contained in each individual for each trophic level will change. All these factors can be described in the form of **ecological pyramids** which consist of **pyramid of numbers, pyramid of biomass** and **pyramid of energy**.

Pyramid of Numbers

Pyramid of numbers is a diagram which shows the number of organisms at every trophic level in a food chain (Figure 9.8).

- The base of the pyramid is the largest part which accommodates the **first trophic level**, representing the number of producers.
- The next tiers of the pyramid are the sections for the **second, third** and **fourth trophic levels** which represent the number of primary consumers, secondary consumers and tertiary consumers.
- Ascending the pyramid, the number of organisms decreases whereas the size of organisms at each level gets bigger.

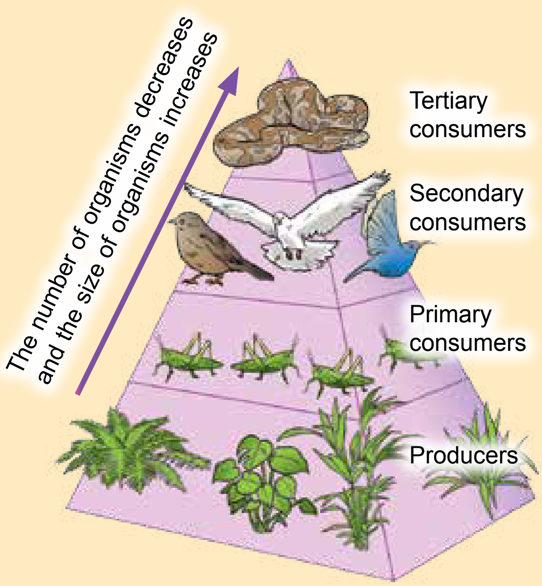


Figure 9.8 Pyramid of numbers

Pyramid of Biomass

Pyramid of biomass is a diagram which shows the total biomass per unit area of all organisms in every trophic level (Figure 9.9). Biomass is measured by using dry mass.

- This pyramid shows the biomass that can be supplied to the organisms in the next trophic level.
- For example, the total biomass of producers that can be eaten by primary consumers is higher than the total biomass of primary consumers in the ecosystem.
- The total biomass of secondary consumers is lower than primary consumers.
- Ascending the pyramid, the total amount of biomass per unit area decreases.

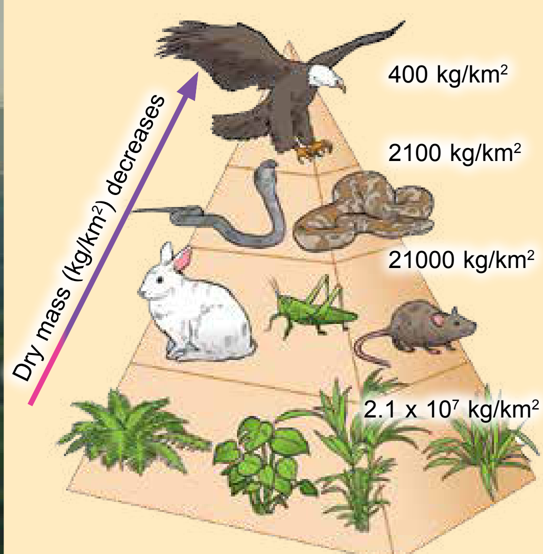
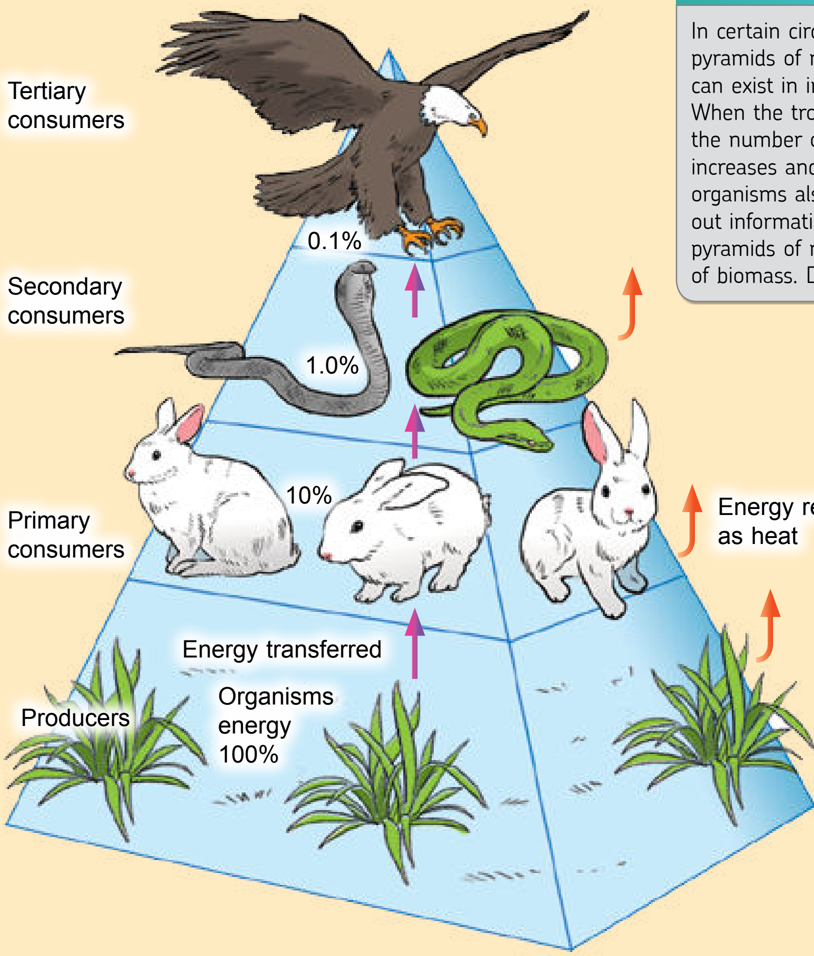


Figure 9.9 Pyramid of biomass

9.1.6

Pyramid of Energy



ACTIVITY ZONE

In certain circumstances, both pyramids of numbers and biomass can exist in inverted position. When the trophic level increases, the number of organisms increases and the biomass of organisms also increases. Find out information on both inverted pyramids of numbers and pyramid of biomass. Draw the pyramids.

Figure 9.10 Pyramid of energy

Pyramid of energy demonstrates the total energy which is present in an ecosystem (Figure 9.10).

- The energy source in an ecosystem is **light energy** from the sun which is absorbed by green plants to carry out photosynthesis and convert it into chemical energy.
- The energy will be transferred to the next trophic level when a primary consumer feeds on a producer.
- The energy contained inside the food molecules may be stored in the body tissues, or transferred into the environment in the form of excrement such as faeces or discharged as urine.
- When food molecules are decomposed for respiration and other reactions, some energy is released into the environment through heat. Only a small part of the energy in food is converted into energy stored in body tissues as a supplement to the organism's biomass.
- Only 10% of the energy is transferred to the next trophic level.
- 90% of the energy is dissipated into the environment through heat, living processes and excretion.
- Hence, organisms that belong to lower trophic levels have greater energy if compared to organisms at higher trophic levels.

9.1.6

Types of Interaction among Biotic Components

As humans, we live in a community. Every member in that community needs one another. It is similar for animals and plants which interact with each other in an ecosystem in various ways. There are a few types of main interactions, which are **saprophytism, symbiosis**, **predation** and **competition** (Figure 9.11). There are two types of competitions, which are **intraspecific competition** and **interspecific competition**. Intraspecific competition happens among organisms of the same species. Interspecific competition happens among organisms of different species.

Saprophytism

Saprophytism is an interaction in which an organism gets its food from dead organic materials.

- For example, mushrooms that live on dead tree trunk.

Photograph 9.19
Mushrooms living on dead tree trunk

Symbiosis

Symbiosis occurs when different species that live together, interact with each other.

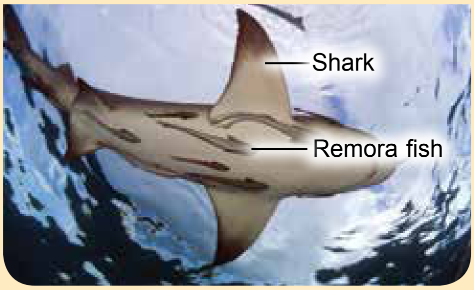
Mutualism

- Mutualism is an interaction that gives benefits to both organisms.
- For example, a myna gets its food (lice) from the body of a buffalo whereas the buffalo is free from the lice.

Photograph 9.20
Mynas and buffaloes

Commensalism

- Commensalism is an interaction that provides benefits to only one organism without causing any harm to the other organism.
- For example, a shark does not gain any benefit but the remora fish gets scraps of the shark's food.



Photograph 9.21
A shark and remora fish

Figure 9.11 Interaction among biotic components

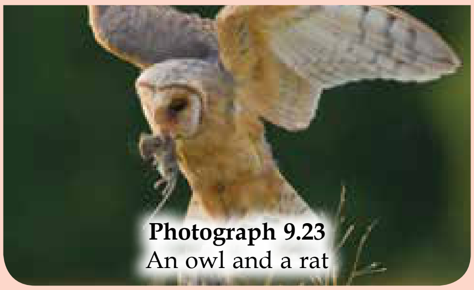
9.1.7

Interaction among Biotic Components

Predation

It is an interaction involving an organism (predator) that eats another organism (prey).

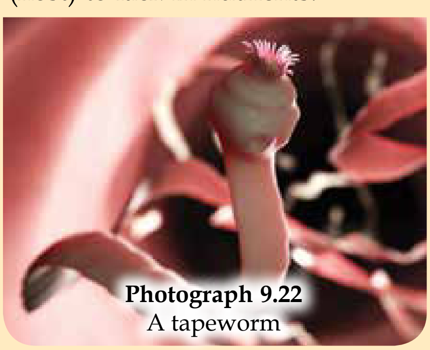
- For example, an owl which is a predator catches and eats rats as its prey.



Photograph 9.23
An owl and a rat

Parasitism

- Parasitism is an interaction that benefits one organism but harms the other organism.
- For example, a tapeworm becomes a parasite in the intestines of a human being by absorbing nutrients and causes the human (host) to lack in nutrients.



Photograph 9.22
A tapeworm

Competition

Competition occurs when organisms in a habitat compete in order to get basic needs such as food, water, light and mates.

Interspecific competition

- For example, competition among different species of plants to get sunlight.

Photograph 9.24
Interspecific competition

Intraspecific competition

- For example, competition among animals of the same species to get mates.

Photograph 9.25
Intraspecific competition

ICT

Video

Interaction between Organisms

http://bukuteksksm.my/Biology/F5/InteractionBetweenOrganisms.mp4

Think Smart

List a few other examples of mutualism, commensalism and parasitism that you have learnt in Form Two.

9.1.7

EXPERIMENT

9.1 The Effects of Intraspecific and Interspecific Competitions among Organisms

Problem statement
What are the effects of intraspecific and interspecific competitions among organisms?

Aim
To study the effects of intraspecific and interspecific competitions among organisms

Hypothesis
If the competition among organisms is high, the growth of organisms becomes slow.

Variables
Manipulated variable: Types of seeds
Responding variable: Height of seedlings
Constant variable: Amount and type of soil, amount of water sprinkled, fertilisers, light intensity

Materials
Fertilised soil, 120 corn seeds, 120 paddy seeds

Apparatus
Three plastic trays with the measurements of 50 cm × 40 cm × 10 cm, a ruler, a mini shovel

Procedure

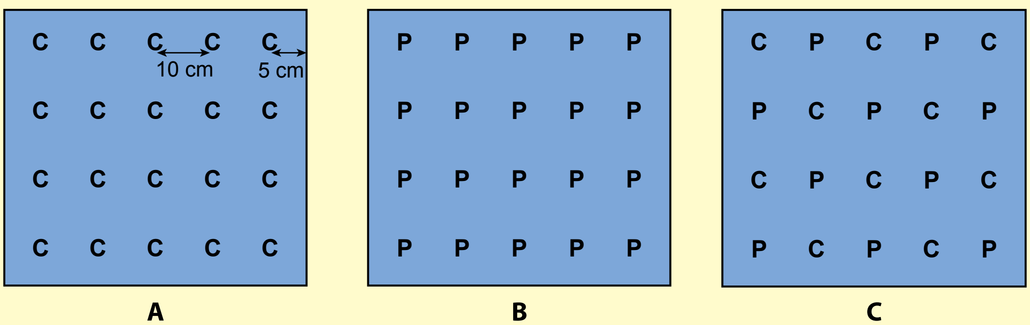


Figure 9.12

1. Label all plastic trays as A, B and C (Figure 9.12).
2. Randomly choose 30 corn seeds (C) and 30 paddy seeds (P).
3. Sow:
   (a) 20 corn seeds in tray A
   (b) 20 paddy seeds in tray B
   (c) 10 corn seeds and 10 paddy seeds in tray C
4. Ensure the distance between each seed is 10 cm whereas the distance between the seeds and the edge of the tray is 5 cm.
5. Put all the trays in a shady place.
6. Water every tray with the same amount of water.
7. After a month, randomly select:
   (a) 10 corn seedlings from tray A
   (b) 10 paddy seedlings from tray B
   (c) 5 corn seedlings and 5 paddy seedlings from tray C.
8. Measure and record the height of every seedling and their average into a table.
9. Based on the table, plot a bar graph using the height of the seedlings in centimetres.

9.1.7

EXPERIMENT

Results

Type of seeds/ Trays	Height of seedlings (cm)										
	1	2	3	4	5	6	7	8	9	10	Average
Corn / Tray A											
Paddy / Tray B											
Corn / Tray C											
Paddy / Tray C											

Discussion

1. Name the type of competition that has taken place in trays A, B and C.
2. What are the sources that cause the competition in trays A, B and C?
3. Which species is more adaptive in the competition in tray C? Explain.
4. Compare the heights of:
   (a) Corn seedlings in trays A and C.
   (b) Paddy seedlings in trays B and C. Explain your answer.

Conclusion

Is the hypothesis accepted? Suggest a suitable conclusion.

Mangrove Ecosystem

Abiotic Components

Mangrove trees are tropical plants which are usually found in estuaries. Estuaries is a place where the sea and river meets. These plants have successfully adapted themselves to the extreme abiotic components (Figure 9.13).

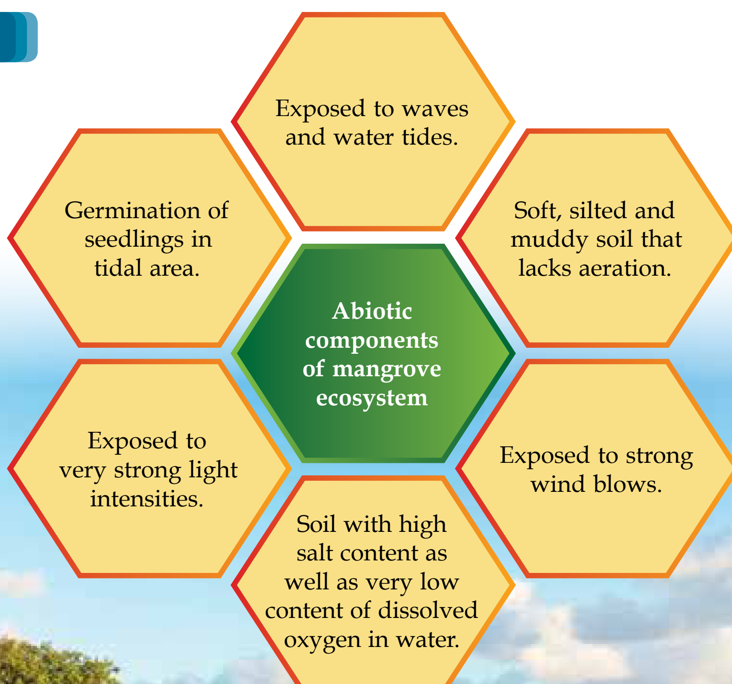


Figure 9.13 Abiotic components of a mangrove ecosystem

9.1.8

Biotic Components

Other than the mangrove plants as producers that dominate the ecosystem, many other species of flora and fauna adapt themselves to live in the mangrove forest (Photograph 9.26). In addition, there are also decomposers such as bacteria and fungi which decompose dead organisms into nutrients for the plants. These organisms form a food web that helps to maintain the dynamic balance of the mangrove forest.

Think Smart

Can you list down other biotic components of mangroves?

Bio Exploration

A firefly is an insect which can be found in a mangrove forest. The mangrove area in Kampung Kuantan, Kuala Selangor is famous for its fireflies, *Pteroptyx tener.*

Photograph 9.26 Biotic components of a mangrove ecosytem

9.1.8

Adaptation Features of the Mangrove Trees

Mangrove trees have special features for survival of the species in an inapt environment. Table 9.2 shows the adaptation features of mangrove trees in dealing with the surrounding conditions.

Table 9.2 Features of mangrove trees to adapt in the surrounding conditions

Parts of mangrove trees	Adaptation features
Leaves	• Mangrove leaves have thick cuticles and sunken stomata which can reduce the rate of transpiration. • These leaves have succulent leaves that can store water and special structure known as **hydathode** to eliminate excess salt. • Mature leaves can store salt, which will fall off when the concentration of salt stored is too high.  **Photograph 9.27** A leaf of a mangrove tree
Pneumatophore roots	• **Pneumatophore roots** are short root projections from the soil surface for aeration in water-submerged areas. • The root allows the gas exchange between the submerged root and atmosphere through lenticels. • Example: *Avicennia* sp.  **Photograph 9.28** A pneumatophore root
Prop roots	• **Prop roots** branch out from the lower part of the stem of a mangrove tree. • The roots are firmly planted in the soil to support the tree to overcome strong winds and waves. • Example: *Rhizophora* sp.  **Photograph 9.29** Prop roots
Buttress roots	• **Buttress roots** are a type of roots with a thick structure that can add in widening the base of a tree. • The roots provide support to the tree that grows on soft soil which borders with solid land. • Example: *Bruguiera* sp.  **Photograph 9.30** Buttress roots
Seeds	• Viviparous seeds germinate and grow when they are still on the parent plant. • This feature enables fallen seedlings to stick into the muddy soil and will not be uprooted by waves.  **Photograph 9.31** Viviparous seedlings

9.1.8

Colonisation and Succession

An ecosystem can change due to natural phenomena such as a volcano eruption, earthquakes, draughts and human activities. Human activities, such as mining can cause organisms to die or migrate to other habitats. However, after a long period of time, this deserted area starts to have inhabitants known as **pioneer species**, a species that begins to colonise an area where there are no other living things (Figure 9.14).

COLONISATION
Plants start to conquer an uninhabited area, breed and form colonies in that area.

SUCCESSION
A few species of dominant plants in a habitat are gradually being replaced by other species called successor.

Coastal zone

- **Coastal zone** is the area that is most exposed to big waves.
- This zone is dominated by **pioneer species**, which are *Avicennia* sp. (*Api-api* tree) and *Sonneratia* sp. (mangrove apple)
- An enlarged root system and pneumatophores help the trees to trap mud and organic substances which are brought by high tides.
- Mud accumulation slowly begins and as a result, the soil becomes higher and denser.
- *Rhizophora* sp. succeeds and replaces the pioneer species.

Middle zone

- **Middle zone** is situated along the river, closer to the estuaries.
- An area inhabited by *Rhizophora* sp. plants (*bakau minyak* tree) that have tangled prop roots. These roots can trap twigs and mud which are washed away and block the flow of water.
- The trapped mud causes sedimentation to occur much faster.
- The river bank becomes higher and drier because less seawater overflows during high tides.
- The soil becomes less suitable for the growth of *Rhizophora* sp. Instead it is more suitable for *Bruguiera* sp.
- *Bruguiera* sp. succeeds and replaces *Rhizophora* sp.

Inland zone

- **Inland zone** is situated further into the land.
- The soil becomes higher, harder and only flows with seawater during high tides.
- The area is inhabited by *Bruguiera* sp. (*tumu merah* tree) which have buttress roots to trap more mud and silt.
- Sedimentation process forms a new swamp that projects out towards the sea.
- The one-time shore gets further away from the sea and the ground changes into a land which is suitable for land trees such as *Nypa fruticans* and *Pandanus* sp.
- The land trees succeed and replace *Bruguiera* sp.

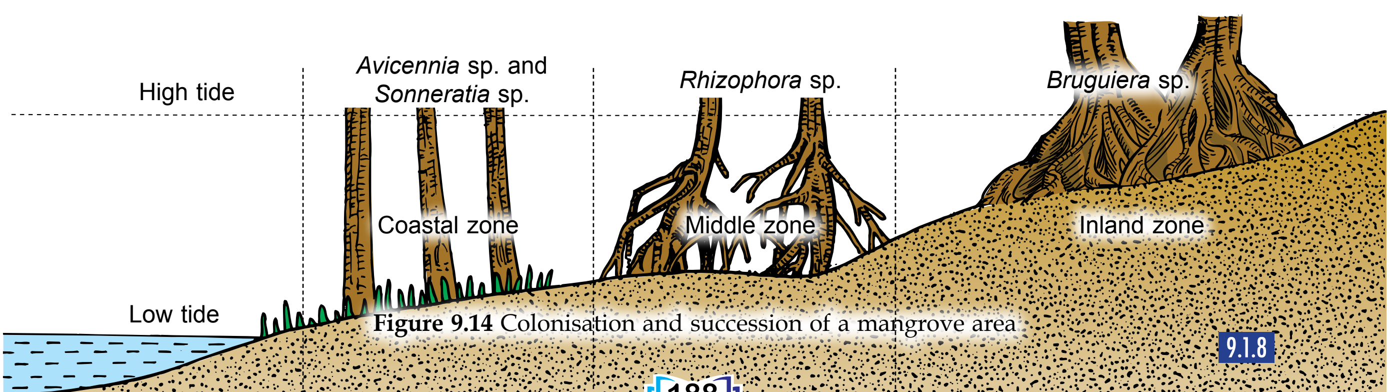


Figure 9.14 Colonisation and succession of a mangrove area

9.1.8

The Importance of the Mangrove Ecosystem

PROTECTION ZONE

- Mangrove forests become a **natural barrier** to lessen the impact of strong waves and wind that reach the seashore area.
- Mangrove forests offer a **protected site** for small fish, shrimps and crabs from predators as well as swift movements of currents and waves.
- Mangrove forests can become preserved areas where various species of migratory birds can search for food.

FISHERY RESOURCES

- Sea products such as fish, shrimps, crabs and sea snails become a **source of income** for fishermen living near the mangrove areas.
- The wetlands in mangrove areas are conducive for **fish rearing in floating cages** and also for breeding commercial species.

FORESTRY RESOURCES

- Mangrove woods can be used to build **boats, fish traps** and **building frames**.
- Mangrove woods can also be used to make **handicrafts**.
- Mangrove wood is burnt in the furnace to produce a type of fuel called **charcoal**.

FOOD AND MEDICINE RESOURCES

- The fruit of *Avicennia* sp. can be consumed as a vegetable. The nut can be boiled and eaten whereas its flower produces honey.
- The fruit of *Sonneratia* sp. is used in the production of drinks.
- The fruit of *Nypa* sp. can be eaten and water from the fruit can be used in the production of vinegar and *nira.*
- The bark of *Bruguiera* sp. tree can be used to treat diarrhoea.

Figure 9.15 The importance of a mangrove ecosystem

Activity 9.2

Aim

To study and carry out a presentation on the importance of the mangrove ecosystem

Procedure

1. Work in groups.
2. Carry out a field study in a mangrove ecosystem. Study:
   (a) The charcoal industry
   (b) A village industry such as *nipah* roofs or palm sugar productions
   (c) The activities available at mangrove swamps such as harvesting cockles, shrimps and crabs
3. Present the findings of your group in the form of multimedia presentation.

9.1.8

Formative Practice 9.1

1. Give the definitions of each of the following:
   (a) Species
   (b) Population
   (c) Community
2. In an ecosystem, biotic components interact with each other as well as with other surrounding factors. Give **one** example of an interaction that occurs in a grass field.
3. Explain how an aspect can affect the distribution of organisms in an ecosystem.
4. The pyramid of numbers shows the relationship between trophic levels with number, size of organisms and also the value of transferred energy. Explain each relationship between:
   (a) Trophic levels and the number of organisms
   (b) Trophic levels and the total number of biomass per unit area
   (c) Trophic levels and the energy values
5. State the importance of mangrove from the aspects of:
   (a) Security
   (b) Source of income
   (c) Tourism
   (d) Education

9.2 Population Ecology

Population ecology is a branch of ecology which studies the interactions of a population with its surroundings. As learnt in Subtopic 9.1, a population is a group of organisms of the same species living in the same habitat. Population distribution shows how the organisms of the same species are able to spread out in a habitat. What are the factors affecting the population distribution?

Factors Affecting Population Distribution

Population distribution is affected by abiotic factors as shown in Table 9.3.

Table 9.3 Factors affecting population distribution of plants and animals

Factors	The effects towards plants
Temperature	• The optimum temperature for plant growth is between **25 °C to 30 °C**. • High temperatures can cause enzymes to denature. Biochemical processes in plants are disrupted and they: ➢ stunt the growth of plants. ➢ increase the rate of water evaporation by transpiration. ➢ slow the rate of photosynthesis. • Low temperatures reduce the activities of enzymes which slow down the biochemical reactions.
Water	• Water is needed for enzyme activities, photosynthesis, transport and support in herbaceous plants. • Dry regions such as a desert and tundra areas such as at the poles have low population distribution and also low density of plants.

9.2.1

Light	• Light is very important for the process of photosynthesis in plants. • Areas which receive little light have a lower number of plants.
pH of soil	• The pH of soil is important for nutrient absorption by the roots. • Soil in which the pH is either too acidic or too alkaline will cause lower absorption of nutrients by plants. • The growth of plants will be disrupted due to lack of nutrients.
Mineral salt content	• Salt content affects the absorption of water through osmosis by the roots. • High salt content in soil will cause plants to lose water through osmosis. • Minerals are needed for the production of proteins, enzymes, nucleotides, vitamins and others compounds. • As an example, phosphorus is used to form phospholipids (in the formation of cell membrane).
Factors	**The effects towards animals**
Temperature	• Areas which are exposed to high temperatures in a habitat are less inhabited by certain animals such as worms and snails.
Water	• Animals are concentrated in areas that have enough water sources for drinking and cooling the body.
Breeding site	• A safe and suitable breeding site is needed by animals to raise their offsprings.
Food supply	• Food is important for survival because animals are heterotrophs which depend on plants and other animals for food.

There are three patterns of population distribution which are **clumped, random** and **uniform** (Figure 9.16).

CLUMPED
- Clumped organisms form separated groups.
- This condition is caused by uneven distribution of resources in an area.

RANDOM
- Organisms are distributed in a free pattern in an area.
- This distribution involves species that have little interaction among individuals.

UNIFORM
- Organisms are distributed all over an inhabited area.
- This distribution involves species in which every individual competes for limited resources in an area.

Figure 9.16 Patterns for population distribution

9.2.1

Estimation of Organism Population Size

Two important factors for studying population ecology are **population size** and **population density**.

Population size: The number of organisms present in a population.
Population density: The number of individuals of a species per unit area of a habitat.

The population size in an area can be estimated by a random sampling technique when the studied area is large and difficult to obtain data. A sample which represents the area is taken to give an estimation of the abundance and the distribution pattern of certain organisms that inhabit the area.

Quadrat Sampling Technique

A **quadrat sampling technique** can estimate the population size of land plants or animals which are **inactive** or move slowly (Photograph 9.32). The number of organisms in the quadrat areas is the sample which represents the whole area of study. The data obtained from all quadrats can be used to estimate the population in the area of study.

A **quadrat** is a square-framed structure which is made of wood, iron or plastic (Figure 9.17). Normally, a quadrat is subdivided into a few parts of the same size to estimate the coverage percentage of any species. The size of the quadrat depends on the types and size of organisms, the area of study as well as the distribution and density of the plants being studied. For example, a one-metre-squared quadrat is suitable to estimate the population of plants in a school field.

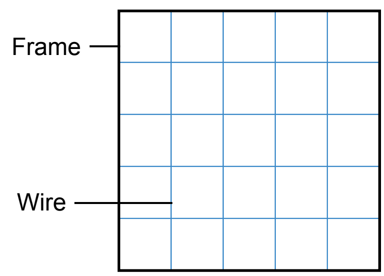


Figure 9.17 A quadrat

Think Smart

Which technique is more accurate than a quadrat sampling technique in determining the distribution of plants in a field? Explain.

Bio Exploration

During quadrat sampling, you should place a quadrat randomly and not based on an area with the most plants being studied can be found.

Photograph 9.32 Quadrat sampling technique

9.2.1 9.2.2

Quadrat sampling technique can estimate the **frequency, density** and **coverage** of any plant species which is being studied in the area of study.

- **Frequency** is the probability to get an individual of any plant species in every quadrat.

$$\text{Frequency} = \frac{\text{The number of quadrats containing studied species}}{\text{Total number of quadrats used}} \times 100\%$$

- **Density** is the average number of individuals in any species per unit area of study.

$$\text{Density} = \frac{\text{Total number of individual species studied in all quadrats}}{\text{Total number of quadrats used} \times \text{Area of a quadrat}}$$

- Coverage is the surface area of the soil which is covered by the shoots of the plant species. The **coverage percentage** is the percentage of soil surface covered by the plants.

$$\text{Coverage percentage} = \frac{\text{Area covered by studied species in all quadrats}}{\text{Total number of quadrats used} \times \text{Area of a quadrat}} \times 100\%$$

Activity 9.3

Aim
To carry out a field study to estimate the population size of plants in the school field

Apparatus
A quadrat measuring 1 m × 1 m, a pen, a note book

Procedure
1. Identify a plant species X present in the school field.
2. A quadrat measuring 1 m × 1 m is randomly placed in a part of the school field.
3. Calculate the number of species X in the quadrat.
4. Repeat steps 2 and 3 at nine other sites of the field, randomly selected, also for the same plant species.
5. Record the results in a table.
6. Calculate the frequency, density and the coverage percentage of sample species X.

Observations

Plant species	Quadrat										Total number of species	Density of species (m^2)
	1	2	3	4	5	6	7	8	9	10		
X												

9.2.2

$$\text{Density} = \frac{\text{Total number of species individual studied in all quadrats}}{\text{Total number of quadrats used} \times \text{Area of a quadrat}}$$

Plant species	Quadrat										Area covered by species	Coverage percentage %
	1	2	3	4	5	6	7	8	9	10		
X												

$$\text{Coverage percentage} = \frac{\text{Area covered by studied species in all quadrats}}{\text{Total number of quadrats used} \times \text{Area of a quadrat}} \times 100\%$$

Discussion

1. State the pattern of species distribution that you have studied. Justify your answer.
2. State the surrounding factors which affect the pattern of population distribution of the species that you have studied.
3. What is the frequency, density and coverage percentage of the species in the school field?

Conclusion

Is the hypothesis accepted? Suggest a suitable conclusion.

Capture-Mark-Release-Recapture Technique

Capture-mark-release-recapture technique can estimate the population size of organisms such as foxes, sharks, snails, millipedes, insects and butterflies which can move freely in the studied area. This technique involves a number of steps such as in Figure 9.18.

Photograph 9.33 Snails which have been marked

Animals under study are captured randomly in the area of study (natural habitat). → The number of animals captured is recorded. → Every animal captured is marked by using nail polish, paint or Indian ink. → The marked animals are then released into the same area of study. → After a certain period of time, a second capture is done randomly in the same area of study. → The total number of animals captured the second time, both marked and unmarked is recorded.

Figure 9.18 The steps for capture-mark-release-recapture technique

9.2.2

Activity 9.4

Aim
To carry out a field study to estimate the population size of animals

Apparatus
Paint brush, Indian ink or nail polish, a pen, papers

Procedure
1. Choose a suitable area in the school compound where you can carry out a study.
2. Identify the type of animals which is abundant in that area to become a sample.
3. Capture five samples of the chosen organism (P) in the study area.
4. Mark all the captured organisms.
5. Release all the marked (P) organisms in the same area where they have been captured.
6. After a few days, recapture another five samples of organisms (Q) in the same area.
7. Record the total of marked samples in the second capture (R).
8. Estimate the population size of the organisms by using the formula:

$$\text{Population size} = \frac{P \times Q}{R}$$

Keys:
P : The number of animals in the first capture
Q : The number of animals in the second capture
R : The number of marked animals in the second capture

Discussion
1. What is the substance that you used to mark the captured animals? Justify the substance that you have chosen.
2. State the interactions that have happened between the studied organisms with both biotic and abiotic components in that area.
3. State the basic needs that enable the studied organisms to inhabit the area.

Activity 9.5

Pleurococcus sp. is a type of green algae growing on areas that are protected from the scorching sunlight to form a slimy layer on places such as tree barks, stones and moist soil. This algae can reproduce very fast through vegetative cell division by binary fission. *Pleurococcus* sp. is a sphere-shaped unicellular organism which can exist individually or in groups. It has thick cell walls to prevent excessive water loss. Every cell is abundant with chloroplasts for photosynthesis.

Aim
To carry out a field study to observe the effects of abiotic components on the population of an organism

9.2.2

Apparatus

Five quadrats (10 cm × 10 cm) which are made from transparent plastic, a marker pen, a roll of string and a metre ruler

Procedure

1. Choose a tree which has an uneven growth of *Pleurococcus* sp. at the lower part of the tree trunk.
2. Identify the side of the tree which receives the most sunlight.
3. Tie a string around the tree trunk at an estimated distance of one metre from the ground.
4. Draw grids measuring 1 cm × 1 cm on each of the transparent quadrats.
5. Put the quadrats at the lower part of the string at different aspects, P, Q, R, S and T as seen in Figure 9.19.

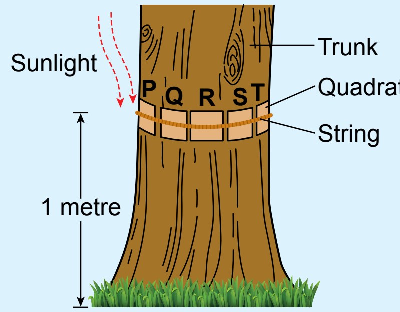


Figure 9.19 The arrangement of quadrats on the tree trunk

6. By using a marker pen, shade all parts where the growth of *Pleurococcus* sp. can be seen in the transparent quadrats.
7. Count the number of squares which contain *Pleurococcus* sp. in the quadrats. (Note: Only count squares which are half-covered or more than half-covered)
8. The coverage percentage for all quadrats is estimated by using the formula:

$$\text{Coverage percentage (\%)} = \frac{\text{Area covered by } \textit{Pleurococcus} \text{ sp. in five quadrats (cm}^2\text{)}}{\text{Total number of quadrats used (5)} \times \text{Area of a quadrat (100 cm}^2\text{)}} \times 100\%$$

Discussion

1. Which quadrat receives sunlight
   (a) the most?
   (b) the least?
2. Which quadrat has the coverage percentage of *Pleurococcus* sp. that is
   (a) the highest?
   (b) the lowest?
3. Explain the influence of sunlight towards the growth of *Pleurococcus* sp.

Formative Practice 9.2

1. An ecosystem has a population size, population density and population distribution.
   (a) What is the difference between population size and population distribution?
   (b) State the factors that can affect population distribution.
   (c) State the patterns of the population distribution. Explain.
2. Quadrat sampling can be used to find the coverage percentage of plants in the school field. You are supplied with a quadrat which consists of a square-shaped wood frame. According to your biology teacher, the quadrat needs to be modified to obtain a more accurate estimation. Explain.

Memory Flashback

ECOSYSTEM

- Definition
  - Habitat
  - Species
  - Population
  - Community
  - Ecosystem
  - Niche
- Components in an ecosystem
  - Biotic
    - Producers
    - Consumers
    - Decomposers
  - Abiotic
    - pH value
    - Temperature
    - Topography
    - Air humidity
    - Microclimate
    - Light intensity
- Types of nutrition
  - Autotrophic
    - Photoautotrophic
    - Chemoautotrophic
  - Heterotrophic
    - Holozoic
    - Saprotrophic
    - Parasitic
- Biotic components and trophic levels
  - Producers
  - Consumers
    - Primary consumers
    - Secondary consumers
    - Tertiary consumers
  - Decomposers
- Nutrition relationship
  - Food chain
  - Food web
- Ecological pyramid
  - Pyramid of numbers
  - Pyramid of biomass
  - Pyramid of energy
- Types of interaction among biotic components
  - Symbiosis
    - Mutualism
    - Commensalism
    - Parasitism
  - Saprophytism
  - Predation
  - Competition
- Mangrove
  - Biotic and abiotic components
  - Adaptation features of mangrove trees
  - Colonisation and succession
  - The importance of a mangrove ecosystem
- Population ecology
  - Population distribution
  - Population density
  - Population pattern
  - Population size
  - Estimating population
    - Quadrat sampling
    - Capture-mark-release-recapture

Interactive Bio 9

SELF-REFLECTION

Complete the following self-reflection to identify the important concepts that you have studied.

Important concepts	Very good	Try again
Definition of species, population, community, habitat, niche and ecosystem		
Biotic components and abiotic components in an ecosystem		
Autotroph nutrition and heterotroph nutrition		
Biotic components according to trophic levels		
Pyramid of numbers, pyramid of biomass and pyramid of energy		
The different types of interactions among biotic components, which are parasitism, commensalism, mutualism, saprophytism, competition and predation		
Mangrove ecosystem from the aspects of biotic components, abiotic components, adaptations of mangrove trees, colonisation and succession, the importance of a mangrove ecosystem		
Factors affecting population distribution		
Quadrat sampling technique and capture-mark-release-recapture technique		

Summative Practice 9

1. Figure 1 shows changes of plant sequence in a mangrove area.

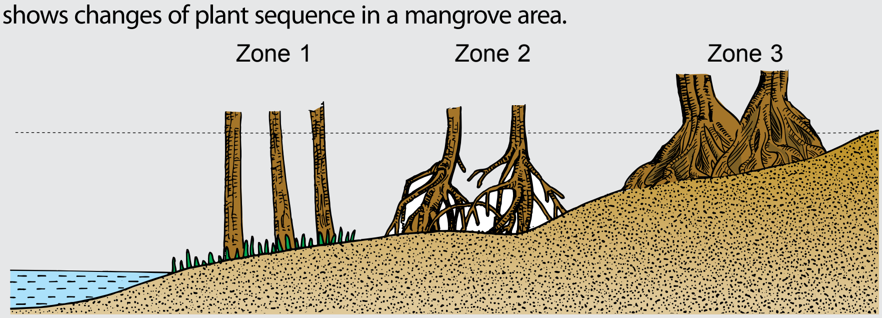


Figure 1

(a) Name the plants in each of the zones: 1, 2 and 3.

(b) (i) Name the process that causes plants in Zone 1 to distribute to a new habitat.
(ii) Name the process that causes plants in Zone 1 to be replaced by plants in Zone 2.

(c) The plants in Zone 2 are cut down to build a fish breeding pond.
Explain how this activity affects the mangrove ecosystem.

2. Figure 2 shows a situation in a grassland.

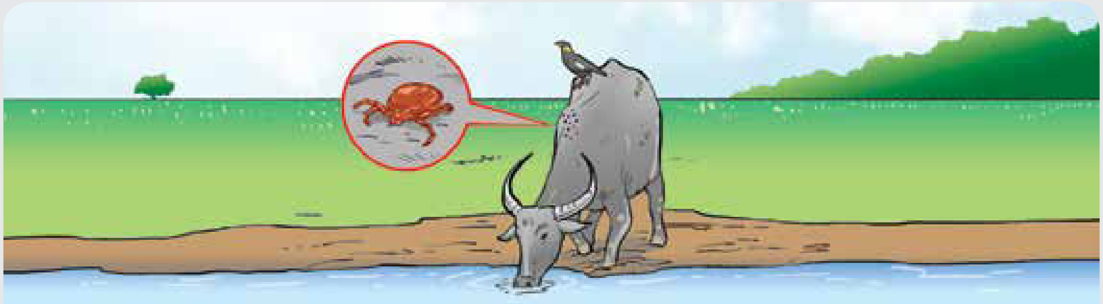


Figure 2

There are more than one interactions that occur in the above situation. What are those interactions? Explain each interaction.

3. A study has been carried out to estimate the population size of fish in a pond. The steps of the study are as below:

- Fish are captured, marked and released back into the pond.
- After a week, fish are recaptured and counted.
- The number of marked fish is recorded.

(a) What is the most suitable substance to be used as a marker?

(b) State the formula to estimate the population size of the fish.

(c) The accuracy of this technique is dependent on assumptions. Give **two** assumptions about the fish population.

4. Assume that you are an operational officer in a company which produces charcoal using mangrove trees. The management of the company that you are working for wants to establish another factory. You have been asked to suggest an area to build the factory. Draw an area plan and list the advantages of the selected location.

21st Century Mind

5. Mrs. Haniza is an ecology lecturer. She wants to take her students to do a field study in a mangrove forest. The purpose of the field study is to study the aeration and support systems of mangrove trees growing in the muddy and silted beach area. She estimates that they will take two days to complete the field study. However, Mrs Roziana who is another lecturer in ecology has estimated that the field research can be done within one day.

(a) In your opinion, whose estimation is more appropriate?

(b) Suggest suitable activities that can be done during the field study.

Chapter 10

Environmental Sustainability

Chapter Exploration

- Threats to the Environment
- Preservation, Conservation and Restoration of Ecosystem
- Practices in Environmental Sustainability
- Green Technology

Learning Standards

Do You Know?

- What is the meaning of environmental sustainability?
- How does environmental pollution affect the ecosystem?
- What do you understand about sustainability development?
- Why is food security very important?
- How will the application of green technology sustain the environment?

Biological Control Agent to Sustain the Environment

Biological control agent is a technology based on ecological concepts that control pest attack on highland vegetables such as cabbages, lettuces and tomatoes. *Diadegma semiclausum* (parasitic wasp), *Cotesia vestalis* (parasitic wasp) and *Coenosia exigua* (tiger fly) are some examples of biological control agents which have been proven to be effective in controlling the attacks of pests.

This technology is a strategy introduced by both Malaysian Agricultural Research and Development Institute (MARDI) and the Department of Agriculture to safeguard the quality and security of food for the country as well as to reduce environmental pollution. These biological control agents are not only safe for consumers but also beneficial towards conserving the stability of the ecosystem.

Keywords

- Biodiversity
- Eutrophication
- Acid rain
- Environmental sustainability
- Greenhouse effect
- Biochemical oxygen demand
- Global warming
- *Ex situ* conservation
- *In situ* conservation
- Noise pollution
- Thermal pollution
- Thinning of the ozone layer
- Air pollution
- Deforestation
- Food security
- Green technology

10.1 Threats to the Environment

Definition of Environmental Sustainability

Environmental sustainability means an environmental condition that remains the same without any reduction or depletion of natural resources, with an assured quality of the surrounding environment, for a long period of time.

Bio & Application

Every colour of the bins (Figure 10.1) represents different substances that can be recycled.

Figure 10.1
Recycle bins

Colour of the bins	Uses
Blue	Paper
Brown	Glass
Orange	Metal and plastic

Environmental sustainability ensures the demands of current needs are met without affecting the needs of future generations. The good quality of the environment will be disturbed when its sustainability is neglected. The increase in human population has caused a conflict between the need to meet the demands of human beings and the need to conserve the environment. Using recycle bins is one of the strategies to sustain the environment which can reduce the usage of non-renewable sources.

Activity 10.1

21st CENTURY SKILLS — DEBATE

Aim
To carry out a discussion about the need of development and the importance of efforts in sustaining the environment

Procedure
1. Work in groups.
2. Gather information about efforts in sustaining the environment.
3. Appoint a representative from each group. One person will take the role to propose the topic and the other one will represent the opposition side.
4. **Affirmative party:** The activity of development should be carried out to benefit the society.
   Opposition party: The activity of environmental sustainability is more important than the activity of development.
5. Prepare a speech with relevant arguments regarding your topic.
6. Discuss your findings.

Threats to the Environment

Threats to the environment are caused by human activities in the ecosystem. The continuous threats and destruction to the environment result in negative impacts to life. Can you explain the environmental threats that are shown in Photograph 10.1?

ACTIVITY ZONE

In groups, discuss the threats of climate change to human beings and the environment.

10.1.1

Photograph 10.1 Examples of environmental threats

Climate Change and Global Warming

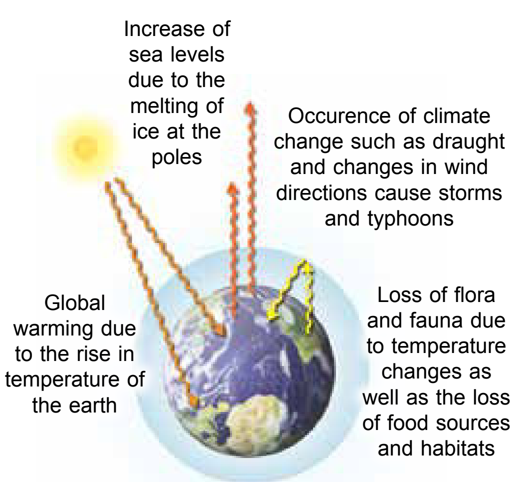
A **climate change** refers to the change in temperature of the earth, rainfall distribution and drastic changes of the winds (Photograph 10.2). These changes can be seen as a result of the greenhouse effect phenomenon (Figure 10.2(a)).

When sunlight enters the atmosphere of the earth, some of the light is reflected back into space in the form of infrared rays. When heat energy is released, most of the energy will be absorbed by the greenhouse gases such as **carbon dioxide, methane, nitrogen oxide** and **chlorofluorocarbon (CFC)** which exist in the atmosphere of the earth, thus preventing the infrared rays from being reflected back into space.

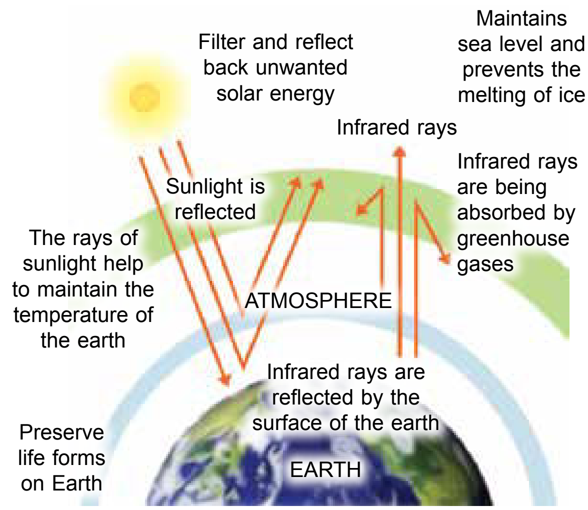
Bio Exploration

Greenhouse technology is implemented in countries with temperate climate to protect crops during winter. The glass panels of a greenhouse allow light to pass through but prevent heat from being released into the surroundings. Hence, the temperature inside the greenhouse can be maintained throughout the year.

Heat energy that is not reflected keeps the earth at an average temperature so it is not too cold for the survival of organisms (Figure 10.2(b)). Gases such as carbon dioxide are naturally formed but human activities have caused the increase in concentration of these gases. Thus, more heat energy is trapped which consequently increases the temperature of the earth (Table 10.1). This condition is known as the **greenhouse effect**.



(a) Negative effects



(b) Positive effects

Figure 10.2 The greenhouse effects

10.1.2

Table 10.1 Factors causing greenhouse effect and greenhouse gases involved

Factors causing greenhouse effect	Greenhouse gases involved
Burning of fossil fuels	Carbon dioxide and nitrogen oxide
Deforestation	Carbon dioxide
Animal farming	Methane
Agricultural activities (nitrogen fertiliser)	Nitrogen oxide
Usage of cooling substances	Chlorofluorocarbon (CFC)

Photograph 10.2 Effects of climate change

Deforestation and Loss of Biodiversity

Can you imagine what will happen to a forest if the trees are cut down without planning? **Deforestation** is the action of clearing a wide area of trees in a large scale. It is the main cause for the loss of biodiversity. Loss of habitats due to deforestation for construction and agricultural activities has caused the extinction of many species of flora and fauna (Table 10.2).

Table 10.2 The purpose of deforestation and the negative impacts of deforestation activities

The purpose of deforestation activities	Negative impacts of deforestation activities
• To obtain timber for construction work, furniture and paper • Mineral mining • Opening new areas to carry out agricultural activities • Building residential areas and roads	• Soil erosion (Figure 10.3) • Flash floods • Climate change • Loss of biodiversity • Disruption of nitrogen cycle, water cycle and carbon cycle • Loss of water catchment areas

History Corner

Malaysia had lost the last female Sumatran rhinoceros when 'Iman' was announced dead on 23rd November 2019 in Borneo Rhino Sanctuary at Tabin Wildlife Reserve, Lahad Datu. Iman had suffered a tumour in her uterus a few years ago.

Photograph 10.3 Iman (a female Sumatran rhinoceros)

10.1.2

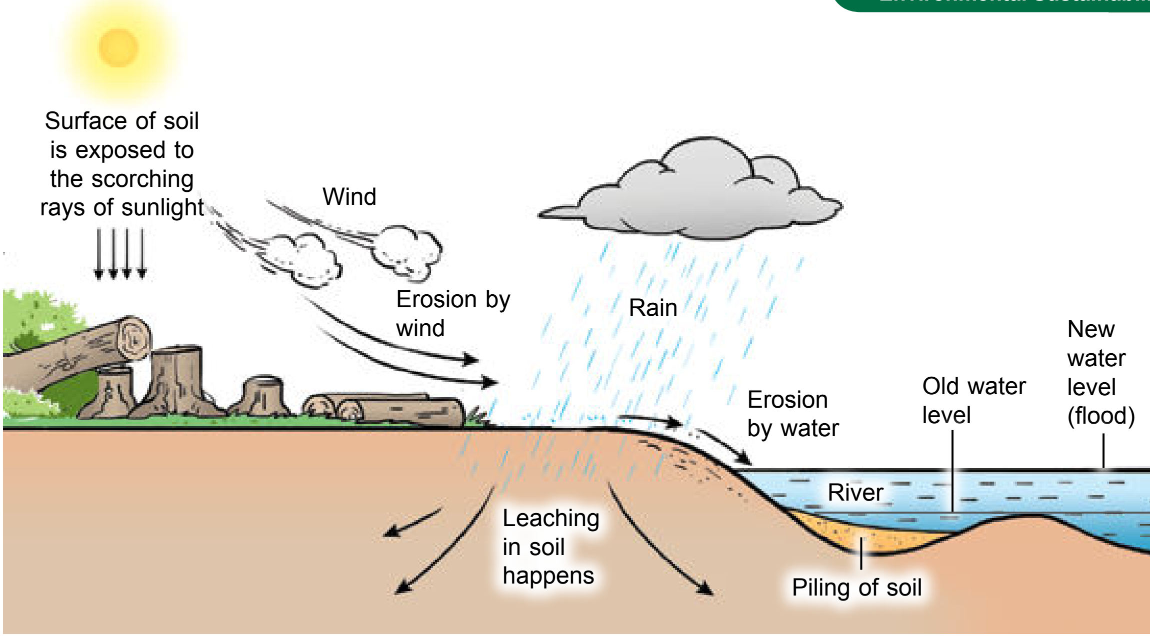


Figure 10.3 Deforestation causes soil erosion and floods

Global changes caused by pollution are contributing to the **loss of biodiversity**. In addition, illegal hunting of wildlife for the purpose of food, medical and handicraft industries has subsequently reduced animal populations, driving certain species to extinction. Furthermore, acid rain causes the pH of water to become low, a condition in which a great number of fish eggs cannot hatch and some adult fish die.

Eutrophication

Algal blooms, death of aquatic life and deterioration of water quality are the effects of **eutrophication**. Eutrophication is a process that occurs when the water ecosystem becomes rich with nutrients, resulting in changes to the structure of the ecosystem. Excessive usage of nitrate and phosphate fertilisers in agricultural activities and other factors can also cause eutrophication (Figure 10.4 and Figure 10.5).

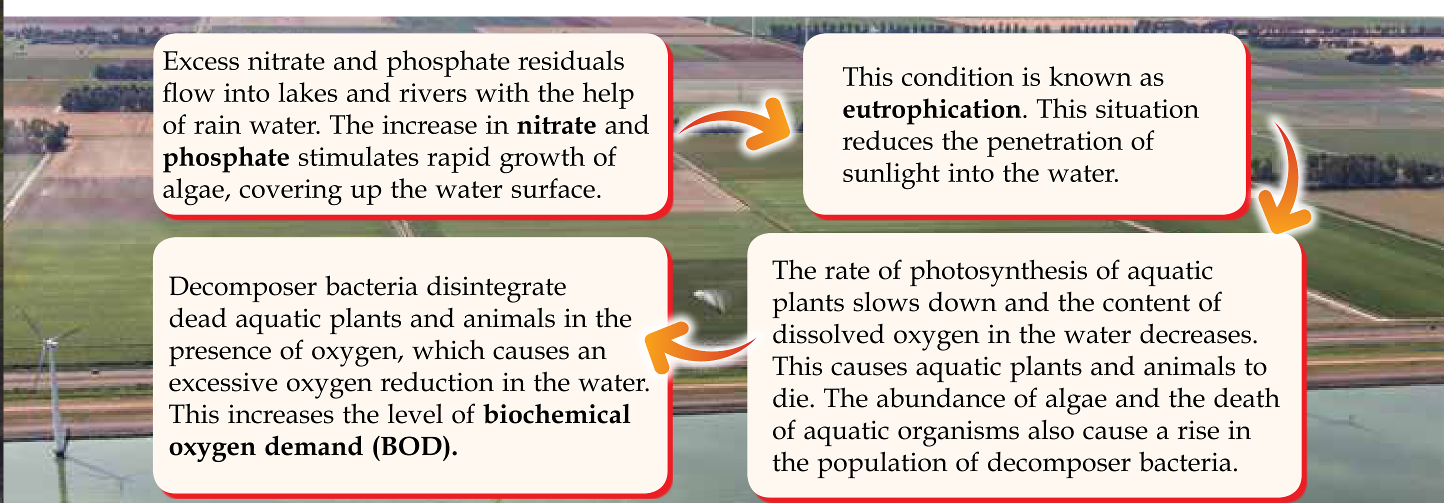


Figure 10.4 Eutrophication

10.1.2

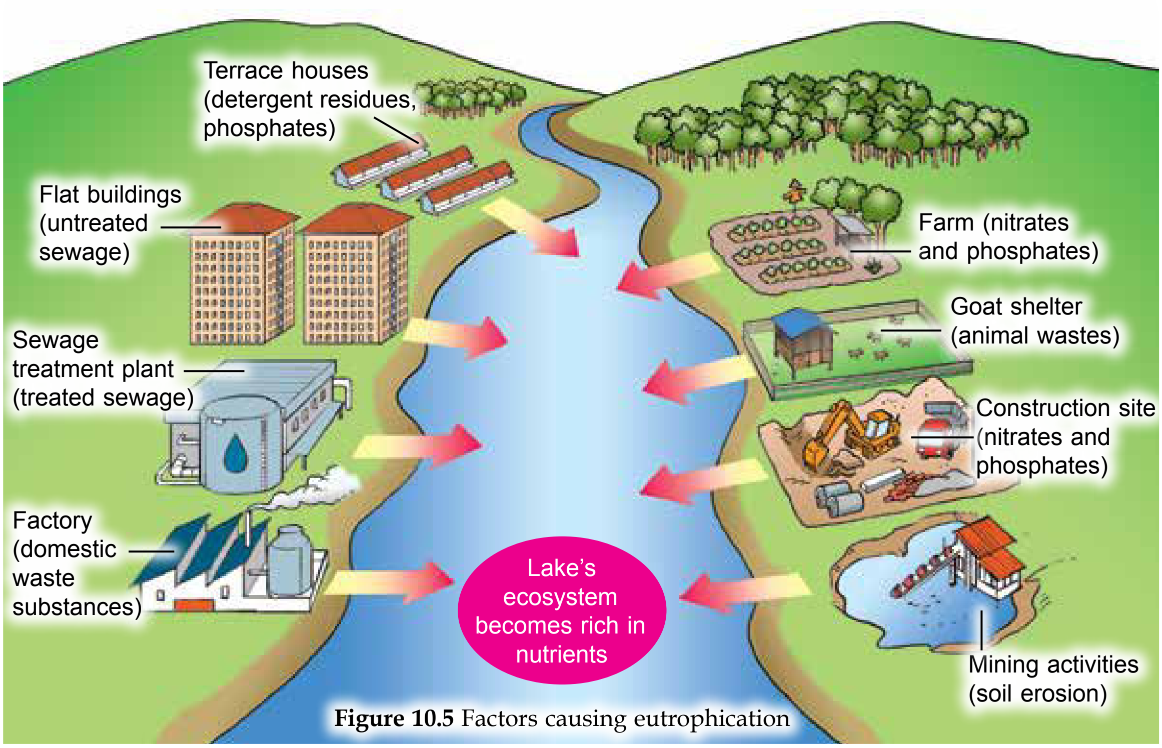


Figure 10.5 Factors causing eutrophication

Biochemical oxygen demand (BOD) is the total amount of oxygen needed by microorganisms such as bacteria and fungi to decompose organic materials in water. A high BOD level indicates low quality of water source, as there are many organic substances and decomposed microorganisms in the water. A low BOD level means the water is of good quality as it is unpolluted and dissolved oxygen content is high.

10.1.2

EXPERIMENT

10.1 Level of Biochemical Oxygen Demand (BOD) Present in Different Water Samples

Problem statement
Which water sample has the highest BOD level?

Aim
To compare the level of biochemical oxygen demand (BOD) present in various water samples

Hypothesis
Drain water has the highest BOD level.

Variables
Manipulated variable: Water samples
Responding variable: BOD level
Constant variables: Volume of water and volume of methylene blue solution

Materials
Labelling paper, water samples from various sources (tap water, drain water, river water, pond water and well water), distilled water, 0.1% methylene blue solution

Apparatus
Reagent bottles with cap, 1 ml syringe with needle, stopwatch, marker pen, measuring cylinder

Procedure

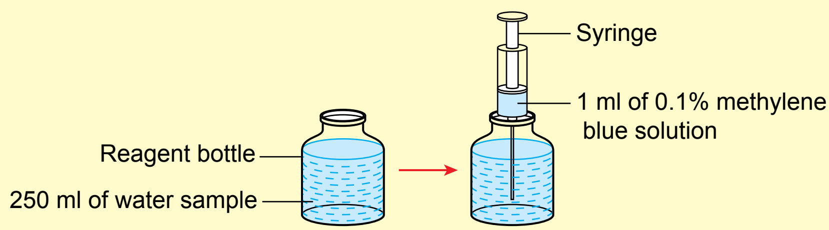


Figure 10.6 The set-up of apparatus

1. Get five water samples, each 250 ml, from five different sources (tap water, drain water, river water, pond water and well water).
2. Pour each water sample into separate reagent bottles until full. Label every reagent bottle (Figure 10.6).
3. Using a syringe, add 1 ml of 0.1% methylene blue solution into each water sample.
4. Put the cap of each reagent bottle immediately and place all the bottles in a dark cupboard. Make sure the reagent bottles are not shaken.
5. Repeat steps 2 to 4 using distilled water.
6. Check the reagent bottles every one hour for the next four hours until 0.1% methylene blue solution is decolourised.
7. Record the time for the 0.1% methylene blue solution to decolourise.
8. The rate of water pollution is calculated using the formula:

PRECAUTIONS
Ensure that the end of the syringe reaches the bottom of the reagent bottle when adding 0.1% methylene blue solution.

$$\text{Rate of water pollution} = \frac{1}{\text{Time taken for 0.1\% methylene blue solution to decolourise (hour)}}$$

10.1.2 10.1.3

EXPERIMENT

Results

Water samples	Time taken for 0.1% methylene blue solution to decolourise (hour)	The rate of water pollution ($hour^{-1}$)	BOD level
Tap water			
Drain water			
River water			
Pond water			
Well water			
Distilled water			

Discussion

1. Explain the reason why the end of the syringe must reach the bottom part of the reagent bottle when putting in the 0.1% methylene blue solution.
2. From the experiment, which one of the water samples
   (a) takes the fastest time for the 0.1% methylene blue solution to decolourise?
   (b) is the slowest for the 0.1% methylene blue solution to decolourise?
3. Compare the BOD levels of all five water samples.
4. Why is this experiment being repeated using distilled water?
5. What is the relationship between time taken for 0.1% methylene blue solution to decolourise and the level of water pollution?

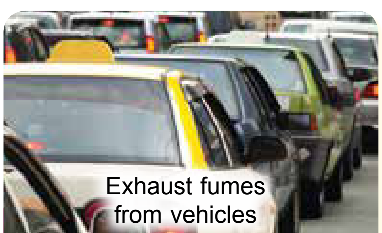
Conclusion

Is the hypothesis accepted? Suggest a suitable conclusion.

Pollution

Air Pollution

Air pollution happens when there is an increase in the pollutant substances such as **gases, smoke, dust** and **particles** in the atmosphere which affect health and lives of human beings, animals and plants. These pollutants increase when there is a rise of smog and gases released by vehicles as well as industrial factories and also from open burning (Figure 10.7).



Pollutant substances:
- Nitrogen oxide
- Carbon monoxide
- Lead
- Smoke and soot (small particles of carbon)
- Hydrocarbon gases (example: benzene)

Pollutant substances:
- Sulphur dioxide
- Nitrogen oxide
- Dust
- Carbon monoxide
- Carbon dioxide

Pollutant substances:
- Carbon dioxide
- Smoke and soot

Figure 10.7 Sources of air pollution and the pollutants

10.1.2

The burning of fossil fuels by charcoal burning plants, industrial factories and vehicles releases carbon monoxide, nitrogen oxide and sulphur dioxide into the atmosphere. These gases combine with water vapour in the atmosphere to form nitric acid and sulphuric acid, and later come down as acid rain (Figure 10.8). Acid rain causes the soil to become infertile due to the pH value of less than 5. Acid rain also destroys leaf tissues and damages the roots of plants. In addition, an increase in water acidity reduces plankton population which is the food source for fish. This affects the food chain and can cause the death of various organisms. Acid rain also causes skin diseases and tissue damage in humans.

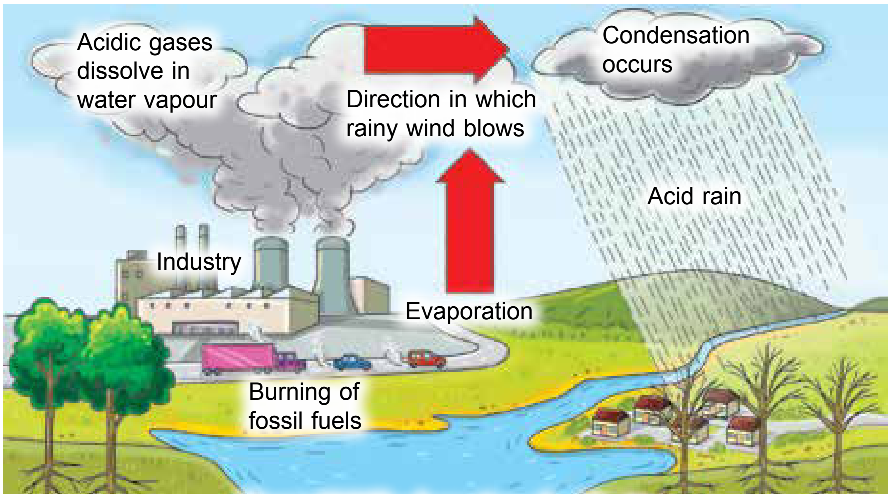


Figure 10.8 The formation of acid rain

Thermal Pollution

Thermal pollution refers to the deterioration of water quality due to excessive heat dissipation into water caused by processes that change the water temperature. Water is used as a cooling agent to cool down generators in industrial factories and hydroelectric power generator plants. The hot water produced is then discharged into rivers or lakes causing thermal pollution. The increased temperature of the river water is unsuitable for aquatic habitats. As the temperature of water rises, the dissolved oxygen content in the water will decrease and threaten the survival of aquatic lives.

Photograph 10.4 Fish die due to increase in the temperature of river water

Thermal pollution endangers the lives of aquatic organisms and is also hazardous to the environment. The rise in water temperature disrupts biochemical processes of aquatic organisms as fish and other aquatic animals normally live in a range of certain temperature. For example, the increase of water temperature can cause early hatchery of fish eggs or worse, they fail to hatch. For certain species, a drastic increase of water temperature can cause instant death (Photograph 10.4). Furthermore, for organisms such as algae, higher temperature enhances their growth and consequently, raises the BOD level.

10.1.2

Noise Pollution

Noise pollution can be defined as sounds that disturb and cause detrimental effects to the health of humans and animals.

Is the sound of a lawn mower coming from the school field considered as a noise pollution? How do you manage noise pollution? The sound of vehicles, construction activities, agricultural and industrial machineries and loud music in event gatherings are some example of noise pollution.

Exposure to high level of noise for a prolonged period of time can also cause health problems such as **high blood pressure, depression** and **headache**.

Bio Exploration

World Health Organisation (WHO) estimates about 1.1 billion of youths and teenagers are at risk of hearing loss due to personal audio devices that are used excessively at unsafe sound level as well as exposure to damaging sound in a noisy place.

Bio with PHYSICS

The pitch of sound depends on the frequency of the sound waves produced. Sound frequency is measured in Hertz (Hz) unit. The sound frequency that can be detected by human ears is limited within the range of 20 Hz to 20 000 Hz.

Human Population Growth Explosion

Population growth explosion is the increase in total number of humans living in a certain area (Photograph 10.5). As a result of the rapid population growth, there is an equally rapid reduction of natural resources, which leads to **deforestation, loss of biodiversity** and **global warming**. Forests are cleared to provide shelters, infrastructures, agriculture lands and various facilities for the increasing population. Hence, living organisms are exposed to threats such as problems in having raw water sources and supply of clean water, increase of pollution and diseases, and the extinction of various organisms among others.

The demand on water and sources available in the local community are not well-managed with the existing natural resources in the area. This has resulted in transporting the sources from another location to the demand zones. Furthermore, sewage also contaminates land areas, a threat to pollute the environment. In order to overcome these problems, **water treatment technology** is used although there is an increase in the cost of water sources as well as the cost of treated water.

Bio with ECONOMY

Population in Malaysia has been estimated at around 32.6 million people in the year 2019 with a yearly population growth rate of 0.6% (Source: Department of Statistics Malaysia). It is important to know the population statistic in a country for planning purposes in order to administer the country.

Photograph 10.5 Human population growth explosion

ACTIVITY ZONE

Carry out a study on the impact of human population growth explosion to the environment.

10.1.2

Activity 10.2 STEM

Aim

To prepare a strategic action plan to reduce the level of air and water pollution around the school for the next 10 years

Procedure

1. Work in groups.
2. Each group needs to prepare a strategic action plan to reduce the level of air and water pollution around the school for the next 10 years.
3. Discuss and generate ideas to gain information on the following aspects:
   (a) Identify the strength and weakness of the school authority in reducing the level of air and water pollution
   (b) Identify opportunities, challenges and threats
   (c) Identify strategic issues
   (d) Outline the aims, objectives and target
   (e) Generate strategies in accomplishing objectives
   (f) Build an action plan, operational plan and contingency plan
4. Gather all information in the form of a folio. Submit it to your teacher for assessment.

Formative Practice 10.1

1. State **three** human activities that have negative impacts on the environment.
2. Explain how an agricultural activity can cause the death of aquatic animals.
3. How does an increase in the concentration of greenhouse gases contribute to the rise in the temperature of the earth?
4. Justify the importance of maintaining rivers as a habitat in an ecosystem.

10.2 Preservation, Conservation and Restoration of Ecosystem

We have studied how human activities can have negative impacts towards the environment. Nevertheless, these human activities do not always affect the environment. In managing development, preventive measures should be taken towards the preservation, conservation and restoration of the ecosystem to ensure sustainable development. What is meant by preservation, conservation and restoration of an ecosystem?

Career Tips

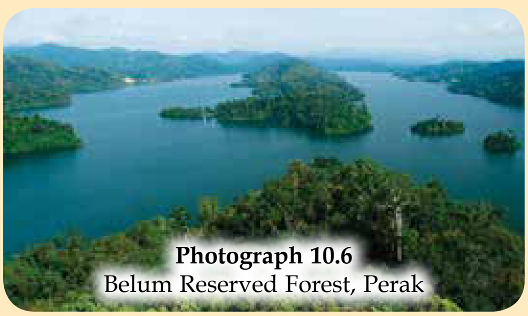
A drainage engineer plans and manages the construction of drainage or sewage systems to maintain environmental stability.

10.1.3 10.2.1

Necessity in the Preservation, Conservation and Restoration of an Ecosystem

ECOSYSTEM PRESERVATION

- **Preservation of an ecosystem** can be defined as the efforts made to protect the components of an ecosystem so it will remain in its natural condition.
- One of the ways towards preserving an ecosystem is by gazetting forests as reserved areas to protect the natural beauty of flora and fauna.
  - Reserved forests are protected from any development activities.
  - 90% in the upper part of Belum Forest Reserve is still unexplored and has yet to become research sites.



Photograph 10.6
Belum Reserved Forest, Perak

ACTIVITY ZONE

Carry out brainstorming sessions with members of other institutions for suggestion on the preservation, conservation and restoration of the environment in the local community.

ECOSYSTEM CONSERVATION

- **Conservation of an ecosystem** means the efforts to restore environmental resources such as water, forests, energy, air, minerals, among others so they will continue to exist.
- Conservation strategies are carried out in order to save the components of an endangered ecosystem.
- There are two strategies of conservation, which are ***in situ*** and ***ex situ***.
  - *In situ* conservation retains wildlife species in their original habitat such as **natural parks** and **marine parks**.
  - *Ex situ* conservation keeps wildlife species outside of their original habitat such as in **zoos** and **botanical parks**.

Photograph 10.7 Lost World Petting Zoo

ECOSYSTEM RESTORATION

- **Restoration of an ecosystem** means efforts for renewing and restoring natural ecosystems that have deteriorated, damaged or destroyed due to human activities.
- Reforestation and planting of cover crops are steps of restoration being taken to ensure the continuity of natural resources for future generations.

Photograph 10.8
Tree replanting programme

Activity 10.3

21st CENTURY SKILLS — MINI PROJECT

Aim
To carry out a project to restore a mangrove ecosystem

Procedure

1. Prepare relevant documents to apply for a permission to carry out a mini project to restore a nearby mangrove ecosystem. Address the documents to the local District Council/ City Council.
2. Before carrying out the project, the teacher should provide some guidelines on the following:
   (a) Tasks are to be carried out in small groups based on assigned areas
   (b) The objective of the project
   (c) Precautionary steps
   (d) Tasks for each group
   (e) Materials needed
3. Prepare a report about the project findings.

Formative Practice 10.2

1. State the meaning of:
   (a) Ecosystem preservation
   (b) Ecosystem conservation
   (c) Ecosystem restoration
2. Name a place that carries out a conservation activity:
   (a) *in situ* (b) *ex situ*
3. A piece of land at a hillside will be developed as a residential area. As a housing developer, suggest steps on the conservation and restoration of the ecosystem in that area. Give some details.

10.3 Practices in Environmental Sustainability

Practices that contribute towards environmental sustainability are intended to ensure sufficient availability of natural resources to benefit all current and future life forms on Earth. In sustaining the environment, steps must be taken to prevent environmental pollution, protect the capacity of ecosystems and avoid development that will endanger the health of human beings or affect their quality of life. All parties are responsible in sustaining the environment. Figure 10.9 shows ways and activities on how everyone can help in sustaining the environment.

Bio Exploration

National Cleanliness Policy is an initiative by the Malaysian government to become a cleaner country and create a society that practises good hygiene and cleanliness in the culture.

10.2.2 10.3.1

Practices that Contribute towards Environmental Sustainability

Riding a bicycle as a way to be environment-friendly

Environment-friendly Transport

- Use environment-friendly transport such as bicycles or hybrid and electric vehicles.
- Practise carpooling.
- Use public transport such as buses, commuters, monorails, Light Railway Transit (LRT), Electric Train Service and KLIA Express/ KLIA Transit

Energy Saving

- The main source of electric energy comes from the burning of non-renewable substances which are fossil fuels such as petrol and diesel.
- Use electricity wisely to reduce the release of pollutant substances such as carbon monoxide.

5R's Concept

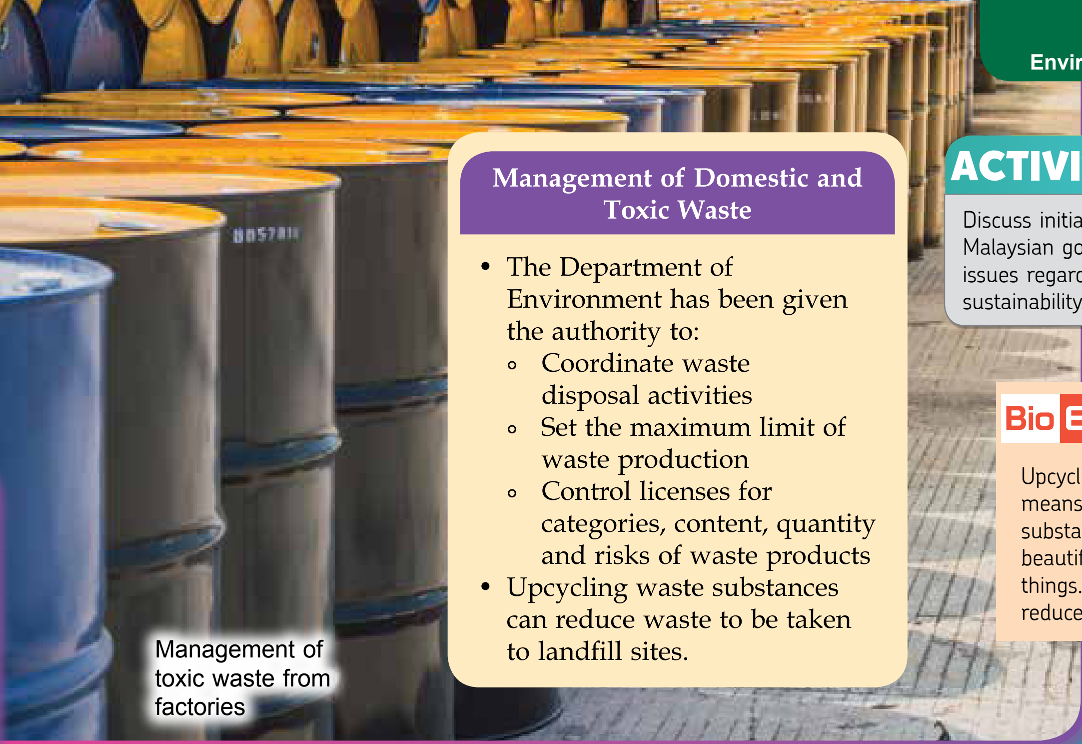
- The disposal of waste materials can be reduced when we practise 5R's:
  - **R**ethink
  - **R**epair
  - **R**euse
  - **R**educe
  - **R**ecycle

The Usage of Alternative Renewable Energy

- Renewable energy means energy that is generated from natural resources such as the sun, wind, waves, water, geothermal and biomass.
- Renewable energy is cleaner, easier and safer.

Figure 10.9 Practices that contribute to environmental sustainability

10.3.1



Management of toxic waste from factories

Management of Domestic and Toxic Waste

- The Department of Environment has been given the authority to:
  - Coordinate waste disposal activities
  - Set the maximum limit of waste production
  - Control licenses for categories, content, quantity and risks of waste products
- Upcycling waste substances can reduce waste to be taken to landfill sites.

ACTIVITY ZONE

Discuss initiatives by the Malaysian government in handling issues regarding environmental sustainability.

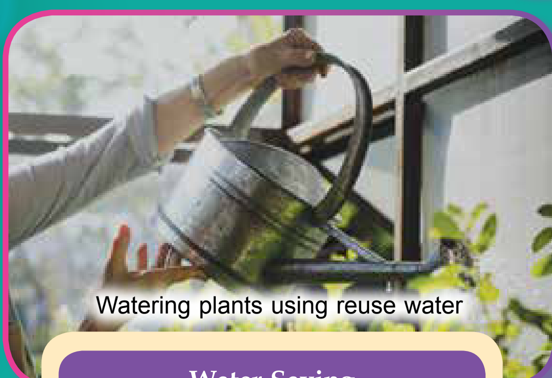
Bio Exploration

Upcycling waste substances means turning the old substances into new, beautiful and creative things. This activity can reduce waste disposal.

Biological Control

- Biological control is a way to control the population of pests using their natural enemies.
- It is a way to reduce the usage of pesticides.

Owls as a biological control agent in oil palm plantations



Watering plants using reuse water

Water Saving

- Collect rain water or reuse water to water plants and wash vehicles.

Innovation in Malaysia

The National Water Services Commission or 'Suruhanjaya Perkhidmatan Air Negara' (SPAN) has introduced water efficient products through Water Efficient Product Labelling Scheme for water efficiency products such as water pipes, toilet equipments, urinals, showers and washing machines. This effort is to reduce the rate of water consumption per individual.

10.3.1

Activity 10.4

21st CENTURY SKILLS

CAMPAIGN

Aim

To discuss initiatives in dealing with issues of environmental sustainability

Procedure

1. Work in groups.
2. Find out information on some of the initiatives in handling the issues of environmental sustainability as follows:
   (a) Sustainable Development Goals (SDGs)
   (b) The effort made by local authorities in supporting Local Agenda 21
3. Present the findings of your group in the form of multimedia presentation.

Bio Exploration

Local Agenda 21 is a programme in which the private sector and the local authority (PBT) work together with the community to plan and manage their surrounding area towards a sustainable development as to lead a better quality lifestyle. There should be a balance of social, economical and environmental needs in all sustainable development.

Activity 10.5

STEM

Aim

To build a model of a city based on the objectives of SDGs

Procedure

1. Work in groups.
2. Gather information about Sustainable Development Goals (SDGs).
3. List down the objectives of SDGs which are related to municipality.
4. Build a model of a city based on the objectives of SDGs.
5. Use recyclable materials as the main materials in building the model.
6. Prepare a paper work which contains:
   (a) Abstract
   (b) Introduction of project
   (c) Cost
   (d) List of materials
   (e) Description of project
   (f) City plan
   (g) References

10.3.1

The Status of Food Security in Malaysia

Food security is defined as having an assurance on the availability of food, as well as sufficient access to food and safe food utilisation.

There are four important components of food security, which are (Figure 10.10):

History Corner

National Agro-Food Policy (NAP) 2012 is an effort by the government in order to succesfully accomplish food security.

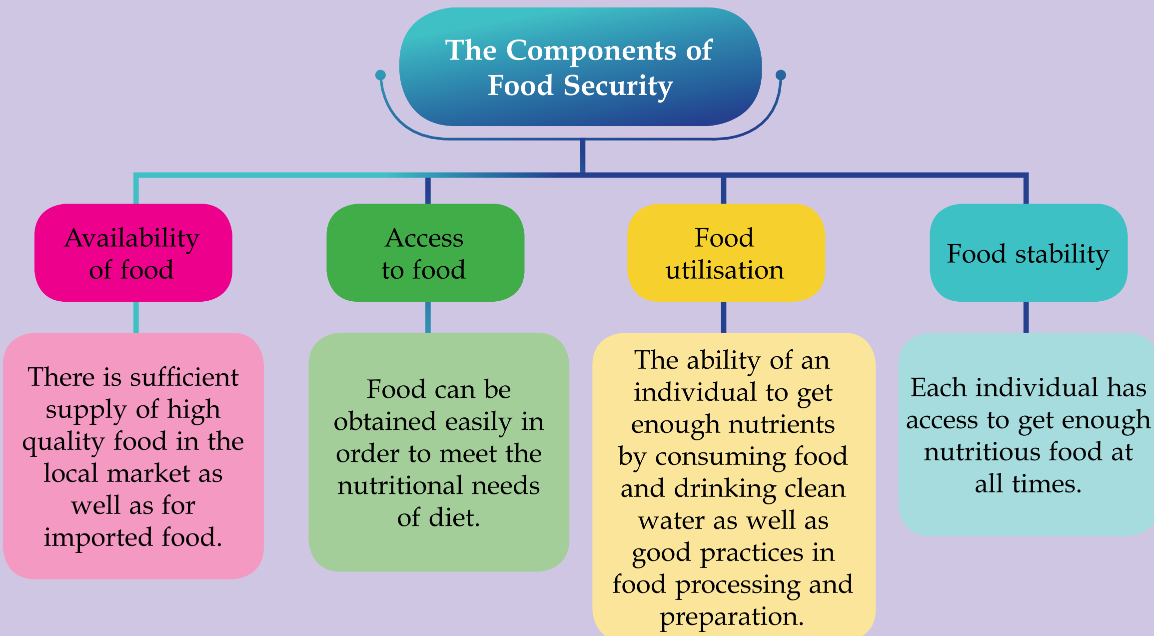


Figure 10.10 The components of food security

Halal is an important element in determining the status of food security. Halal food must be manufactured in clean surroundings using methods which emphasise on hygiene and orderliness during the production process. Halal means an inclusive in all aspects, beginning from the farm to the final food product. Other guidelines which are implemented in order to determine food security are **Good Manufacturing Practices (GMP)** and **Hazard Analysis and Critical Control Points (HACCP)**. Just like the halal factor, the two guidelines also emphasise on the quality of processes that are hygienic, healthy and safe during food preparation.

History Corner

Even before Independence Day, the National Food Security Policy had been implemented in Malaysia through the National Rice and Paddy Policy. However, this policy only emphasises on the production of rice. After the world food crisis in 2008, the government drafted the *Dasar Jaminan Bekalan Makanan Negara*. This policy provides a guarantee on sufficient food security for the Malaysian population.

10.3.2

Activity 10.6

21st CENTURY SKILLS

GALLERY WALK

Aim

To gather information and make a presentation on the steps to increase global food security

Procedure

1. Work in groups.
2. Gather information about the steps to improve global food security.
3. Present all information on posters and carry out activities in the Gallery Walk.

Formative Practice 10.3

1. List the **four** important components in food security.
2. In your opinion, what are the responsibilities of a food entrepreneur in achieving food security?
3. You are the proprietor of a private company. Suggest **five** steps in saving electricity by all your employees at the office.

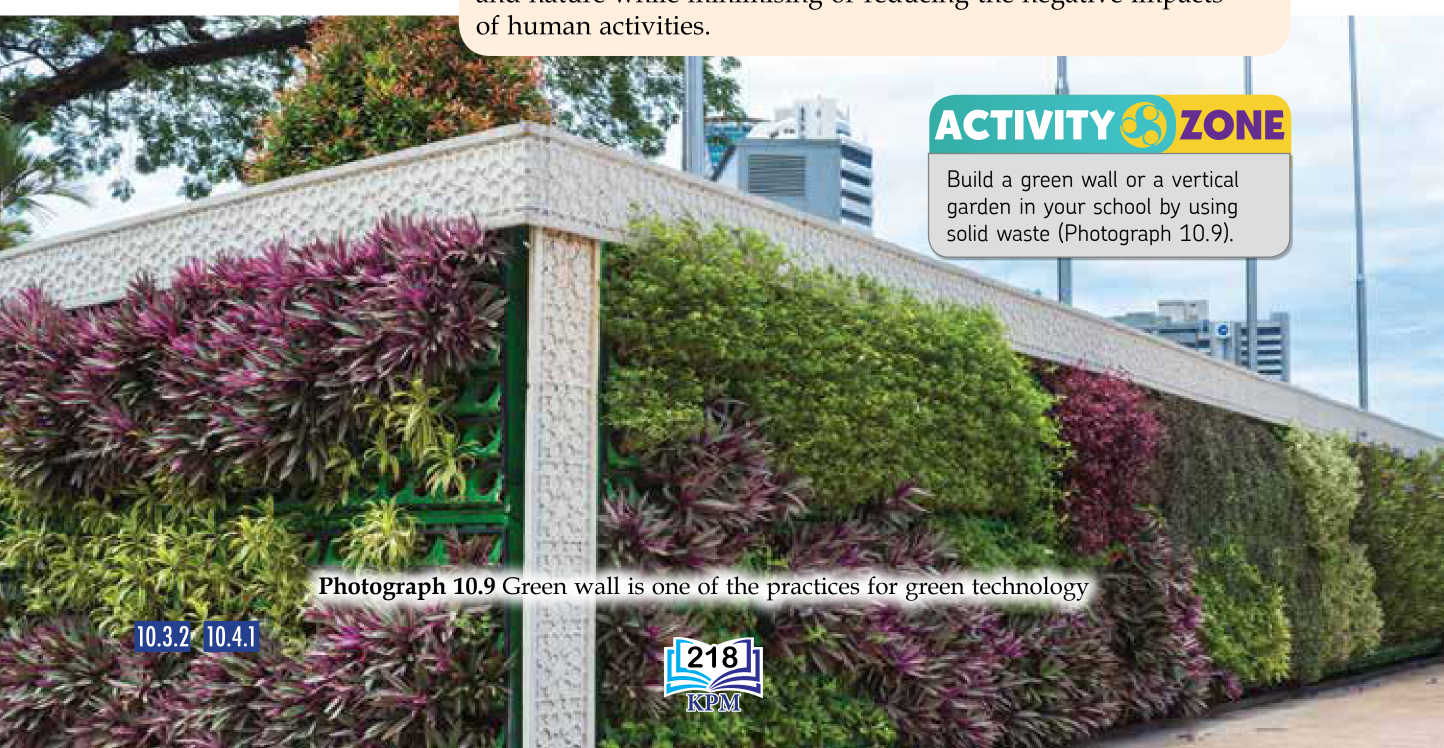
10.4 Green Technology

Definition of Green Technology

Green technology refers to the development and application of products, equipment and system to preserve the environment and nature while minimising or reducing the negative impacts of human activities.

ACTIVITY ZONE

Build a green wall or a vertical garden in your school by using solid waste (Photograph 10.9).



Photograph 10.9 Green wall is one of the practices for green technology

The Use of Green Technology in Environmental Sustainability

Green technology had been a portfolio of the Ministry of Science, Technology and Innovation (MOSTI) which was established on 27th March 2004, accounting for the long-term and short-term effects of human activities on the environment. National Green Technology Policy (2009) states that any product, equipment or system that fulfilled the criteria such as in Figure 10.11 can be categorised as green technology.

Figure 10.11 Criteria requirement for green technology product, equipment or system

National Green Technology Policy (NGTP), launched in July 2009 gives emphasis on the growth of economy and sustainable development of the country.

Sustainable development must fulfil the needs of current society without abandoning the needs of future generations. NGTP is based on four pillars, which are **energy, environment, economy** and **social** (Figure 10.12).

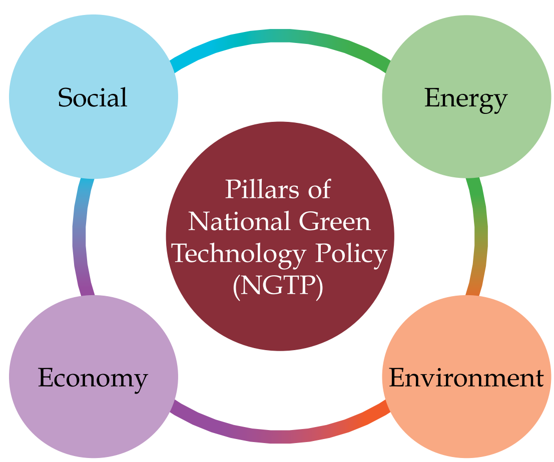


Figure 10.12 The pillars of National Green Technology Policy (NGTP)

10.4.1

Innovation in Malaysia

Green building is a building concept which has the characteristics of nature-friendly technology. The main purpose of the concept is efficient use of natural resources such as energy, water and materials (Table 10.3).

Table 10.3 Natural resources and its uses

Natural resources	Uses
Solar energy	Solar panels convert solar energy into electrical energy for lighting inside the buildings
Water	Water catchment systems collect rain water that can be used for plants watering and cleaning of toilets
Building materials	Encourage the usage of recycled materials

The advantages of a green building:
- Reduces negative effects towards human health due to development
- Reduces negative effects towards the environment due to construction activities
- Saves the cost of operation, maintenance and construction

Examples of green building found in Malaysia:

Photograph 10.10
The Perdana Putra building, Putrajaya

Photograph 10.11
Cyberjaya Community Recycling and Collection Centre

Bio Exploration

The walls of Cyberjaya Community Recycling and Collection Centre are built from recyclable materials such as cans and empty plastic bottles.

Activity 10.7

21st CENTURY SKILLS

MIND MAP

Aim
To gather information on the four pillars of the National Green Technology Policy and present the findings in class

Procedure
1. Work in groups.
2. Find information on the four pillars of the National Green Technology Policy.
3. Draw a mind map to present the information gathered.
4. Present your mind map in class.

When a country develops rapidly, the population increases. This causes the demand for certain needs to increase too. Unplanned or bad management of natural resources such as uncontrolled logging, extensive land exploration, release of carbon dioxide into the atmosphere and disposal of solid waste lead to pollutions. If this is not managed well, the quality of humans' life and the environment can be threatened.

10.4.1

Green technology means practices in the community towards sustaining the environment in order to lead a better lifestyle. What are the practices based on the concept of green technology that you can apply at school or at home to sustain the environment (Figure 10.13)?

Career Tips

Environmental supervisor is a person supervising the quality and cleanliness of the environment according to existing rules and regulations.

Practices using the concept of green technology

- Producing eco-enzymes from fruit waste into cleaning agents
- Recycling kitchen waste and food waste to produce natural fertiliser or growth booster for crops
- Producing biogas from organic solid waste
- Using banana peels to make flour which can be used as an ingredient to produce natural bioplastic
- Producing liquid foliar fertiliser from kitchen waste to be used on leaves as a growth booster for vegetables

Figure 10.13 Practices using the concept of green technology

Activity 10.8

Aim

To recycle kitchen and food waste which have exceeded expiry dates to produce natural fertiliser or growth booster for crops

Procedure

1. Work in groups.
2. Gather information from the Internet about producing natural fertiliser or growth booster for crops using kitchen and food waste.
3. Every group is required to prepare a paperwork on the project which contains:
   (a) Abstract
   (b) Introduction
   (c) Cost
   (d) List of materials
   (e) Description of project
   (f) References
4. After completing the project, test the effectiveness of the fertiliser on potted plants around your school.
5. Present your report in class.

10.4.2

Bio & Application

You can produce your own eco-enzymes at home as follows.

Apparatus and materials

100 g of brown sugar, 3 g of yeast, 1 L of warm water, 300 g of fresh lemon and orange zests, a 2-L plastic bottle, a sieve, a filter funnel and an airtight container

Procedures

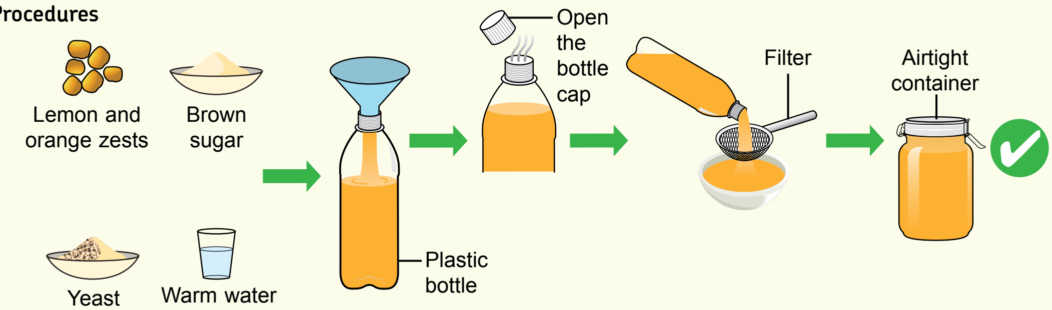


Figure 10.14 Steps to make eco-enzymes

1. Put all the ingredients shown in Figure 10.14 into a 2-L plastic bottle.
2. Close the cap of the bottle tightly. Shake the bottle vigorously for a few minutes till the brown sugar is dissolved. Open the bottle cap to release the pressure from inside of the bottle.
3. For two weeks, let out the gas produced at least three times a day.
4. Put the bottle in a place where the temperature is about 35 °C, such as on a refrigerator.
5. After two weeks, filter the solution to remove the lemon and orange zests.
6. Keep the filtered solution in an airtight container. The enzyme solution can be used to clean the floors of your house.

Application of Social Science to Solve Environmental Problems and Challenges

Social science makes use of scientific methods to investigate the field of humanity. One of the branches in the field of social science is **education**. In the **Third Malaysia Plan**, emphasis on environmental education has been introduced into the **Malaysian education system**. Environmental education aims in creating an awareness among the population into being responsible towards environment and environmental issues. Figure 10.15 shows the objectives of the environmental education.

The Objectives of Environmental Education

Increasing the awareness of individuals and society towards environmental conditions and its problems

Providing knowledge to individuals and society about environment, problems and the role and responsibility of each individual

Gaining skills in solving environmental problems

Taking care of the environment and willing to protect and develop the environment

Figure 10.15 The objectives of environmental education

10.4.3

Communication is also one of the aspects in social science which plays important roles in solving environmental problems and challenges using mass media, pamphlets, magazines, posters and films. Various activities can be implemented to rouse the interest of people in taking care of the environment. For example, promoting awareness campaigns to discourage tree-cuttings as well as to preserve water and soil resources. Other activities include coordinating a large-scale *gotong-royong* in residential areas, schools, recreation parks or beaches, and organising competitions for cleanliness and beautification of schools and house compounds.

Think Smart

"Without developments, there will be no pollutions." How far is the truth of this statement?

Activity 10.9

21st CENTURY SKILLS

FIELD RESEARCH

Aim

To cooperate with villagers in carrying out a survey to identify and solve local environmental issues

Procedure

1. Work in groups.
2. Set an area for study and identify an environmental issue in that area.
3. Carry out interviews with villagers and other parties involved.
4. Prepare a report containing:
   (a) Title of the survey
   (b) Acknowledgement
   (c) Contents
      (i) Introduction – explaining the background of the survey
      (ii) Explain the issue of the environment
      (iii) Explain suggestions in dealing with the environmental issue
      (iv) Implementation of suggestions
   (d) References
5. Present the report of your findings in class.

Formative Practice 10.4

1. State the meaning of green technology.
2. What are the roles of an individual in order to materialise the National Green Technology Policy?
3. The campaign of forbidding the usage of plastic straws is one of the initiatives towards sustainable development. As a restaurant owner, discuss the effects of the enforcement of this campaign to your business.

10.4.3

Memory Flashback

ENVIRONMENTAL SUSTAINABILITY

- Threats to the environment
  - Definition of environmental sustainability
  - Threats to the environment
    - Climate change
    - Global warming
    - Deforestation
    - Loss of biodiversity
    - Eutrophication
    - Pollutions
    - Human population growth explosion
- Preservation, Conservation and Restoration of Ecosystems
  - Definition
    - Preservation of ecosystem
    - Conservation of ecosystem
    - Restoration of ecosystem
  - Needs
    - Preservation of ecosystem
    - Conservation of ecosystem
    - Restoration of ecosystem
- Practices in environmental sustainability
  - Practices that contribute towards environmental sustainability
  - The status of food security in Malaysia
- Green technology
  - Definition of green technology
  - The use of green technology in environmental sustainability
  - Application of social science to solve environmental problems and challenges

Interactive Bio 10

SELF-REFLECTION

Complete the following self-reflection to identify the important concepts that you have studied.

Important concepts	Very good	Try again
Definition of environmental sustainability		
Threats to the environment		
Levels of biochemical oxygen demand (BOD) needed in different water samples		
Definition of preservation, conservation and restoration of ecosystems		
The needs in the preservation, conservation and restoration of ecosystems		
Practices that contribute towards environmental sustainability		
The status of food security in Malaysia		
Definition of green technology		
The use of green technology in environmental sustainability		
Application of social science to solve environmental problems and challenges		

Summative Practice 10

1. Figure 1.1 and Figure 1.2 show activities that threaten the ecosystem.

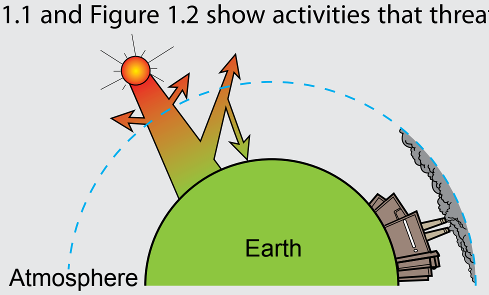


Figure 1.1

Figure 1.2

(a) State the environmental threats shown in Figure 1.1 and Figure 1.2.

(b) Name **two** pollutants being released from the activity shown in Figure 1.1.

(c) Based on Figure 1.1 and Figure 1.2, explain how those activities can cause the world to experience climate change.

(d) Discuss the effects of the activities in Figure 1.1 and Figure 1.2 towards the ecosystem.

2. A country is deemed to have food security when individuals, households or all citizens get sufficient, safe and nutritious food to lead a healthy and active life. Photograph 1 shows a situation where children in an area are experiencing food security threats.

Photograph 1

(a) What is meant by food security?

(b) Predict one of the health problems that might be experienced by the children in that area.

(c) In your opinion, what can be the cause of food security threats in that area?

(d) Through National Agro-Food Policy (NAFP), discuss the responsibilities of the government in order to overcome the problems experienced by the children in that area.

3. The Malayan tiger is an animal facing the threat of extinction in Malaysia. Currently, the number is dwindling to less than 200 throughout the whole country. These animals that can be sold at a high price in the international markets have become the target of illegal hunters.

(a) State the physical characteristics of a Malayan tiger.

(b) Explain how the extinction of the Malayan tiger will affect the stability of the ecosystem.

(c) Other than illegal hunting, predict other factors that may contribute to the extinction of the Malayan tiger.

(d) What are the steps of preservation and conservation that can be done by the Department of Wildlife and National Parks (PERHILITAN) in order to overcome the extinction of Malayan tigers?

21st Century Mind

4. The practice of 5S, *sisih* (separate), *susun* (arrange), *sapu* (sweep), *seragam* (uniform) and *sentiasa amal* (always practice) are practices taken from the Japanese culture with the objective of enhancing a better workplace in an organisation. As an employee, would you carry out these practices? Give your reasons.

Theme 3

Inheritance and Genetic Technology

This theme aims to provide an understanding of inheritance, variation and genetic technology in life. Genetic and environmental factors play an important role to variation in a species.

The theme also emphasises on the application of knowledge in genetics in Genetic Engineering and Biotechnology field.

- What are the meaning of allele and locus as well as their association with gene in a chromosome?
- What are the causes of chromosomal mutations?
- What are the examples of genetically modified organisms (GMO) produced by genetic engineering technology?

Chapter 11

Inheritance

Chapter Exploration

- Monohybrid Inheritance
- Dihybrid Inheritance
- Genes and Alleles
- Inheritance in Humans

Learning Standards

Do You Know?

- What is the meaning of monohybrid inheritance?
- What is the meaning of dihybrid inheritance?
- What are the relationships between genes and alleles in human inheritance?
- Which characteristics can be inherited in human inheritance?

Dimple, A Genetic Defect

An individual who has indentations on his/her cheek or more popularly known as dimples looks cute when he/she smiles. Do you know that dimple or gelasin is actually a genetic defect of a facial muscle called zygomaticus major?

Zygomaticus major muscle is shorter than normal, which pulls the cheek skin to form an indentation. Dimple is a dominant trait which can be inherited. In Chapter 11, you will learn how each trait is inherited from one generation to another.

Keywords

- Monohybrid cross
- Dihybrid cross
- Genes
- Alleles
- Traits
- Characteristics
- Dominant
- Recessive
- Homozygotes
- Heterozygotes
- Purebreeds
- Hybrids
- Parental generation
- Filial generation
- Genotype
- Phenotype
- Locus
- Autosome
- Sex chromosome
- Karyotype
- Sex-linked inheritance
- Pedigree

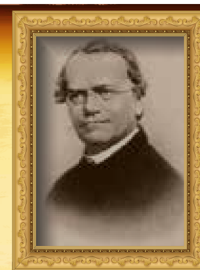
11.1 Monohybrid Inheritance

Definition of Monohybrid Cross

Monohybrid inheritance involves inheritance of one characteristic and contrasting traits controlled by a gene.

History Corner

The study of heredity and the variation of inherited characteristics is called genetics. The first person who scientifically explained the principles of inheritance was Gregor Mendel (Photograph 11.1). Mendel is known as the father of modern genetics.



Photograph 11.1 Gregor Mendel

Mendel Experiments

Mendel figured that pea plants, *Pisum sativum*, possessed seven different characteristics. Pea plants have contrasting traits which are obvious and easy to identify (Figure 11.1). Mendel suggested in his theory that a characteristic in a parent plant is passed down to its next generation through male gametes and female gametes. This shows that the nuclei of the male and female gametes carry genetic materials of the inherited characteristic. The inheritance factor which determines a characteristic is known as a gene.

Characteristic	Traits	
	Dominant	Recessive
Seed shape	Round	Constricted
Seed colour	Yellow	Green
Pod shape	Inflated	Constricted
Pod colour	Green	Yellow
Flower colour	Purple	White
Flower position	Axial	Terminal
Plant height	Tall	Dwarf

Figure 11.1 Seven characteristics studied by Mendel

Career Tips

Careers which involve genetics are genetic counsellors, medical genetic specialists and clinical and medical research officers.

ACTIVITY ZONE

Gather information on the history of Mendel's Laws. Then, present it in your class.

11.1.2

In the monohybrid inheritance experiment, Mendel used purebreed pea plants as the parental generation to study the inheritance of pea plant traits. **Purebreed pea plants** are produced through self-cross plant which have similar traits to that of its parent plant in terms of genetic contents. Therefore, self-cross of purebreed tall pea plants produce only tall offsprings.

In the dominance principle, Mendel explained that in a pea plant with a pair of contrasting traits, its trait is determined by a **dominant inheritance factor** whereas another contrasting trait is determined by a **recessive inheritance factor**. The dominant inheritance factor suppresses the effect of the recessive inheritance factor. Hence, the recessive trait is not visible although its inheritance factor exists together with the dominant inheritance factor in a pea plant.

Bio Exploration

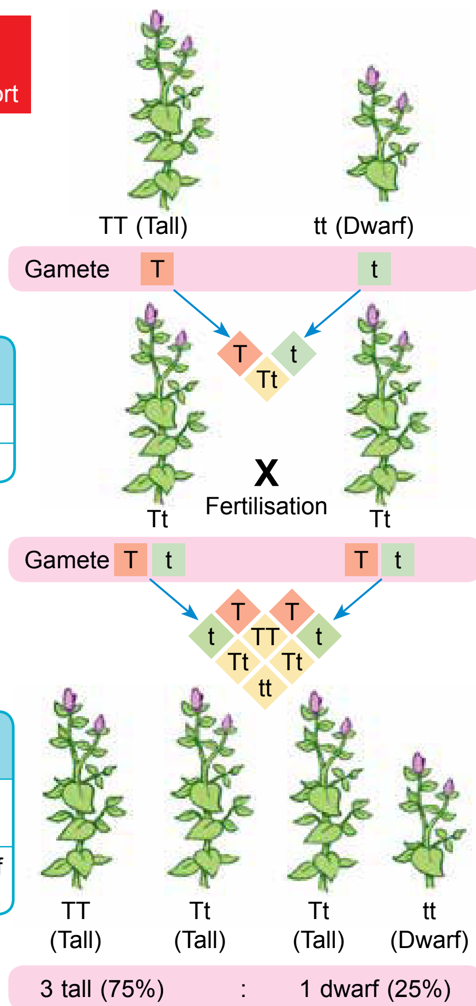
Mendel chose the pea plant as his research materials because,
- it can be easily grown and bears many seedlings,
- it has both male and female reproductive structures,
- it has a short generation interval, and
- it possesses contrasting traits or characteristics that are obvious.

Key:
T: dominant allele for tall
t: recessive allele for short

Parent

First filial generation, F_1	
Genotype	All Tt
Phenotype	All tall

Second filial generation, F_2	
Genotype	TT : Tt : tt =1 : 2 : 1
Phenotype	Tall : Dwarf = 3 : 1



Mendel crossed a purebreed tall (TT) pea plant with a purebreed dwarf (tt) pea plant (Figure 11.2).

The cross product between the two purebreed plants was the F_1 generation which consisted of only tall (Tt) pea plants. This shows that the tall trait (T) is **dominant** whereas the dwarf trait (t) is **recessive**.

Mendel then crossed the **F_1 generation** by **self-pollination** (Tt × Tt).

The ratio of tall plant to dwarf plant in **F_2 generation** was **3:1**

Figure 11.2 Monohybrid cross carried out by Mendel

11.1.2

Terms Related to Inheritance

There are a few important genetic terms that you have to understand before you continue to learn more about inheritance.

GENES AND ALLELES

Gene

- A **gene** is the basic unit of inheritance which consists of a DNA segment located on a specific locus of a chromosome.
- A gene controls a specific characteristic of an organism.

Allele

- An **allele** is an alternative form of a gene for a specific trait that is located on the same locus of a pair of homologous chromosomes.

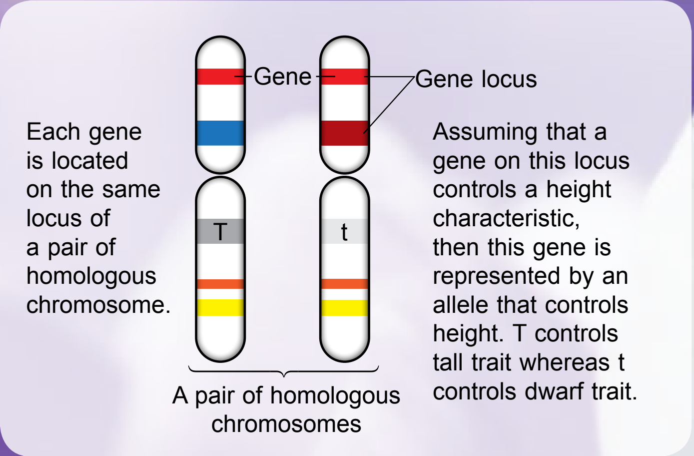


Figure 11.3 Gene locations on homologous chromosomes

PHENOTYPES AND GENOTYPES

Phenotype

- **Phenotype** is the observable characteristic of an organism.
- For example, height.

Genotype

- **Genotype** is the genetic composition of an organism that cannot be seen.
- For example, TT and Tt (genotypes for tall); tt (genotype for dwarf).

CHARACTERISTICS AND TRAITS

Characteristic

- A **characteristic** is a heritable feature such as height, eye colour, blood group and presence of dimples.
- Each characteristic is a feature of an organism.

Trait

- A **trait** is a variation of a specific characteristic. Each inherited characteristic consists of a specific trait. For example, height is a characteristic whereas tall or dwarf is a trait.

Table 11.1 Characteristics and traits

Characteristic	Trait	Genotype	Phenotype
Height	Tall	TT, Tt	Tall
	Dwarf	tt	Dwarf
Colour	Red	RR, Rr	Red
	White	rr	White
Blood group	A	I^AI^A, I^AI^O	A
	B	I^BI^B, I^BI^O	B
	AB	I^AI^B	AB
	O	I^OI^O	O

11.1.3

DOMINANT ALLELES AND RECESSIVE ALLELES

Dominant allele

- **Dominant allele** is an allele which always shows its trait when it is present, and suppresses the effect of recessive allele.
- It is represented by a capital letter. For example, B.

Recessive allele

- **Recessive allele** is an allele which shows its trait when both alleles are recessive allele.
- The effect of recessive allele is suppressed by the presence of dominant allele.
- It is represented by a small letter. For example, b.

HOMOZYGOTES AND HETEROZYGOTES

Homozygote

- Both alleles at loci of a pair of homologous chromosomes are the same. For example, BB or bb.

Heterozygote

- Alleles at loci of a pair of homologous chromosomes are different. For example, Bb.

PARENTAL GENERATIONS AND FILIAL GENERATIONS

Parental generation

- **Parental generation** refers to the first generation of two individuals which are mated to predict or analyse genotypes of their offsprings.

Filial generation

- **Filial generation** refers to a successive generation as a result of mating between individuals of purebreed parental generation.

DOMINANT TRAITS AND RECESSIVE TRAITS

Dominant trait

- Dominant trait is expressed when both alleles are dominant alleles or one dominant allele is paired with a recessive allele.
- For example, BB or Bb.

Recessive trait

- Recessive trait is expressed if a recessive allele is paired with another recessive allele.
- For example, bb.

PUREBREEDS AND HYBRIDS

Purebreed

- **Purebreed** refers to individual which carries two identical alleles for a trait. Self-cross always produces offsprings with the same characteristics in every generation.

Hybrid

- **Hybrid** is the product of mating between two purebreed varieties.

Innovation in Malaysia

In 2019, Malaysian Agricultural Research and Development Institute (MARDI) had successfully produced MR12H, the first hybrid paddy variety, which could increase paddy yield per hectare by up to 20%.

Photograph 11.2 Hybrid flower, *Lilium asiatica*

11.1.3

MEMORI Tip

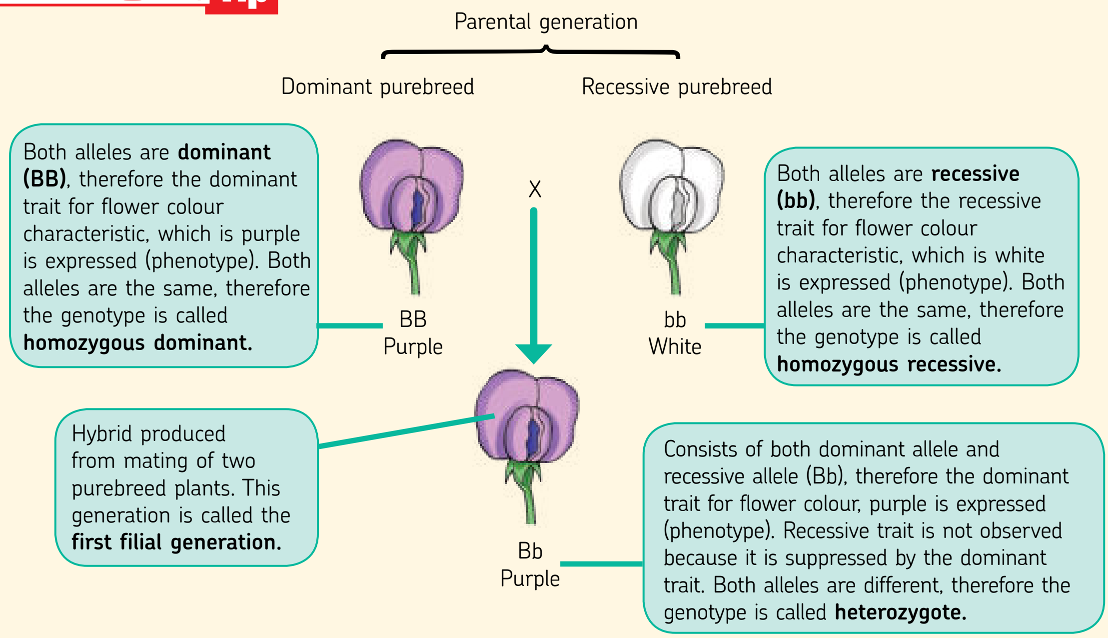
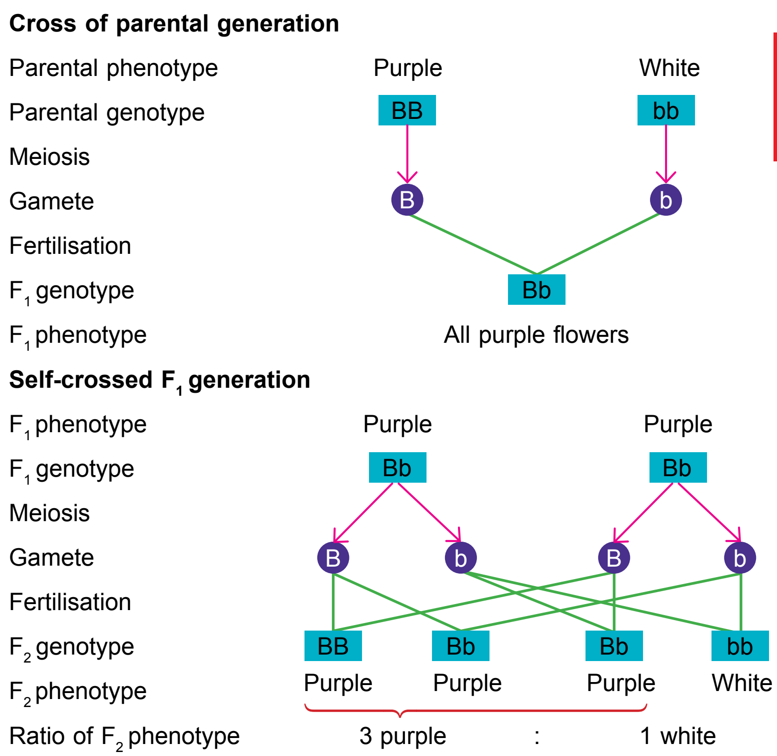


Figure 11.4 Relationship among a few important terms in genetics

How can we explain inheritance of flower colour in Figure 11.4 in a systematic and scientific manner? If allele for the dominant purple trait is labelled B (capital letter), then the allele for recessive white trait is labelled b (small letter). Therefore, each purebreed parent has two identical alleles, either BB for purple flower or bb for white flower.

During formation of gametes, **homologous chromosomes** separate during **meiosis** and produce gametes that carry one B allele from purple flower and one b allele from white flower. Fertilisation between a gamete which carries B allele and a gamete which carries b allele produces offsprings with genotype Bb in the **first filial generation (F_1)**. Since B allele is dominant, the Bb genotype combination expresses only **phenotype** with purple flower. The effect of recessive allele is suppressed by the presence of the **dominant allele**.

If the first filial generation is self-crossed, the **second filial generation (F_2)** will have offsprings with BB, Bb and bb genotypes. BB and Bb genotypes express phenotype with purple flower whereas bb genotype expresses phenotype with white flower. The trait that is not observed in the F_1 generation (white flower colour) reappears in the F_2 generation. The above explanation for inheritance of flower colour can be explained in the form of a schematic diagram of inheritance (Figure 11.5).



Key:
B: dominant allele for purple trait
b: recessive allele for white trait

Bio Exploration

Based on monohybrid cross, Mendel obtained a phenotypic ratio of 2.9:1 in F_2 generation which is close to the ratio of 3:1 if the number of pea plants used was big. Small sample size causes the ratio to be less accurate. In a natural environment, the ratio obtained is dependent on chance and probability. Therefore, the actual ratio of offsprings produced is probably different from the expected ratio.

Figure 11.5 Monohybrid schematic diagram for flower colour characteristic

Based on the fertilisation diagram in Figure 11.5, for monohybrid inheritance, the genotypic ratio in F_2 generation is 1 BB : 2 Bb : 1 bb; whereas the phenotypic ratio in F_2 generation is 3 purple : 1 white. **Punnett square** can also be used to predict the ratios and probabilities of genotype and phenotype in the offsprings produced. Boxes in the Punnett square represent different allelic combinations of zygote or offsprings that are produced (Figure 11.6).

Bio with MATHEMATICS

Phenotypic ratio calculation is based on mathematical principle. For example, if the number of round bean seed shape is 5474 and constricted seed is 1850, therefore the ratio is:

Ratio number of round seed : ratio number of constricted seed =

(5474 ÷ 1850) : (1850 ÷ 1850) = 2.96 : 1

The value can be rounded up to 3 : 1

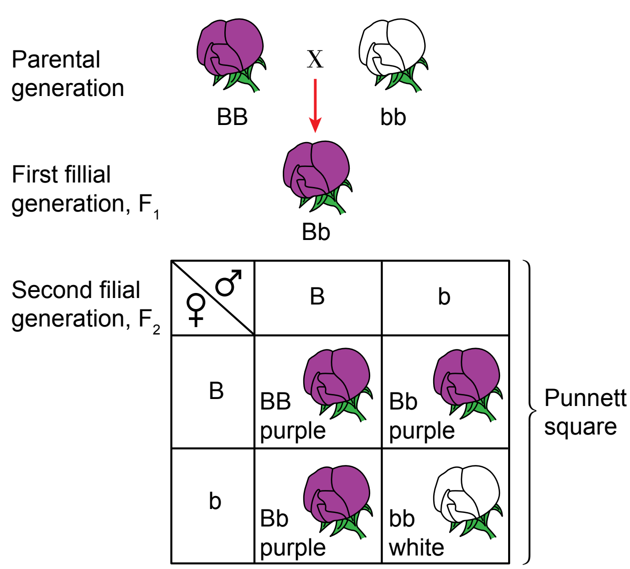


Figure 11.6 Monohybrid cross using Punnett square

Is the phenotypic ratio in monohybrid fertilisation always 3:1? To determine ratio of a monohybrid fertilisation, let's carry out Activity 11.1.

Activity 11.1

21st CENTURY SKILLS

ANALOGY

Aim

To carry out an experiment using beads to illustrate monohybrid fertilisation by analogy

Apparatus

Two black plastic bags, 100 red beads, 100 white beads

Analogy

Red bead represents dominant allele for red-coloured flowers (R)
White bead represents recessive allele for white-coloured flower (r)

Procedure

Fertilisation between two heterozygous or hybrid plants of first filial generation F_1:

1. Place 50 red beads and 50 white beads into the first black plastic.
   This represents pea plants with coloured flowers which are heterozygous.
2. Repeat step 1 with a different black plastic bag.
3. Both plastic bags are shaken to mix the beads well.
4. Without looking into the plastic bags, place a hand inside the first plastic bag and remove one bead. Remove another bead from the second plastic bag.
5. Place both beads on the table. Both beads represent combination of two gametes.
6. Record the probability of genotype and phenotype in F_2 generation in a table.
7. Return the two beads into their respective plastic bags.
8. Ensure that the beads are returned to the correct bags.
9. Repeat steps 3 to 7 for a total of 50 times.
10. Count the total combinations of genotype and phenotype that are produced.

Discussion

1. Which type of inheritance is shown by the characteristic studied in the above experiment?
2. (a) Is the result obtained in accordance with the expected ratio of 3:1?
   (b) Explain your answer.
3. Why is the bead returned into its plastic bag after each observation was recorded?
4. Suggest ways to improve the accuracy of the experiment.

11.1.5

Mendel's First Law

Mendel introduced Mendel's First Law or **Law of Segregation** which states:

> A characteristic of an organism is controlled by a pair of alleles, and only one of the allelic pair is inherited in a gamete.

Summary of Mendel monohybrid experment

- A characteristic inherited from a parent to the next generation is determined by a genetic factor, which is now known as **gene.**
- A trait is controlled by a pair of genetic factor known as **allele.**
- A pair of alleles segregates (separates) randomly during formation of gametes. Only one allele from the pair is found in a single gamete.
- During fertilisation, a zygote formed possesses two alleles (one allele from each parent) for a specific characteristic.
- Fertilisation is random. Genotypic combination which is **homozygous dominant** shows dominant trait whereas, **homozygous recessive** shows recessive trait. **Heterozygous genotype** (combination of one dominant allele and one recessive allele) shows dominant trait.

Formative Practice 11.1

1. What is meant by purebreed?
2. In a fertilisation between two rats, B represents dominant allele for black fur, whereas b represents recessive allele for white fur. If the outcome of fertilisation is ¼ BB : ½ Bb : ¼ bb, what are the fur colours and genotypes of their parents?
3. Assume that an allele for a tall trait is represented by symbol T and allele for a dwarf trait is represented by symbol t. What are the genotypes and phenotypes of offsprings from a fertilisation between a tall plant and a dwarf plant in which both are purebreed?

11.1.6

11.2 Dihybrid Inheritance

Definition of Dihybrid Cross

Dihybrid inheritance involves inheritance of two characteristics, each characteristic is controlled by a different gene located at a different locus.

Figure 11.7 shows a schematic diagram of a dihybrid inheritance between two purebreed parents to study the characteristics of pea, namely seed colour and seed shape. The two purebreed parents either have a pair of homozygous dominant alleles or a pair of homozygous recessive alleles. Fertilisation between the two purebreed parents produce offsprings in F_1 generation with the dominant traits of round and yellow seeds.

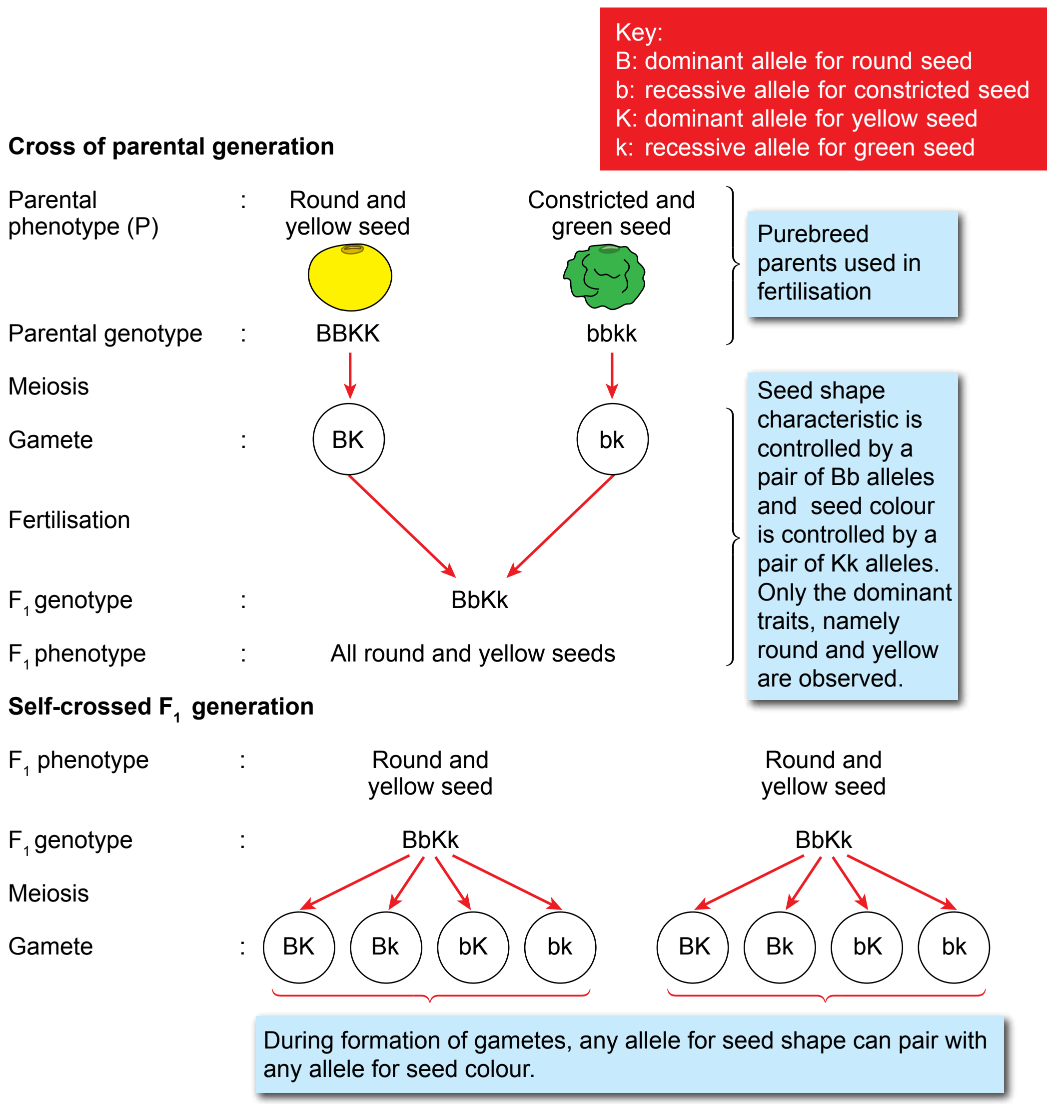


Figure 11.7 Schematic diagram of dihybrid inheritance for seed shape and seed colour of pea plant

11.2.1 11.2.2 11.2.3

When the F_1 generation produced from dihybrid cross in Figure 11.7 was self-crossed, 16 F_2 genotype combinations are produced. The cross shows four phenotypic characteristics in F_2 generation. Outcome of the dihybrid cross is presented in a Punnett square as shown in Figure 11.8.

Male gamete / Female gamete	BK	Bk	bK	bk
BK	BBKK Round, yellow	BBKk Round, yellow	BbKK Round, yellow	BbKk Round, yellow
Bk	BBKk Round, yellow	BBkk Round, green	BbKk Round, yellow	Bbkk Round, green
bK	BbKK Round, yellow	BbKk Round, yellow	bbKK Constricted, yellow	bbKk Constricted, yellow
bk	BbKk Round, yellow	Bbkk Round, green	bbKk Constricted, yellow	bbkk Constricted, green

Figure 11.8 Dihybrid cross of F_1 generation using Punnett square

Phenotypic ratio produced in F_2 generation:

Round, yellow seed : Round, green seed : Constricted, yellow seed : Constricted, green seed
9 : 3 : 3 : 1

Mendel's Second Law

Mendel introduced Mendel's Second Law, also known as **Law of Independent Assortment** which states:

During gamete formation, each allele from a pair of alleles can combine randomly with any allele from another pair of allele.

Summary of Mendel dihybrid experiment

New combinations of characteristics are produced in the F_2 generation namely constricted yellow seed and round green seed.

Two characteristics (seed shape and colour) are combined in F_1 generation but later they separate and react freely in F_2 generation.

ACTIVITY ZONE

Gather information on Mendel's Second Law of Inheritance. Then, present it in your class.

11.2.4 11.2.5

Formative Practice 11.2

1. Mendel performed cross between pea plants to study two characteristics, namely flower position and flower colour. Which type of inheritance is this?
2. The following table shows dihybrid cross between two pea plants.

Parental phenotype	Round and yellow seed	Constricted and green seed
Parental genotype	RrYy	rryy

Key:
R: dominant allele for round seed
r: recessive allele for constricted seed
Y: dominant allele for yellow seed
y: recessive allele for green seed

Which F_1 generation phenotypes are probably produced?

11.3 Genes and Alleles

Definition of Locus

Locus is a specific location of a gene in a chromosome.

Each chromosome carries many genes. In human, the number of genes that code for proteins in a set of haploid chromosome is estimated to be 25 000.

Allele which represents a gene is located at the same locus as the gene. Figure 11.9 shows five genes with their respective alleles on specific loci of a pair of homologous chromosome.

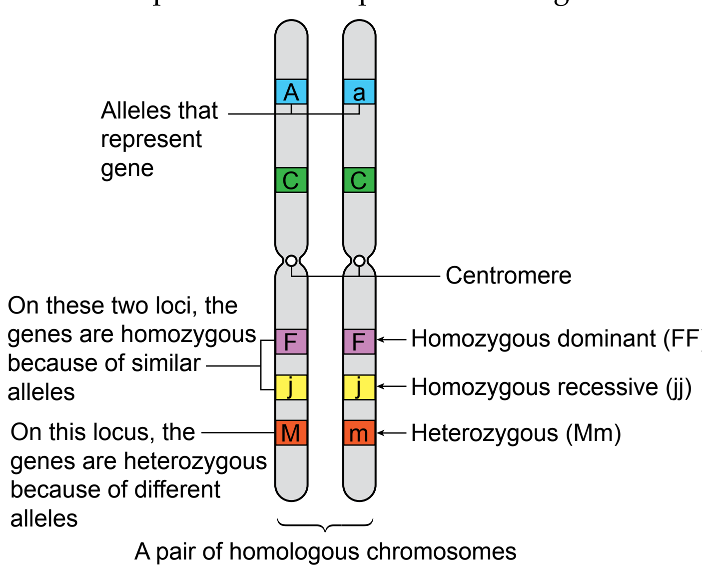


Figure 11.9 Locus, gene and allele on a pair of homologous chromosomes

11.2.5 11.3.1 11.3.2

Activity 11.2

21st CENTURY SKILLS — ANALOGY

Aim
Make analogy to relate allele, locus and gene of a chromosome

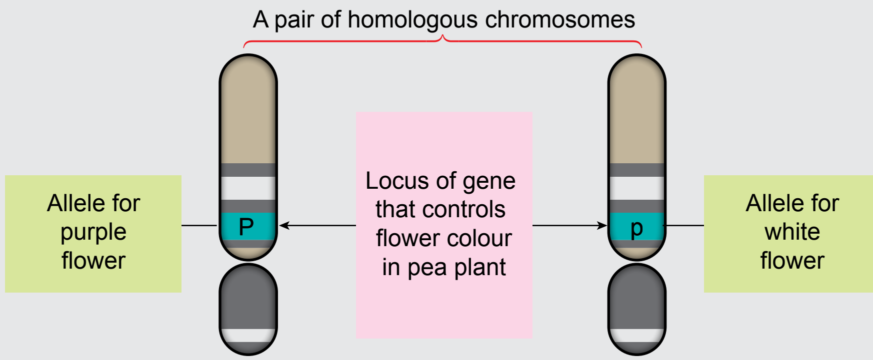
Procedure
1. Work in pairs.
2. Figure 11.10 shows an example of an analogy to relate allele, locus and gene on a chromosome.
3. Think and draw an example of another analogy to relate allele, locus and gene on a chromosome.
4. Present your analogy in class

Chromosome:
Shopping mall X
Locus:
Level 1 car park, boxes 212, 213, 214
Gene:
Sedan car
Allele:
Sedan car model P
Sedan car model Q
Sedan car model R

Figure 11.10 Example of analogy of alleles, loci and genes on a chromosome

Formative Practice 11.3

1. State the meaning of:
   (a) locus
   (b) allele
2. Based on the figure below, explain the relationship between locus, gene and allele.



11.3.2

11.4 Inheritance in Humans

There are two types of human chromosomes, namely **autosomes** and **sex chromosomes** (Table 11.2). Human somatic cell consists of **44 autosomes** and **2 sex chromosomes**. Autosomes vary in terms of size and length.

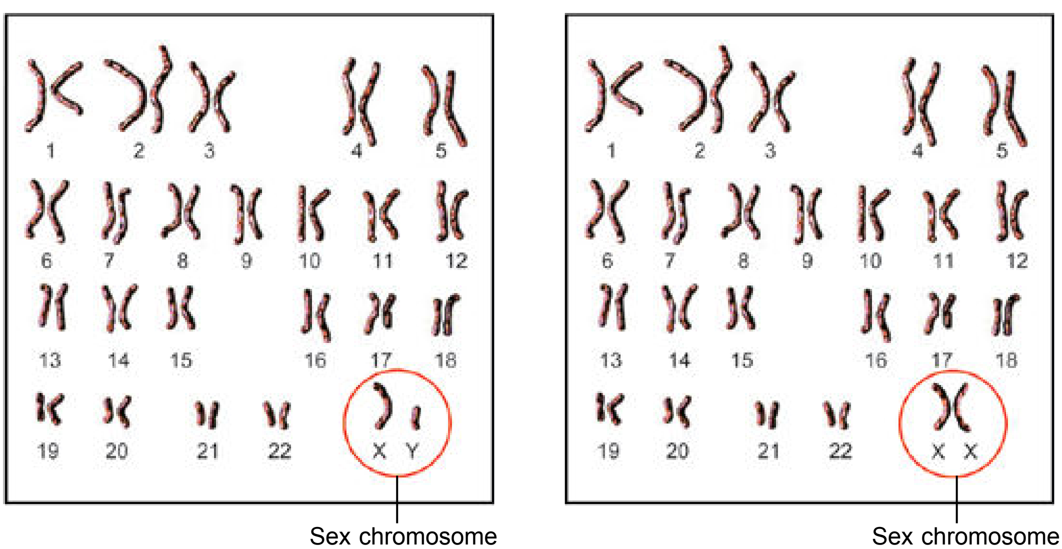
Table 11.2 Types of human chromosomes

	Autosome	Sex chromosome
Feature	Consists of chromosome pairs from number 1 to 22	Consists of one chromosome pair, that is number 23
Function	Controls all characteristics of somatic cells	Consists of genes which determine gender
Example	Types of blood groups, height and skin colour	Male has XY chromosomes whereas female has XX chromosomes

Bio Exploration

Male sex chromosomes of XY are different in size. X chromosome is longer than Y chromosome. Y chromosome only carries genes which determine sex characteristics.

The number and structure of chromosomes present in a cell nucleus is known as **karyotype** (Figure 11.11). Chromosomes are arranged in pairs, based on homologous chromosomes in terms of their **sizes**, **centromere locations** and **banding pattern** of chromosomes.



Male karyotype (44 + XY)

Female karyotype (44 + XX)

Figure 11.11 Human karyotype

Let's carry out Activity 11.3 to understand how human chromosomes are arranged to obtain a karyotype as performed by a geneticist.

Activity 11.3

21st CENTURY SKILLS ANALOGY

Aim

To match chromosomes from father (paternal) and chromosomes from mother (maternal) in a human chromosome chart to build a complete karyotype of an individual

Materials

Printed photographs of human chromosomes, blank papers

Apparatus

Scissors, glue

Procedure

1. Obtain printed photographs of human chromosomes from your teacher.
2. Build a complete karyotype of an individual by matching paternal chromosomes and maternal chromosomes using micrographs of human chromosomes from the printed photographs given.
   (a) Cut and paste pairs of homologous chromosomes by arranging them from the biggest and the longest to the smallest and shortest.
   (b) Provide a number for each pair of homologous chromosomes based on its size and length.
   (c) Complete the karyotype arrangement by placing a pair of sex chromosomes at the last position.

Changes in number of chromosome can occur due to failure of homologous chromosomes to separate during **anaphase I** or failure of sister chromatids to separate during **anaphase II**. This disorder is known as nondisjuction which can occur in some chromosomes. When nondisjunction occurs in humans, either male gamete (sperm) or female gamete (ovum) can possess chromosome number of less than 23, that is 22 or more than 23, which is 24. Therefore, fertilisation that involves the abnormal gamete with a normal gamete produces a zygote with **45 chromosomes** or **47 chromosomes**. Examples of genetic diseases caused by nondisjunction are **Down syndrome** (Figure 11.12), **Turner syndrome** (Figure 11.13) and **Klinefelter syndrome** (Figure 11.14).

- Total chromosome number is 47, which is **45 + XY**. There is an extra chromosome for chromosome pair number 21.
- Down syndrome is also known as **trisomy 21**. Down syndrome can occur in both males and females.

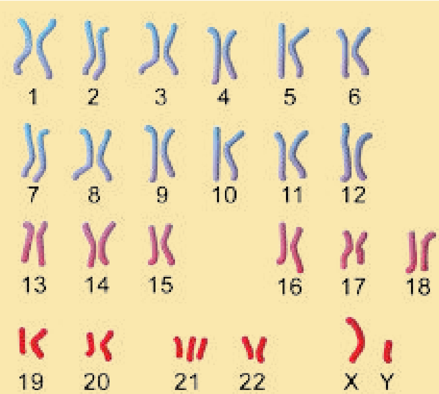


Figure 11.12 Karyotype of a male with Down syndrome

11.4.3

- In **Turner syndrome**, total number of chromosomes is 45, which is **44 + XO**.
- There is a missing X chromosome in the pair of sex chromosomes.
- The gender of individual with Turner syndrome is a female.

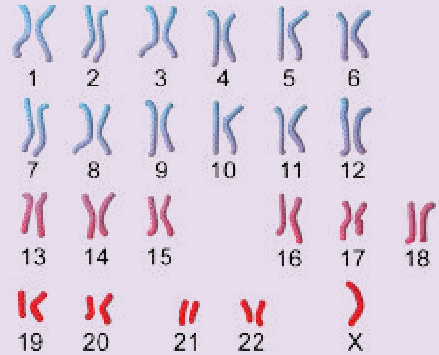


Figure 11.13 Turner syndrome karyotype

- Karyotype of **Klinefelter syndrome** has a total of 47 chromosomes, that is **44 + XXY**.
- There is an extra X chromosome in the pair of sex chromosomes. The gender of individual with Klinefelter syndrome is male.
- However, his secondary sex characteristics are not well-developed.

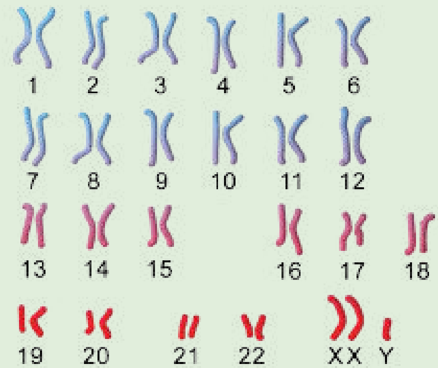


Figure 11.14 Klinefelter syndrome karyotype

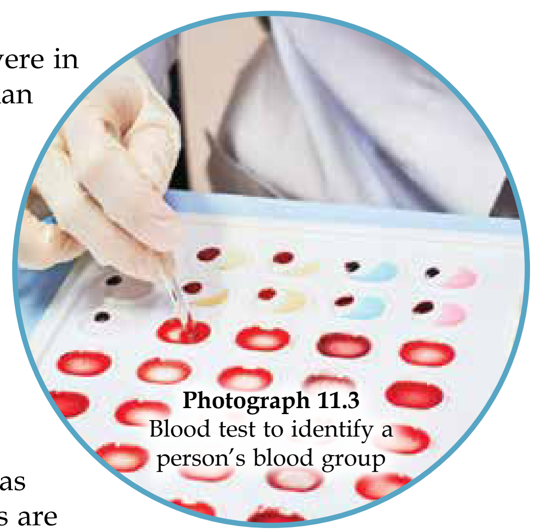
Human Inheritance

ABO Blood Groups

You have learnt about the ABO blood group when you were in Form 4. As you already know, in ABO blood group, human blood is classified into **A**, **B**, **AB** and **O**.

ABO blood group in humans is an example of multiple alleles. Blood group is controlled by a gene which consists of three different alleles, namely **allele I^A, I^B** and **I^O**. These alleles determine the types of antigens present on the surface membrane of red blood cells. However, a person only possesses two alleles to determine his/her blood group.

Both I^A and I^B are dominant alleles whereas I^O is recessive allele. Therefore, a combination of I^A and I^O (I^AI^O) alleles expresses a group A blood phenotype whereas I^BI^O expresses a group B blood phenotype. I^A and I^B alleles are **codominant** to one another. When these two alleles are present together, effects of both alleles show. A combination of both alleles gives an AB blood group phenotype. Table 11.3 shows a summary of phenotype and genotype human ABO blood group.



Photograph 11.3 Blood test to identify a person's blood group

Table 11.3 Phenotype and genotype of human blood group

Phenotype (blood group)	Genotype
A	I^AI^A or I^AI^O
B	I^BI^B or I^BI^O
AB	I^AI^B
O	I^OI^O

Key:
I^A and I^B: dominant allele
I^O: recessive allele

How do you solve a blood group inheritance issue in the following problem?

A man with A blood group married a woman with B blood group. Explain the probability of the couple in getting a child with O blood group.

Answer:
Both mother and father are heterozygous for A blood group and B blood group. Schematic diagram for blood inheritance is shown in Figure 11.15.

Bio Exploration

Inheritance of blood group is an example that does not follow Mendel's Law. According to Mendel, one gene only has two alleles (one dominant allele and one recessive allele).

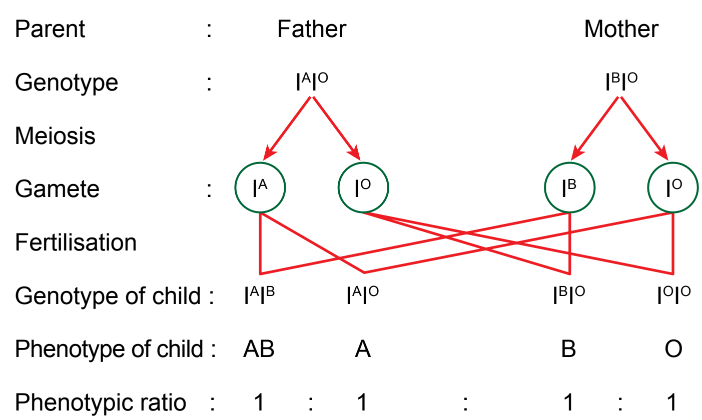


Figure 11.15 Schematic diagram of ABO blood group inheritance

Rhesus Factor (Rh)

Besides **antigen A** and **antigen B** on the surface of human red blood cell, there is another antigen called **antigen D** which is known as **Rhesus factor (Rh)**. An individual whose red blood cell has Rhesus factor is said to be **Rhesus positive (Rh^+)** whereas an individual without the Rhesus factor is said to be **Rhesus negative (Rh^-)**.

11.4.4

Inheritance of Rhesus factor from parents to children is based on principles of Mendel's Law. Rhesus factor is controlled by genes which consists of a pair of alleles, namely **Rh^+ dominant** and **Rh^- recessive**. Genotype of an Rh positive individual is either **homozygous dominant** (Rh^+Rh^+) or **heterozygous** (Rh^+Rh^-). Rh negative individual is **homozygous recessive** (Rh^-Rh^-). Figure 11.16 shows inheritance of Rhesus factor. Can you build a schematic diagram based on Figure 11.16 below?

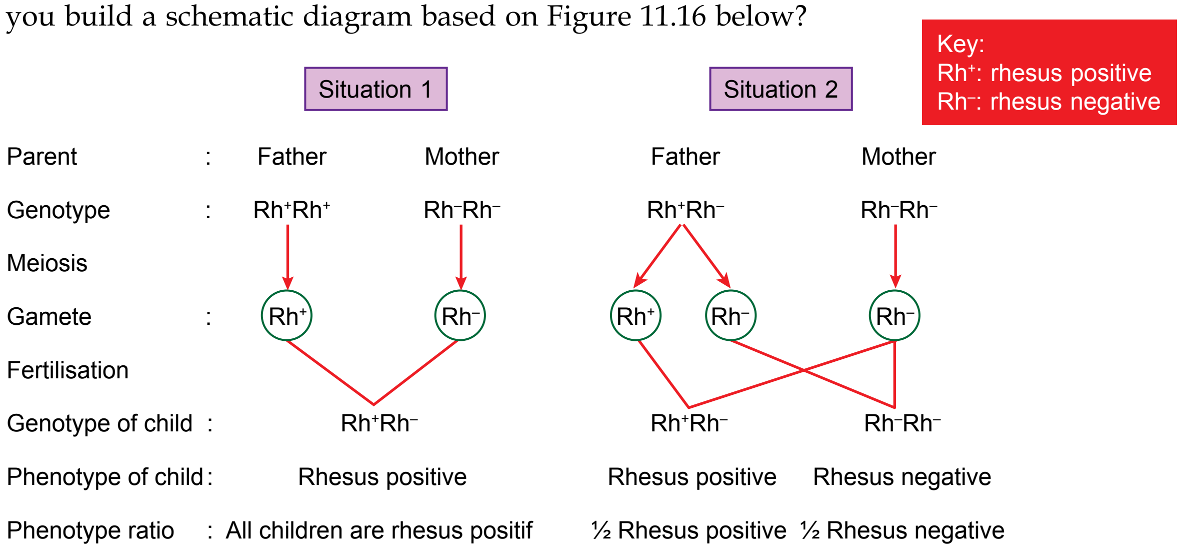


Figure 11.16 Schematic diagram of Rhesus factor inheritance

Thalassemia

Thalassemia is an inherited disease. The disease can be passed down from generation to generation.

Thalassemia is due to **gene mutation** on an **autosome**, that is on chromosome **11** or **16**. Thalassemia is due to the abnormality and low number of haemoglobin. The red blood cell is smaller and paler. Figure 11.17 shows the probability of inheriting thalassemia.

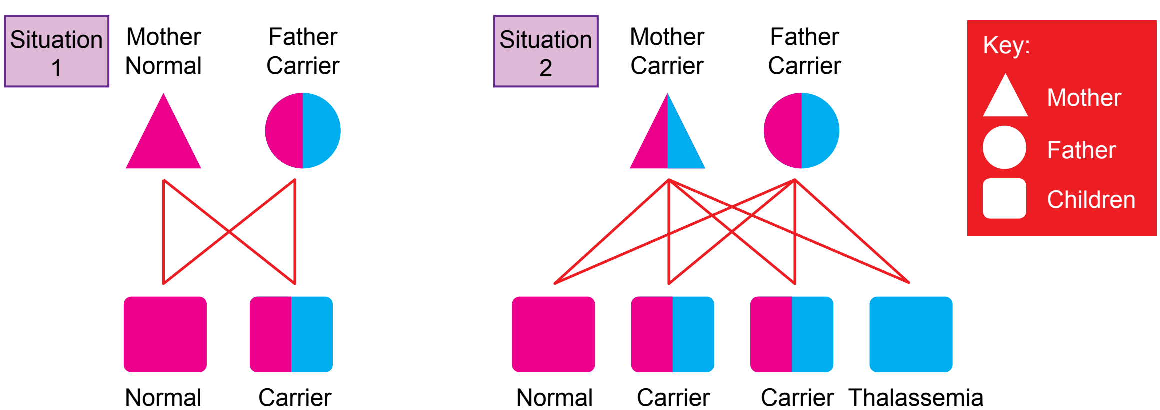


Figure 11.17 Inheritance of thalassemia

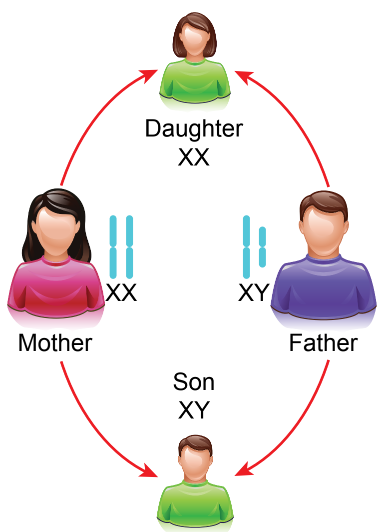
Thalassemia carrier is said to have a **thalassemia minor** condition in which the individual possesses recessive allele of thalassemia but the individual does not show any symptoms of the disease. Detection of thalassemia can only be confirmed by a blood test. A **thalassemia** patient is said to have **thalassemia major** when the individual has both the recessive alleles. A thalassemia patient shows symptoms such as tiredness, paleness, breathing difficulty and changes in facial bone formation from the age of 3 to 18 months.

History Corner

Thalassemia screening programme to identify thalassemia carriers among form four students was launched in 2016 by the Ministry of Health Malaysia.

Sex Determination

A male has **44 + XY** chromosomes and a female has **44 + XX**. Sperms produced in the testis are haploid, and each sperm has either **22 + X** or **22 + Y** chromosomes. Secondary oocytes produced in the ovary are also haploid and each secondary oocyte has only one set of chromosome, namely **22 + X** chromosomes. Sex or gender of a child is determined during fertilisation (Figure 11.18).



Parent	:	Father		Mother
Genotype	:	44 + XY		44 + XX
Meiosis				
Gamete	:	22 + X, 22 + Y		22 + X
Fertilisation				
Genotype of child	:	44 + XX		44 + XY
Phenotype of child	:	Female		Male
Phenotypic ratio	:	1	:	1

Figure 11.18 Determination of children's gender

Sex-linked Inheritance

Genes located on sex chromosomes which control specific characteristics but are not involved in sex determination are known as **sex-linked genes**. Genes of **colour blindness** and **haemophilia** are located in the X chromosome. These genes are called **sex-linked genes**. Characteristics of colour blindness and haemophilia are caused by recessive genes linked to X chromosome. Y chromosome is shorter than X chromosome and does not contain as many alleles as X chromosome. Therefore, any traits in males caused by either the dominant allele or recessive allele on chromosome X is observed.

11.4.4

Colour Blindness

Colour blindness is a condition in which a person cannot differentiate some specific colours such as red and green. Colour blindness is caused by the recessive allele found in the X chromosome and most people with colour blindness are males.

In sex-linked inheritance research, X and Y chromosomes must be shown when writing the genotypes. Dominant allele is represented by a capital letter whereas recessive allele is represented by a small letter on the X chromosome. Genotypes of colour blindness inheritance are written as shown in Table 11.4.

Table 11.4 Genotype and phenotype of colour blindness inheritance

Phenotype	Genotype	
	Male	Female
Normal	X^BY	X^BX^B
Carrier	–	X^BX^b
Colour blind	X^bY	X^bX^b

Key:
X^B: dominant allele
X^b: recessive allele

Figure 11.19 shows a schematic diagram for colour blindness when a man with normal eyesight marries a woman who is heterozygous for colour blindness.

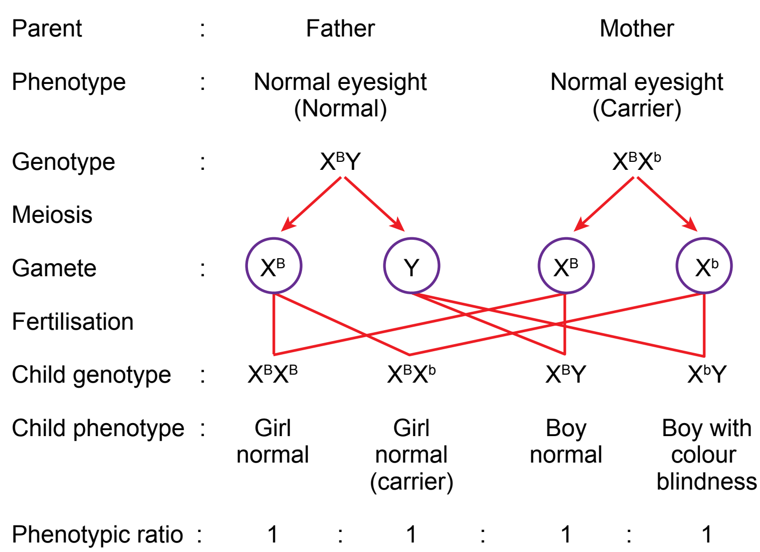


Figure 11.19 Schematic diagram of colour blindness inheritance

ACTIVITY ZONE

Perform Ishihara test to identify colour blindness among friends in your class.

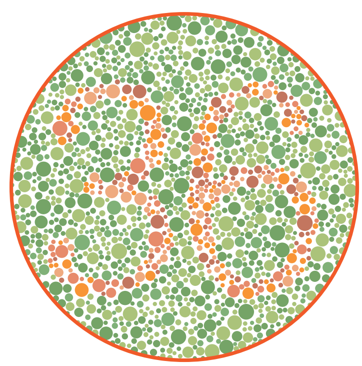


Figure 11.20 An example of Ishihara test plate

Bio Exploration

Ishihara test is a famous colour blindness screening test that has been used worldwide since 1917. The test was developed by Shinobu Ishihara (1879 - 1963), a Japanese opthalmologist. It is invented to screen for the common green-red colour blindness defects. Individuals with normal eyesight can identify the numbers or pattern in the Ishihara test plates (Figure 11.20) whereas individuals with colour blindness defects would report wrong numbers or fail to identify the numbers and patterns.

11.4.4

Haemophilia

Haemophilia is a condition in which blood cannot clot in normal circumstances due to the lack of blood clotting factor. This can result in excessive internal or external bleeding which may be fatal. Haemophilia is due to the presence of the **recessive allele** in the **X chromosome**, which causes the male to be haemophilic. The female will only be haemophilic if both recessive alleles are present on both X chromosomes. Table 11.5 shows how genotypes and phenotypes are written in a haemophilic inheritance. Figure 11.21 shows a schematic diagram for haemophilia inheritance.

Table 11.5 Genotypes and phenotypes of haemophilic inheritance

Phenotype	Genotype	
	Male	Female
Normal	X^HY	X^HX^H
Carrier	-	X^HX^h
Haemophilic	X^hY	X^hX^h

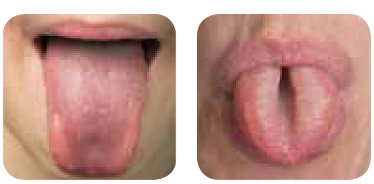
Key:
X^H: dominant allele
X^h: recessive allele

Parent	:	Father		Mother	
Phenotype	:	Normal male (Normal)		Normal female (Carrier)	
Genotype	:	X^HY		X^HX^h	
Meiosis					
Gamete	:	X^H	Y	X^H	X^h
Fertilisation					
Genotype of child	:	X^HX^H	X^HX^h	X^HY	X^hY
Phenotype of child	:	Girl normal	Girl normal (carrier)	Boy normal	Boy haemophilic
Phenotypic ratio	:	1 :	1 :	1 :	1

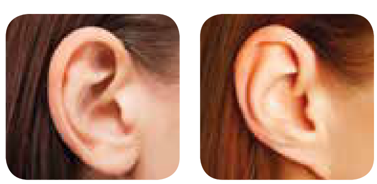
Figure 11.21 Schematic diagram for haemophilia

Ability to Roll Tongue and Types of Earlobe

The ability to roll tongue and the types of earlobes (Photographs 11.4 (a) and (b)) are two characteristics that can be inherited from parents to children according to Mendel's Law. Ability to roll tongue is a dominant trait. Free earlobe is a dominant trait whereas attached earlobe is a recessive trait.



(a) Ability to roll tongue



(b) Type of earlobe

Photograph 11.4

ICT

Info

Ability to roll tongue and type of earlobe

http://bukutekskssm.my/Biology/F5/Pg249.pdf

11.4.4 11.4.5

Family Pedigree

Family pedigree or lineage can be analysed to investigate inheritance of human characteristics. Family pedigree is a flowchart through a few generations to show **ancestral relationship** and **inheritance of characteristics** from ancestors to individuals in the present generation.

Analysis of family pedigree enables the geneticist to predict an inherited characteristic of interest and also to identify the features of dominant or recessive gene. Normally a dominant gene appears in every generation whereas a recessive gene is probably hidden in certain generations. Figure 11.22 shows a pedigree chart of a family for three generations. Based on the figure, can you explain the inherited disease in the family?

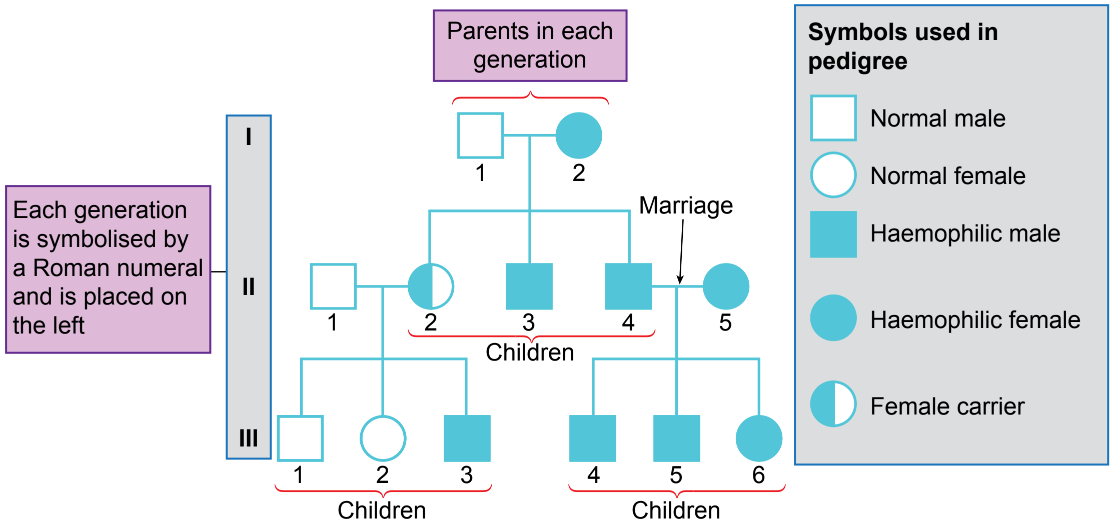


Figure 11.22 Haemophilic inheritance in a family

Activity 11.4

Aim

To build a family pedigree based on phenotypic and genotypic information of family members

Procedure

1. Carry out the activity individually.
2. Observe one characteristic (phenotype) that is inherited in your family.
3. Beginning with you, build a family pedigree chart through a few generations to show the inherited characteristic that you investigate.
4. Present the family pedigree chart that you built in your class.

Formative Practice 11.4

1. A woman has heterozygous B blood group and a man has heterozygous A blood group. If the couple has an unidentical twins, what are the chances of both children having A blood group? Explain the inheritance of blood group of this family by using a schematic diagram using appropriate symbols.
2. A woman who is heterozygous for haemophilia married a normal man. What are the chances of the couple having a haemophilic son?
3. A man who is homozygous for the ability to roll his tongue married a woman who is heterozygous for tongue rolling. What are the implications of their mating?

Memory Flashback

INHERITANCE

- Mendel Inheritance
  - Monohybrid inheritance
    - Mendel's First Law
  - Dihybrid inheritance
    - Mendel's Second Law
  - Inheritance factor
- Human karyotype
  - Autosome
  - Sex chromosome
- Human Inheritance
  - ABO blood group
  - Rhesus factor
  - Thalassemia
  - Sex determination
  - Sex-linked inheritance
    - Colour blindness
    - Haemophilia
  - Ability to roll tongue
  - Type of earlobe
  - Family pedigree

Interactive Bio 11

SELF-REFLECTION

Complete the following self-reflection to identify the important concepts that you have studied.

Important concepts	Very good	Try again
Meaning of monohybrid inheritance		
Monohybrid cross based on Mendel's experiment		
Terms related to inheritance		
Schematic diagram for monohybrid inheritance		
Mendel's First Law		
Dihybrid cross based on Mendel's experiment		
Schematic diagram for dihybrid inheritance		
Mendel's Second Law		
Meaning of locus		
Relationship of allele, locus and gene on a chromosome		
Types of human chromosomes		
Human karyotype and genetic diseases		
Mendel's Laws and inheritance in humans		
Family pedigree		

Summative Practice 11

1. Figure 1 shows a cross between two pea plants, X and Y. If:

P : dominant allele for purple flower
p : recessive allele for white flower
S : dominant allele for inflated pod
s : recessive allele for constricted pod

Parent	:	Pea X		Pea Y
Genotype	:	PPss	×	ppSS
Meiosis				
Gamete	:	(i) ____		(i) ____
Fertilisation				
F_1 Generation	:		PpSs	
Progeny phenotype	:	(ii)		

Figure 1

(a) State the phenotypes of parental plants X and Y.

(b) Complete the gamete genotypes produced by each parent, and phenotypes in F_1 generation in Figure 1.

(c) Table 1 shows the genotypes of F_2 generation after F_1 was crossed with another F_1 generation. The total number of F_2 progenies was 16.

Table 1

Gamete	PS	Ps	pS	ps
PS	PPSS	PPSs	PpSS	PpSs
Ps	PPSs	PPss	PpSs	Ppss
pS	PpSS	PpSs	ppSS	ppSs
ps	PpSs	Ppss	ppSs	ppss

(i) State the probability of the pea plant in F_2 generation with purple flower and constricted pod.

(ii) State the probability of the pea plant in F_2 generation with purple flower and inflated pod.

(iii) In Table 1, circle the genotypes of pea plant in F_2 generation with white flower and inflated pod. Then, determine the probability of F_2 generation for the phenotypes.

(d) State the phenotypic ratio of the progeny in F_2 generation.

Purple flower, inflated pod	Purple flower, constricted pod	White flower, inflated pod	White flower, constricted pod
______	______	______	______

(e) Based on Figure 1 and Table 1, state Mendel's Second Law.

2. A man has normal eyesight whereas his wife is colour blind. X^B is a dominant allele for normal eyesight whereas X^b is a recessive allele for colour blindness. What is the probability of their children having:

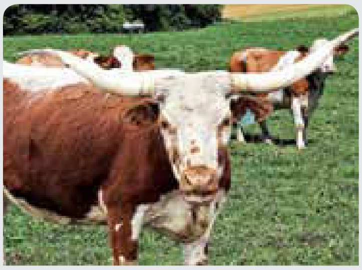
(a) Colour blindness?

(b) Normal eyesight but a carrier?

Explain your answers using a schematic diagram.

21st Century Mind

3. In a type of cattle, white face and long horns are dominant traits as opposed to those with black face and short horns as shown in Photograph 1. A breeder plans to breed all white face and long horns cattle in his farm. Prior to that, he has to ensure that his bull and cow are purebreed. As a geneticist, explain how you can assist the breeder in determining whether his cattle is purebreed or hybrid?



Photograph 1

Chapter 12 Variation

Chapter Exploration

- Types and Factors of Variation
- Variation in Humans
- Mutation

Learning Standards

Do You Know?

- What are the existing types of variations?
- What are the differences between continuous and discontinuous variation?
- Can you give examples of variation in humans?
- What is the meaning of mutation?

CCR5 GENE MUTATION

Human Immunodeficiency Virus (HIV) invades the human body by entering the cell through CD4 receptor and CCR5 co-receptor found on the cell surface. Medical experts in Washington found an extraordinary mutation on CCR5, which is called CCR5 gene mutation. The mutation prevents HIV from entering the human cell and infecting the human body.

CCR5 gene mutation was discovered in an AIDS patient who recovered from HIV infection after undergoing a bone marrow transplant from a donor who had CCR5 gene mutation .

Keywords

- Survival of species
- Natural selection
- Continuous variation
- Discontinuous variation
- Mutagen
- Mutation
- Mutant
- Gene mutation
- Chromosomal mutation
- Crossing over
- Independant assortment of chromosomes
- Random fertilisation

12.1 Types and Factors of Variation

Definition of Variation

Variation refers to the differences in characteristics found within the same population or species.

No two organisms are the same although they are from the same species including identical twins (Photograph 12.1). There will always be differences between them. Normally, variation refers to physical characteristics observed in phenotypic differences caused by changes in structure, physiology and biochemistry. Variation enables us to identify individuals within a population.

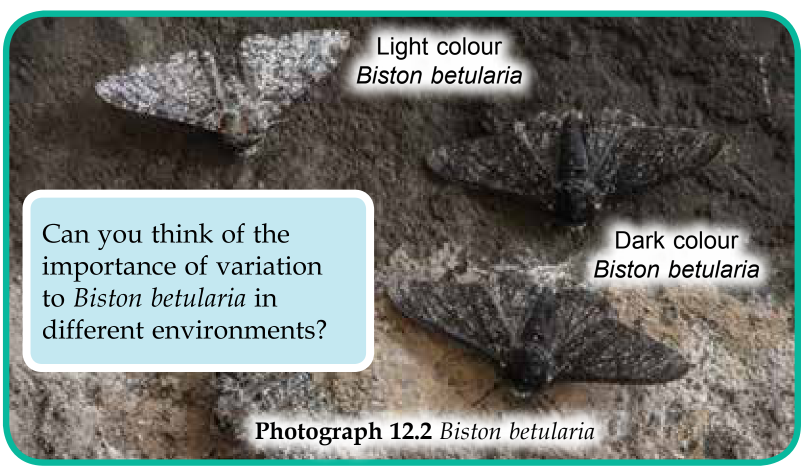

Photograph 12.1 Identical twins

Think Smart

Do identical twins have variation in their phenotypes? Why?

The Necessity of Variation for the Survival of Species

Variation plays an important role in evolution and forms the basis of natural selection. Natural selection is an evolutionary force that selects beneficial genes and removes the non-beneficial ones from the natural environment. Through natural selection, species that possess phenotypes which enable them to adapt to their surrounding will continue to live and breed for the survival of the species (Figure 12.1).



Photograph 12.2 *Biston betularia*

Bio Exploration

The industrial revolution in the United Kingdom caused environmental pollution. *Biston betularia* which is darker in colour survives better compared to the one in bright colours because it is not easily seen by birds of prey (Photograph 12.2).

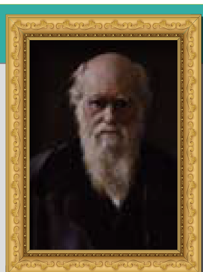
12.1.1 12.1.2

Necessity of variation

- Enables natural environment to continue selecting beneficial characteristics and remove the non-suitable ones
- Ensures survival of the species when the environment changes
- Allows cross breeding among species to form new species

Figure 12.1 Necessity of variation

ACTIVITY ZONE



Photograph 12.3 Charles Darwin

> "It is not the strongest of the species that survives, nor the most intelligent that survives. It is the one that is most adaptable to change..."
>
> – Charles Darwin

Charles Darwin (1809 – 1882) is the scientist who pioneered the evolution theory based on natural selection as described in his book Origin of Species. Describe your opinion on the above statement by Darwin.

Activity 12.1

21st CENTURY SKILLS

INDIVIDUAL PRESENTATION

Aim

Collect information and present your opinion on variation in various animals and plants

Procedure

1. Work in groups.
2. Search for information on the Internet on variation of animals and plants.
3. Present the findings of your group using multimedia presentation.

12.1.1 12.1.2

Types of Variation

The two types of variation are **continuous variation** and **discontinuous variation.**

Continuous variation

- **Continuous variation** is the variation in which the differences in the characteristic is not distinct. Individuals show gradual differences in characteristic from one extreme to the other extreme. A spectrum of phenotype is observed.
- If data is obtained and plotted on a graph, a **normal distribution** or a **bell-shaped curve** will be obtained. Most members of the population have intermediate phenotypes, which are characteristics found in between the two extremes. (Figure 12.2).
- Continuous variation is **quantitative**, it can be measured and graded from one extreme to the other extreme.
- The characteristics are influenced by environmental factors. Examples of characteristics which show continuous variation are **height**, **body weight** and **skin colour** (Photograph 12.4).

Photograph 12.4 Examples of characteristics that show continuous variation

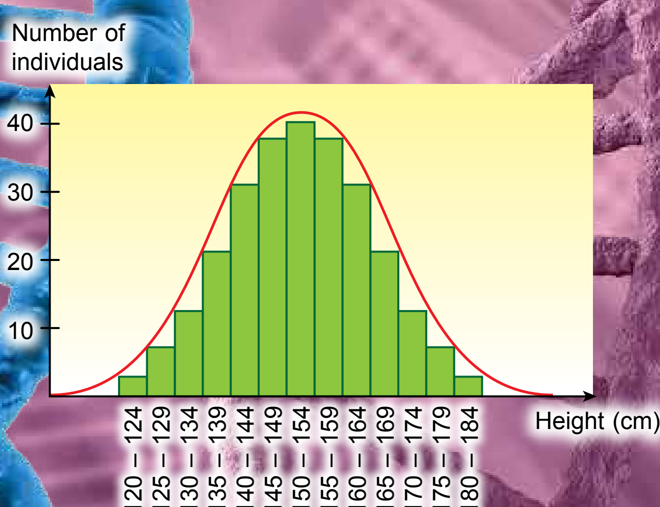


Figure 12.2 Graph of continuous variation

12.1.3

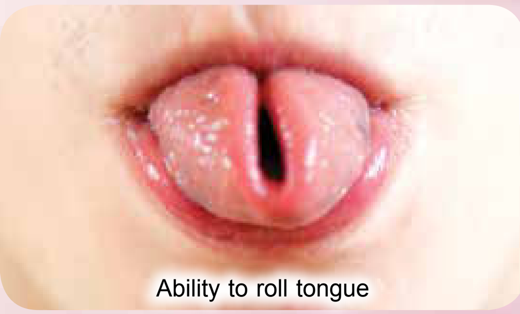
Types of Variation

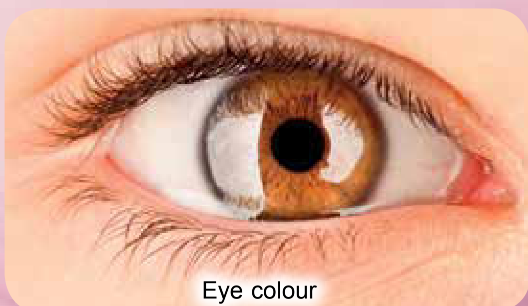
Bio Exploration

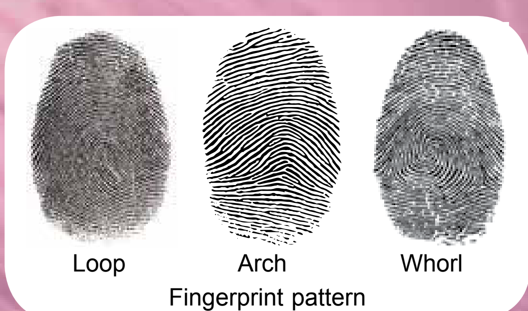
A total of 8%-10% of the human population worldwide has blue eyes, which is caused by low level of melanin content in the outer layer of iris.

Discontinuous variation

- **Discontinuous variation** shows distinct differences in characteristic.
- If data is obtained and plotted on a graph, a **discrete distribution** or a bar chart with separate bars are obtained. There are no intermediate characteristics (Figure 12.3).
- The characteristic is **qualitative**, it cannot be measured or graded because the characteristic can only be determined by genetic factor.
- The characteristic is not influenced by environmental factors.
- Occurence of discontinuous variation is due to genetic factors, therefore it can be inherited.
- A characteristic is determined by a single gene with two or three alleles. Therefore, the characteristic is easily seen.
- Examples of discontinuous variations are the **ability to roll tongue, eye colour** and **fingerprint pattern** (Photograph 12.5).







Photograph 12.5 Examples of characteristics that show discontinuous variation

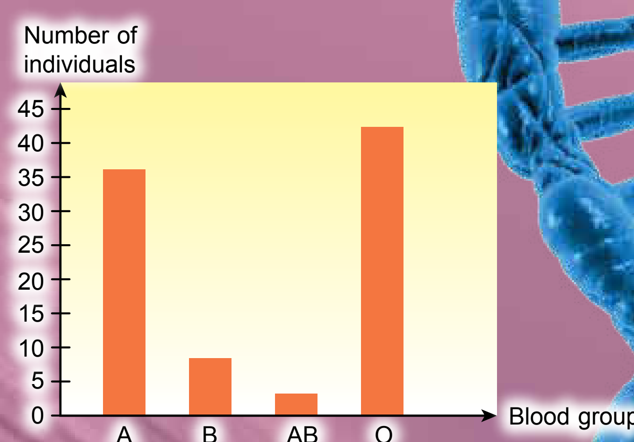


Figure 12.3 Graph of discontinuous variation

12.1.1

12.2.4

Comparison between Continuous and Discontinuous Variation

What are the differences between continuous variation and discontinuous variation (Figure 12.4)?

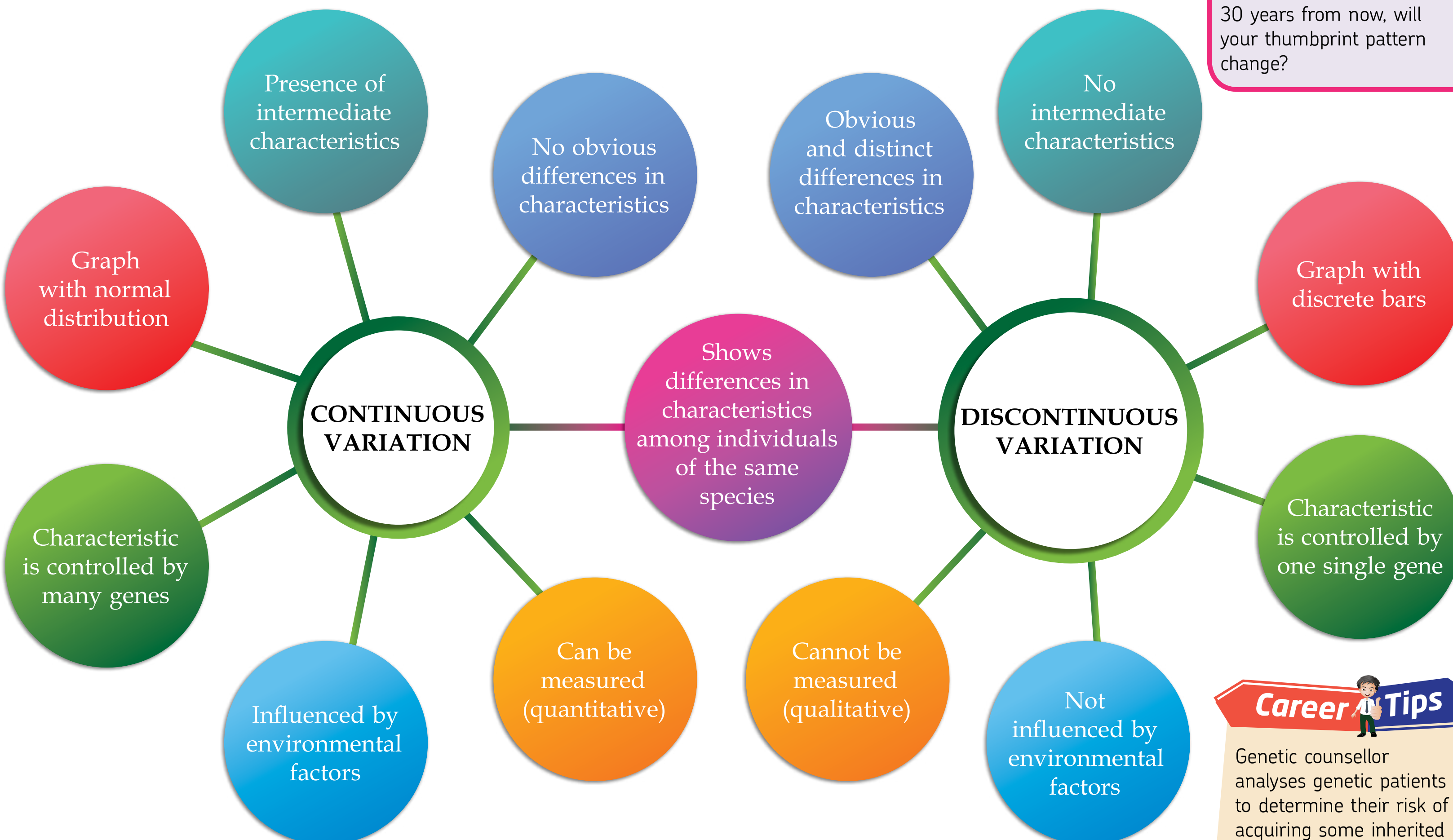


Figure 12.4 Comparison between continuous variation and discontinuous variation

Think Smart

30 years from now, will your thumbprint pattern change?

Career Tips

Genetic counsellor analyses genetic patients to determine their risk of acquiring some inherited diseases, which are found in their genes.

Causes of Variation

Organisms of the same species differ in terms of **morphology, physiology** and **genetics**. What are the causes of variation among these organisms (Figure 12.5)?

Photograph 12.6 Variation on sea shells

CAUSES OF VARIATION

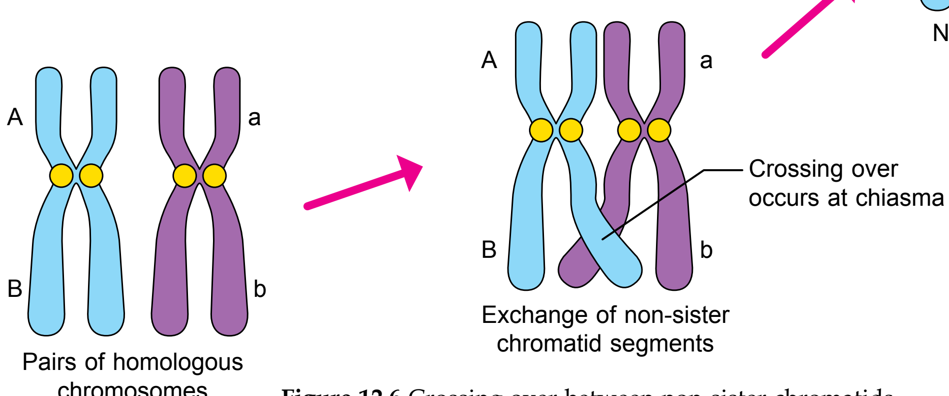
- Continuous variation
  - Environmental factors
    - Temperature
    - Light
    - pH
- Discontinuous variation
  - Genetic factors
    - Crossing over
    - Independent assortment of chromosomes
    - Random fertilisation
    - Mutation

Figure 12.5 Factors that cause continuous variation and discontinuous variation

Genetic Factors

Crossing Over

- Crossing over occurs between non-sister chromatids of homologous chromosomes during prophase I of meiosis.
- Recombination produces new combinations of genes.
- Sister chromatids that separate during anaphase II of meiosis form gametes with different genetic materials at the end of meiosis (Figure 12.6).



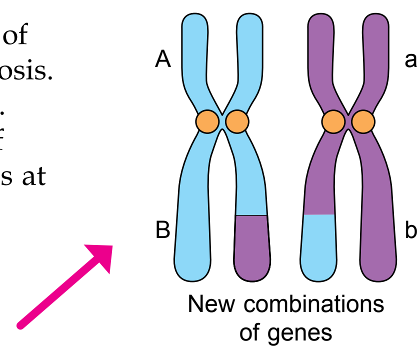


Figure 12.6 Crossing over between non-sister chromatids

12.1.5

Independent Assortment of Chromosomes

- During **metaphase I of meiosis**, a homologous chromosome pair (one **maternal chromosome** and one **paternal chromosome**) is arranged randomly on the equatorial plane of a cell.
- Figure 12.7 shows two probabilities on the arrangement of homologous chromosomes on the **equatorial plane** for each **diploid cell (2n=4)**.
- At the end of meiosis, different gametes will be produced with different combinations of paternal and maternal chromosomes, which results in the genetic contents of each gamete to be different from the others.

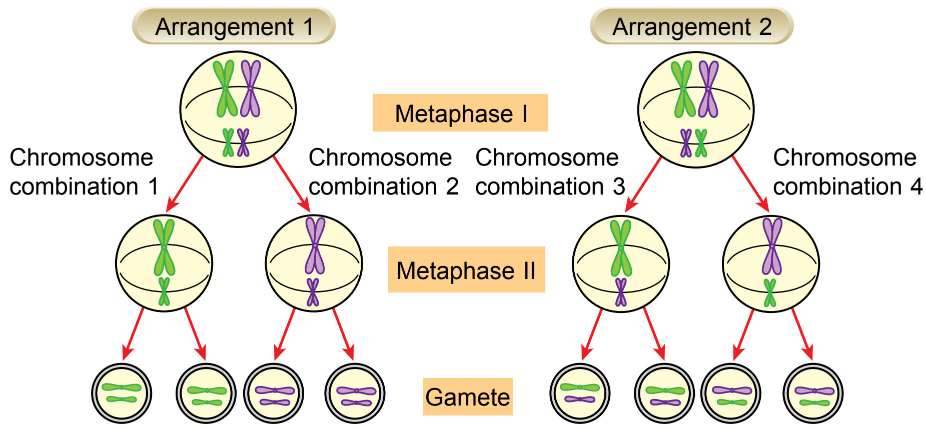


Figure 12.7 Random arrangements of homologous chromosomes during metaphase I

Random fertilisation

- Fertilisation between sperm and secondary oocyte is random.
- Genetic recombination which occurs during crossing over and random arrangement of homologous chromosomes in **meiosis,** produces gametes with different genetic contents from their parents.
- Therefore, a diploid zygote which is produced after fertilisation will have a new genetic combination (Figure 12.8).

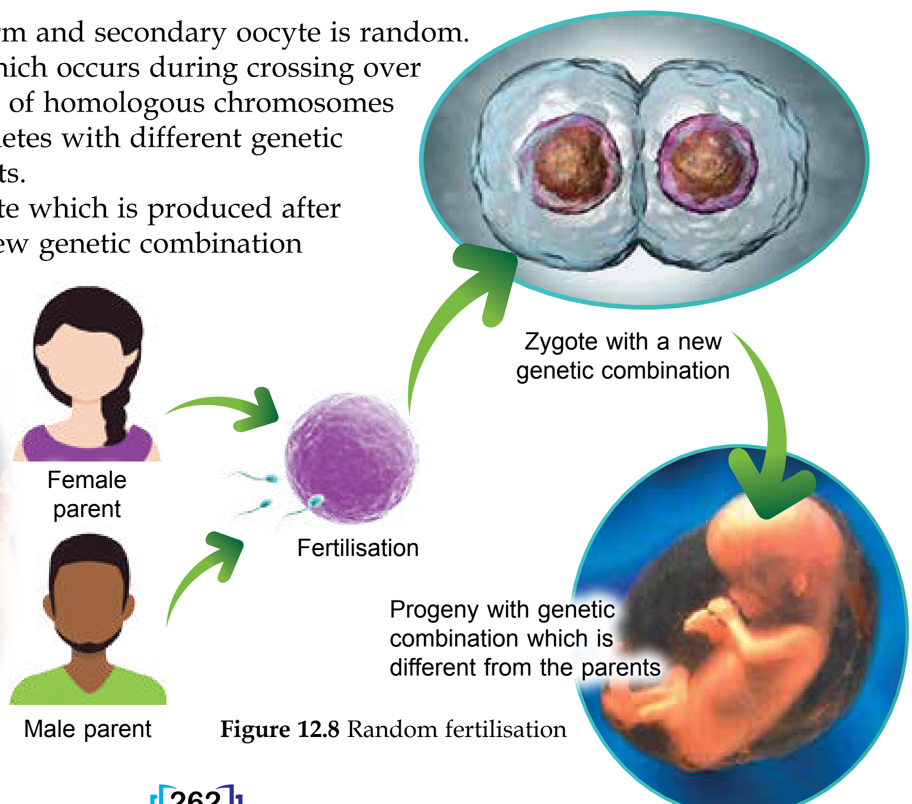


Figure 12.8 Random fertilisation

Mutation

- **Mutation** is a permanent change which occurs spontaneously on genes or chromosomes.
- Mutation creates new genotypes.
- If mutation occurs in the gamete (mutation of germ cell), the characteristics determined by mutated genetic materials can be inherited (Figure 12.9).
- Mutation of the somatic cell can cause variation but the characteristics cannot be inherited by the next generations.

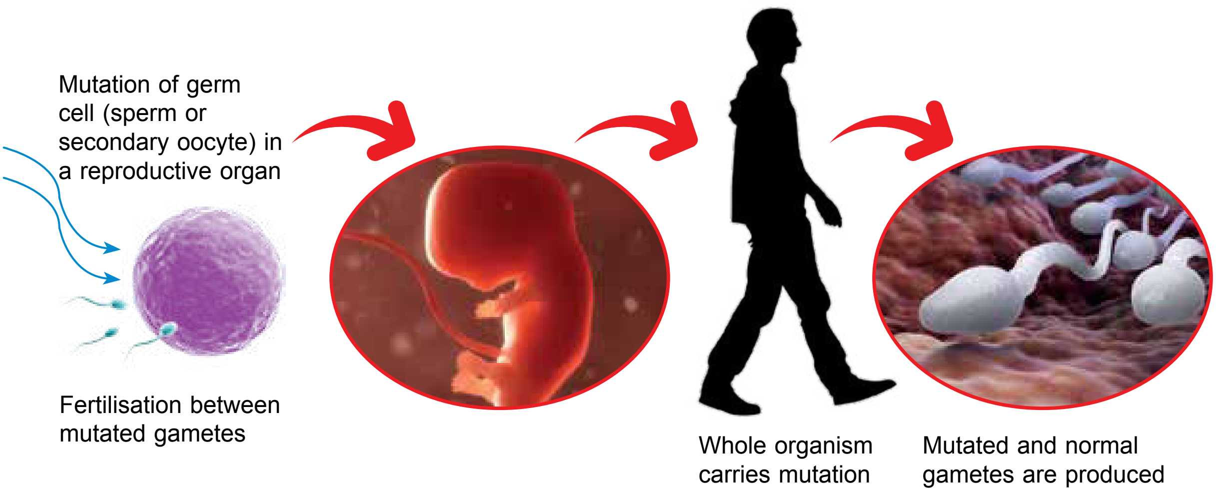


Figure 12.9 Mutation of germ cell

Environmental Factors

Variation caused by environmental factors is known as **environmental variation**. Environmental factors that cause variation include **abiosis factors** such as **temperature, light** and **pH**. In contrast to variation caused by genetics, the effect of environment on variation is small since it only involves phenotypic differences and not genotypic differences.

Environment can change allele frequency and genotype frequency in a population but cannot change the genotype. Therefore, environmental variation cannot be inherited from one generation to the next (Figure 12.10).

Which environmental factors cause *Hydrangea* sp. plant to produce different coloured flowers (Photograph 12.7)?

Photograph 12.7
Hydrangea sp. plant

12.1.5

Environmental Factors

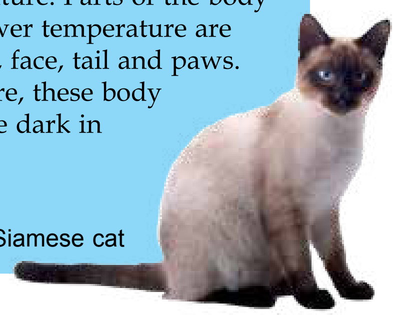
Soil pH

Hydrangea sp. plant produces blue flowers in acidic soil (pH less than 5.5) and pink flowers in alkaline soil.

Hydrangea sp.

Temperature

Siamese cat inherited the gene which produces dark pigment enzyme for fur colour. This enzyme only functions at temperature less than the body temperature. Parts of the body with lower temperature are the ears, face, tail and paws. Therefore, these body parts are dark in colour.



Siamese cat

Light

Sunlight can alter skin colour. People who are under the sun for a long period of time will have tanned skin. For example, a construction worker. Ultraviolet rays in sunlight can destroy melanin pigment of exposed skin. Therefore, more melanin pigment will be produced, which cause the skin to be darker.

Construction worker

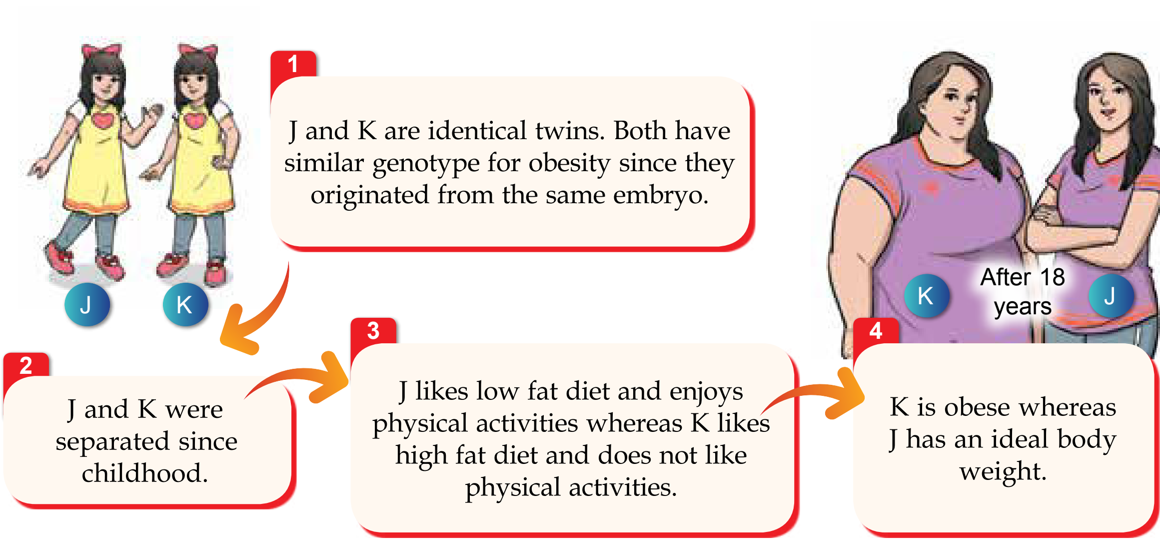
Think Smart

Is the flower colour of all plants influenced by pH of the soil? Explain.

Figure 12.10 Effects of environmental factors on variation

Interactions between Genetic and Environmental Factors

Environmental factors can interact with genetic factors to cause variation, in which the environmental factors determine the phenotypes. Characteristics inherited from parents such as height, intelligence and skin colour are greatly influenced by environmental factors. An example which supports the effect of environmental factors on genetic factors can be observed in identical twins (Figure 12.11).



Conclusion: Differences in eating habits and environment while growing up produce different phenotypes.

Figure 12.11 Interactions of environmental variations in determining phenotypes of identical twins who possess similar genetic composition

Activity 12.2

21st CENTURY SKILLS

INDIVIDUAL PRESENTATION

Aim

To collect and present information on the effects of environmental factors in determining gender of reptiles and fish

Procedure

1. Work in groups.
2. Study the statement below carefully.

   Gender of embryos of most reptiles and fish depend on environmental factors such as temperature.

3. Present the findings of your group using multimedia presentation.

Formative Practice 12.1

1. How can variation increase the survival of species?
2. Determine the following variations:
   (a) Intelligence
   (b) Presence of dimples
   (c) Type of hair
   (d) Height
   (e) Type of earlobes
3. State **two** causes of variation.
4. Variation occurs because of sexual reproduction

   Explain the above statement.

12.1.6

12.2 Variation in Humans

Relation of Variation to Human Inheritance

As you have learnt in Chapter 11 on Inheritance, human trait is controlled by a pair of alleles, in which an allele can be dominant or recessive. Dominant trait is observed when both dominant alleles are present or when one dominant allele is paired with a recessive allele whereas recessive trait is only shown when both recessive alleles are present. These genetic information causes variation in humans. Table 12.1 and Figure 12.12 show examples of dominant and recessive traits in humans.

Table 12.1 Examples of characteristics and traits in humans

Characteristics	Traits in humans	
	Dominant	Recessive
Height	Tall	Short
Type of hair	Curly hair	Straight hair
Tendency to use hands	Right-handed	Left-handed
Presence of dimples	Presence	Absence
Ability to roll tongue	Can roll tongue	Cannot roll tongue
Type of earlobes	Free earlobes	Attached earlobes

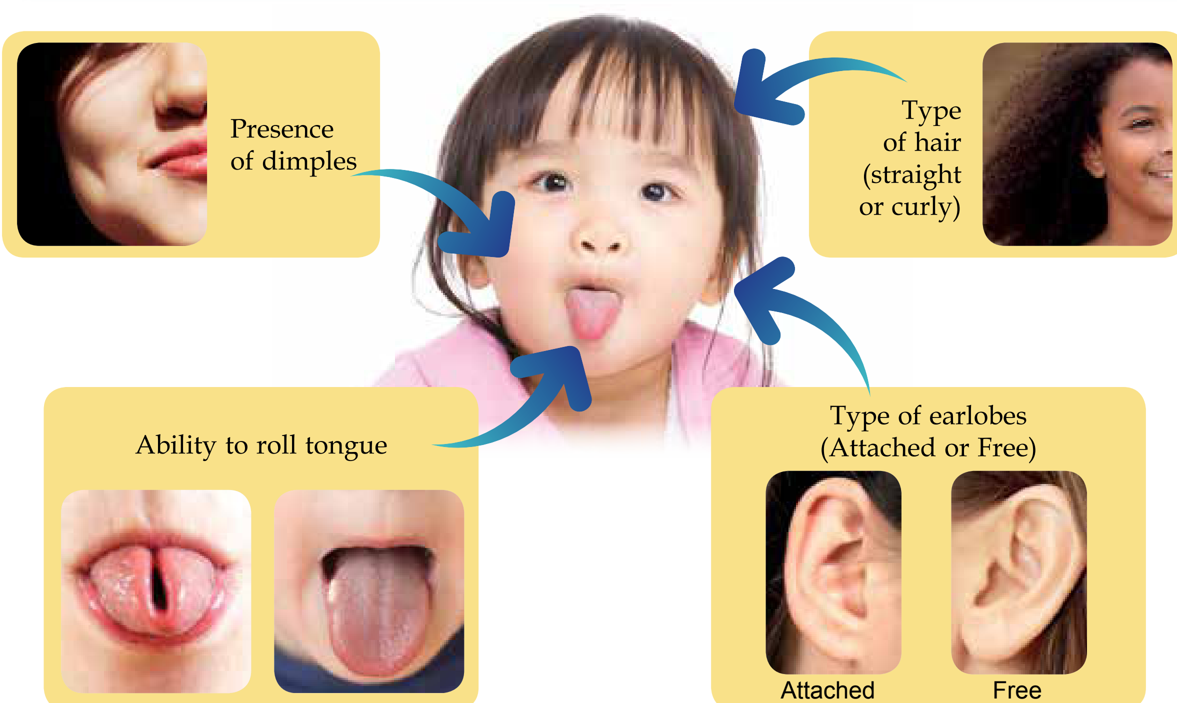


Figure 12.12 Different characteristics in humans

12.2.1

EXPERIMENT

12.1 Continuous and Discontinuous Variation in Humans

Problem statement: Is the height, body weight and fingerprint of each pupil different?

Aim: To study continuous variation and discontinuous variation in humans

Hypothesis: Height, body weight and fingerprint of each pupil is different.

Materials
Graph paper, white papers

Apparatus
Height measuring equipment, weighing machine, ink pad

Procedure

A. Height
1. Measure and record height of each pupil in the class in the results table.
2. Plot a graph of number of pupils against height range.

B. Body weight
1. Weigh and record body weight of each pupil in the class in the results table.
2. Plot a graph of number of pupils against body weight range.

C. Fingerprint
1. Use the fingerprint patterns shown in page 259 for this activity.
2. Place a thumb surface of each pupil on an ink pad, then press the thumb on a piece of white paper.
3. Record the thumbprint pattern of each pupil in the results table.
4. Build a bar chart based on the results obtained.

Results

A. Height

Height range (cm)	<135	135-139	140-144	145-149	150-154	155-159	160-164	165-169	>169
Number of pupils									

B. Body weight

Mass range (kg)	<35	35-39	40-44	45-49	50-54	55-59	60-64	>64
Number of pupils								

C. Fingerprint

Thumbprint pattern	Loop	Arch	Whorl
Number of pupils			

Discussion
1. What are the shapes of the graphs plotted for height and body weight?
2. Give inferences for distribution of height, body weight and thumbprint pattern of the pupils in your class.

Conclusion
Is the hypothesis accepted? Suggest a suitable conclusion.

12.2.2

Activity 12.3

Aim
To study the level of human tongue sensitivity towards phenylthiocarbamide (PTC) solution

Hypothesis
PTC taste trait can be classified into specific groups.

Materials
Drinking water, PTC paper

Procedure
1. Rinse your mouth with clean water before starting the activity.
2. Place a piece of PTC paper on your tongue for a few seconds.
3. Record your tongue sensitivity based on the taste of the PTC paper in the results table.
4. Remove the PTC paper from your tongue. Repeat the above steps with other pupils.
5. Build a bar chart based on the results that you obtained.

Bio with CHEMISTRY
Phenylthiocarbamide (PTC) is a non-toxic chemical if tasted in small amount.

Results

PTC taste	Bitter	Salty	Sour	Sweet	No taste	Others
Pupil 1						
Pupil 2						
Pupil 3						

Discussion
1. What is the type of variation for PTC taste based on the shape of the graph that is plotted?
2. Is the PTC taste trait dominant or recessive? Explain.

Conclusion
Is the hypothesis accepted? Suggest a suitable conclusion.

Formative Practice 12.2

1. State the meaning of:
   (a) Inheritance
   (b) Characteristic
2. Give **two** examples of inheritable characteristics in humans.
3. Give **two** examples of traits for eye colour.

12.2.2

12.3 Mutation

Mutation is a spontaneous and random change of genetic material, namely DNA of the cell in an organism. A substance which causes mutation or increases the mutation rate to a dangerous level is called a **mutagen**. Mutation occurs spontaneously in natural conditions. New genetic material produced by mutation is called a **mutant**. A mutant can exist as **mutant gene, mutant cell, mutant organelle** or **mutant individual**.

Types of Mutagen

Mutagen is divided into three types of agents, namely **physical agent**, **chemical agent** and **biological agent** (Figure 12.13).

TYPES OF MUTAGEN

Physical agents
- Ultraviolet from the sun
- Ionising rays such as X-ray, alpha ray and beta ray

Chemical agents
- Carcinogen in cigarette smoke
- Food preservatives
- Formaldehyde
- Benzene

Biological agents
- Virus
- Bacteria

Figure 12.13 Types of mutagen

Bio Exploration

Mutation that occurs in somatic cells, for example, cells in bone marrow can cause blood cancer.

Types of Mutations

Gene Mutation

Gene mutation occurs when there is a change in nucleotide base sequence of a gene (Figure 12.14). Gene mutation is also known as **point mutation**. The change alters the genetic code that is used to synthesise amino acid. Therefore, there will be a change in protein structure and this new protein cannot function. Gene mutation occurs by **base substitution**, **base deletion** and **base insertion** (Figure 12.15).

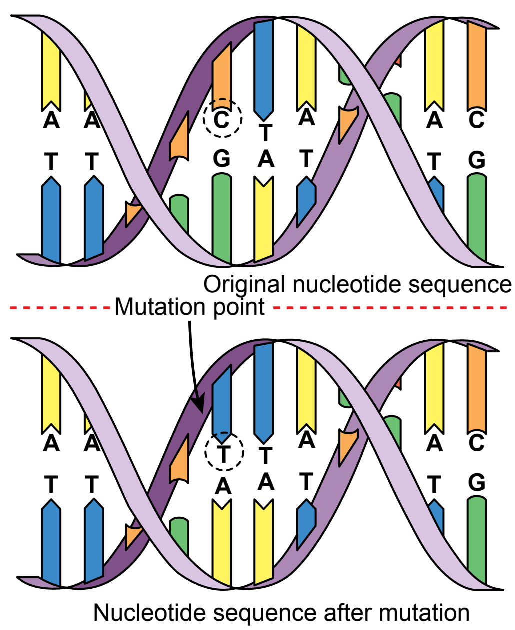


Figure 12.14 Changes of nucleotide in gene

12.3.1 12.3.2 12.3.3

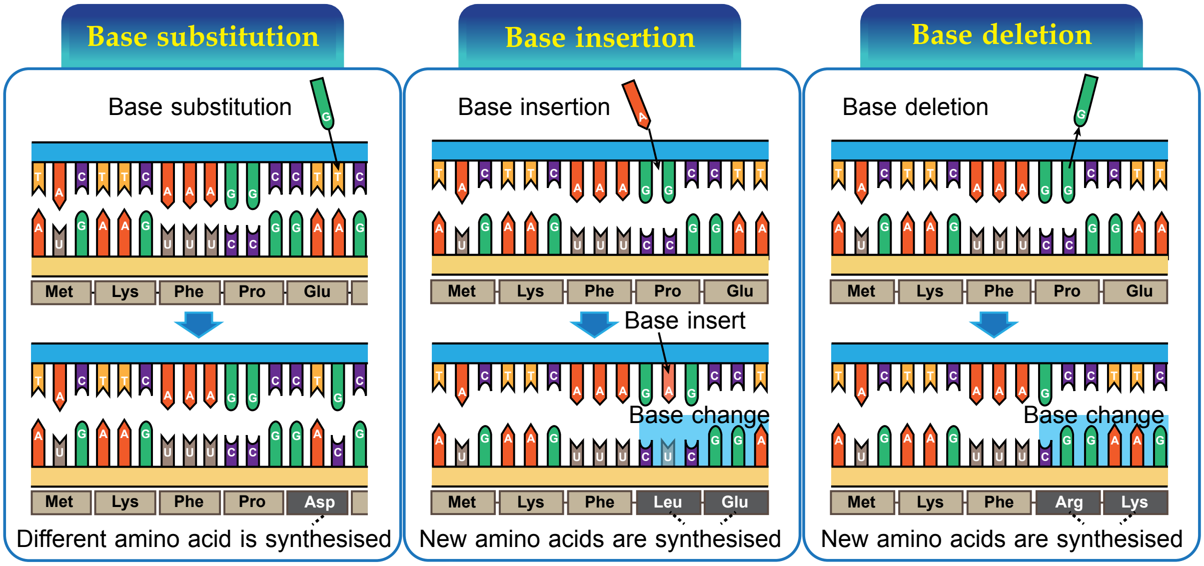


Figure 12.15 Gene mutation

Gene mutation causes genetic diseases such as **thalassemia**, **cystic fibrosis**, **sickle cell anaemia**, **albinisme** and **haemophilia** (Table 12.2).

Table 12.2 Examples of genetic disease

Types of gene mutation	Examples of disease
Base substitution	Sickle cell anaemia
Base insertion	Cystic fibrosis
Base deletion	Thalassemia

Sickle Cell Anaemia

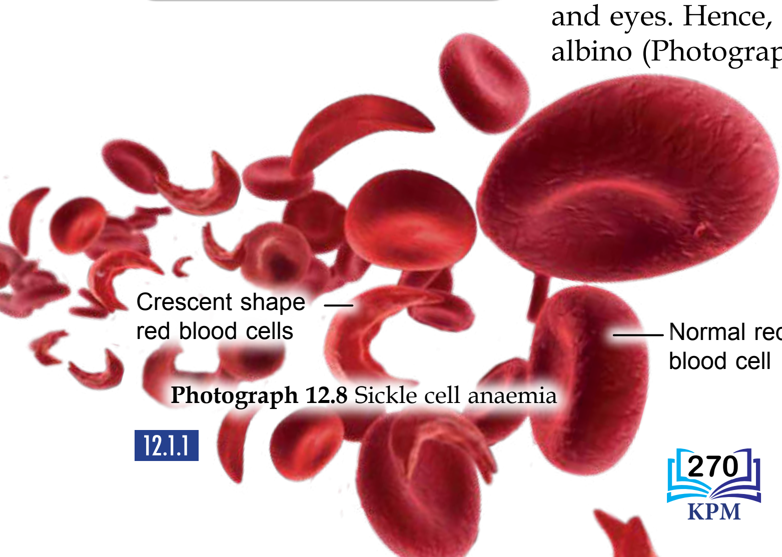
Sickle cell anaemia is caused by a gene responsible for the synthesis of **haemoglobin**. The red blood cells of a patient are in the shape of a crescent. This is because the red blood cells are not properly formed. Some red blood cells are normal whereas the rest are **crescent shape** (Photograph 12.8).

ACTIVITY ZONE

Collect information of haemophilia inheritance in the community. Present your findings in class.

Albinism

An individual who experiences albinism is an **albino**. Albinism is due to the mutation of a gene which is responsible for producing pigments of skin, hair and eyes. Hence, the pigments are not produced in the albino (Photograph 12.9).



Photograph 12.8 Sickle cell anaemia

Photograph 12.9 Albino boy

12.1.1

Chromosomal Mutation

Chromosomal mutation involves changes to **chromosomal structure** or changes to the **chromosomal number**. Chromosomal mutation can change the characteristics of an organism.

Changes in chromosomal structure involve changes to the gene sequence in a chromosome. The structural change causes abnormality to the chromosome, which is known as **chromosomal aberration**. Types of chromosomal aberration include **deletion, duplication, inversion** and **translocation** (Figure 12.16).

Bio Exploration

The risk of mutation in a foetus increases as the age of the mother increases.

Key:
A ⟶ L
Segment in chromosome

Deletion
A part or a segment of chromosome is deleted or lost (loss of a few genes).

Duplication
A part of a chromosome is copied which causes repetition of gene sequence.

Inversion
A segment of chromosome is reversed end to end at 180° then rejoin (change in DNA sequence of chromosome).

Translocation
Part of the chromosome is cut, then join to another non-homologous chromosome.

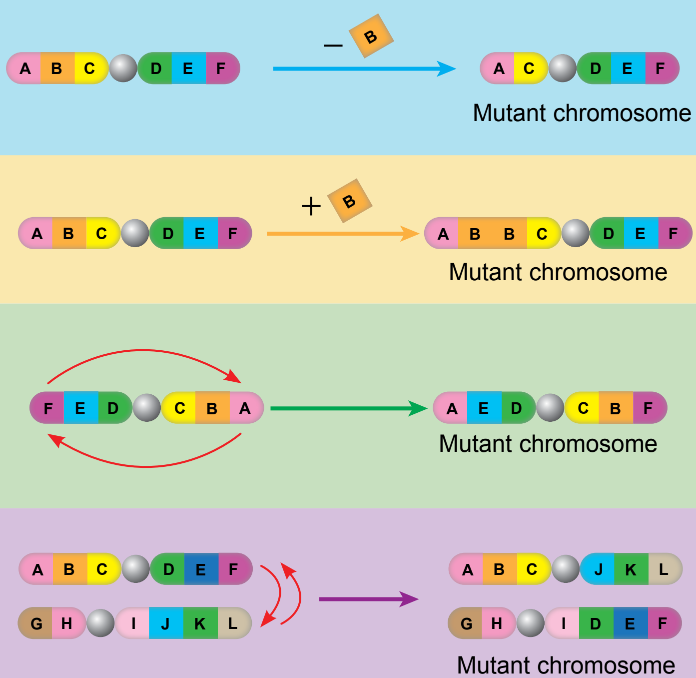


Figure 12.16 Chromosomal mutation

A change in chromosomal number causes a diploid organism to lose one or more chromosomes, or gain one or more chromosomes. The change occurs when homologous chromosomes fail to separate during **anaphase I in meiosis** or sister-chromatids fail to separate during **anaphase II in meiosis**. This is probably because the normal **spindle fibres** fail to form during meiosis. The phenomenon is known as **nondisjunction** and it causes abnormality in the number of chromosomes and in a gamete. The gamete may lose one or more chromosomes or gain one or more chromosomes (Figure 12.17).

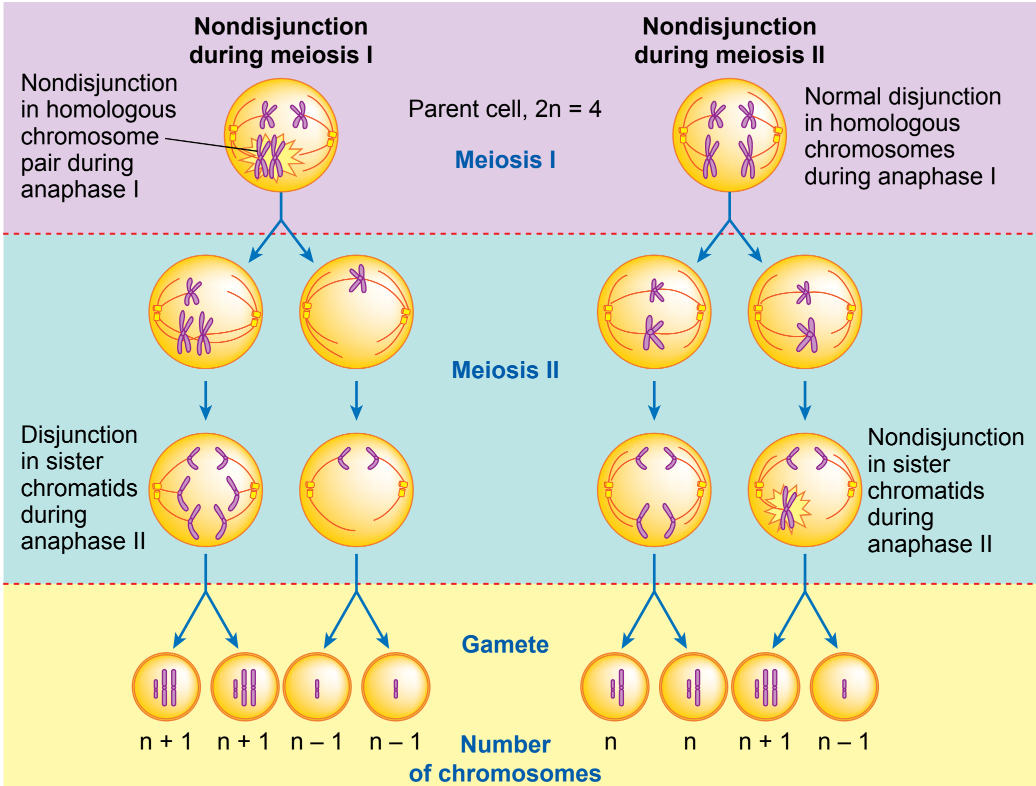


Figure 12.17 Nondisjunctions in chromosomes during meiosis

Abnormality in the number of chromosomes can be due to nondisjunction during **spermatogenesis** or oogenesis. Fertilisation that involves abnormal gametes will produce a zygote that develops into an individual with abnormal characteristics. The individual experiences change in phenotype (Figure 12.18).

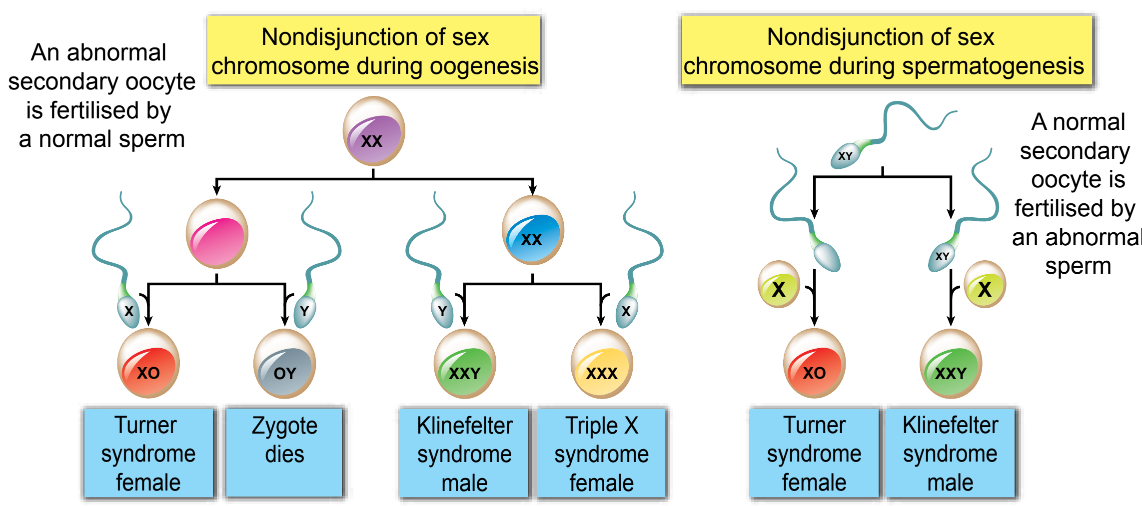
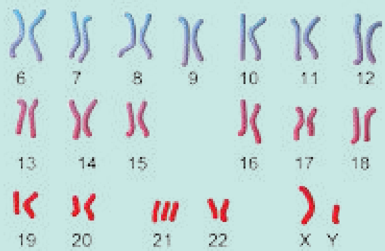
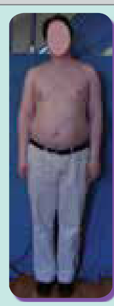
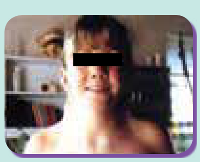


Figure 12.18 Diseases caused by mutation of chromosomal number

Table 12.3 Characteristics of diseases caused by chromosome mutation

Diseases	Chromosome number	Characteristics of diseases
	Abnormalities in autosomes	
Down Syndrome	(2n + 1) = 47 Has three number 21 chromosomes  **Figure 12.19** Caryotype	An individual (male or female) has slant eyes, flat nose, protruding tongue, broad forehead and is usually mentally retarded (Photograph 12.10).  **Photograph 12.10** A Down syndrome individual
Cri du chat syndrome	The structure of chromosome changes due to a partial deletion on the short arm of chromosome number 5.	The cry of affected infants is similar to that of a meowing kitten. Affected individual shows delayed development with mental and physical retardation. Most patients die during childhood.
	Abnormalities in sex chromosomes	
Klinefelter Syndrome	(2n + 1) = 47 44 + XXY  **Photograph 12.11** Klinefelter syndrome individual	A sterile man with small testes that fail to produce sperms. Possesses voice and chest similar to those of a woman. Has long legs and hands.
Jacob Syndrome	(2n + 1) = 47 44 + XYY  **Photograph 12.12** A Jacob syndrome individual	Male who is taller than normal and has problem with pimples on his face. Slow in acquiring speech and has learning disability. Possesses weak muscles (hypotonia).
Turner Syndrome	(2n - 1) = 45 44 + XO  **Photograph 12.13** A Turner syndrome individual	Sterile female with lack of secondary female characteristics, undeveloped breasts and ovaries. Weblike neck and low IQ.

12.3.3

Mutation of Somatic Cells and Gametes

Mutation can occur in somatic cells and gametes to produce variation in a population. What are the differences between mutation in somatic cells and gametes (Table 12.4)?

Table 12.4 Differences between mutations of somatic cells and gametes

Mutation in somatic cells	Mutation in gametes
Involves somatic cells such as skin cell and eye cell	Involves germ cell that produces gamete (secondary oocyte or sperm)
Cannot be inherited by the next generation	Can be inherited by the next generation
Disease is present only in the individual with the mutation	Disease is present in the individual with the mutation and is also inherited by his/her descendants
Example: Disease related to nervous system	Example: All inherited diseases such as thalassemia

Activity 12.4

21st CENTURY SKILLS

INDIVIDUAL PRESENTATION

Aim
To carry out a study and present the impact of nuclear accidents and Vietnam War on plants, animals and humans

Procedure
1. Work in groups.
2. Scan the QR codes below and find information on:
   (a) The use of agent orange during the Vietnam War
   (b) Nuclear accidents at Fukushima and Chernobyl

Info **Vietnam War** bukuteksksm.my/Biologi/T5/Ms274a

Info **Fukushima nuclear accident** bukuteksksm.my/Biologi/T5/Ms274b

Info **Chernobyl nuclear accident** bukuteksksm.my/Biologi/T5/Ms274c

3. Discuss the impacts of the above events on plants, animals and humans.
4. Present the findings of your group.

Formative Practice 12.3

1. State the differences between gene mutation and chromosomal mutation.
2. Explain briefly the following statement by giving suitable examples:

Food can be a source of mutation.

12.3.4

Memory Flashback

Variation

- Type of variation
  - Continuous variation
  - Discontinuous variation
  - Comparison
- Sources of variation
  - Genetic factors
    - Crossing over
    - Independent assortment of chromosomes
    - Random fertilisation
    - Mutation
      - Mutagen
        - Physical agents
        - Chemical agents
        - Biological agents
      - Gene mutation
        - Sickle cell anaemia
        - Albinism
      - Chromosomal mutation
        - Down syndrome
        - Cri du chat syndrome
        - Turner syndrome
        - Klinefelter syndrome
        - Jacob syndrome
  - Environmental factors
    - Temperature
    - Light
    - pH

Interactive Bio 12

SELF-REFLECTION

Complete the following self-reflection to identify the important concepts that you have studied.

Important concepts	Very good	Try again
Meaning of variation		
The importance of variation for survival of species		
Types of variation, namely continuous variation and discontinuous variation		
Comparison between continuous variation and discontinuous variation		
Causes of variation		
Relationship between types of variation and human inheritance		
Meaning of mutagen, mutation and mutant		
Types of mutagen and mutation		
Relationship between somatic cell mutation and gamete mutation with variation		

Summative Practice 12

1. Tables 1.1 and 1.2 show data that were collected for two different characteristics from 35 pupils in Form 5 Bunga Raya.

Table 1.1 Body mass of pupils in Form 5 Bunga Raya

Body mass (kg)	40-44	45-49	50-54	55-59	60-64
Number of pupils	5	7	9	8	6

Table 1.2 Types of earlobes of pupils in Form 5 Bunga Raya

Earlobes	Attached	Free
Number of pupils	6	29

(a) (i) State the types of variation for body mass and types of earlobes.

(ii) State **two** differences between body mass variation and types of earlobes variation.

(b) Figure 1.1 shows a karyotype of an individual who has a genetic disease caused by mutation.

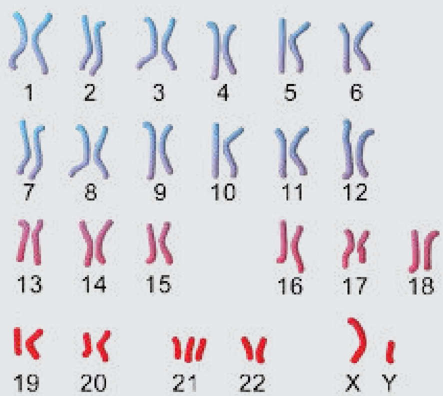


Figure 1.1

(i) State the disease shown in Figure 1.1.

(ii) Which type of mutation causes the disease stated in 1(b)(i)?

(iii) Explain how the type of mutation in 1(b)(ii) causes the disease.

(c) The statement below describes trees of the same species planted in two different plots, X and Y on a farm.

Plot of land X: trees grown from the same tissue culture
Plot of land Y: trees planted from seeds

The plantation was infected and all trees in plot X were killed whereas only part of the plants in plot Y died of the infection. Explain why all the plants in plot X were killed.

2. (a) Figure 2.1 shows patterns of a few thumbprints.

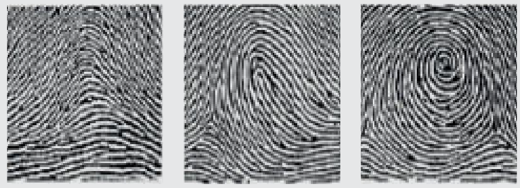


Figure 2.1

Identify the types of variations for the thumbprint pattern and discuss the factors that cause these variations.

(b) (i) State the difference between gene mutation and chromosomal mutation.

(ii) Figure 2.2 shows four types of chromosomal mutations K, L, M and N. Based on Figure 2.2, explain the mutation types of K, L, M and N.

Normal chromosome	A B C D E F
K	A A B C D E F
L	A B C D E
M	A B C F E D
N	A B C X Y Z

Key:
A to F and X to Z are gene segments of a chromosome

Figure 2.2

21st Century Mind

3. Sickle cell anaemia is an inherited disease. The disease is caused by a gene mutation in which a DNA base substitution results in the replacement of a glutamic acid (a type of asid amino) by a valina (another type of amino acid) in haemoglobin. This causes the patient to possess haemoglobin S, HbS which causes the red blood cell to look like a sickle or crescent instead of the normal biconcave shape. The sickled cells cause chronic anaemia. Africa is a continent endemic for malaria in which a proportion of the population carries the sickle cell trait. As a scientist, discuss the relationship between sickle cell and malaria in Africa.

Chapter 13

Genetic Technology

Chapter Exploration

- Genetic Engineering
- Biotechnology

Learning Standards

Do You Know?

- What is the meaning of genetic engineering?
- What are the biotechnology applications used to solve problems faced by humans?

Genetic Engineering

Genetic knowledge gained through Mendel's inheritance experiments and molecular structure of DNA enables scientists worldwide to actively perform researches in genetics to improve the quality of humans' life.

Beneficial genes can be transferred from animals or plants and inserted into genome of microorganisms such as bacteria to produce useful products that are useful to humans. Through gene manipulation processes, new genotypes can be produced which ultimately lead to production of new genotypes.

Although genetic engineering brings a lot of benefits to humans, it also creates many ethical and moral issues. Experts in genetically modified food (GMF) committees have to monitor abuses or malpractices in genetic engineering and the decisions made must be guided by the existing code of ethics.

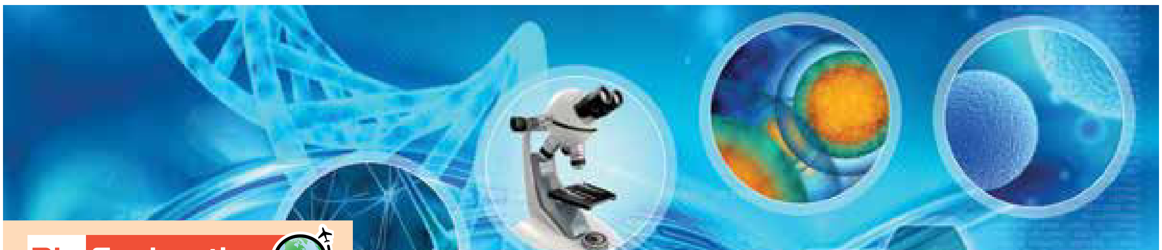
Keywords

- Genetic engineering
- Genetically modified organisms (GMO)
- Genetically modified food (GMF)
- Biotechnology
- Gene therapy
- DNA profiling
- Plasmid
- Cloning vector

13.1 Genetic Engineering

Genetic Engineering and Genetically Modified Organism (GMO)

Have you ever heard of genetic engineering? What are the purposes of performing this technique in an organism?



Bio Exploration

Genome definition:
- A complete set of DNA for an organism that includes all the genes of that organism.
- The genome contains all information needed to build and carry out the life processes of an organism.

Genetic engineering is a gene manipulation technique to modify an organism's genetic material to produce new combination of genes.

An organism such as animal, plant or microorganism that is produced by recombinant DNA technology is known as a **genetically modified organism (GMO)**.

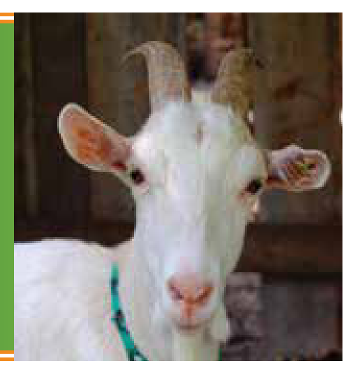
Genetic engineering involves the transfer of a DNA segment from one organism to another by DNA recombinant technology. By using the techniques and procedures in the recombinant technology, biologists can recombine the DNA or **genome** (a complete set of DNA) of an organism.

Genetically Modified Organism (GMO)

Genetically modified organisms (GMOs) are organisms that contain recombinant DNA. Recombinant DNA technology enables production of new gene combinations. An organism that contains recombinant DNA is known as a **transgenic organism** (Photograph 13.1)

This genetically modified cow produces milk which does not contain β-lactoglobulin, a type of protein that causes allergy among some children.

This genetically modified goat possesses the human gene which codes for a blood clotting factor. This blood coagulation factor is found in the goat's milk and can be purified and used to treat haemophilic patients.



Photograph 13.1 Examples of genetically modified organisms (GMO)

13.1.1 13.1.2

Genetically Modified Food (GMF)

Recombinant DNA technology has successfully produced many beneficial varieties of crops (paddy, oil palm, pineapple, corn and soya bean) and livestock (salmon, cattle and goat) (Figure 13.1). **Genetically modified food (GMF)** possesses DNA from other species of plant or animal. Consumption of GMF by humans may cause health implications which are still unknown.

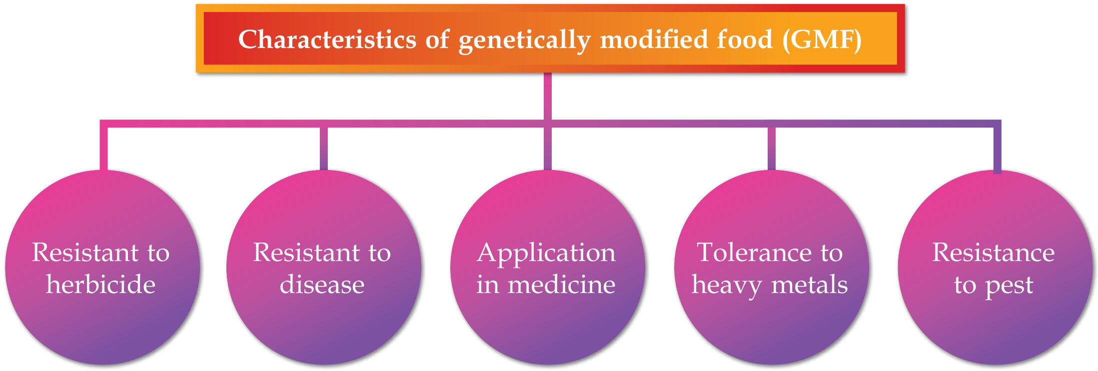
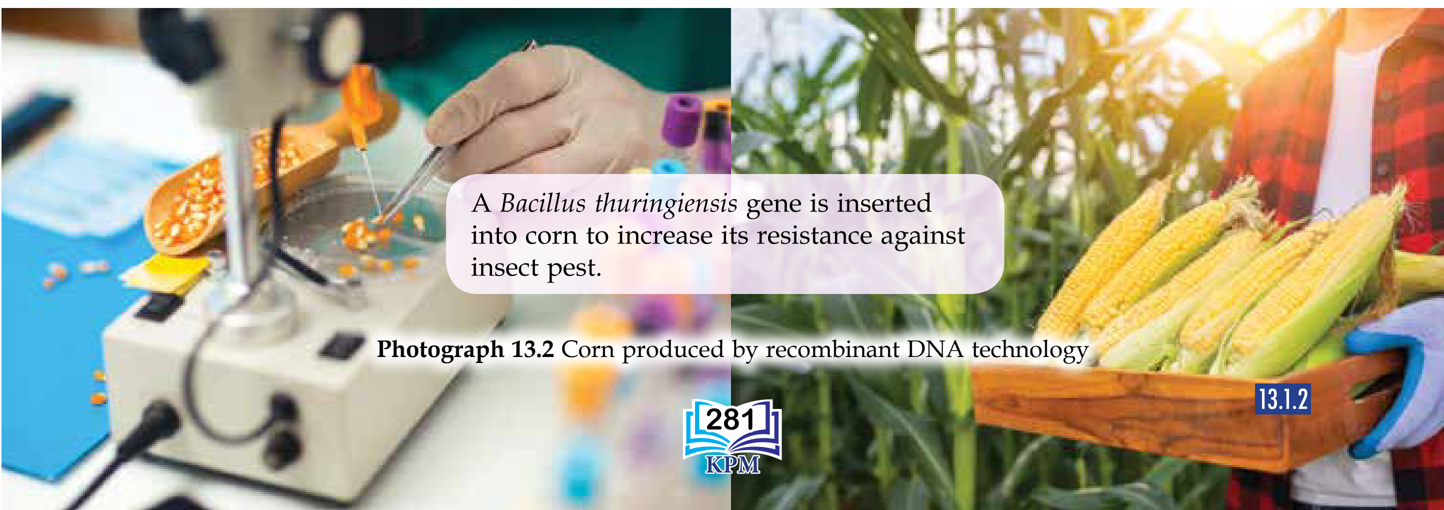


Figure 13.1 Characteristics of genetically modified food (GMF)

Table 13.1 Advantages and disadvantages of GMF

Advantages of GMF	Disadvantages of GMF
• Overcome worldwide food shortage by producing high quality transgenic crops and livestock • Reduce cost of food production • Increase nutritional value of crops • Reduce problems of crops related to pests • Reduce usage of pesticides • Increase in production reduces price of food, thus increase food availability	• Endangered natural species • There is a slight possibility that the foreign gene in GMF may be transferred to humans, for example, antibiotic-resistance gene • May have adverse effects on human health and genetic material



Photograph 13.2 Corn produced by recombinant DNA technology

13.1.2

Photograph 13.3 Normal salmon and Super Salmon

Super Salmon is a genetically modified fish which is approved by the Food and Drug Administration (FDA) as a safe food for consumption in United States of America and Canada. It is modified by inserting a growth hormone gene from a Chinook salmon into the genome of an Atlantic salmon. Hence, a Super Salmon is created which grows at a faster rate and can be produced throughout the year.

Potato is an important crop to people who live in cold climates. It is very sensitive to low temperature and frost. A gene from *Arabidopsis* sp. plant, which enables the plant to tolerate freezing condition is inserted into the potato genome to create a genetically modified potato that can grow well in cold climates.

Photograph 13.4 Effect of frost on potatoes

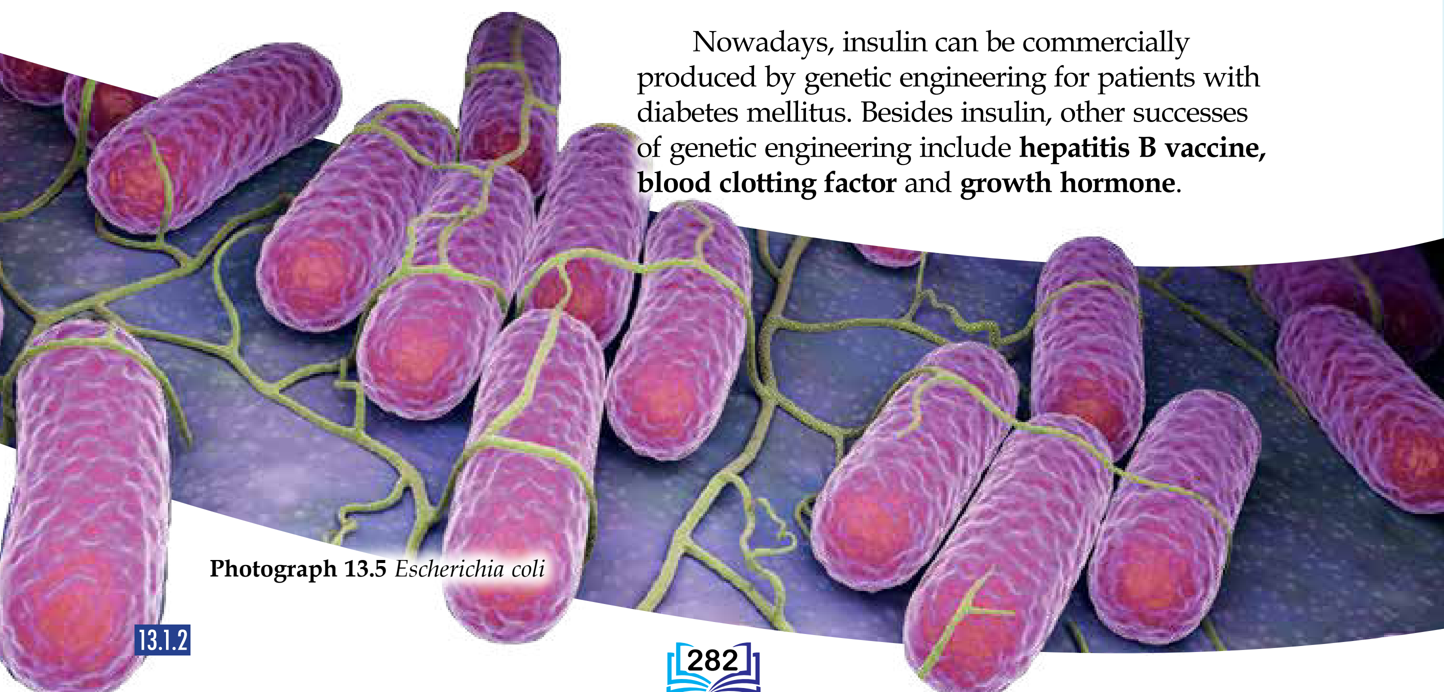
Insulin

You have already learnt the concept of homeostasis in regulating blood glucose level. **Insulin** is an important **hormone** which controls blood glucose level. In the older days, insulin was extracted from the pancreases of cattle or pigs to treat diabetes mellitus patients.

Bio Exploration

Escherichia coli can be used to synthesis insulin (Photograph 13.5).

Nowadays, insulin can be commercially produced by genetic engineering for patients with diabetes mellitus. Besides insulin, other successes of genetic engineering include **hepatitis B vaccine, blood clotting factor** and **growth hormone**.



Photograph 13.5 *Escherichia coli*

13.1.2

Figure 13.2 shows how the human insulin gene is transferred to a bacterium by genetic engineering to produce insulin.

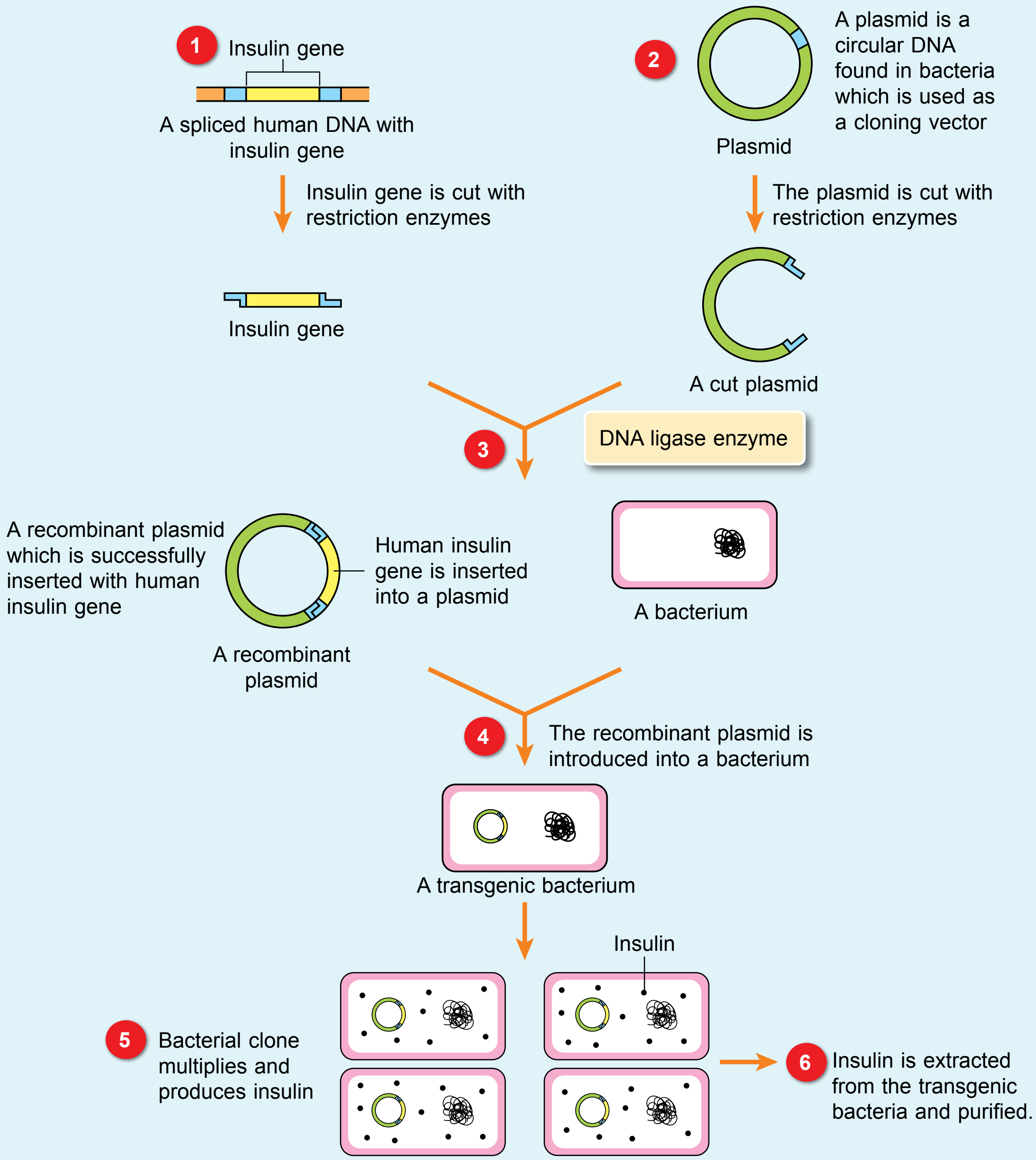


Figure 13.2 Production of insulin by genetic engineering technique

There are many examples of genetically modified organisms (GMOs) and genetically modified food (GMF) which have been produced by genetic engineering. Can you make a list of other GMOs and GMF? What are the advantages and disadvantages of producing these GMOs and GMF to humans and the environment? Carry out Activity 13.1 to obtain further information on the issue.

13.1.2

Activity 13.1

21st CENTURY SKILLS — DEBATE

Aim
To debate on the advantages and disadvantages of producing GMO and GMF

Procedure
1. Work in two groups.
2. Gather recent information on GMO and GMF.
3. Appoint a representative from each group. The representative either leads the affirmative team or the opposing team.
   (a) **Affirmative team:** GMO and GMF bring advantages
   (b) **Opposing team:** GMO and GMF bring disadvantages
4. Prepare your arguments on the debate entitled 'Advantages and Disadvantages of Producing GMO and GMF'.
5. Debate on the above topic.

Formative Practice 13.1

1. What is the meaning of genetic engineering?
2. What is a transgenic organism?
3. State **one** issue on genetically modified food (GMF) that is often debated.

13.2 Biotechnology

Definition of Biotechnology

Biotechnology is a field which utilises technology or method to manipulate organisms for the production of biological products.

Biotechnology aims to improve the quality of livestock and crops as well as to develop the application of microorganisms for specific purposes. Since biotechnology involves various disciplines of science, therefore each discipline that involves the use of living organisms for a specific purpose is given a specific colour code as shown in Figure 13.3. Although ten biotechnology activities are identified, the main ones are the green, white, yellow and blue biotechnology activities. Do you know the meaning of each biotechnology colour?

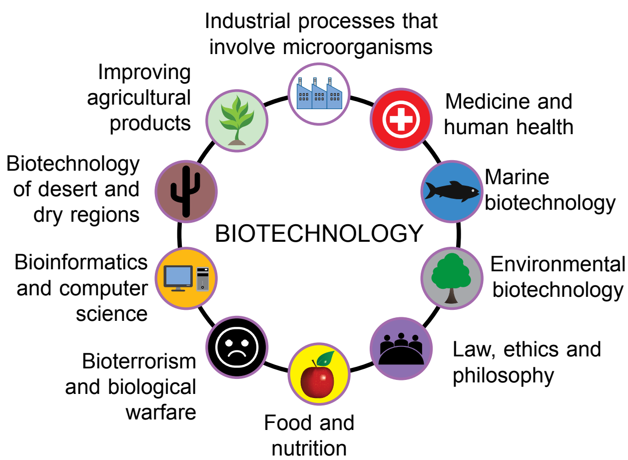


Figure 13.3
Types of biotechnology activities based on colours

13.1.2 13.2.1

Activity 13.2

21st CENTURY SKILLS GALLERY WALK

Aim

To search and present information on classification of the fields in biotechnology

Procedure

1. Work in groups.
2. Gather information on classification of the fields in biotechnology.
3. Present your information in the form of a poster.
4. Carry out Gallery Walk to observe presentations from the other groups.

Activity 13.3

Aim

To visit and gather information on yellow biotechnology at FRIM, MPOC, MARDI, MRB and universities to collect information related to yellow biotechnology

Procedure

1. Work in groups.
2. Teacher organises trips for pupils to one of the following organisations:
   (a) FRIM (c) MARDI
   (b) MPOC (d) MRB
3. As a group, gather information related to yellow biotechnology through interviews or from pamphlets.
4. Write a report based on the visit.

Applications of Biotechnology in Life

Gene Therapy

Gene therapy is used to treat or prevent genetic diseases. In gene therapy, a normal gene is inserted into the patient to replace the abnormal gene (Figure 13.4). The diseases that can be cured by gene therapy are **cystic fibrosis**, **muscular dystrophy** and a few types of **cancer**.

History Corner

The first successful gene therapy was performed in 1990 on Ashanti DeSilva, a patient with ADA-SCID, a genetic disease that interfered with her body immune system.

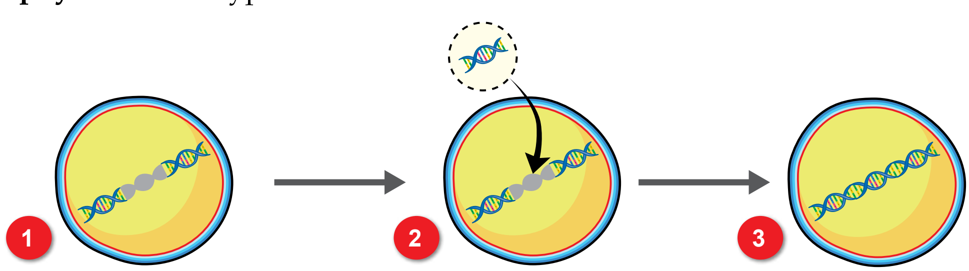


Figure 13.4 Basic steps in gene therapy

13.2.1 13.2.2

Activity 13.4

21st CENTURY SKILLS: INDIVIDUAL PRESENTATION

Aim

To discuss a gene therapy technology called Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR)

Procedure

1. Work in groups.
2. Read the passage below.

   > Active researches have been ongoing using Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR) technology to edit genome during gene therapy.

3. Gather information on CRISPR technology.
4. Discuss the information that you have gathered and present it in your class using multimedia presentation.

DNA Profiling

DNA profiling is a technique used in forensic to identify individuals, based on their DNA. This is due to the fact that an individual's DNA is unique, except between identical twins. A human DNA set is different from animals. An individual can be identified based on the DNA obtained from his/her blood, semen (for male) or skin. Figure 13.5 shows a few applications of DNA profiling. Figure 13.6 shows the steps used in DNA profiling technique.

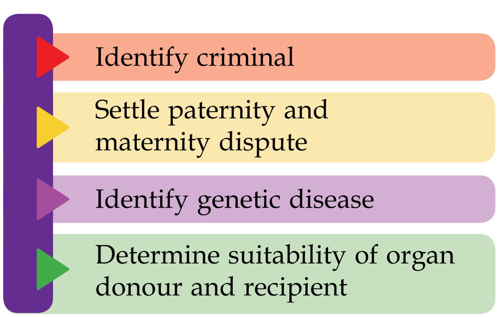


Figure 13.5 Applications of DNA profiling

Photograph 13.6 Sir Alec Jeffreys

History Corner

DNA profiling technique was invented by Sir Alec Jeffreys in Leicester University in 1985. He was awarded for his achievement the Copley Medal, the oldest award before the Nobel Prize was introduced.

Bio with LAWS

DNA profiling can be used as a strong evidence in a criminal case if:

- the biological sample is obtained and processed correctly and consensusly
- the forensic scientist tests the sample and analyses it meticulously in a transparent manner
- the test results are interpreted precisely
- the jury and judge obtain an accurate report

13.2.2

Blood, semen or skin sample is obtained from an investigation scene (e.g. a crime scene).

↓

DNA is extracted from the sample.

↓

Restriction enzymes cut the DNA into different sizes of DNA fragments.

→

The DNA fragments of different sizes are then separated by gel electrophoresis.

↑

DNA fragments of different sizes are transferred from the gel to a nylon membrane.

↑

Radioactive probes are added to the nylon membrane. X-ray film is then placed on top of the nylon membrane.

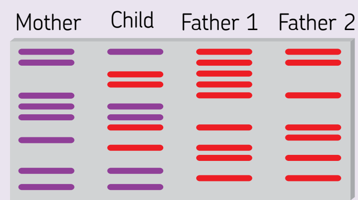
→

X-ray film is processed to show the positions of DNA bands that form the DNA profile.

Figure 13.6 Steps used in DNA profiling

Think Smart

Based on the DNA profile below, can you determine who is the biological father of the child?



Production of Insect Tolerant Plants

Farming cotton breed with high yield and resistant to pests such as **Bt cotton** (Table 13.2) in cotton farms has reduced the use of pesticides. The Bt crop is injected with genes from *Bacillus thuringiensis* (Bt), a type of soil bacteria that secretes toxins (Figure 13.7). This effort has saved cost by reducing the use of pesticides and also increases cotton yield. Besides cotton, other Bt crops are corn and brinjal.

Table 13.2 Comparison between normal crop and GMO crop

Normal crop	GMO crop
 Normal cotton	 Bt cotton
 Normal corn	 Bt corn

Gene that produces Bt toxins from *Bacillus thuringiensis* is inserted into the plant's genome.

↓

Pest feeds on the plant which produces Bt toxins.

↓

The toxins affect the digestive system of the pest and kills it.

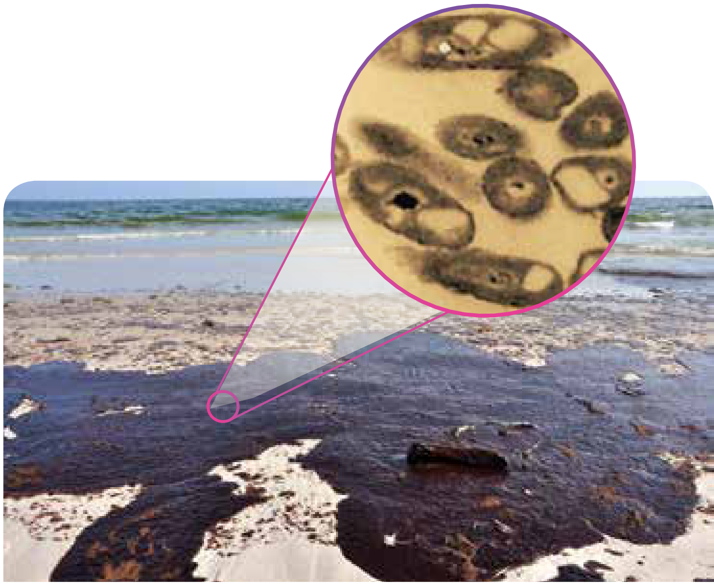
Figure 13.7 Effect of Bt crops on pest

13.2.2

Cleaning of Oil Spills

Bioremediation is a method which uses bacteria to clean up environmental pollutants. It is effective to treat oil spillage in the ocean. Most molecules in crude oil and purified oil products can be degraded by bacteria.

For example, *Alcanivorax borkumensis* (Photograph 13.7), a type of bacteria that depends on oil for its source of energy is widely used to treat oil spills. Can you state the advantages of this bioremediation?



Photograph 13.7 *Alcanivorax borkumensis* is used to treat oil contamination

ACTIVITY ZONE

Collect information of other biotechnology applications such as the production of microbial metabolites, nanobiotechnology and bioinformatics. Present your findings.

Activity 13.5 STEM

Aim

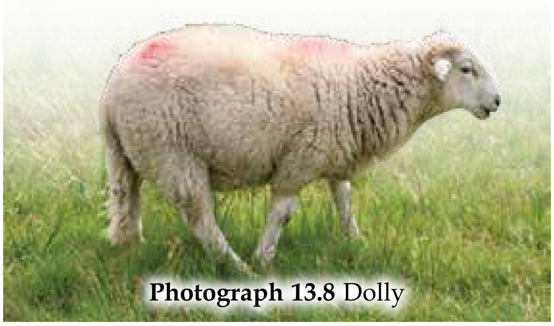
To design a product which uses cheap, discarded and biodegradable materials to solve oil spills in the aquatic ecosystem

Procedure

1. Work in groups.
2. Search for information on biological products that can degrade oil molecules.
3. Based on the information that you have gathered, design a prototype that uses cheap, discarded and biodegradable materials to solve oil spills in the aquatic ecosystem.
4. Test your prototype and present it in your class.

Importance of Biotechnology in Life

The field of biotechnology has developed rapidly in Malaysia and has improved human lives in both developing and developed countries. Have you ever heard of the first clone sheep called Dolly?



Photograph 13.8 Dolly

13.2.2 13.2.3

Biotechnology is often associated with agriculture, industry, nutrition, medicine and other fields. Rapid development in biology and technology has replaced the old methods with the current and sophisticated approaches in producing many types of products that benefit humans. Besides contributing to increase the yields in food, agriculture and medicine, biotechnology also improves a country's economy specifically in the industrial sector. Table 13.3 shows the contributions of biotechnology to life today.

Table 13.3 Contributions of biotechnology to life

Field	Contributions
Agriculture	• Produce the best livestock and crop breeds. The tissue culture method and cloning technique have expedited plant reproduction. • Produce paddy varieties which give more yield and mature faster. • Animal cloning enables mass reproduction and produces disease-resistant clones. • Use of hormones expedite animal growth and maturity.
Medicine	• Can modify the genetic contents of an individual. • Reduce risk of mental disease. • Prevent specific diseases such as cancer and inherited diseases. • Human with dwarf genetics can have normal children. • Assist mothers with difficulty to conceive.
Forensic	• Can identify criminal based on tissue or body fluid such as blood, semen, skin or hair follicle.
Environment	• Microbes can expedite decay of waste products created by humans. • Microbes can also degrade faeces completely. • Reduce pollution to protect humans and the environment.

Activity 13.6

21st CENTURY SKILLS — DEBATE

Aim

To debate on the effect of biotechnology on humans, animals and the environment

Procedure

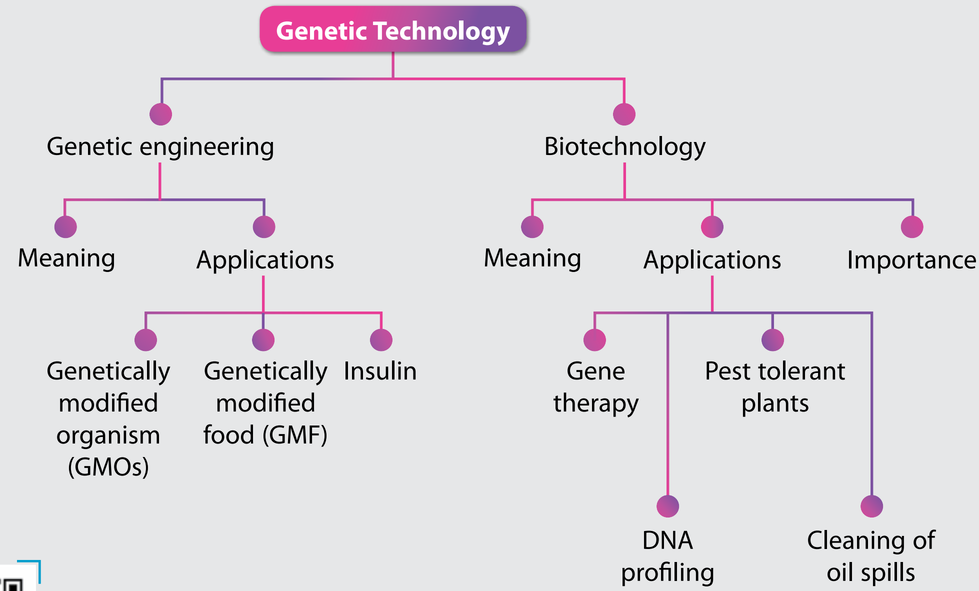
1. Divide the class into two groups.
2. Search for information on the effects of biotechnology on humans, animals and environment.
3. Elect a representative for each group. One represents the affirmative group, and another represents the opposing group.
4. Prepare your complete arguments on the topic entitled "Biotechnology brings more positive effects to humans, animals and environment".
5. Carry out the debate in your class.

Formative Practices 13.2

1. How can the DNA of an individual with a genetic disease be changed?
2. Provide **two** benefits of biotechnology to life.

13.2.3

Memory Flashback



Interactive Bio 13

SELF-REFLECTION

Complete the following self-reflection to identify the important concepts that you have studied.

Important concepts	Very good	Try again
Meaning of genetic engineering		
Meaning of GMOs and GMF		
Application of genetic engineering in the production of GMOs, GMF and insulin		
Meaning of biotechnology		
Application of biotechnology in life		
Importance of biotechnology in life		

Summative Practice 13

1. Damage to gen X of the pancreatic cell prevents the production of protein X. This causes blood glucose level to increase and cannot be controlled. However, the genetic engineering technique has enabled large-scale production of protein X by the following steps:
(P, Q, R and S are not arranged in the right sequence)

P:	Bacteria that carries gene X is cultured in a large quantity
Q:	Normal gene X is removed from human pancreatic cell
R:	Gene X is inserted into a bacterial cell
S:	Protein X is extracted and purified

(a) Name protein X.

(b) Use letters P, Q, R and S to show the correct sequence in steps to produce protein X.

(c) Give **two** reasons why bacteria are commonly used in the genetic engineering technique.

(d) Give **two** examples of medical products produced by genetic engineering.

(e) In a murder case, a knife with blood stains was found by police at a crime scene. By using DNA extracted from the sample on the knife, DNA profiles of the victim and three suspects were obtained as shown in Figure 1.

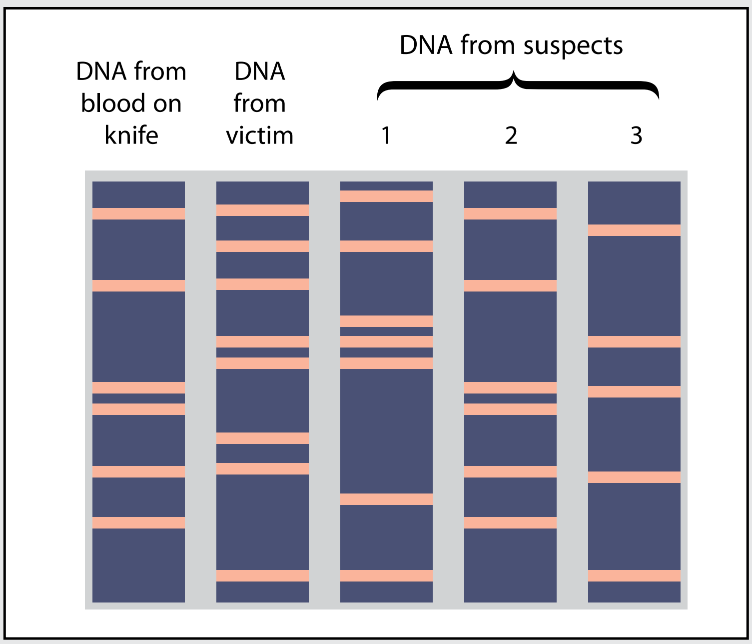


Figure 1

(i) Among the three suspects 1, 2 and 3, who is most likely the murderer? Give reasons.

(ii) Is this DNA profiling technique useful? Why?

(iii) One of the identical twins is found to have committed a crime. Can both of them be distinguished by this DNA profiling technique? Explain.

2. (a) Discuss the advantages of genetically modified food towards human lives.

(b) A bacterial strain can synthesise a protein with a known benefit to humans. Explain briefly how a geneticist can acquire the bacterial gene and mass produce it immediately.

(c) Explain why a plant variety which is modified by genetic engineering to tolerate herbicide can be a threat to the environment.

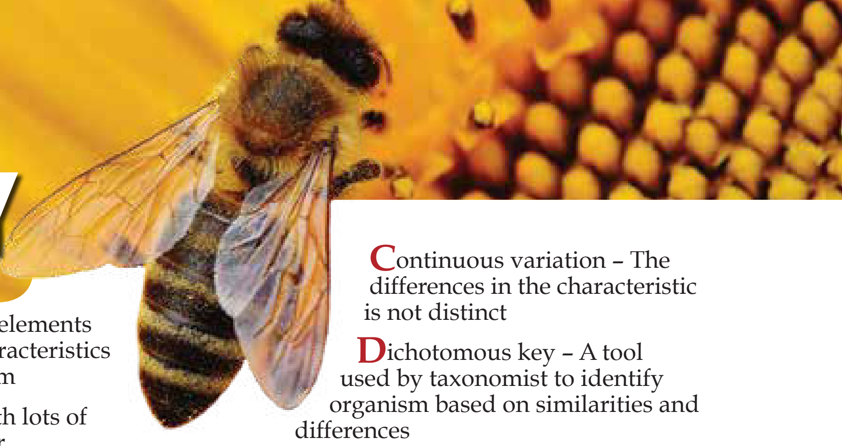
21st Century Mind

3. Recently, many genetically modified food (GMF) have been produced and are available in the market. As a representative of a non-governmental organisation (NGO), you proposed that GMF should be labelled as shown in Photograph 1 and with its contents printed. Justify your proposal.

Photograph 1

4. The illegal ivory trade is rampant in some African countries. It is estimated that 50,000 African elephants have been killed to get their tusks. The authorities find it difficult to identify the real syndicates who run the illegal trade since most suspects caught were non-syndicate members but individuals who merely transport the ivory. Recently, a group of scientists have been actively producing DNA profiles of elephant tusks confiscated by the authorities. In your opinion, explain why communities have so much interest in elephant tusks and how DNA profiling technique can eradicate the smuggling of elephant tusks.

GLOSSARY



Abiotic components – All the non-living elements including their physical and chemical characteristics that can affect an organism in an ecosystem

Aerenchyma tissues – Spongy tissues with lots of air spaces that assist plant to float in water

Allele — An alternative form of a gene for a specific trait that is located on the same locus of a pair of homologous chromosomes

Annual plant – A plant that has only one life cycle for a season or a year

Autotrophic plant – Plant that can form its own food by synthesising complex organic compounds from simple inorganic substances

Auxin — Plant hormone that is involved in cell growth at tip of shoot

Aspect — Directions of wind blows and the rays of sunlight

Biennial plant – A plant which takes two years with two seasons of growth to complete its biological life cycle

Biochemical Oxygen Demand – Total amount of oxygen needed by microorganisms such as bacteria and fungi to decompose organic materials in water

Biodiversity — The variety of living organisms such as microorganisms, animals and plants that interact with one another

Biotechnology — A field which utilises technology or method to manipulate organism for the production of biological product

Biotic components – Living components in an ecosystem

Capillary action – Water potential to move upwards against gravity in the stem with the help of adhesion and cohesion forces

Chemotropism – Plant response to chemical

Chlorosis – A condition in which leaves turn yellow due to insufficient production of chlorophyll

Commensalism – An interaction that provides benefits to only one organism without causing any harm to other organisms

Community – The populations of all organisms from different species living in the same habitat whilst interacting with each other

Compensation point – Level of light intensity when rate of respiration equals to the rate of photosynthesis

Continuous variation – The differences in the characteristic is not distinct

Dichotomous key – A tool used by taxonomist to identify organism based on similarities and differences

Discontinuous variation –The differences in the characteristic is distinct

Ecosystem — A few communities that live together in a habitat and interact with each other including non-living components (abiotic) such as water, air and soil

Ecosystem diversity — The biotic community and ecological process in ecosystems on the land, in the sea and other aquatic environments

Gene — Basic unit of inheritance that consists of a segment of DNA located at specific locus of a chromosome

Genetic diversity — The genes variation of an individual within a population and the genes variation between different populations of the same species

Genetic engineering – A gene manipulation technique to modify genetic material of an organism to produce new combination of genes

Geotropism — Plant response to gravity

Guttation — Secretion of water droplets through a special structure at the end of leaf veins without involving the stomata, caused by a high root pressure

Halophyte — A plant that is adapted to live in an area which is very hot, dry and has minimum water such as in a desert

Herbarium — A specimen collection from plant which are preserved through a certain method

Heterotrophic plant – A plant that depends on other organisms for nutrients

Hybrid — A product of mating between two purebreed varieties

Hydrophyte — An aquatic plant that lives either on the surface or submerged in water

Hydrotropism — Plant response to water

Lignin – Organic polymer that provides mechanical support to plant tissues

Mesophyte – A plant that needs only a moderate amount of water

Micro balance – A balance that can measure accurately a very small mass up to 0.1 milligram

Microclimate – Climatic condition for a small area which is different from the surrounding area

Mutagen – A physical, chemical or biological agent that can cause mutation or increase the rate of mutation to a dangerous level

Mutualism – An interaction which gives benefits to both organisms

Nastic response — Responses of certain parts of a plant that is independent of the direction of the stimulus

Niche – The role of an organism in an ecosystem which includes its behaviour and interactions with biotic and abiotic components in the surrounding of its habitat

Non-vascular plant – A plant that does not have a transport system

Nucellus – A central part of a plant ovule which contains an embryo sac

Nutrition – A way for an organism to obtain nutrients and energy from the food for its life processes

Ovule - A structure that gives rise to and contains the female reproductive cells; it is a structure in a flower that is formed inside the carpel

Parasite – An organism that benefits from its host yet causes harm or even kills it

Pathogen – An organism that causes disease

Pectin – A material found in cell wall of plant

Perennial plant – A plant that lives more than two years

Phylogeny — The evolutionary history of a species or a group of organisms that are genetically linked

Phytoremediation — Treatment method which uses plants for the purpose of degradation, extraction or elimination of pollute substances from soil and water

Phototropism — Plant response to light

Pneumatophore – Short root projections from the soil surface for aeration in water-submerged areas

Pollination – A process that involves transfer of pollen grain from anther to stigma

Population – A group of organisms of the same species that live in the same habitat

Population growth – The increase in total number of humans living in a certain area

Primary growth - A growth that occurs after germination and is experienced by all plants

Pyramid of biomass – Diagram that shows the total biomass per unit area of all organisms in every trophic level

Pyramid of number – Diagram that shows the number of organisms in every trophic level of a food chain

Root pressure – Pressure that forces water in root xylem vessels absorbed from soil to move up the stem of a plant

Species – A group of similar organisms, able to interbreed and produce offspring

Species diversity — Variation and variability of organisms on Earth

Stoma – A minute pore found mostly on the lower surface of a leaf

Taxonomy – A field in biology which involves the classification, identification and naming of organisms in an organised manner

Thigmotropism - A plant response to touch

Translocation – A process of transporting of organic materials such as sucrose, amino acids and hormones in the phloem from leaves to other parts of a plant such as roots and stem

Transpiration – An evaporation of excess water in the form of water vapour by diffusion from the plant to the atmosphere

Tropism — Response of certain parts of plant such as root or shoot towards or away from a stimulus

Vascular plant – A plant that has a transport system

Vascular tissues – Plant tissues that transport water and nutrients to all cells

Xerophyte – A salt-tolerant plant grows in soil or water of high salinity such as mangrove swamps and seashores

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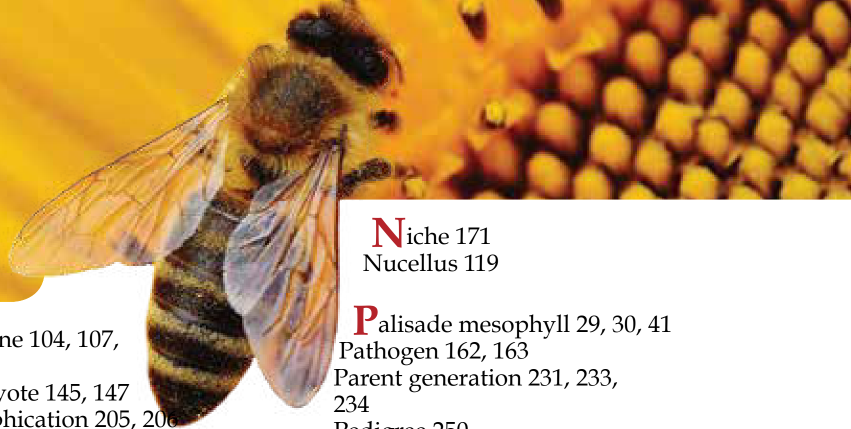

Dengan ini **SAYA BERJANJI** akan menjaga buku ini dengan baiknya dan bertanggungjawab atas kehilangannya serta mengembalikannya kepada pihak sekolah pada tarikh yang ditetapkan.

Skim Pinjaman Buku Teks

Sekolah ____________________

Tahun	Tingkatan	Nama Penerima	Tarikh Terima

Nombor Perolehan: ____________________

Tarikh Penerimaan: ____________________

BUKU INI TIDAK BOLEH DIJUAL