Natural Sciences

Grade 7

Learner's Book

Natural Sciences Grade 7 Learner's Book

First published in 2017

This project is funded as an ongoing project of the Sasol Inzalo Foundation, and has been developed with the participation of Magic Moments Consulting and Services and ACP Project Management and Publishing Services.

Cover design by ACP Project Management and Publishing Services
Cover image 123RF Stock Photos: Buchachon (Image ID 16097618)
Illustrations by Will Alves, Shameema Dharsey and Nazley Samsodien
Layout and typesetting by Nazley Samsodien in ITC Stone Serif Std 10.5 pt over 13.5 pt
Editing, Proofreading and Project Management by ACP Project Management and Publishing Services

ISBN: 978-1-4315-2885-1

Image attribution

123RF Stock Photos: p.1; p.3; p.6; p.8; p.9; p.12–13; p.16; p.18–19; p.22–24; p.26–45; p.50; p.53–54; p.56–59; p.61; p.63–65; p.73; p.79–80; p.83; p.87; p.90; p.95–99; p.101–102; p.109 (top); p.110; p.114–115; p.117–121; p.123–124; 130a; p136–143; p.145; p.154–155; p.162; p.164–165; p.168–169; p.175–183; p.192; p.195–196; p.198; p.206; p.210–211; p.213; p.215; p.220–222; p.226; p.229; p.233–234; p.237; p.240–244; p.248–249; p.252–253; p.252–257; p.265; p.270; p.272; p.282; p.285; p.300; p.304–305; p.307; p.312–314; p.318–323; p.326; p.328–329; p.332–336

NASA Images: p.7; p.266; p.295–299

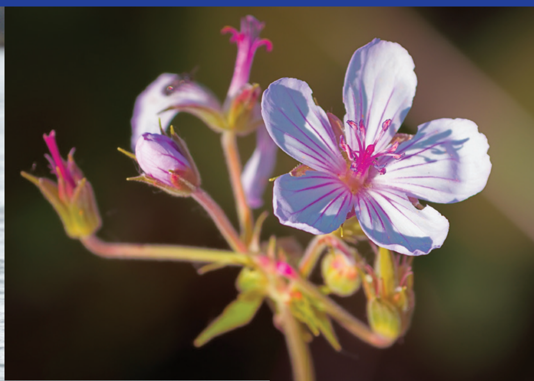
SALT Photo Library: p.269; p.272

Contents

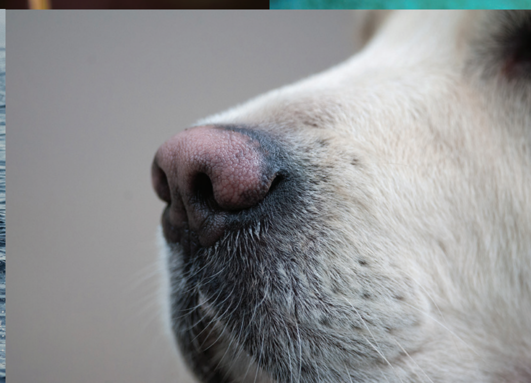


STRAND

Life and Living











1 The biosphere

Key questions

What is the biosphere?

- What are the coldest or hottest places where life can exist?
- How deep can you go in the sea before you do not find anything living anymore?
- Are there living organisms on top of the world's highest mountains?
- How can you tell if something is alive or if it was never alive?
- What do organisms need to stay alive?
- Why can some organisms can live in certain places while others cannot.

Keywords

- biosphere
- depend
- habitat
- hydrosphere
- lithosphere
- micro-organism
- organic
- organisms

Take note

All the 'Keywords' listed in the boxes in the margin are defined in the glossary at the end of this strand.

Let's start exploring the world around us and how it works! Remember that this is your book! You must use it to explore and ask questions about the world around you, and also to learn about yourself and who you are. Do not be afraid to make notes in the margins of this book – make your own scribbles and notes to yourself about points to remember or questions you would like to ask. Be curious! Explore and imagine the possibilities of what you can do with science!

1.1 What is the biosphere

Have you heard the word 'sphere' before? Do you know what it means? A sphere is normally used when talking about a round shape (like a ball). Now, what do we mean when we talk about the **biosphere**? The prefix 'bio' indicates something to do with life. For example, 'biology' is the study of living organisms. So, can you put these two meanings together to work out what 'biosphere' means?

The Biosphere

The biosphere is the place where life exists on planet Earth. When we talk about the biosphere, we are talking about a huge system (the whole world!) and how all the different parts work together to support life. We will look at these different parts in more detail a bit later. Do you remember learning about the different states of matter? The hydrosphere includes all water in all the states of matter.

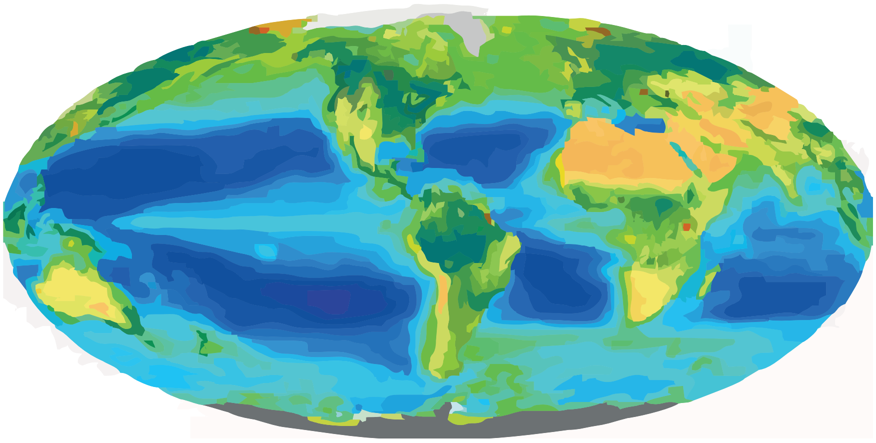


Figure 1.1 The biosphere is where life exists on our planet, including the soil and rocks, water and air.

We can also use the term biosphere in different ways. When we speak of all life on Earth as it interacts with the non-living rocks and soil, water and air (**atmosphere**), we call this the biosphere.

We can also call a specific part or region on Earth that supports life a biosphere, especially when we refer to the living organisms and the **environments** in which they live.

Figure 1.2 A biosphere refers to the living organisms and the environments in which they live.

Keywords

- adapted
- aquatic
- atmosphere
- environment

ACTIVITY Where do you think life exists on Earth?

Instructions

- The following table contains some photos of different places on Earth. Describe what each photo is showing.
- Then decide if you think life exists there or not. If you do think so, list some of the organisms which you think live in this place.
- Many plants, animals and microorganisms have **adapted** to live in an **aquatic** habitat.

A place on Earth	What is this image showing?	Do you think there is life there? If so, what?
		
		
		

Components of the biosphere

In the previous activity we saw that life can be found in water, soil and rocks, or the air around us. These components form part of the biosphere and have special names:

- **Lithosphere**, which includes the soil and rocks.
- **Hydrosphere**, which includes all the water.
- **Atmosphere**, which includes all the gases

The biosphere includes the lithosphere, hydrosphere and atmosphere. The biosphere includes all living organisms, and also dead organic matter.

ACTIVITY **Describe the components of the biosphere.**

Instructions

Study the following illustration that shows the components of the biosphere.

Did you know?

The Earth's atmosphere has changed overtime. Our oxygen rich atmosphere was formed by algae millions of years ago.

Figure 1.3 The lithosphere, hydrosphere and atmosphere on Earth.

Identify and describe the elements of the lithosphere, hydrosphere and atmosphere that you can see in the photo.

a) Lithosphere
b) Hydrosphere
c) Atmosphere
d) Even though you cannot see living organisms in this photo, there are many living and dead plants and animals that could live on a beach found in this biosphere. Make about 10 plausible (believable) guesses of the types of organisms which would live in this environment.

(Hint: Think about what might be living in the sea, sand or air.)

Different organisms can exists in different places in the biosphere. Let's have a look at the different components of the biosphere and which types of organisms exist there.

Atmosphere

The atmosphere is the layer of gases that surrounds the Earth. The three most important gases in the atmosphere are nitrogen, oxygen and carbon dioxide. The atmosphere is made up of several layers.

ACTIVITY The atmosphere

Questions

1. Discuss with your partner whether you think organisms could live on Earth without the atmosphere. Explain why you think so.

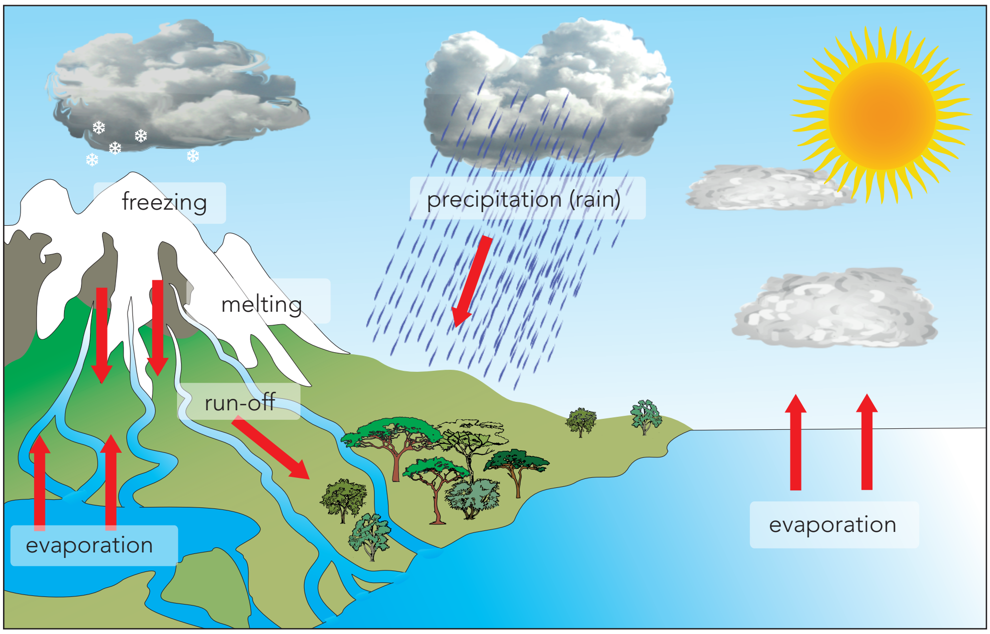
Hydrosphere

The hydrosphere consists of all water on Earth in all its forms.

ACTIVITY The water cycle

Instructions

Study the following diagram describing the water cycle on Earth. Answer the questions that follow.



Questions

1. Look at the diagram of the water cycle and identify water in the different states of matter.
2. The water cycle shows different sources of fresh water and salt water. A very small percentage of the world's water sources are fresh water and the rest is salt water. Write down as many different types of aquatic habitats that you can think of where different organisms exist.

Take note

The word 'aquatic' is used to describe something to do with water. Therefore aquatic animals are animals that live in or near water. The word 'marine' describes organisms that live in salt water or the sea. So someone studying the organisms in the sea is called a marine biologist.

Lithosphere

As we have said, the lithosphere includes the rocks, soil and sand on Earth. Organisms depend on the lithosphere in many different ways. We find out how in the next activity.

ACTIVITY How do organisms depend on the lithosphere?

Instructions

1. Below are several photos depicting different ways that organisms depend on and interact with the lithosphere.
2. Use these images to write a paragraph about how different organisms depend on the lithosphere in different ways.

Figure 1.4 Birds' nests

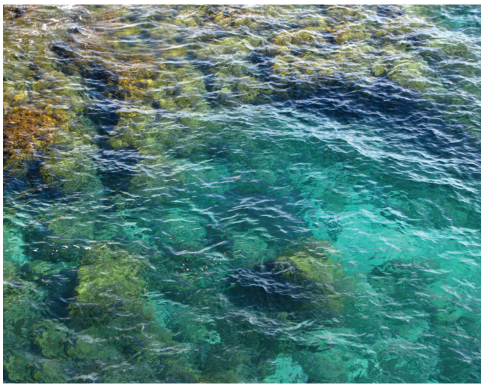


Figure 1.5 A rock pool

Figure 1.6 A termite mound

Figure 1.7 A tree growing in the ground

Figure 1.8 An earthworm in soil

Figure 1.9 A mud hut

Characteristics of living plants and animals

There are seven processes that all living organisms perform that determine whether they are alive or not. Let's have a look at the seven life processes:

1. All living things need to be able to move. Moving does not have to consist of big movements. Even plants move, for example as the flowers and leaves turn to face the sun during the course of the day.
2. All living things need energy to perform the life processes.
3. All living things need to be sensitive to their environment. Think of an example of why animals need to be sensitive to their environment and write it down below.
4. All living things need to be able to grow.
5. All living things need to be able to reproduce so that they do not die out.
6. All living things need to be able to excrete waste.
7. All living things need nutrition, as they need to break down nutrients during cellular respiration to release energy.

Keywords
- abiotic
- cellular respiration
- respire

1.2 Requirements for sustaining life

After studying the seven life processes, we now know what animals, plants and other living organisms need to do in order to be classified as living. In order to stay alive these living organisms require (need) certain things or specific conditions. In this section we are going to study the requirements necessary to **sustain** life.

ACTIVITY Identify the requirements for sustaining life

Imagine that you are the design team for the first International Moon Space Station, similar to the International Space Station already orbiting Earth, but situated on the Moon!

Figure 1.10 The international space station that orbits Earth, seen from above.

Take note

'Sustain' means to keep things alive or in existence. We also use the word 'sustainable' when we want to say that something can continue or be continued for a long time.

Instructions

1. Work in groups of four.
2. What do you think the astronauts and plants living on the new Moon Station will need in order to live? Discuss the five most important requirements that you need to provide in order for the astronauts and plants to remain alive on your Moon Space Station.
3. Explain why your group chose these five requirements as the most important to sustain life. Write down your notes from your group discussion. Decide which member of your group is going to report back your findings to the rest of the class.
4. Have a class discussion after you have finished discussing this in your group.

Keyword

- favourable

Figure 1.11 All living things need a source of energy. The grass and trees get their energy from the Sun to photosynthesise. The cow gets its energy by eating the grass.

Figure 1.12 All living things need oxygen to respire, such as this dog, which is breathing air in through its nose.

Did you know?

When astronomers search for life outside of our solar system, they search for planets that might contain liquid water, believing that where there is water there is life.

WATER is vital to life. Every organism on our planet needs water to live.

Figure 1.13 Water is vital for life on Earth.

Figure 1.14 Most plants need soil to grow in.

Requirements for growing seedlings

Let's find out what the requirements are to grow seedlings. We will learn how to conduct a scientific investigation to do this.

Investigation: What are the requirements to sustain life in plants?

In this investigation, we are going to germinate bean seeds (or any other seeds that your teacher provides you with). Each group in the class is going to be testing a different requirement for germination and growth of the seedling.

Aim

A scientific investigation always has an aim or question that needs to be answered. What is the aim of this investigation? Write down what you aim to find out.

Hypothesis

A hypothesis is where you propose (suggest) what the outcome of the investigation will be. It is a prediction of what the results will be. Write a hypothesis for this investigation.

Variables

Scientists often use investigations to search for cause and effect relationships. This means that they design experiments to investigate how changes to one part will cause an effect on another. These changing quantities are called **variables**. There are usually three kinds of variables:

1. **Independent variables**: These are the things that you are changing in the investigation. You are in control of the independent variables. For example, if you wanted to investigate if eating a lot of sugar makes you gain weight, then the amount of sugar you eat is the independent variable. You control how much sugar you eat. We want to achieve something called a FAIR TEST which means that only ONE independent variable is changed at any given time. Once the independent variable has been changed, the scientist then observes what the effect will be. In the example of investigating if sugar makes you gain weight, you cannot at the same time investigate whether exercise makes you lose weight. This would not be a fair test.
2. **Dependent variables**: The dependent variable is the thing that you observe in an investigation. You do not change it. The dependent variable will change depending on the independent variable. For example, in the investigation to see if eating a lot of sugar makes you gain weight, the dependent variable will be how many kilograms you gain (or lose) as a result of eating sugar. How much weight you gain will depend on how much sugar you have eaten. Dependent variables should be measured in an objective way using numbers as far as possible.

Take note

In Natural Sciences, when we use the word 'favourable' we mean something that is advantageous, helpful, or optimal. For example, we can talk about favourable conditions for life.

Keywords

- dependent variable
- fair test
- hypothesis
- independent variable
- scientific method
- variables

Take note

A hypothesis is an educated or calculated guess about what the outcome of the investigation will be. The hypothesis is stated before starting the investigation, must be written as a statement and must be in the future tense.

Take note

Remember your control group is a special kind of comparison group.

Did you know?

Every solar system has a habitable zone, which is a region that is not too hot (close to the sun), and not too cold (far from the sun) to be able to sustain life.

Earth is in the middle of our solar system's Goldilocks.

3. **Controlled variables**: These are the quantities that a scientist wants to remain the same or unchanged throughout the experiment. The controlled variable needs to be carefully monitored to make sure that it stays the same. In the example to see if sugar makes you gain weight, you could have one person eat a lot of sugar and the other person eat no sugar and then see the changes in weight. There are some things that need to stay the same for both of these people so that it is a fair test. For example, both people must do the same amount of exercise so that this does not influence their weight. This is a controlled variable.

You can also do a control test. For example, in this investigation about the growth of plants, you will be taking away one of the requirements for growth. You need to do a control test where another plant is given all the requirements, including the one you took away in the other plant. You can then compare your plant where you took one requirement away to the control plant that has that same requirement to see if there is a difference.

Identify the variables for this investigation.

1. **Independent variable.** What will you change?
2. **Dependent variable**. What will you measure to see the effect of the independent variable on the germination and growth of the plant?
3. **Controlled variables and control group**. What will your control test be, and what will you keep the same between the control plant and the tested plant?

Method

In your group, plan how you are going to do the investigation. Think about which requirement you are testing and how you will take this requirement away. For example, if you are looking at light, where could you place the seeds so that they do not receive light? Remember, if you are looking at light, then you need to make sure that the control and test seeds both receive the same amount of water. Once you have planned the investigation on rough paper and discussed it with your teacher, write up the method below (in numbered steps), explaining what you will do.

Materials and apparatus

Write a list of all the materials and apparatus that you will be using in this investigation.

Results and observations

Use this space to record the results for your investigation. If you are seeing whether plants germinate or not, then you need to draw a table to show this. If you are measuring how much the plants grow, then you will also need a table for this.

Analysis

Once we have collected our results in a scientific investigation, we need to analyse them. This often involves drawing and interpreting the graph. If you measured the growth of the seedlings over time, then you can draw a line graph to show this. If you have counted the number of seeds that germinated, you can express this using a bar chart (provided you used the same number of seeds in each group), or you can express the percentage of seeds that germinated as a pie chart. Your teacher will help you do this.

Conclusion

After collecting all your results and drawing a graph using these results, you will need to use this to draw a conclusion about the requirements to sustain life in plants. The following questions will guide you in drawing your conclusion.

1. I found out...
2. I know this because...
3. The investigation was fair because...
4. I can trust the results because...
5. While I conducted (did) this investigation I also discovered that...
6. If I did this investigation again I could improve it by...

Did you know?

Not all plants need to grow in soil. Epiphytes, such as mosses and orchids, are a group of plants which grow on other plants or rocks. They get their moisture and minerals from the air and rain

Adapted for life

Do you think you could put a polar bear in the Kalahari desert or a gemsbok in Antarctica, and they would survive? Why, or why not?

These animals are specifically adapted to live in their specific environments. All organisms are adapted to their specific environments. In the next activity we examine some more examples of how organisms are adapted to their environments.

ACTIVITY Adaptations in organisms

Instructions

1. Study the photos below showing different organisms in different environments.
2. Answer the questions.
3. You may need to do some extra research in books and on the Internet to complete your answers.

Questions

Look at the photos of a penguin in the water and an eagle flying in the air. Both of these are birds, but they live in very different environments that make the penguin adapted for the water and the eagle adapted for flight.

Figure 1.15 A penguin in the water.

Figure 1.16 A flying fish eagle about to catch some food.

1. How do you think the penguin is adapted to swim in water?

> **Hint**: What are its wings used for? Does it have small or large feathers? How do you think this helps?

2. How do you think the eagle is adapted to fly and catch its prey?

> **Hint**: Look at its feathers and wings.

South Africa is home to two very skilled predators, the great white shark and the lion. Both of these animals are very skilled at catching their prey, but in very different environments.

Figure 1.17 A great white shark in Gansbaai, Western Cape.

Figure 1.18 A lion attacking a buffalo in Kruger National Park.

3. What characteristics does the shark have that makes it adapted to living and feeding in the sea? Hint: Look at its streamlined body shape and sharp teeth.
4. What characteristics does a lion have that makes it adapted to living and hunting in the savanna? Hint: Look at the colour of its fur and the colour of the grass, and its strong limbs.

Summary

Key concepts

- Life on planet Earth exists in the biosphere.
- The biosphere consists of the lithosphere, hydrosphere and atmosphere, as well as the many living organisms and dead, organic matter.
- Many different kinds of living organisms exist in the biosphere.
- Things can be classified as living if they perform the seven life processes:
  - Movement
  - Reproduction
  - Sensing the environment
  - Growth
  - Respiration
  - Excretion
  - Nutrition
- Living things need energy, gases, water, soil, and a favourable temperature to survive.

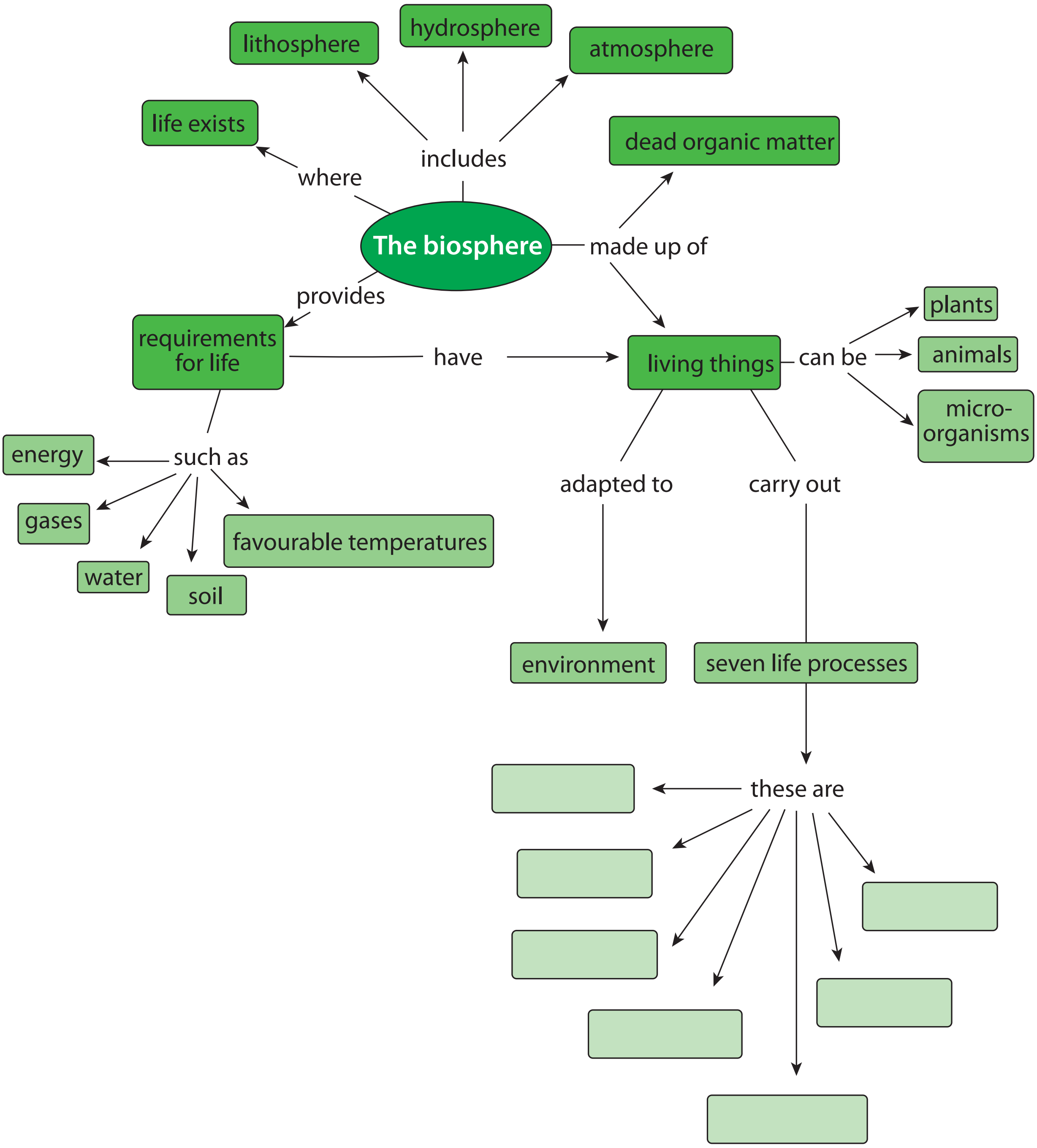
Concept map

Do you know what a concept map is? This year in Natural Sciences, we are going to learn more about how to make our own concept maps.

Above you have the 'Key concepts' for this unit. This is a written summary and the information from this unit is summarised using words. We can also create a concept map of this unit, which is a map of how all the concepts (ideas and topics) in this unit fit together and are linked to each other. A concept map gives us a more visual way of summarising information.

Different people like to learn and study in different ways: some people like to make written summaries, while others like to draw their own concept maps when studying and learning. These are useful skills to have, especially for later in high school and after school!

Have a look at the concept map for 'The Biosphere'. Complete it by filling in the seven life processes in the blank spaces.



Revision

1. Explain what the biosphere is. (2)

2. What makes up the following?
   a) Lithosphere:
   b) Hydrosphere:
   c) Atmosphere: (3)

3. Discuss why the atmosphere is important for life on Earth. (2)

4. Imagine an alien creature arrives on Earth attached to a meteorite (fallen space rock). You were tasked with deciding whether it lives in the conventional way that we understand organisms to live. Draw up seven questions to determine how this organism lives and whether it can be classified as alive. (7)

5. What are the requirements for sustaining life on Earth? (5)

6. Look at the following photos of different organisms in their environments. Answer the questions about how they are adapted.
   a) Giraffe (1)

      How are giraffe adapted to eat their food?

      Hint: They eat the leaves of trees.

   b) Cactus (1)

      This cactus is adapted to live in hot environments. How do you think it stores water for long periods?

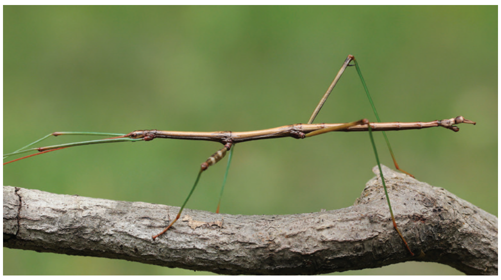
      Hint: Look at its leaves.

      How do you think the cactus has adapted to prevent other animals from eating it? (1)

      Hint: What is on the leaves?

   c) Stick insect (1)

      Can you see the stick insect in this photo? How do you think it is adapted, especially to hide away from predators?



7. Think back to the scientific investigation you did in this section. Evaluate how well you think you followed the scientific method to make your experiment fair or not fair. (2)

Total [25 marks]

2 Biodiversity

Key questions

- How do we group or classify all the living organisms in the world?
- Why do we need to group or classify living things?
- How can we classify all the animals on Earth?
- What is the difference between reptiles and amphibians?
- Are insects and arachnids (spiders) different?
- Is there a way to classify plants?
- What is the diversity of plants and animals in South Africa.

Over millions of years each species living today has changed and adapted to live in a specific type of environment in order to ensure the survival of that species. Biodiversity is a term used to describe the great variety of living organisms on Earth and their varied habitats.

There are just so many types of organisms. How can we make sense of all the organisms on Earth? We need some way to group them. This is called classifying. Let's find out how we do this!

2.1 Classification of living things

Grouping has been a common activity in humans for thousands of years as we make sense of the world around us.

Think back to the example of how we classify learners at school. First, school is divided into pre-primary school, primary school and high school. If we compare school to the way we classify organisms, we can say that the school system has three kingdoms. But we need to divide learners up further. So primary school is divided into seven grades (Grades 1–7) and high school is divided into five grades (Grades 8–12). The classification system for organisms also needs to divide organisms up further as each kingdom contains thousands of different types of organisms.

Think of your school again. Your primary school contains many learners. When you divide your entire school into grades, there are fewer learners in each grade. Your grade might be divided into different classes, and each class has fewer learners in it. When we classify organisms, the same thing happens.

ACTIVITY Group some everyday objects

Materials

- objects from home
- shoeboxes/ice-cream tubs

Keywords

- characteristics
- classify
- kingdom
- order
- phylum

Instructions

1. Work in groups of four.
2. Each member of the group should bring five items from home. Choose items that are easy to carry around and will fit into a standard shoebox.
3. Carefully observe each of the items that everyone in your group has brought.
4. Use the shoeboxes to group the items according to your observations.
5. Place all objects brought by the whole class on a display table in the front of the class.
6. Discuss the different grouping methods that each group has used as a class. Work towards a standard grouping or classifying method that you could use to classify ALL the items that all of you brought to school.

Questions

1. Draw a table in the space below and record all the items in your **class** in the groups you assigned them to.
2. How did your small group classify your items to begin with? What features did you use to **classify** the items?
3. Write three or four sentences about the standard classification method that you decided to use in your class. What **characteristics** of the items did you use to classify and group them? Were these different from what you used in your small group?

Aristotle's classification system

Aristotle was a Greek philosopher and thinker who lived about 2 400 years ago. Aristotle came up with the following grouping system that was used for almost 2 000 years after his death!

- He divided all organisms into either animals or plants.
- Then he divided animals into those 'with blood' and those 'without blood'.
- Lastly animals are divided into three groups based on their method of movement: walkers, flyers or swimmers.

ACTIVITY Aristotle's classification system

Instructions

1. Look at the following photos of different kinds of animals.
2. Use Aristotle's method of classification to group the animals based on the way that they move.
3. Draw a table of your groupings in the space provided after the photos. Give your table a heading.

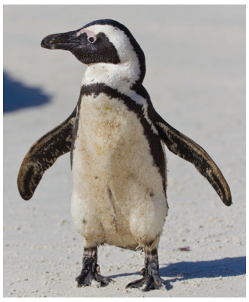


Figure 2.1 A penguin

Figure 2.2 A butterfly

Figure 2.3 A cat

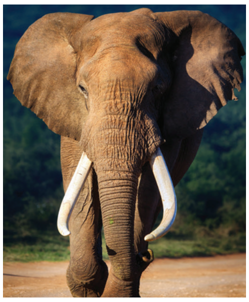


Figure 2.4 An elephant

Figure 2.5 A crocodile

Figure 2.6 An eagle

Figure 2.7 A human

Figure 2.8 Dolphins

Figure 2.9 Bats

Did you know?

Scientists estimate that there are up to 30 million species of organisms on Earth! If they use systems to classify these organisms, they can see patterns in nature and can see how organisms relate to each other

Take note

The kingdom Bacteria is often also referred to as Monera.

Questions

1. Were there any animals which you battled to classify into one group? Which ones were these?
2. Do you think Aristotle's classification system has any problems? Explain any problems that you might find when using it.

Carl Linnaeus classification system

In the 1700s Carl Linnaeus developed the classification system that classified organisms according to their similarities, functions and relationships with other organisms.

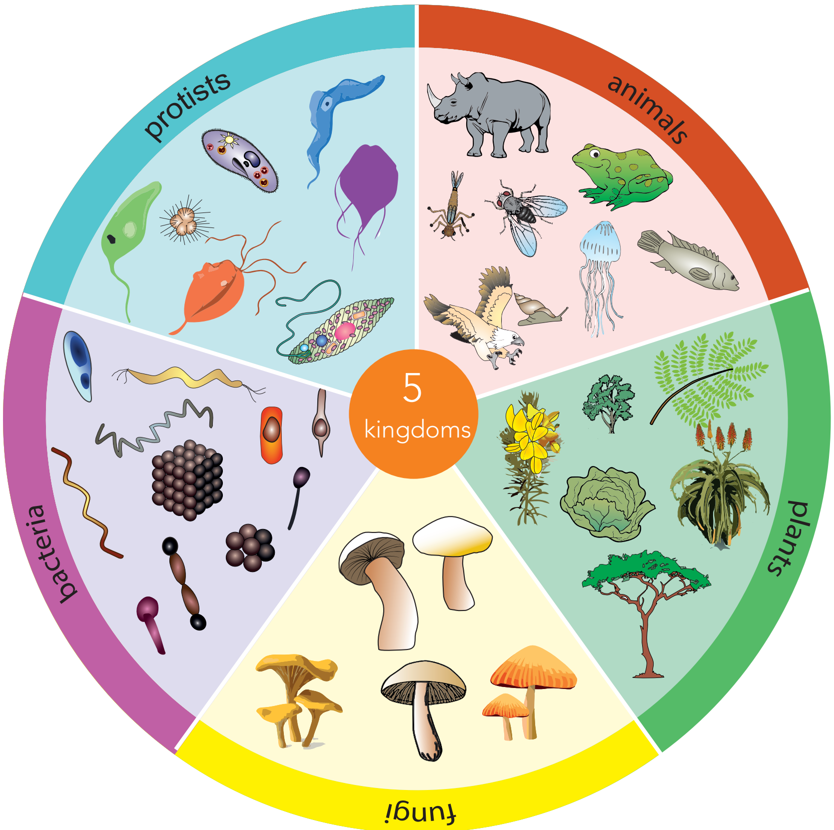
Today with the use of modern microscopes and genetics we can classify living organisms very accurately. In this way we are able to classify living organisms according to their shared characteristics.

> **Take note**
>
> Be careful to use these words correctly: one phylum, many phyla. Similarly, one genus, many genera.

Our classification system living organisms

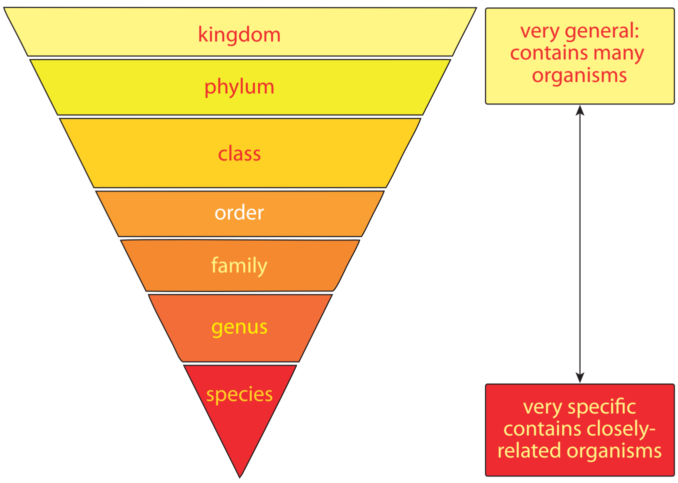
All living organisms can be divided into five **kingdoms**:

a) Animals
b) Plants
c) Fungi
d) Protists
e) Bacteria



> **Take note**
>
> A mnemonic takes the first letters of a group of terms to make a funny phrase that helps us to remember something.

Each kingdom is divided into smaller groups or divisions called **phyla**. Organisms with similar traits (characteristics) will occupy a similar phylum. In each phylum, smaller divisions called **classes** are found and each class is further divided into **orders**, **families**, **genera** and then **species**.



Study this diagram to help you remember the order:

A kingdom is a very big group, whereas a species is a much smaller group.

A mnemonic to help you remember this order is: King Phil Cuts Open Five Green Snakes

We need to be able to distinguish between organisms too.

Now that we have seen how to classify organisms, let's take a closer look at the differences between plant and animal kingdoms.

Differences between plant and animal kingdoms

ACTIVITY Comparing plants and animals

Instructions

1. Study the diagram on page 20 that shows the five kingdoms that we commonly use to classify organisms. Pay close attention to the plants and animals kingdoms.

Questions

1. What are some common features that you can see in all the animals?
2. What are some features that are common to all plants?
3. Draw a table in the space below and compare the characteristics of plants that make them different to animals. Discuss your plant and animal comparisons with your group and then with the class.

Take note

When we compare plants and animals we can often compare them based on the way that they move, what they eat and how they get food or nourishment, and how they reproduce.

Fungi

Most people will not eat bread covered in bread mould but will eat a plate of fried mushrooms, truffles and morels. These are all examples of fungi, including yeast.


Figure 2.10 Morel


Figure 2.11 A truffle


Figure 2.12 Bread mould

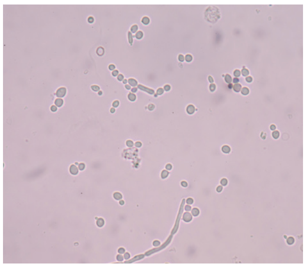


Figure 2.13 Yeast cells


Figure 2.14 A very poisonous mushrooms


Figure 2.15 Button mushroom (like the ones we buy in shops)

Did you know?

Morels are a type of edible mushroom. They have a distinctive appearance because of their caps, which have pits and ridges that resemble a honeycomb.

Fungi play a very important role in our biosphere since they break down dead organic material and return nutrients to the soil for plants to use. Some fungi cause diseases while others, such as penicillin (an antibiotic) are very useful to us. Yeast is used in many of our products, such as making bread rise and fermenting wine and beer.

Protists and Bacteria

We will look at Protists and Bacteria in more detail later on in Grade 9. For now, let's look at some of the basic features of these kingdoms.

Organisms in these two kingdoms are microscopic which means you cannot see them with your naked eye. However, we can see them if we look at them under a microscope.

Different bacteria

Figure 2.16 *Escherichia coli* bacteria, commonly found in the intestines of animals

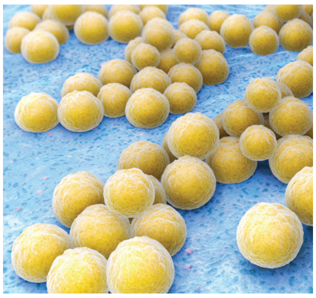


Figure 2.17 *Staphylococcus aureus* (yellow cells) which often causes skin infections and pneumonia

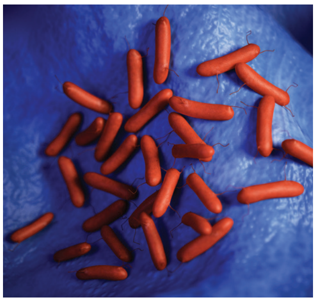


Figure 2.18 *Pseudomonas aeruginosa* found in soil and water causes infections in animals

Figure 2.19 *Actinomyces* bacteria cause diseases in the mouth

Different Protists

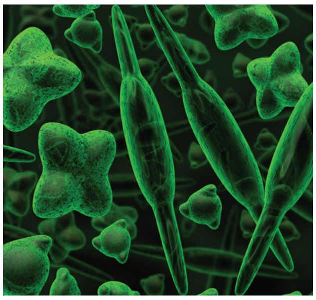


Figure 2.20 Phytoplankton from the Antarctic sea

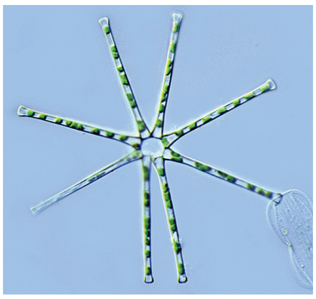


Figure 2.21 *Asterionella formosa*

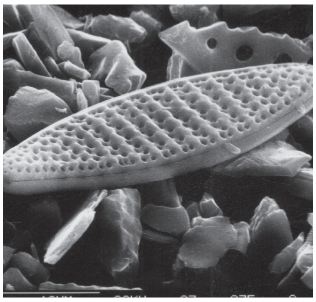


Figure 2.22 *Nitzschia kerguelensis*

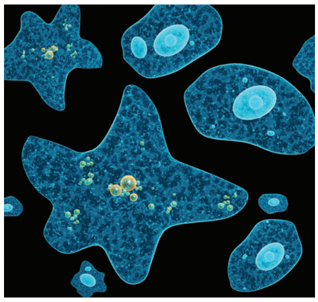


Figure 2.23 Different coloured amoebas

Did you know?

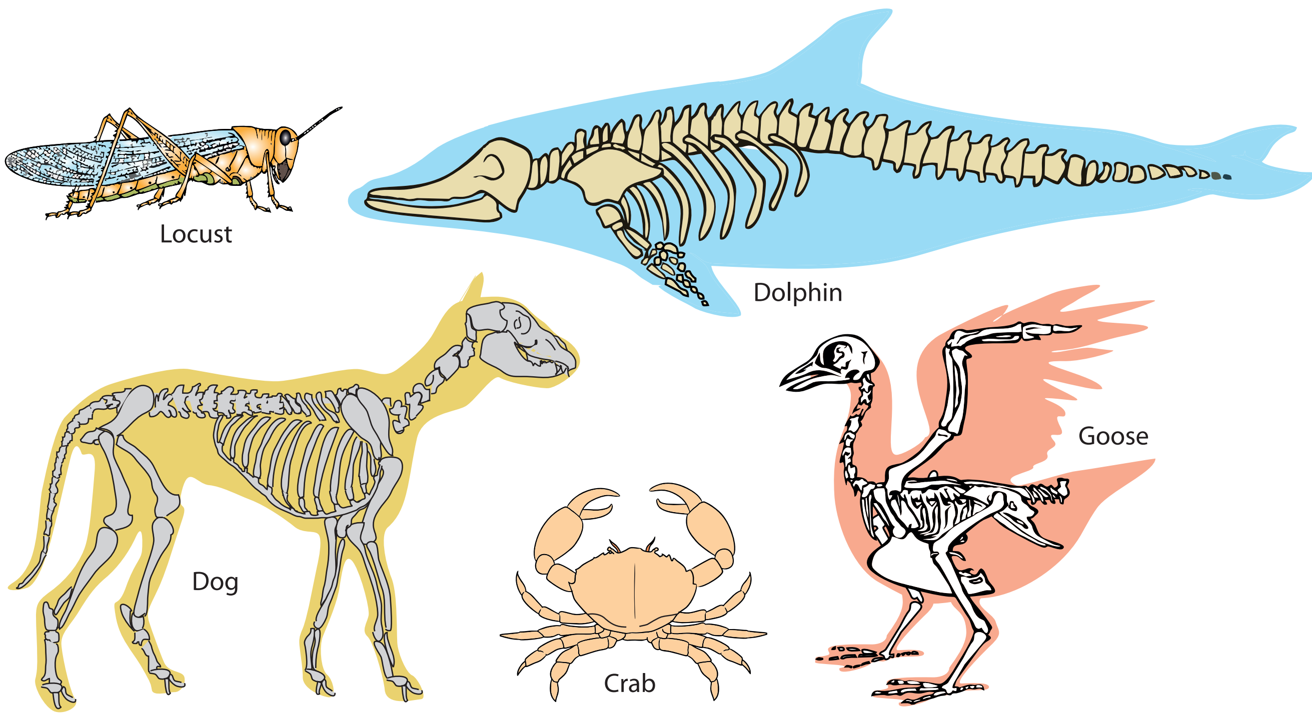
You can find out lots more online by visiting the links provided in the Visit boxes. Be curious and discover the possibilities!

Now we will look at the amazing diversity of animals and plants on Earth, and especially in South Africa.

2.2 Diversity of animals

Classifying animals

All the animals in the world form part of the animal kingdom. There are two distinct divisions or groups of animals within the animal kingdom: the vertebrates and the invertebrates. Can you remember what is used to classify an animal as a vertebrate or invertebrate? Look at these x-rays of animals for a clue.



Animals that have a backbone with a hollow tube inside to hold the nerves are vertebrates. As we can see in the x-ray images of the dolphin, dog and goose, we can see the skeletons of these vertebrates. They are made of bone. We say that vertebrates have an endoskeleton.

What about the grasshopper and the crab? Why can we not see their bones? This is because crabs and grasshoppers are invertabrates and do not have skeletons. The grasshopper and crab have a hard shell covering on the outside of their bodies. This supports their soft bodies inside. We say they have an exoskeleton. But not all invertebrates have an exoskeleton.

What about a jellyfish? It does not have a backbone, so it is not a vertebrate, so it must be an invertebrate. Does it have a hard, outer covering called an exoskeleton? Discuss this with your class. Make sure to take note of the third type of skeleton in your discussion.

Keywords

- diversity
- invertebrate
- vertebrate

ACTIVITY Classifying animals as either vertebrates or invertebrates

Instructions

1. In the table identify the type of skeleton that each animal has and write it down beneath each picture.
2. Write down whether the animal is an invertebrate or a vertebrate.

Did you know?

Almost 98% of all the animals that have been discovered on Earth are invertebrates.

Figure 2.24 A grasshopper

Figure 2.25 A bluebottle

Figure 2.26 Cape sparrow

Figure 2.27 Butterfly

Figure 2.28 Tortoise

Figure 2.29 Frog

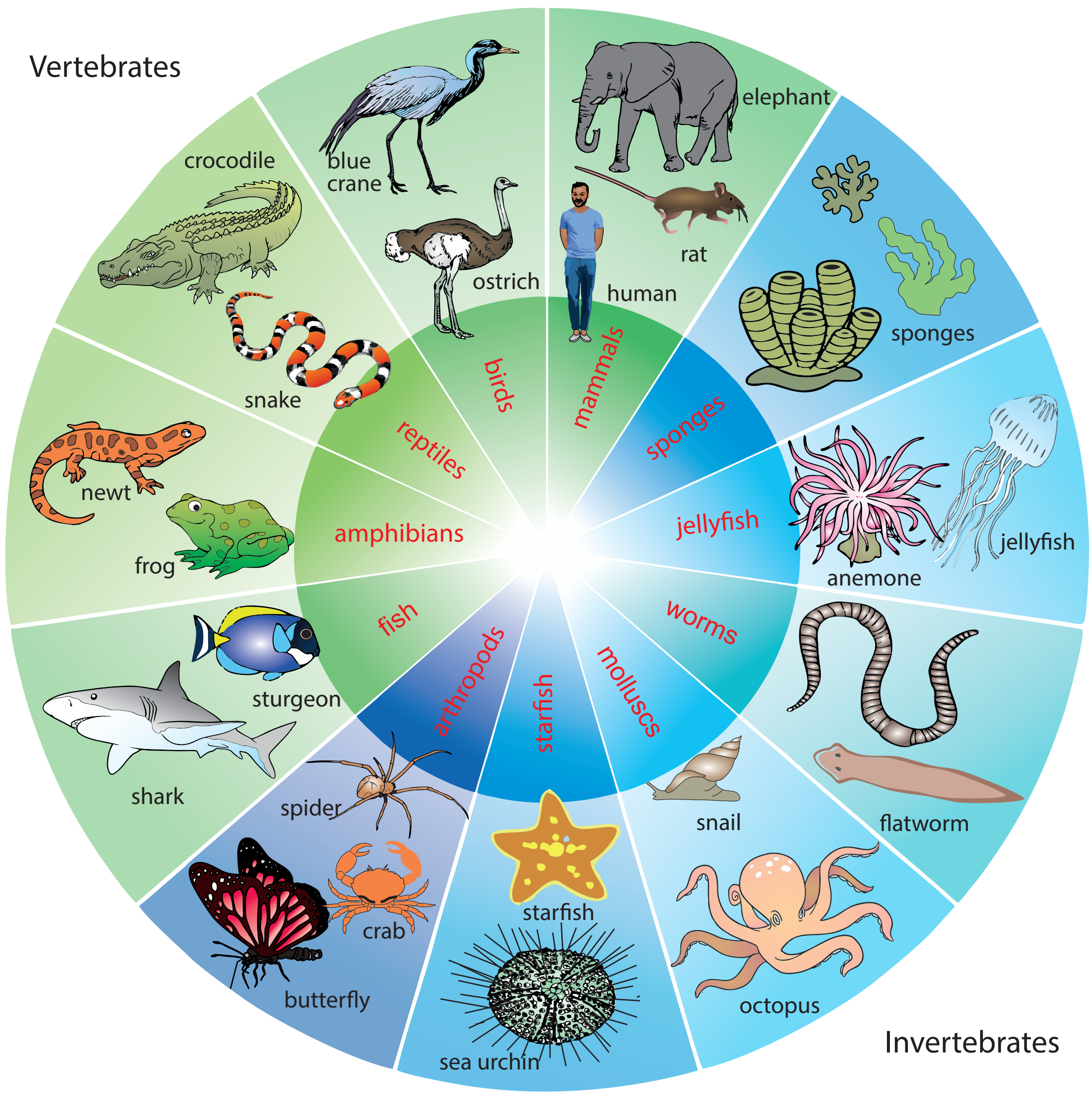
Figure 2.30 Crab

Figure 2.31 Earthworm

Classification of vertebrates and invertebrates

Vertebrates belong to the phylum Chordata. Vertebrates are subdivided into five classes.

Have a look at the following diagram which shows the different classes of vertebrates and phyla of invertebrates. Remember, all vertebrates belong to the phylum Chordata.



ACTIVITY Identify the five classes of vertebrates

Instructions

1. Study the previous chart showing vertebrates and invertebrates and identify the names of the five classes of vertebrates.
2. Collect different picture of different animals that can be classified as vertebrates and invertebrates.

Questions

Identify at least one distinguishing characteristic that each class shares or has in common (that makes that class different from other classes.) Write this on the line next to the classes that you identified above.

Keywords

- amphibian
- cartilage
- ectothermic
- endothermic
- gill
- larva/larvae
- mammary gland

Did you know?

Only about 2% of all the animals on Earth have a backbone.

Did you know?

The coelacanth was thought to be extinct for 65 million years, but was discovered in a catch of fish in 1938. Since then, more have been found along the coast of Southern Africa.

Vertebrates

The five classes of vertebrates are:

1. Fish
2. Amphibians
3. Reptiles
4. Birds
5. Mammals

Fish

Fish come in all sorts of shapes, sizes and colours. There is huge diversity among fish. Have a look at some of the following drawings of different types of fish.

Figure 2.32 Scorpion fish

Figure 2.33 Swordfish

Figure 2.34 Sole fish

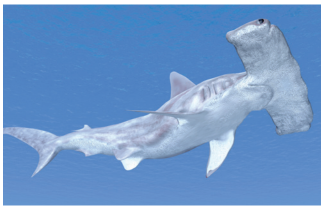


Figure 2.35 Hammerhead shark

Figure 2.36 Puffer fish

Figure 2.37 Goldfish

ACTIVITY Identify defining features of fish

Questions

1. Carefully study the drawings of the fish shown above. Although they are different shapes, sizes and colours, you should be able to identify features common to all fish. List as many of the defining features of fish as you can.
2. Some of the features that you listed might apply to other animals that are not fish. Look at your list again. Make a tick next to any of the features you listed that apply only to fish, or perhaps a combination of characteristics that apply only to fish.

The largest group of all vertebrates are bony fish. Bony fish have a hard, bony skeleton.

Challenge question: Is a seahorse a fish? Search books and the internet to find out and explain why we can or cannot consider it to be a fish.

Figure 2.38 A sea horse

Amphibians

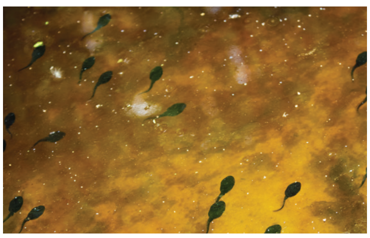
Did you know that the word 'Amphibia' comes from two Greek words, 'amphi' meaning both, and 'bios' meaning life? So an amphibian is an animal that has 'both lives'. What does this mean?

Amphibians are animals that include salamanders, newts, caecilians, frogs and toads. Let's find out what is meant by amphibians having 'both lives'.

ACTIVITY Describing amphibians

Instructions

1. Study the photos of different amphibians in the following table.
2. Answer the questions which follow.

Amphibian	Larvae (young)	Adult
Frog		

Did you know?

A whale shark is a shark and not a whale. It is the world's largest fish and eats only plankton.

Did you know?

The male seahorse actually becomes pregnant! The female squirts her eggs into the male's pouch and he then fertilises them and incubates them until they are ready to hatch.

Did you know?

A group of birds is called a flock, a group of cattle is called a herd, a group of lions is called a pride, but a group of frogs is called an army.

Did you know?

Salamanders can regenerate (regrow their limbs and tail) within a few weeks if they are lost due to predator attacks.

Did you know?

You can tell the difference between frog eggs and toad eggs because frogs lay their eggs in clumps and toads lay their eggs in strings. Have you ever seen frog or toad eggs?

Toad		
Salamander		
Newt		

Questions

1. What do you notice about the habitat of the young amphibians compared to the adult amphibians?
2. What do you think the larvae need to breathe underwater? What do the adult amphibians need to breathe when they are on land?
3. Can you now explain why amphibians have a name which comes from two Greek words and means 'double life' or 'both lives'? Write your explanation below.
4. Amphibians are ectothermic. Explain how an amphibian keeps its body warm.
5. Most amphibians have a slimy, moist skin. Discuss possible reasons why they need to have this specific type of skin.
6. Is a caecilian a snake, a worm or an amphibian? Give distinguishing characteristics to support your answer.
7. Caecilians lay their eggs in water, like this frog. Why do you think they need to do this? Give two reasons.

Figure 39 A caecilian that lays eggs

Reptiles

Reptiles have survived on Earth for millions of years. The first reptiles on earth lived 310 to 320 million years ago and included the dinosaurs.


Figure 2.39 A lizard lying in the sun to warm up

Most reptiles live on land although some, like crocodiles, terrapins and turtles, and some snakes and lizards spend large portions of their lives in water. Reptiles are ectothermic. They cannot regulate their body heat but depend on their environment for heat.

Reptiles are covered in dry scales. Reptiles reproduce by laying their eggs on dry land. The eggs are covered by a leathery or hard shell.

ACTIVITY Reflect on reptiles

Questions

1. Complete these sentences.
   a) Since reptiles all have a backbone they are one of the classes of …………….
   b) Reptiles are ectothermic which means that …………………..
2. Draw and label a lizard.
3. We can divide reptiles into four main groups. Each of the photos in the table below shows an example of a reptile from each of these groups. Try to identify the four groups based on the animal in the photo.

Did you know?

Turtles are found only in the sea, terrapins are found in fresh water, and tortoises do not swim around, but walk on land.

Birds

Figure 2.40 The blue crane is South Africa's national bird.

ACTIVITY Identify characteristics of birds

Instructions

1. Work in groups of three.
2. List the identifying characteristics of birds following these steps:
3. Do you remember learning about birds in previous years? Work with a different group and brainstorm identifying characteristics of birds. Study the photo of the blue crane above for some clues.
4. Use one specific colour to list the characteristics that your group can think of.
5. As you learn more about characteristics of birds add these in a different colour to help you remember the new characteristics.

Questions

1. Birds are one of the five classes of vertebrates. Write a sentence to explain what all vertebrates have in common.
2. Just like mammals, birds are also **endothermic**. What does this tell us about their bodies?
3. What type of body covering do all birds have in common?
4. Is it accurate to say that birds have wings and can therefore fly? Explain your answer. What would be a better way to write this statement?
5. Study the pictures of these flightless birds and compare them with the flying birds in the next column. Use the pictures to write a paragraph explaining the observable differences between flightless and flying birds and why you think these characteristics help some to fly and others not.

Flightless birds	Flying birds
	
Ostriches	An albatross
	
Penguins	A hummingbird

Did you know?

While the larger cats (lion and leopard) prefer to hunt at night to avoid overheating, cheetahs hunt in the middle of the day. There is then less chance of their losing their catch to the larger cats.

Mammals

Mammals are vertebrates, meaning that have a backbone. Almost all mammals are endothermic. This means they are also able to maintain (keep) their body temperature at a constant level.

Mammals give birth to live young which are fed milk. The milk is produced by the mother's **mammary glands** (in the teats or breasts). Mammals also have hair on their bodies. This varies greatly between mammals. Mammals also have teeth that look different in different parts of the mouth.

Figure 2.41 Kittens drinking milk from the mother cat.

Figure 2.42 A seal pup suckling from its mother.

Did you know?

The Naked Mole Rat has lost the ability to regulate its body temperature, while other mole rats have weakened abilities to do this since they live underground in areas where the temperatures are generally very stable.

Figure 2.43 Lions are mammals.

Figure 2.44 A warthog is a mammal.

Take note

'Thermic' means to do with temperature and 'endo' means inside, so mammals are endothermic as they can regulate their body temperature from the inside.

All mammals breathe using lungs. Many mammals therefore live on land. Those mammals that do live in water, such as whales and dolphins, have to come to the surface of the water to breathe.

Figure 2.45 Dolphins surfacing to breathe air

Now that we have studied the five main classes of vertebrates it is easy to compare them!

Keywords

- antennae
- arthropod
- exoskeleton
- jointed (segmented) limbs

ACTIVITY Comparing vertebrates

Instructions

1. Use the table below to compare the vertebrates shown in the photos based on the features in the first column.

	Tortoise	Chimpanzee	Frog	Guinea fowl	Goldfish
					
Class					
Skin covering					
How babies are born					
Habitat					
Ectothermic or endothermic					
Distinguishing features					

Now that we have looked at all the classes of vertebrates, let's have a look at the invertebrates.

Invertebrates

What should you look out for when you have to decide if an animal is an invertebrate?

- All invertebrates do not have a backbone. They either have a hard outer shell or a fluid-filled structure that acts as a skeleton (for example jellyfish and slugs).
- All invertebrates are ectothermic.

Did you know that 98% of the animals on Earth are invertebrates? Due to the huge diversity in the invertebrates, it can sometimes make classifying them a bit tricky. The invertebrates are divided into several phyla. Some of the invertebrate phyla are:

1. Molluscs (for example snails and octopuses)
2. Arthropods (for example insects, spiders and crabs)
3. Echinoderms (for example sea urchins and starfish)
4. Cnidaria (for example jellyfish)
5. Porifera (sponges)
6. Annelids (segmented worms)
7. Platyhelminthes (flatworms)

There are also some other phyla. As you can see, the invertebrates are a very large and diverse group of animals. We are only going to focus on two phyla, Arthropods and Molluscs.

The word *arthropod* comes from two Greek words *arthron* meaning 'joint' and *podos* meaning 'leg', so together it means 'jointed legs'. Arthropods have an exoskeleton and they have jointed (segmented) limbs.

Let's now find out more about Arthropods!

Arthropods

The invertebrates that fall into the phylum Arthropoda all have a hard outer covering called an exoskeleton. The exoskeleton protects the animal and provides a place for its muscles to attach and function.

Take note

Centipedes are venomous and have a very painful sting!

Did you know?

The mosquito is responsible for more human deaths each year than any other animal on earth! Malaria is carried by mosquitoes and passed to humans when an infected female bites.

ACTIVITY Classifying arthropods

Instructions

1. Study the photos of different arthropods below.
2. Answer the questions that follow.

Figure 2.46 A spider

Figure 2.47 A prawn

Figure 2.48 A butterfly

Figure 2.49 A scorpion

Figure 2.50 A millipede

Figure 2.51 A centipede

Figure 2.52 A crab

Figure 2.53 A grasshopper

Figure 2.54 A crayfish

Figure 2.55 A dung beetle

Did you know?

The coconut crab (*Birgus Latro*) is the largest land-living arthropod on Earth and weighs up to 4 kg! It can crack whole coconuts with its pincers.

Questions

1. Study the bodies of each of these animals.
   a) Describe how the bodies of the different arthropods look. If you could touch them, what do you think they would feel like?
   b) Do you think their bodies would be warm or cold?
2. Study the legs of the different arthropods.
   a) Describe how the legs of the different arthropods look in general.
   b) How are the legs able to bend?
   c) One way to classify an arthropod is to count its legs and to group these animals according to this. Count the legs on each of these arthropods and write their names in the appropriate column in your exercise books using the table below. You will know the groups they belong to.

Insects = 6 legs	Arachnids = 8 legs	Crustaceans = 10 legs	Diplopodia and Chilopoda = many legs

3. As you probably noticed, an arthropod's body is covered by a hard exoskeleton. Explain how you think an arthropod can grow and get bigger since the hard exoskeleton cannot grow with it.
4. What habitat would you say most crustaceans live in? How does this differ from the habitat of the other classes of arthropods?
5. Which class of arthropods has wings? Do all of the animals in the class have wings?

Molluscs

Molluscs are a very diverse phylum of invertebrates. They have a huge range of body shapes and sizes. Molluscs are often given a general description, which is that they have internal or external shells and a single muscular 'foot'. However, there are lots of molluscs which do not strictly fit this description, such as slugs.

The group of molluscs includes snails, squid, octopuses, periwinkles, abalone, mussels, oysters, and other soft-bodied animals.

Figure 2.56 A reef squid

Figure 2.57 An octopus

Figure 2.58 A sea slug (nudibranch)

Figure 2.59 Blue Dragon nudibranch

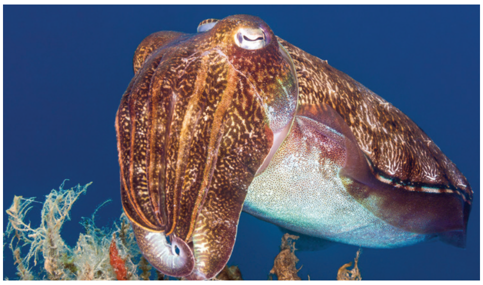


Figure 2.60 A cuttlefish

Figure 2.61 Limpets in a rock pool

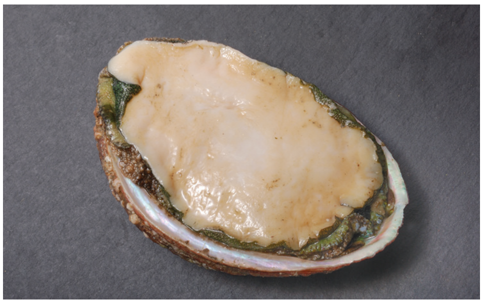


Figure 2.62 An abalone

Figure 2.63 A garden snail

ACTIVITY Observing molluscs

Instructions

1. Carefully study the above photos of different animals that form part of the phylum Mollusca.
2. Answer the following questions.

Questions

1. Identify some characteristics that molluscs have in common.
2. Most of the molluscs shown in the photographs live in the sea. What do you think would happen if these molluscs were exposed to the air for a long time?
3. Walk through the school garden and see if you can find any garden snails. If you do, or perhaps you have seen them elsewhere before, think about their habitat. Describe the areas where you found snails.
4. If possible, collect a few snails to study in class. If you have a glass terrarium or an old aquarium, keep the snails in there, or else keep a few in large, clean, glass jars.
5. Carefully study their bodies and especially their long, slimy foot.
   a) What do you think the slime is used for?
   b) Describe how the snail moves.
   c) How many tentacles (**antennae**) does the snail have? What do you think these are used for?
   d) What markings are on the shell? Why do you think the shell is marked in this particular way?
   e) Try and see if you can find male and female snails. What conclusion can you draw from this.
6. Make a drawing of a snail. Include the following labels: hard shell, foot, head, mouth, tentacle, eyespot.

In this section we will take a closer look at the organisms in the plant kingdom. So how do we classify plants?

2.3 Diversity of plants

We can easily compare plants based on their characteristics. For example, their leaf size and shape, whether there are flowers or not and what the petals look like, the length and depth of the roots and the type of root system, and many others.

One particularly useful way is grouping plants according to how they reproduce sexually. If we group plants based on the way that they sexually reproduce we can quickly see two distinct groups:

- Plants with seeds
- Seedless plants (or spore-bearing plants)

Keywords

- bulb
- rhizome
- roots
- seeds
- shoot
- spore
- stem
- symbiotic

Did you know?

Ferns have been around for about 400 million years. That is even older than dinosaurs, and they are still living on Earth today.

Seedless plants (or spore-bearing plants)

Plants that do not produce seeds include ferns, mosses and algae. These plants produce spores. The spores often develop in structures found on the underside of the leaves or fronds. The spores grow into new plants.

Figure 2.64 A common fern in South Africa

Figure 2.65 The structures that produce and release spores on the underside of a fern leaf

The photo on the right above shows a close-up of the underside of a fern leaf. Can you see the clusters of capsule-shaped structures that form the tiny spores? The close-up photo on the right below shows a moss sporophyte. This contains the spores of the moss plant.

MFigure 2.66 oss growing on the forest floor

Figure 2.67 Close-up of a spore-producing moss plant

Take note

Alga is singular and algae is plural!

Figure 2.68 Lichen growing on a tree

Figure 2.69 Lichen growing on an old rock

Lichen actually consist of two different organisms growing together! A fungus and a green alga grow together in a symbiotic relationship.

The fungus absorbs water from the environment and provides the algae with an environment to grow in. The green algae photosynthesises, providing food for itself and the fungus. Why can the fungus not make its own food? Is the fungus a plant? Can you come up with a definition for a symbiotic relationship? Discuss this with your class and take some notes.

Seed-bearing plants

The other group of plants produces seeds. These plants can either produce seeds in flowers or they can produce seeds in cones. Most plants that you see around you produce seeds. Plants that produce seeds in flowers are called angiosperms and plants that produce seeds in cones are called gymnosperms.

Gymnosperms

Have you ever seen a living prehistoric plant? If you thought about it, you probably have without even realising it!

In South Africa we have plants called cycads that are often referred to as 'living fossils'. Cycads grew in great numbers during the Jurassic period. They have not been around for as long as ferns and algae, but they have been on Earth for longer than all flowering plants. Flowering plants (angiosperms) evolved after gymnosperms.

Figure 2.70 A cycad with cones.

Figure 2.71 Cycads at Kirstenbosch Gardens in Cape Town.

Figure 2.72 This is a gymnosperm plant as it produces seeds in cones.

Can you see the large cones in the photo of the cycad above? They are in the centre of the plant. The cones are made up of many individual seeds. Look at the following close up images of cones.

Figure 2.73 A cycad cone.

Figure 2.74 A cone from a pine tree.

Figure 2.75 A Mountain Cypress.

Take note

Plants can also reproduce asexually by making a clone or copy of themselves. In this way new plants can grow from cuttings and tubers (like potatoes), from **bulbs** and **rhizomes**, or from **shoots** and side branches.

The word gymnosperm means 'naked seed'. Gymnosperms are considered to have naked seeds as the seeds are not covered in a fruit, such as we will see in angiosperm plants.

Another gymnosperm which is native to South Africa, and grown a lot in the Cape, is the Mountain Cypress, as shown in the photo. They grow especially well at high altitudes, such as in the Cederberg Mountains.

There are several species of gymnosperms which are not indigenous to South Africa. What does this mean? Let's find out.

Indegenous and Invasive Plants in South Africa (topic and discussion)

Some examples of indigenous plants in South Africa are aloes, acacia thorn trees, strelitzia flowers, rooibos, and the King Protea. An example is the Jacaranda trees with the purple flowers which are very common in Pretoria.

ACTIVITY Invasive plants in South Africa

Instructions

1. Study the following photograph of an invasive gymnosperm plant in South Africa.
2. Answer the questions that follow.
3. You will need to do some research in books and on the internet.

Keywords

- cotyledon
- dicotyledon
- herbaceous
- leaf vein
- monocoty-ledon
- tap root

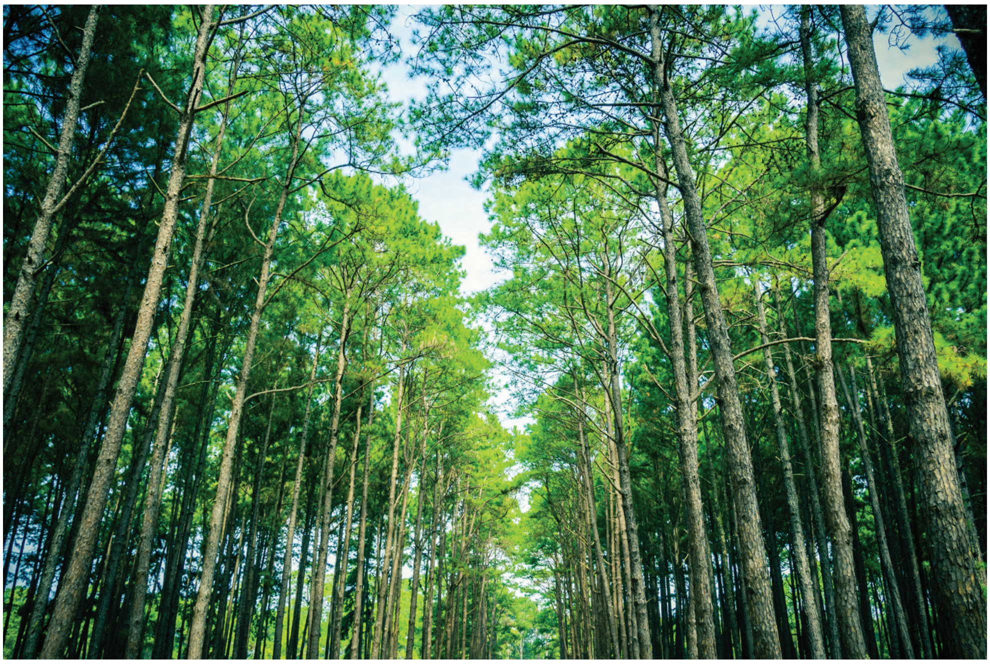


Figure 2.76 Pine trees in Tokai Forest, Cape Town

Questions

1. Find out what it means if a plant is indigenous to South Africa.
2. What is an alien species? Why do we call it invasive?

3. How do gymnosperm plants reproduce?
4. In many parts of South Africa, plantations of pine trees are regulated so that they do not impact on the biodiversity of the indigenous plants. But there are some forests of pine trees which are not used for timber anymore. The Tokai Forest in Cape Town is one of these. Many mountain bikers and runners enjoy doing their activities in this forest. The city of Cape Town started to clear these trees in 2011 so that they could get natural, indigenous fynbos to grow again. There was an outcry from some people as they said their shady riding spot had been ruined. What are your thoughts on this? Do you think Cape Town should, be cutting down these trees or not? Give reasons for your answer.

Did you know?

South Africa is considered a diversity hotspot for cycads. Along with Australia, Mexico, China and Vietnam, we account for 70% of Earth's cycad species.

Angiosperms

Angiosperms are flowering plants. They produce flowers which develop into seeds that can grow into new flowering plants. We will learn more about reproduction in angiosperms in the next unit. Most of the plants that you probably see around you in the gardens are flowering plants.

Figure 2.77 This is an angiosperm plant as it produces seeds in flowers.

We can group flowering plants into two major groups:
- monocotyledons
- dicotyledon

Define these terms.

All the angiosperm plants that we are studying have the following characteristics in common:
- roots
- stems
- leaves
- flowers
- fruits
- seeds

A huge thorn tree does not look anything like a maize plant, yet they are both flowering plants. They both have roots, stems, and leaves, and their flowers produce seeds. So why can we group the one as a dicotyledon and the other as a monocotyledon? Let's find out!

ACTIVITY Discovering the differences between monocotyledons and dicotyledons

Instructions

1. Study the photos of South African monocotyledons and then dicotyledons.
2. Answer the questions which follow about each group.

Monocotyledons

Figure 2.78 Maize

Figure 2.79 Sugar cane

Figure 2.80 Agapanthus

Figure 2.81 Bull rushes

Questions

1. Describe the leaves of the monocotyledons in the photos. How would you describe the veins in the leaves? Make a drawing to accompany your description.
2. Describe the stems. Are they woody stems or green (herbaceous) stems?

3. Look at the following photos of typical monocotyledonous flowers. Count how many petals are on each flower. What can you generalise about the number of petals (and other flower parts) in monocotyledonous flowers?

Figure 2.82 A disa

Figure 2.83 Agapanthus flowers

4. Many of the crops that we grow are monocotyledons, such as maize and sugar cane. Name two others.

Dicotyledon

Figure 2.84 Plumbago bush

Figure 2.85 A geranium

Figure 2.86 Fig tree

Figure 2.87 Protea bush

Questions

1. Describe the leaves of the dicotyledons in the photos. How would you describe the veins in the leaves? Make a drawing to accompany your description.
2. Describe the stems. Are they woody stems or green (herbaceous) stems?
3. Look at the following photos of typical dicotyledonous flowers. Count how many petals are on each flower. What can you generalise about the number of petals (and other flower parts) in dicotyledonous flowers?

Did you know?

Hydrangea flowers can tell us about the soil acidity! An acidic soil (pH below 7) will normally produce blue flowers, whereas an alkaline soil (pH above 7) will produce more pink flowers.


Figure 2.88 Geranium flowers


Figure 2.89 Plumbago flowers

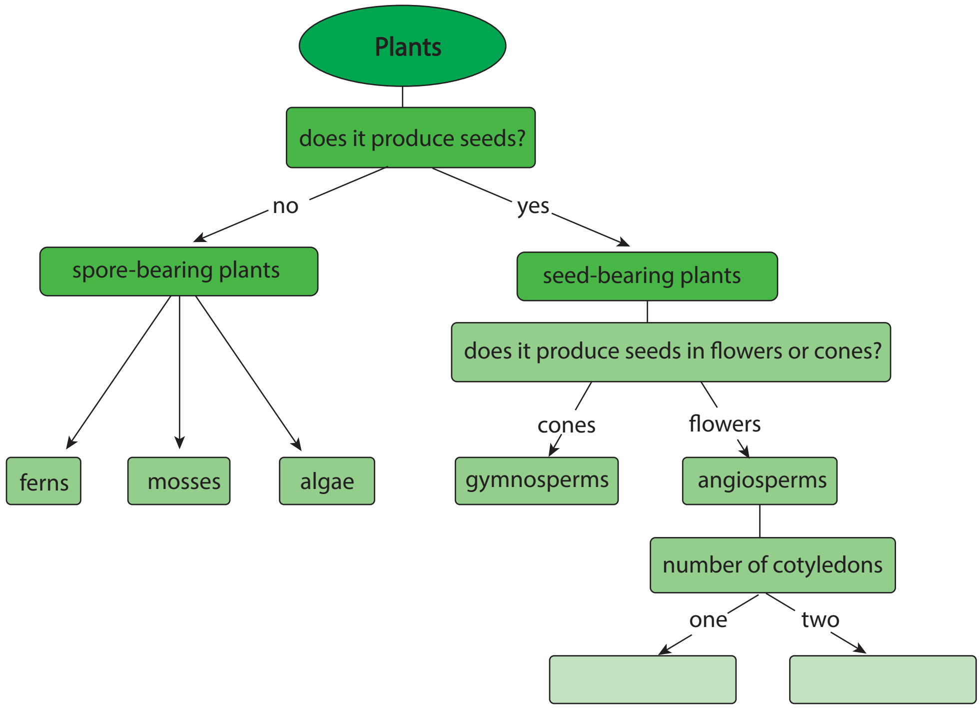

Figure 2.90 Hibiscus flower


Figure 2.91 Hydrangea flowers

4. Look at the image of monocotyledonous seeds and dicotyledonous seeds. Write the difference between the two.
5. Using the information, you have discovered in this activity, copy and complete the following table in your exercise books to summarise the differences between monocotyledons and dicotyledons.

	Monocotyledons	Dicotyledons
Cotyledons		
Stems		
Flowers		

We can therefore classify plants as follows:



Come back to complete this diagram once we have learned more about angiosperms.

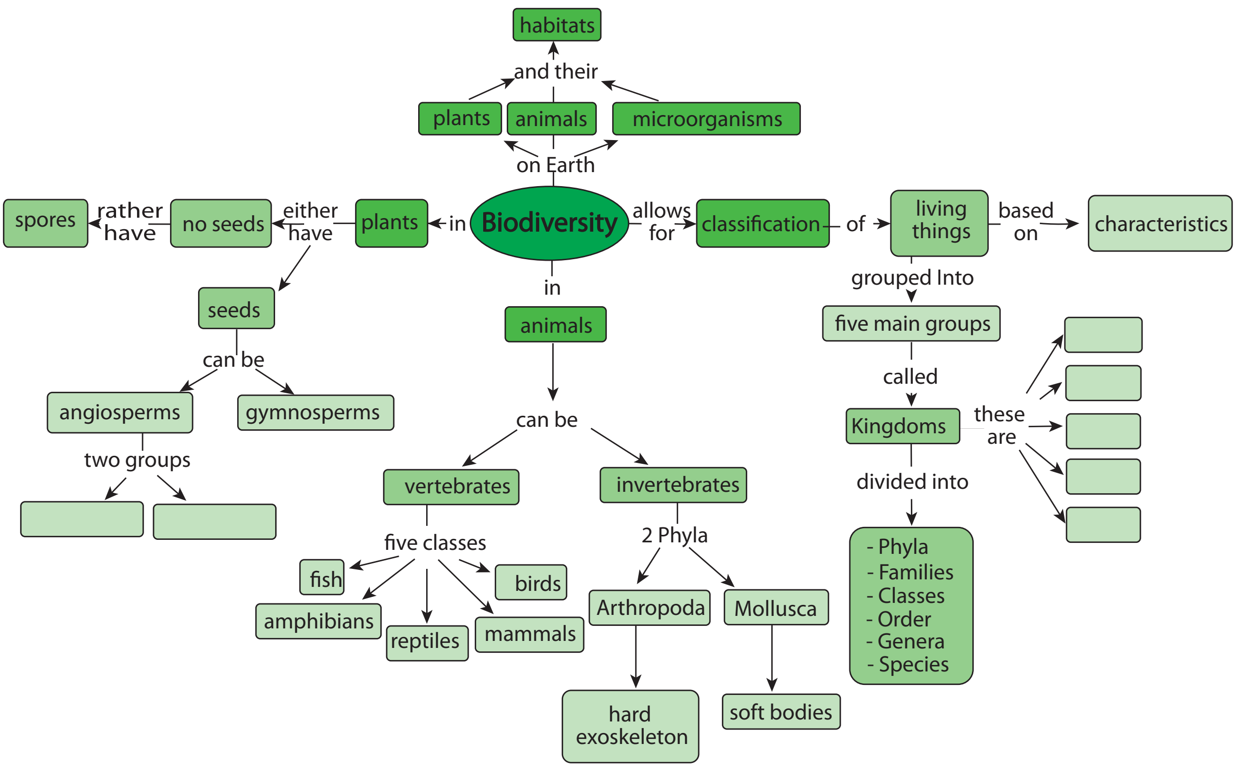
Summary

Key concepts

- All the plants, animals and microorganisms and their habitats make up the total biodiversity of planet Earth.
- Living organisms are sorted and classified according to their shared characteristics.
- We use a classification system that groups living organisms into five main groups or kingdoms: Bacteria, Protists, Fungi, Plants and Animals.
- All living organisms have to perform the seven life processes and the way in which they perform these help us to classify them into different groups, putting plants into one group and animals into another for instance.
- We can divide a kingdom into smaller and smaller groups, in this order: phyla, classes, orders, families, genera and species.
- Animal kingdom, have get two main groups of animals: those with a backbone, called vertebrates, and those without a backbone, called invertebrates.
- The vertebrates are divided into five groups: Mammals, Birds, Reptiles, Fish and Amphibians.
- The invertebrates make up the largest group of animals and there are many thousands of species. We also divide the invertebrates into different groups or phyla like the arthropods, molluscs, sponges and jellyfish, and many others.
- All arthropods have a hard exoskeleton and jointed legs, such as insects, arachnids (spiders) and crustaceans (crabs).
- Molluscs have a soft body with or without a shell, such as snails and octopuses.
- Plant kingdom has, we also get two main groups: plants that produce seeds and plants that do not produce seeds, but spores.
- Seedless plants produce spores, such as ferns and some mosses.
- Seed-producing plants can be further divided into angiosperms (seeds in fruit) and gymnosperms (seeds in cones).
- Angiosperms can be divided into monocotyledons and dicotyledons.
- Monocotyledons have seeds that have only one part or cotyledon. Their stems are herbaceous. The leaves are simple, long and narrow, and their flower parts are arranged in multiples of three.
- Dicotyledons have seeds with two parts or cotyledons from which their tap root grows deep into the soil. Their stems can be woody or herbaceous. The leaves are varied in shape and size and have a network of leaf veins. Flower parts are usually arranged in multiples of four or five.

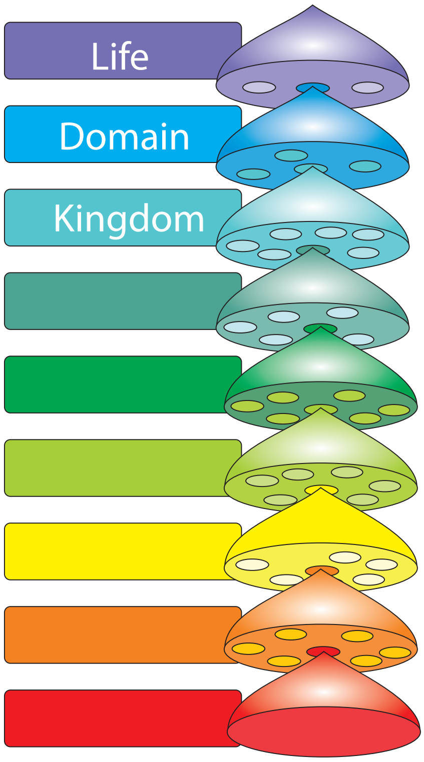
Concept map

This concept map shows how the concepts in this unit on Biodiversity link together. Complete the concept map by filling in the five Kingdoms that living things are classified into, and also giving the two major groups of angiosperm plants. Can you see how the arrows show the direction in which you must 'read' the concept map?



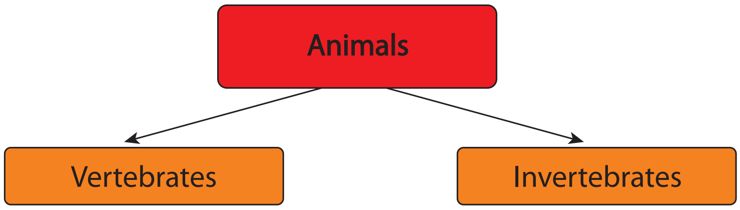
Revision

1. Use the following diagram to fill in how we classify organisms. The first 3 have been filled in as we did not discuss domains in this unit. You will learn more about domains in later grades. [6]



2. Why was Aristotle's method of classifying animals as walkers, swimmers or flyers not very effective? [2]

3. Draw a vertebrates and invertebrates classification diagram of the animal kingdom. Include the phyla and classes that we studied in detail. [11]



4. Give one word for the following or complete the sentence required:
   a) The existence of a large number of different kinds of plant and animal species which make a balanced environment. [1]
   b) The animal kingdom can be divided into two main groups. [2]
   c) The five classes of vertebrates are: [5]
   d) The phylum of animals that have a hard exoskeleton. [1]
   e) The phylum of animals that have a soft body often protected by a shell. [1]

5. Write true or false next to each of the following sentences. If the sentence is false, rewrite it so that it is true. [10]
   a) A small percentage of the living organisms on Earth are invertebrates.
   b) Invertebrate animals do not have a backbone.
   c) Spiders are examples of arthropods.
   d) All molluscs have exoskeletons in the form of shells.
   e) Birds have only feathers as their body covering.
   f) Endothermic animals need to keep very still when it is cold.

6. Look at the following sentences and underline the one that best describes mammals. [1]
   a) Mammals are animals that breathe, move, eat, reproduce and excrete.
   b) Mammals are animals that can regulate their body temperatures.
   c) Mammals are warm-blooded animals that feed their young and have special organs for breathing and a backbone.
   d) Mammals are warm-blooded animals with mammary glands, a hairy body, lungs and a backbone.
   e) Mammals give birth to live young, can be found living on land and in water, and can sense their environment with well-defined smell and touch senses.

7. Describe how the seeds of angiosperms differ from those produced by the cycads. [2]

8. Draw a classification diagram of plants. [10]

9. Differentiate between monocotyledons and dicotyledons by completing the table below:

Characteristic	Monocotyledons	Dicotyledons
Roots		
Stems		
Leaves		
Flowers		
Seeds		

[10]

Total [62 marks]

3 Sexual reporoduction

Key questions

In angiosperms

- How do plants make seeds?
- What is the role of flowers in reproduction?
- Flowers come in so many different colours, shapes and sizes. So, are there some structures that are common to all flowers?
- What is a 'pollinator'?
- Why are pollinators also important to humans?
- Is the flower on a rose the same as the flower on a sweet pea or on a daisy bush?
- Why are seeds in different shapes and sizes, or contained in fruits? Does it have something to do with the way seeds are spread to new areas?
- Does fertilisation mean the same things in plants as it does in animals?

In humans

- Why is your body starting to change?
- What is puberty and what does it mean when we "reach puberty"?
- How is it possible that we all go through puberty at different times and rates?
- What changes take place inside our bodies during puberty?
- What do our reproductive organs look like when they are mature?
- How does reproduction occur?
- What is menstruation and why does it occur once a month?
- How does a baby grow inside a woman's uterus?

Keywords

- angiosperm
- asexual reproduction
- cell
- fertilisation
- fuse
- genetic information (DNA)
- mate
- pollen
- pollination
- pollinator(s)
- sexual reproduction

There is a lot of awareness now of HIV/AIDS and STDs, but what exactly can we learn in Natural Sciences to help us lead a safe and healthy lifestyle for the rest of our lives?

All living organisms on Earth need to be able to reproduce so that their species does not become extinct. There are two basic ways in which reproduction can take place:

- asexual reproduction
- sexual reproduction

Asexual reproduction occurs when one parent organism makes offspring which are identical to the parent. The parent organism therefore does not need to **mate** to produce new organisms. Archaea, Bacteria, Fungi and Protists reproduce asexually. Many plants and algae reproduce asexually and also some animals, such as some species of insects, reptiles, sharks, snails and crustaceans.

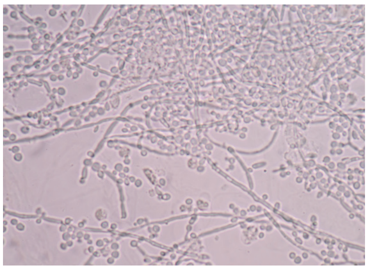


Figure 3.1 These yeast cells are undergoing budding, a type of asexual reproduction. Can you see the smaller offspring 'budding' off the parent?

Figure 3.2 A mother aphid with offspring which were produced asexually or sexually, depending on the conditions.

In this unit we are going to learn about sexual reproduction where two parent organisms mate and their genetic information (DNA) combines to make offspring which look similar, but they are not identical. Sexual reproduction takes place in most plants and animals. We will look at flowering plants (angiosperms) as an example of sexual reproduction in plants and at human reproduction as an example of reproduction in animals.

3.1 Reproduction in angiosperms

How do plants make new plants? In this unit we will learn about how angiosperm plants reproduce. Sexual reproduction in angiosperms results in the formation of seeds. Under the right conditions, these seeds will germinate and grow into a new plant.

ACTIVITY Growing a bean plant

Materials

- bean seeds
- paper towel, toilet paper or tissue
- glass jar (or transparent plastic tub/jar)
- water
- measuring tape or ruler

Instructions

1. Place some kitchen roll, toilet paper or tissue in your transparent jar.
2. Insert the bean into the paper and place it against the side of the jar so that you can observe the changes that occur.
3. Add a little bit of water so that the paper towel is damp.
4. Place in an area which gets sunlight.
5. Add a little sprinkling of water every day to keep the paper towel damp.
6. Each day, starting on the day that you plant your seed, measure the length of the bean or height of the bean plant and record it in the following table.
7. Take notes of your observations from day to day. For example, on what day did your bean start to grow roots? On what day did the stem sprout? When did you see the first leaf (or leaves)? How many were there and what did they look like? Copy and use the table below to record your results in your exercise books.

Did you know?

Some species are able to switch between asexual and sexual reproduction, depending on certain conditions, such as whether there is a mate available for sexual reproduction. Aphids are able to do this. This is called heterogamy.

Day	Height of plant (cm)	Comment /notes
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		

Questions

1. What is the term for when a seed starts to grow?
2. What are the requirements for a seed to grow?
3. Use your table of measurement to draw a graph of plant growth (height) over the 14 days of your investigation.

Keywords

- anther
- component embryo sac
- filament
- ovary
- ovule
- peduncle
- petal(s)
- pistil (carpel)
- pollen
- receptacle
- sepal(s)
- stamen
- stigma
- style

External flower structures

Many plants have both the male and female reproductive organs in the same flower, although some may have male and female structures on different plants altogether.

Flowers come in many different shapes, sizes and colours, as in the photographs in the next activity illustrate, but there are components which can usually be identified in all flowers. These are:

- peduce (or flower stalk)
- receptacle
- petals
- sepals
- the male structures
- the female structures.

Flowers are typically set on a stem which may be long and rigid like a rose or agapanthus stem, or short and flexible like those on a petunia. The stalk or stem of a flower is called the **peduncle**.

The **receptacle** is the top part of the flower stalk, where the different flower parts attach.

While the flower bud is forming, small green leaves protect and enclose the young bud. These are the **sepals**. The sepals are often green and look like small leaves, and since they are green they can also photosynthesise. Sometimes the sepals may be the same colour as the petals, like in lilies or tulips.

Flower **petals** are usually the brightly coloured parts of the flower. They attract **pollinators**, such as insects and birds, and also bats and mice. We will look more at **pollination** a bit later. In some plants, such as grasses, the petals are very small and may even be absent. This is often because these flowers depend on the wind to carry the **pollen** away and therefore do not need petals to attract animals.

Figure 3.3 Grass flowers

Did you know?

Sunflowers are in fact composite flowers, made up of hundreds of individual flowers working together. The 'petals' are in fact individual flowers called ray florets, and the centre is made of many disc florets. Each of these has a pistil and stamens.

ACTIVITY Identify the outer structures of flowers

Figure 3.4 Rose

Figure 3.5 Water lilies

Figure 3.6 Petunias

Questions

1. What do we call the part of the stalk where the flower petals and sepals attach to the flower stalk?
2. Explain why the petals on some flowers are brightly coloured, while on other plants we can hardly see the petals, and sometimes they are absent altogether.
3. Study the photos of the different flowers above. Describe the outer structures of each of these flowers based on their peduncles (stalks) and receptacles, and their sepals and petals.

Take note

What are cells? Cells are the smallest building blocks of organisms. There are many different kinds of cells, for example, cheek cells, muscle cells and nerve cells in some animals; or leaf cells, root cells and petal cells in plants.

Take note

Each carpel consists of a stigma, style and ovary. Some flowers have one carpel, and some have many. Therefore, in some flowers, the carpel and the pistil are the same thing, but in others, many carpels make up one pistil!

Internal Structures of the Flower (Reproductive structures)

Male reproductive structures

The **stamen** is the male part of the flower. There are two parts to the stamen: the **anthers** and the **filaments** on which the anthers rest.

Anthers produce the pollen that contain the male reproductive sex cells.

Filaments are stalk-like structures that support the anthers. In some flowers the filaments may be long and in others relatively short.

Figure 3.7 The male structures are clearly seen in this close up photo of a flower with the anthers covered in pollen and supported by the stalk-like filaments.

Female reproductive structures

The **pistil** is the female organ of the plant and is usually at the centre of the flower. It consists of a stigma, style and ovary. All the parts of the pistil work specifically to help the plant receive pollen, transport it, and have it fertilise the **ovules** (wich contain female sex cells). Ovules become seeds after **fertilisation**.

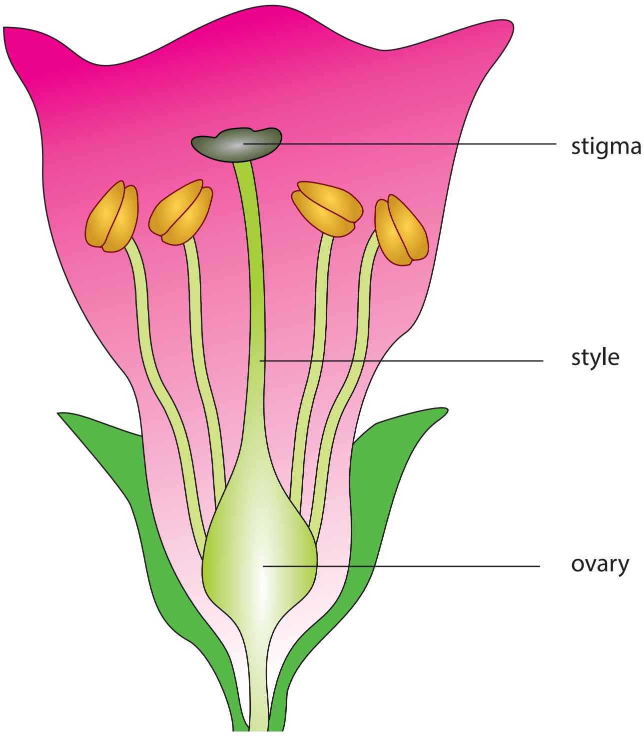


Figure 3.8 The female flower parts making up the pistil.

The **stigma** is the structure that receives the pollen during pollination. It is on top of a long narrow style and when it is ready to receive pollen it becomes sticky providing a place for the pollen to stick to.

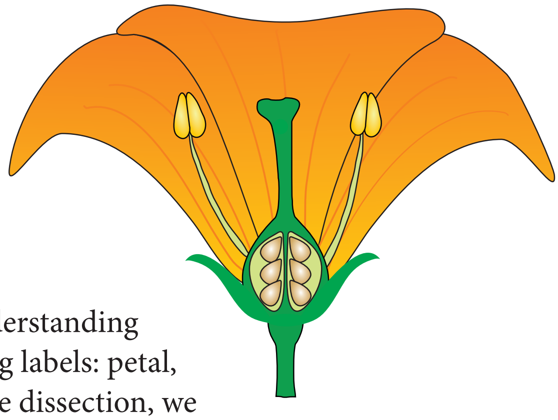
The **style** is a long tube that connects the stigma with the ovary and the ovules. The style supports the stigma and holds it in the best possible position to receive the most pollen grains. After the pollen has landed on the stigma, the pollen grows long tubes called pollen tubes down through the style from the stigma to the ovules in the ovary.

The **ovary** is the enlarged structure at the base of the pistil. It may be divided into different parts (or locules) and produces the ovules that contain the female reproductive sex cells. Within the ovule is the **embryo sac**. The embryo or tiny seed will develop in here.

ACTIVITY Flower dissection

Materials

- dissecting needle
- dissecting knife
- petunia or hibiscus flowers



Instructions

1. Study the following diagram of a flower. Use your understanding of the **outer structures** of a flower to add the following labels: petal, sepal, receptacle and peduncle. Once we have done the dissection, we will come back to label the inner structures.
2. Go out into your garden or explore the school grounds and surroundings and select a flower of your own to dissect. If your teacher has petunias or hibiscus flowers, dissect one of those.
   a) First remove the outer sepals.
   b) Then remove the petals. You have now exposed the ovary.
   c) Identify the male and female structures. Label these on the diagram above.
   d) Using your dissecting knife or scalpel, cut the ovary in half.
   e) Use the dissecting needle to carefully open up the ovary. See if you can identify the ovules.
   f) Label the ovary and ovule on the above diagram.

Questions

Can you identify the stamens covered in pollen and the stigma in this hibiscus flower?

Now that we have learnt about the structures of flowers, let us take a look at how flowers are pollinated.

Pollination

In order for a flowering plant to reproduce sexually, the male sex cells need to fuse (join) with the egg inside the ovules. The stamen produces pollen that contain the male sex cells. The pollen grains are usually very small – about the size of a speck of dust.

Figure 3.9 This person's hand is covered in millions of tiny grains of pollen.

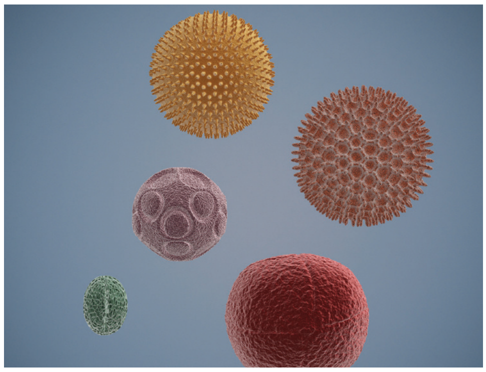


Figure 3.10 A photograph of a variety of pollen grains from different plants taken under a very strong microscope

Pollen from the stamen needs to be transferred to the stigma of the flower, on either the same plant or another plant of the same species. This process is called **pollination**. If pollination does not occur, there will be no fertilisation and the plant will not be able to produce seeds or fruit.

Generally, plants produce a large amount of pollen to maximise the chances of the pollen being transferred to as many different stigmas on as many different flowers (of the same species) as possible.

Pollination involves the pollen moving from the stamens to the stigma of the same or another flower. There are different ways that pollination of flowers can take place. For example, flowers can be pollinated with the help of the wind, water or animals. Angiosperm flowers have special adaptations which help a specific type of pollination. Let us look at some of these methods for pollination and how flowers are adapted to promote pollination.

Pollination by animals

Figure 3.11 Can you see this bee has been covered in pollen as it is feeding on the nectar?

Animals that pollinate flowers are called pollinators. These animals come to flowers to feed on the nectar produced by the flowers. As they are feeding, pollen sticks to their bodies. When they move on to the next flower to feed, some of the pollen rubs off onto the new flower parts. We call this process pollination.

Since pollinators feed on specific plants, they usually travel from flower to flower of the same species, therefore pollinating them effectively.

ACTIVITY Identifying pollinators

Instructions

1. There are many different types of pollinators, some of which are shown below.

Questions

1. Identify the pollinator in each photo in the table and write the name down.
2. What do you notice about most of these pollinators? (Which type of animal is most common?)
3. What do you think these pollinators are getting from the flowers that they visit?
4. What do you think attracts insects to flowers? In other words, how do you think flowers are adapted to attract pollinators to them? See if you can think of three adaptations and list them below.

Did you know?

There is a direct relationship between the length of the tongue or beak of the main pollinator and the length of the nectar pouch in the flower! This is a very good example of natural selection at play. You will learn more about that in the last unit of this term's work.

Did you know?

Some animals can see only certain colour ranges. Although butterflies, birds (and humans) can see red, bees cannot see red colours but they can see ultraviolet (UV) rays. Some flowers adapt their petal colours especially for this reason to attract different insects.

5. Flowers are also adapted so that when the pollinators visit them, they make sure the pollen rubs off onto the pollinator to be transferred to another flower. Look at the image of a bird visiting a flower to drink nectar. How do you think this flower is adapted to make sure that it is pollinated by the bird?
6. Unlike the flowers we have looked at so far which give off a sweet scent to attract pollinators, the flower called a Voodoo Lily below gives off a really bad smell, like rotting meat or cow dung. The colour of the petals is also dark, like meat. This shows that different flowers have adapted to different pollinators.
   What types of pollinators do you think will pollinate this flower? Hint: Think of which insects you normally find when there is rotting food around.

Figure 3.12 A bird drinking nectar from a flower

Figure 3.13 A Voodoo Lily

6. Work in pairs for the next 4 questions. Take a walk around your school and identify plants that you think are pollinated by pollinators. Make a drawing of at least 3 of these.
7. Identify the common names of these plants and try to find the correct scientific name.
8. Explain how each of these plants' flowers have been adapted to be pollinated by pollinators.
9. How could you easily distinguish which plants used pollinators to pollinate them?

Pollination by wind and water

Many flowers are pollinated by animals, as we discussed in the last section, but wind and water can also help pollination.

There are some challenges that plants face if they rely on the wind or water for pollination. These plants have adapted to overcome these challenges so that they can be pollinated by the wind or water.

Plants that are pollinated with the help of water usually live in water. We say they are aquatic. When pollen is released it floats on the surface of the water. The stigmas of the receiving plant are generally close to the water surface. This is so that they can be pollinated when the pollen in the water washes up against them.

ACTIVITY Studying the flowers of wind- and water-pollinated plants

Instructions

1. Study the following photos of the flowers of different types of grasses that are pollinated with the help of the wind.

Figure 3.14 In this grass plant you can see the small yellowish flowers attached to the green stem.

Figure 3.15 These white, feathery ends are the flowers of this grass.

Figure 3.16 Can you see the small, brown flowers sticking up from the maize plants? These are the male flowers of maize.

Figure 3.17 This image shows the silky female flower of the maize plant.

Questions

1. Write a description of the flowers in the photos. Your description must show that you have observed the colour of the flowers, the size, the shape, and how many there are on each plant.
2. Why do you think these flowers are not colourful like the flowers in the previous activity?
3. Do you think the flowers in wind pollinated plants produce nectar? Why do you say so?
4. What types of plants are generally pollinated by the wind?
5. The flowers in these photos generally produce a huge amount of pollen. They produce much more pollen compared to the flowers pollinated by animals. Why do you think this is so? Hint: Think of the chances of a flower being pollinated by an animal which visits it to drink nectar, compared to the chances of being pollinated by pollen that is carried in the wind.

6. In animal-pollinated flowers, the pollen is often sticky and clumps together. This is so that it sticks to the animal which is visiting the flower for nectar and can then be carried to the next flower. In wind-pollinated flowers, the pollen is very different. The pollen is smooth and not sticky. It is also very light and small. Why do you think this is so?
7. The structures of the male and female parts in wind-pollinated and animal-pollinated flowers are also different. For example, in wind-pollinated plants, the stamens (male structures) often have much longer filaments, and the anthers hang down and can move easily. The stigmas (female structures) are also often large and look like feathers, as you can see in the photos in this activity. How do you think these adaptations of the stamen and stigma help the flowers to be pollinated by the wind?
8. Copy the table below into your exercise books and complete it. Use the results to compare the structures of wind-pollinated plants and pollinator- (animal-) pollinated plants.

Structure	Wind-pollinated plants	Animal-pollinated plants
Petals		
Scent		
Nectar		
Amount of pollen		
Structure of pollen		
Anthers		
Stigma		

9. Do you think plants that are pollinated by the wind or water need colourful, sweet-smelling flowers with nectar? Why do you think this?

Plants that are pollinated with the help of water usually live in water. We say they are aquatic. When pollen is released it floats on the surface of the water. The stigmas of the receiving plant are generally close to the water surface. This is so that they can be pollinated when the pollen in the water washes up against them.

Pollinators and us

Pollinators play an extremely important role in the life cycle of flowering plants. These flowering plants include the crops that farmers grow for us to eat, such as maize and sunflowers. Since angiosperms produce a very large amount of the world's food crops, without pollinators, we would be without most of the food crops produced for us to eat.

ACTIVITY Article from *The Earth Times*

Instructions

1. Imagine it is the future – it is the year 2056!
2. Read the following article from a newspaper called *The Earth Times*.
3. Answer the questions that follow.

Loss of pollinators lead to crop destruction – third year of famine

23 May 2056

The loss of pollinators in Southern Africa, specifically wild bees and butterflies, has led to further crop failures three years in a row. Very few viable seeds remain to plant the next crop. The next crops planted may be the last ones unless another means of pollination can be found.

The entire region has been severely affected by the sudden death of large swarms of bees and butterflies in the past 5 years. Bees and butterflies, which were once so common, are almost extinct.

One group of researchers has been working to preserve the last remaining colony of bees. It was found hidden away in the mountains of the Helderberg Nature Reserve. So far they report that the colony is doing well they and have added 127 new worker bees this week. It is hoped more colonies will be found in other remote mountain regions.

The researchers are still trying to identify the cause of the extinction of these insects. They think that the huge increase in air pollution and acid rain has affected the wings and flight of these insects. They are therefore not able to fly to food sources, such as the nectar of flowers, and therefore die.

The lead researcher, Dr Wimple, has indicated that they have wild bee larvae from other parts of the world which were frozen several years ago to preserve them. The team is now close to reintroducing these bee larvae into the remaining colony. They hope this will increase the diversity of the population. Dr Wimple's team is working closely with other similar teams around the world to find a possible solution.

The team is also looking at ways to modify the crop plants to increase how efficient they are at being pollinated by the wind, for example maize crop plants. They hope that this will increase the production of maize. They need to do this by changing the DNA of the existing crop plants. This is called genetic modification. "It's a long shot, but one we hope will bear fruit," commented Dr Wimple.

Figure 3.18 Bees, and other pollinators, are dying as a result of air pollution.

Questions

1. Find the following words in the article and underline them. Then look up a definition for each word and write it down. Identify whether the word is a noun, verb, adverb or adjective. Do not copy the definition word for word, but write it in your own words.
   a) famine:
   b) failure:
   c) severely:
   d) extinct:
   e) preserve:
   f) remote:
   g) diversity:
   h) modify:

Keywords

- disperse
- pollen tube

2. Write down the title of this article.
3. What is the message that is brought across by the title and article?
4. Explain what the link is between the loss of pollinators and crop failures.
5. Which specific pollinators were lost?
6. What reason did the article provide for the loss of these pollinators?
7. Explain at least two ways in which the structure of wind-pollinated plants' is adapted for wind-pollination.
8. How do you think the researchers could modify the crops' flowers so that they are able to be pollinated more efficiently by wind?
9. Do you think the situation described in this article could happen in the future? Write a paragraph where you explain your reason for your answer.

Fertilisation

We have now looked at pollination, but what happens next? What happens after the pollen lands on the stigma of the flower?

Take note

An ovary can contain more than one ovule. If each ovule is fertilised, then the fruit will contain more than one seed. For example, think of an apple which has a few seeds inside the fruit.

Do you remember that the pollen grains contain the male sex cells, and the ovary contains the ovules or female sex cells? The male and female sex cells each contain only half of the genetic material (DNA) from the parent plant. After pollination, the male sex cell in the pollen grain needs to fuse with a female sex cell in the ovary to produce a fertile seed. This is called fertilisation.

In angiosperms, each pollen grain contains two male sex cells. See if you can identify the reason for this as you read through the steps for fertilisation.

The process of fertilisation in plants occurs in clearly defined steps:

1. After the pollen grain lands on the mature stigma of a flower from the same species, the pollen produces a tube called a pollen tube.
2. This **pollen tube** starts to grow from the stigma and down the style. This transports the male sex cells to the ovules.

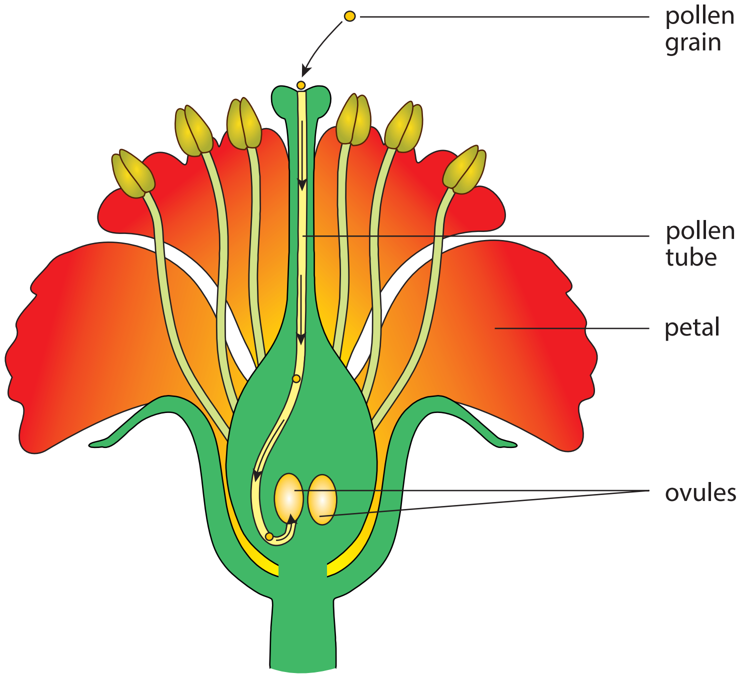


Figure 3.19 The pollen tube growing down the style to the ovary.

3. There is a small structure inside the ovule called the **embryo sac**. When the pollen tube bursts into the ovule, one of the male sex cells fertilises the female sex cell in the embryo sac.
4. This fertilised egg develops into a seed.
5. The other male sex cell joins with another cell in the embryo sac to form the **endosperm**. The endosperm is the starchy food that is stored in the seed once it has ripened. Later this food is used to feed the germinating seed until it has formed leaves and can produce its own food through photosynthesis.
6. The ovary then starts to swell and enlarge, and becomes a fruit.

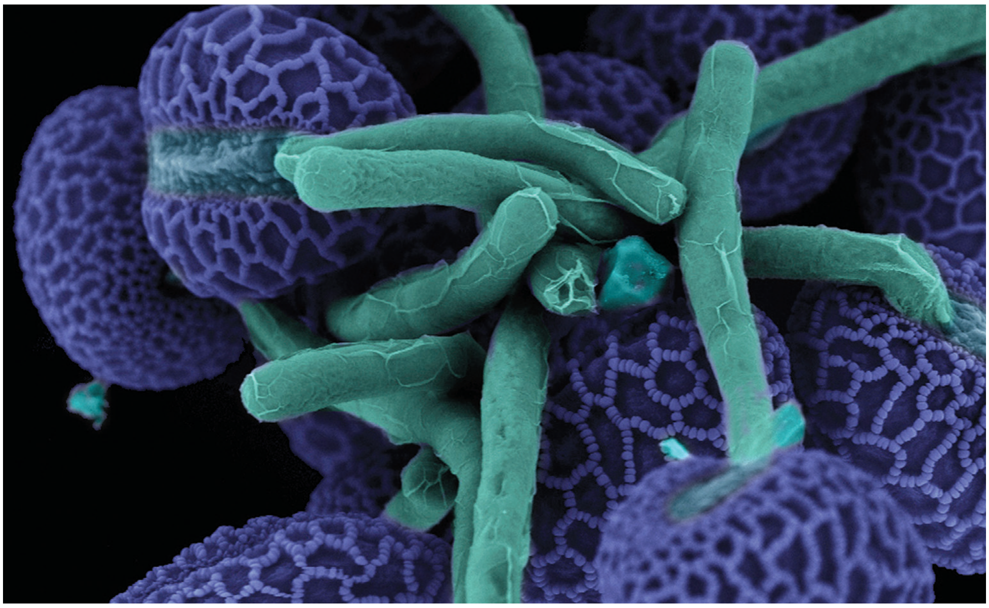


Figure 3.20 Can you see the pollen tubes growing here from individual pollen grains?

After fertilisation, the ovule inside the ovary starts to develop into a seed and the ovary wall becomes the rest of the fruit. There is huge variety in the types of seeds and fruit in the world.

Figure 3.21 This is one seed from the Coco de Mer plant, and it has been cut in half.

Figure 3.22 Seeds from different orchid species. They are really small – like dust particles.

Think about all the different fruits that you can buy in the shops – there are many different shapes, sizes and colours!

Did you know?

There is a direct relationship between the length of the tongue or beak of the main pollinator and the length of the nectar pouch in the flower! This is a very good example of natural selection at play. You will learn more about that in the last unit of this term's work.

Did you know?

The Coco de Mer seed is larger than the size of the human head!

Keyword

- gravity

Figure 3.23 There are many colours, shapes and sizes of fruit!

This is because the seeds need to be spread to other areas to grow into a new plant. The shapes and structures of seeds help with this, and so too does the fruit. We say the fruit and seeds are dispersed. Let's look at some ways that seeds can be dispersed.

Seed dispersal

Plants use different methods to disperse their seeds as far from the parent plant as possible. Why do you think seeds need to be dispersed? Discuss this with your teacher and your class and take some notes.

Different plants have different ways of dispersing the seeds and fruit. Let's have a look at some of these.

Did you know?

The tiny hooks on seeds and burrs that stick to fur inspired the design of Velcro. One part of Velcro tape hooks into the other part of the Velcro tape in just the same way as seeds hook into fur.

Gravity: Fruit can fall off a tree and roll as far as possible from the parent tree. When the fruit has fallen it can be taken further from the parent plant by water, by rolling along the ground, or by animals.

Animals: Animals may eat the fruit from the plant or the fallen fruit, and carry the seeds in their digestive systems. The seeds have a tough outer covering so that they are not digested by the animal. Some seeds also have spiky structures that can stick to the fur of animals. They are then carried along as the animal walks and drop off later.

Figure 3.24 Many wild animals love to eat the fruit from the marula tree, such as this elephant, which has pushed the tree over to get to the fruit. The seeds are dispersed later far away in the elephant's dung.

Explosive force: In some plants their seed capsules mature and then 'explode', shooting the small, light seeds far away from the parent plant.

Figure 3.25 The seed pods of jewelweed (shown on the left) explode when they are touched (shown on the right) and shoot out the seeds to disperse them.

Did you know?

The Sandbox tree that grows in the Amazon Rain Forest can fling its seeds anything from 45 to100 m away at speeds of up to 252 km/h!

Wind: Wind dispersal requires very light, small seeds that can be carried on the wind. Some seeds have 'wings', such as dandelion seeds that can be carried across great distances by the wind.

Figure 3.26 Dandelion seeds are dispersed by the wind.

Figure 3.27 A mangrove seed floating in the water.

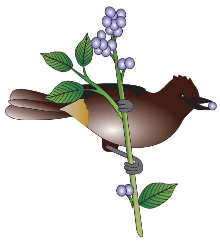
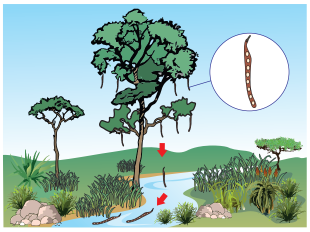
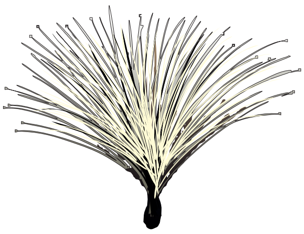
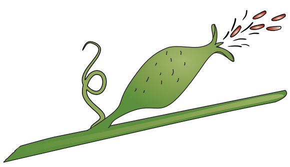
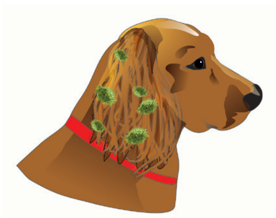
Water: Plants that grow in or near water use the water to disperse their seeds. Mangrove seeds start to germinate while still on the parent plant, then drop into the ocean and wait until the sea washes them onto a shore, where they can continue germinating and growing.

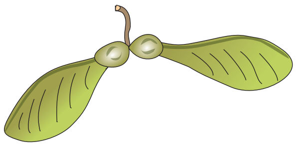
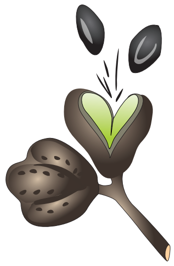
Do you remember how we spoke about the different flower structures and how they are adapted for pollination by either animals or wind or water? In the same way, the seeds and fruit are adapted for their method of dispersal.

ACTIVITY Studying different kinds of seeds

Instructions

1. Look at the following table which contains different kinds of seeds. Each one is dispersed in a different way.
2. In the second column, state how the seed or seeds are dispersed (for example, by an animal, by the wind, by water, and so on.)
3. In the third column, write a couple of sentences describing how you think this seed is adapted for dispersal. You need to think about what would most help this seed to be dispersed.

Seed	How is it dispersed?	What adaptations does the seed or plant have for dispersal?
		
		
		
		
		

Seed	How is it dispersed?	What adaptations does the seed or plant have for dispersal?
		
		
		

We have now finished looking at how angiosperm plants reproduce. We are now going to look at how animals reproduce. Specifically, we are going to look at how humans reproduce so that we can learn about our own bodies and how they function.

Keywords

- hormone
- maturing
- menstruation
- penis
- puberty
- sperm

3.2 Human reproduction

If you look around at your Grade 7 classmates, you will probably notice that your friends, and you, have changed quite a bit since you started Grade 1. Apart from growing taller, changing hairstyles, or changing the way you dress, your bodies are changing and growing up. We say you are **maturing**.

Understanding the changes that occur in your body and more specifically, understanding why they occur, will help you to manage and cope in the next few years until you become a young adult.

Why do humans need to reproduce?

Humans need so that we can reproduce to have children to continue the existence of our species. As with angiosperm plants, humans reproduce sexually. This means that human reproduction requires a male and a female and a new human being is formed by combining the genetic material (DNA) from the parents. The child will have half its genetic material (DNA) from its mother and half from its father. In order for this to happen, the **sperm** (from the male) has to combine with the **egg cell** (from the female) to produce a baby. Our sexual organs are adapted for these functions.

Our sexual organs need to reach maturity. This takes place during a stage in our lives called puberty.

Puberty

When a boy or girl reaches a certain point of growth and development, the sexual organs in the body also start to mature. Girls and boys do not, generally, go through puberty at exactly the same time:

- Girls go through puberty between 10/11 – 14/15 years of age
- Boys go through puberty between 12/13 – 15/16 years of age

During puberty, you will experience different physical and emotional changes as your body develops towards sexual maturity and adulthood. Let's take a look at some of these changes that take place during puberty.

Puberty is a time when the human reproductive organs start to develop, maturing about 5 – 6 years after puberty has started.

ACTIVITY What happens during puberty?

Instructions

Study the images of a girl at 10, 12 and 17, and of a boy at 10, 12 and 17 shown below.

Questions

1. Identify the changes that both go through during puberty and write your results in a table.

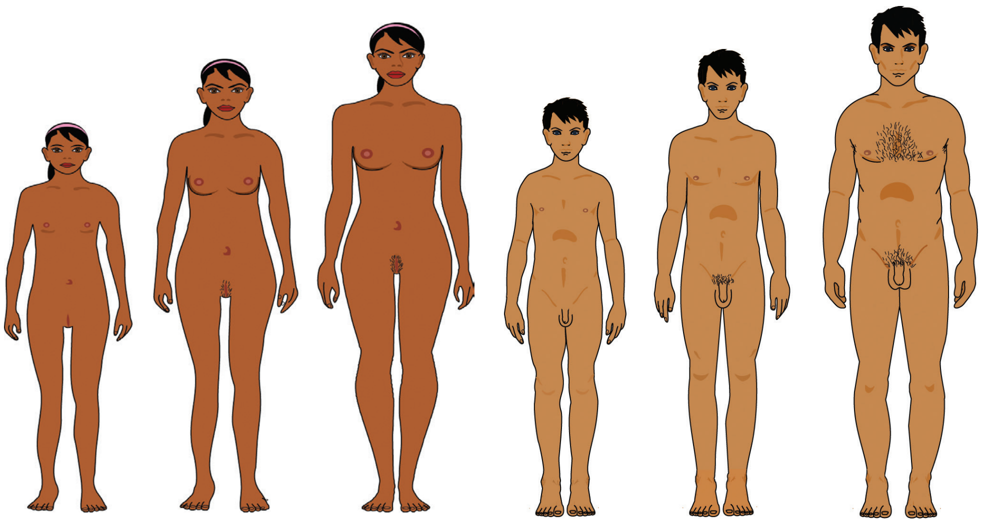
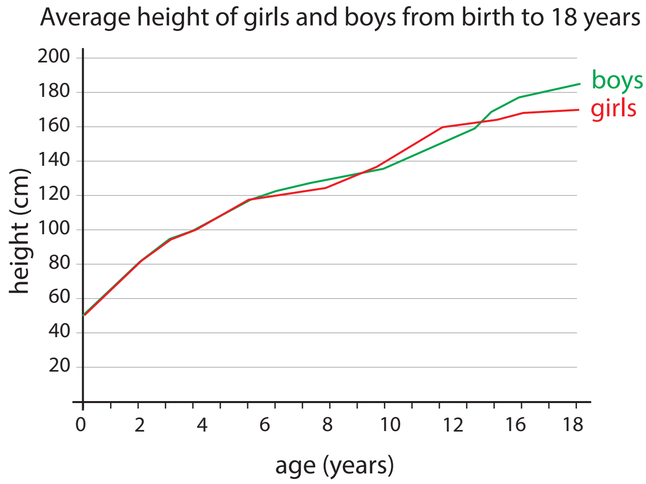


Figure 3.28 Changes in the girl   Figure 3.29 Changes in the boy

2. Study the following graph and answer the questions that follow.



2.1 What type of graph is this?

2.2 What information is this graph providing?

2.3 In a graph, there are two variables. The independent variable is placed along the horizontal x-axis. The dependent variable is the variable that changes according to the independent variable. It goes along the vertical y-axis. Identify the independent variable and the dependent variable that was used in this study based on the graph.

2.4 What is the unit of measurement that height is recorded in? What is the unit of measurement for age?

2.5 Explain in words what you think this graph is telling us about how boys and girls grow from 0 to 18 years old. Compare the two different lines for boys and girls and see what you can tell from the average heights as they grow older. Answer the following questions to help you interpret this graph.

- **a)** There are two lines on this graph. What does each line represent? Use the colours in your answer.
- **b)** Why are the graph lines for boys and girls overlapping from 0 to 6 years old? What does this tell us about the height of boys and girls up until 6 years old?
- **c)** After 6 years old, and until 10 years old, the graph lines for boys and girls split. Which line is on top? What does this tell you?
- **d)** At what age are boys and girls on average the same height again? How can you tell this from the graph?
- **e)** At age 18, are boys or girls generally taller? What is the average height of boys and of girls at 18 years old? Read this off the graph.

2.6 A growth spurt occurs when children grow quite rapidly over the years, faster than over other years. Answer the following questions to help you understand this.

- **a)** What can you use to identify a growth spurt in the graph? Hint: A growth spurt means that the boys' and girls' height is increasing faster than at other times.
- **b)** On the graph, we can see that there is a growth spurt for girls and a growth spurt for boys. Do the growth spurts take place at the same age for boys and girls?

c) At what ages do the growth spurts take place for boys and girls?
d) Why do you think these growth spurts took place when they did? Hint: Think back to the ages of puberty for boys and girls and how they differ.

2.7 Make an X on the graph to indicate where you are in this process according to your age.

2.8 Using the data on the graph, what changes in your height can you expect to experience if you were to follow the typical growth trend?

2.9 Based on your family history and the height of other members of your family, predict whether you will 'follow the curve' or whether you will be shorter or taller than the average person your age.

During puberty, many young people have commented that their emotions are like a roller-coaster. This time in your lives is not only about growing up and maturing physically, but also emotionally.

Many events are taking place in your life, so let's draw a timeline to show this!

Keywords

- fallopian tube (oviduct)
- ovary(ovaries)
- ovulation
- scrotum
- testes
- uterus
- vagina
- conception
- ejaculate
- sexual intercourse
- umbilical cord

ACTIVITY Draw a timeline of your life

A timeline shows us a representation of how time passes and the events which take place.

Instructions

1. Draw a personal timeline of your life so far.
2. You can include photos and pictures.
   a) You can possibly include:
   b) Your birth – where and when
   c) Your first tooth, first word, first step that you took, and so on.
   d) Your different birthdays – perhaps you have some photos you can stick on for some of your birthdays
   e) Your first day at school, playing a team sport, on stage as a performer, and so on.
3. Celebrations and memorable events in your life.
4. Locate puberty on your timeline.

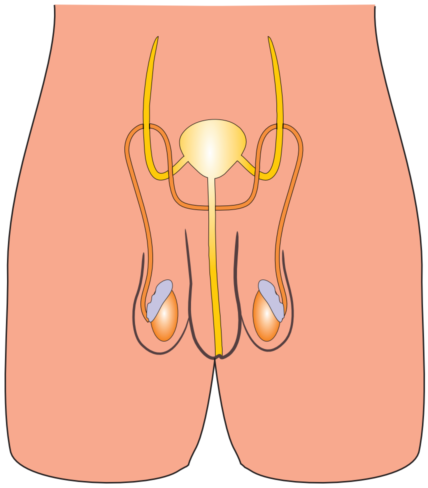
Human reproductive systems

Male Reproductive system

In males, the reproductive organs include the **penis** and two **testes** hanging in a pouch or bag of skin called the scrotum.

- At the start of puberty, the scrotum starts to grow larger and pubic hair starts to appear. The penis also grows bigger.
- Inside the scrotum, the testes mature and start to produce sperm.

When the male reproductive organs are mature in an adult, they will look as they do in the following illustration:



> **Take note**
>
> 'Sustain' means to keep things alive or in existence. We also use the word 'sustainable' when we want to say that something can continue or be continued for a long time.

Female Reproductive system

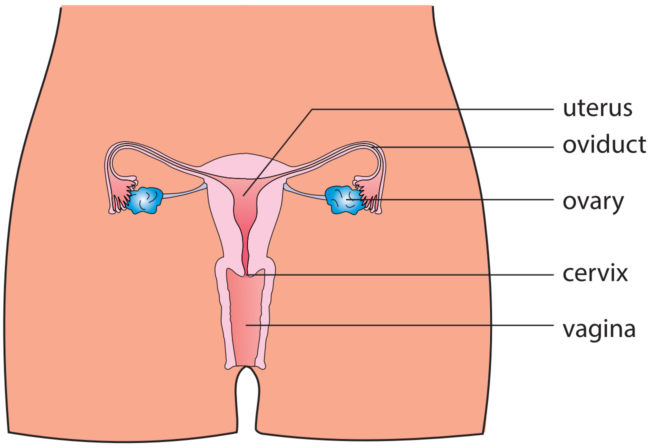
The female reproductive organs include the **vagina**, **uterus**, two **fallopian tubes** (**oviducts**), and two **ovaries**.

- Inside the girl's body the uterus becomes longer and the lining of the uterus becomes thicker.
- When a girl is born she already carries millions of eggs (also called ova) in two organs called the ovaries. During puberty, the ovaries mature, and start to release one mature egg each month. This is called ovulation.
- Two tubes connect the uterus with the ovaries – these are called the fallopian tubes or the oviducts.

> **Take note**
>
> You are 100% unique – there is no one like you on Earth!

When the female reproductive organs are mature in an adult, they will look as they do in the following diagram:

We now know more about the male and female sexual organs and how these organs mature during puberty.



Different stages in human reproduction

Although you are not ready for the responsibility of having a baby and parenthood, your body starts to prepare itself for reproduction during puberty. The main purpose of the human reproductive organs is to produce a mature sperm or egg that can fuse and create a new human baby.

Ovulation

Normally once in 28 days, one of the ovaries in a girl or woman's body will release a mature egg into the fallopian tube (oviduct). From here it moves to the uterus. This Process is called ovulation. During this time the uterus develops a thick lining of blood in preparation for the possible arrival of a fertilised egg.

Menstruation

After ovulation, if the egg in the oviduct does not fuse with a sperm and fertilisation does not take place, then the egg cell will still travel down to the uterus. But instead of implanting into the uterine wall, the unfertilised egg cell will be discarded through the vagina, together with the thick blood-rich uterus lining that had developed in case of fertilisation. This is called menstruation.

Figure 3.30 Do you think the myth about Medusa is true?

Myths about menstruation

Do you know what a myth is? A myth is a story that may or may not be true. Often, myths are quite old stories that are passed down from one generation to the next. Myths are often told and people believe them even when there is no proof that they are actually true.

One such Greek myth is about a lady called Medusa. She had hair made of real snakes and could turn anyone into stone if they looked directly at her. One day, the hero Perseus fought her by looking at her reflection in his shield instead of directly at her. He was protected from her deathly stare and managed to cut off her head and kill her.

There are many myths about menstruation and sex which are told by people in our society. A lot of these myths are not based on proof. Now that you know more about human reproduction, you need to decide if these stories and myths are true or not. Let's discuss this some more.

Human reproductive systems

ACTIVITY Conduct a survey

Instructions

1. Read some of the following comments people have made about menstruation and sex.
2. As a homework assignment, read these to at least five separate members of your family and friends.
3. Copy the following table into your exercise books and make a small cross if the people you are consulting thinks it is not true, and tick if they think it is true or correct.

Myth	Responses (tick or cross)
"Women who are menstruating are dirty and unclean."	
"During your period you should never have cold food or walk with bare feet. If you get cold your period will be worse."	
"Exercise is bad for you when you menstruate."	
"Don't ever swim when you are having a period!"	

Myth	Responses (tick or cross)
“Virgins cannot use tampons - they will lose their virginity.”	
“It is unhealthy to have sex at the time of the month when you are menstruating.”	
“You cannot fall pregnant during your period.”	
“You cannot fall pregnant or make someone pregnant if you have sex in water.”	
“Women are always moody and irrational during menstruation.”	
“Drinking and drugs make sex more fun.”	
“If you have a shower after sex, you will not fall pregnant.”	
“You cannot fall pregnant if it is your first time.”	
“Everyone is having sex.”	

Take note

A virgin is someone who has not had sexual intercourse.

Questions and discussion

1. How many people in the homework survey believed that the comments were in fact true? Tabulate your results as indicated in the table below

Most believed they were true	About half believed they were true and the other half believed they were not.	None believed they were true

2. Discuss with your class which of the comments were most widely believed to be true by the people you surveyed. Take some notes on the following lines.
3. Which of these comments had the strongest reaction from the people you surveyed? (Either positive or negative reaction.) Discuss their reactions with your class. Take some notes on the following lines.
4. Did anyone laugh at any of the comments? Which ones? Did they tell you why they laughed? Share this with the class.

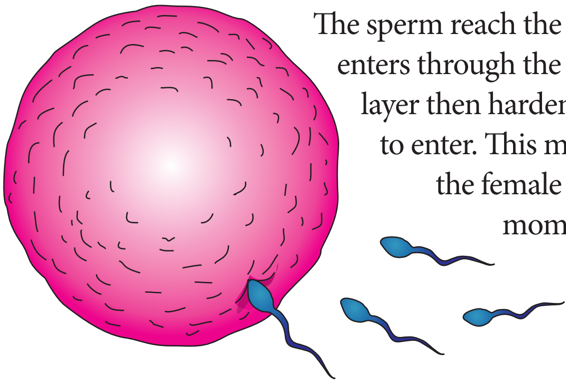
Take note

‘Contra-’ means against, so ‘contraception’ means ‘against conception’.

Which of these statements do you think are true? Discuss this with your class and take some notes on the following lines.

Fertilisation

In order for a baby to develop in the mother’s uterus, the egg needs to be fertilised. During sexual intercourse, the male ejaculates (releases) millions of sperm into the woman’s vagina. From the vagina, the sperm travel into the uterus and up into the oviducts and to the egg cell.



The sperm reach the egg cell, and only one of them enters through the outer layer of the egg cell. The layer then hardens and no other sperm are allowed to enter. This moment, when the male sperm and the female egg cell fuse, is referred to as the moment of conception, or fertilisation.

Figure 3.31 Only one sperm will fertilise the egg cell. The millions of others will not be able to enter.

Pregnancy

This leads to pregnancy as the foetus starts to develop.

Once the egg cell is fertilised, it continues its journey to the uterus. When it arrives in the uterus, it is safely attached in the thick lining of the uterus. The foetus starts to grow and develop. An umbilical cord grows between the foetus and the uterus. A placenta forms to supply food and oxygen to the developing baby and to remove waste. The developing foetus receives food and oxygen from the mother through the placenta and umbilical cord.

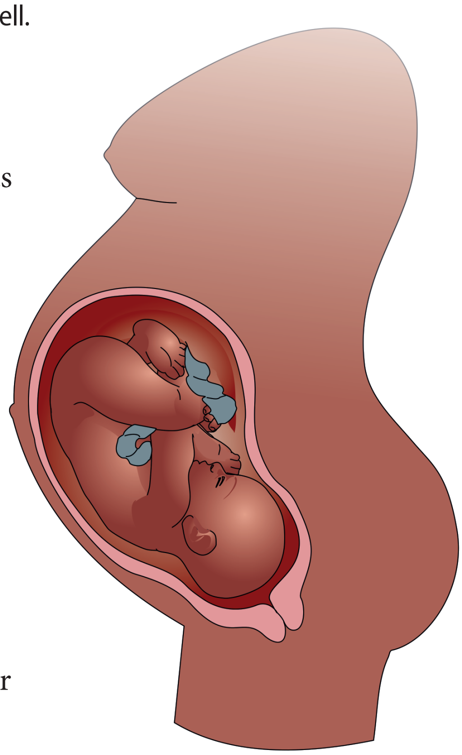


Figure 3.32 A baby developing inside the mother's uterus. Can you see the umbilical cord?

Birth

At the end of pregnancy, the mother gives birth to the baby through the vagina. Sometimes there are complications and the doctors perform a Caesarean section. This is a surgical procedure where a cut is made in the mother's abdomen and the baby is removed.

As we have seen, if the egg is fertilised after sexual intercourse, the mother falls pregnant. But what happens to the egg if it is not fertilised?

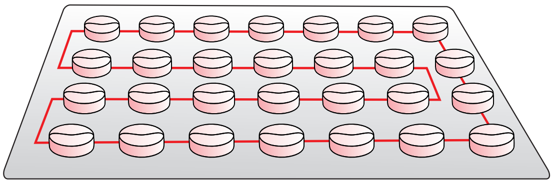
Contraceptives

To avoid falling pregnant, you can use contraceptives. There are different contraceptives available today. They prevent the sperm from reaching the egg and thus prevent fertilisation from taking place. Or else, they can prevent the fertilised egg from implanting in the uterus wall.

Male condoms are rubbery sheaths that are placed over a man's erect penis before sex, and are worn during sexual intercourse to prevent the sperm from entering the woman's vagina. Condoms also help to prevent the spread of STDs.

Female condoms also prevent the sperm from reaching the egg. However, these are placed in a woman's vagina to act as a barrier to the sperm, and are much less commonly used.

Oral contraceptive pills are used by many women today. Many of these prevent ovulation. Pills need to be taken at the same time every day, otherwise they are not effective. If the woman has an infection with a high temperature, or is on antibiotics, this may also reduce the pill's effectiveness. While the pill is excellent at preventing pregnancy, it offers NO protection against STDs.



Sexually Transmitted Diseases (STDs)

There are various very dangerous and harmful diseases that are spread from one person to another during sexual intercourse. Some of these are life-threatening, like the Human Immunodeficiency Virus (HIV), while others cause very painful and long-term symptoms.

You can prevent yourself from being infected with an STD by doing the following:

- Get the facts: Make sure you know up-to-date information about STDs and how they are spread, their symptoms, and how you can protect yourself during sexual intercourse.
- Take control of your sex life: The more sexual partners you have, the higher your risk will be of contracting an STD.
- Be faithful: If you or your partner has sex with someone else, you risk infecting the other person with the STD.
- Using condoms significantly reduces the risk of contracting STDs.

It is your decision whether you want to participate in sexual intercourse with a romantic partner or not. There are two very important points to remember here:

1. No one, no matter who they are, has the right to force you or pressurise you to have sex with them or with anyone else. Therefore, you are the only one who should be permitted to decide when you are ready to have a sexual relationship.
2. If you decide to have sex, you should do so in a responsible manner. This includes protecting yourself against possible pregnancy and against any STD infection.

Take note

If you have been a victim of sexual abuse you can receive guidance and help by contacting Lifeline at 0800150150. The Lifeline website for victims of sexual abuse can be found at http://www.lifelinesa.co.za/

Ways to prevent pregnancy and Sexually Transmitted Diseases (STDs)

As we discussed above, your body prepares itself to reproduce during puberty. However, you are in control of your body and can make the decision when you are ready to become a parent and to fall pregnant.

If you decide to become sexually active, it is important to think very carefully of two risks involved in sexual activity:

- Pregnancy

- Being infected by a Sexually Transmitted Disease (STD) like HIV/AIDS, Herpes or Syphilis.
- There are different things that you can do to prevent pregnancy.

ACTIVITY Write a letter

Often we make promises to other people and work very hard to keep them, but when we make promises to ourselves we often neglect to honour these.

Write a letter to yourself in which you explain what you want to do with regard to sexual activity. Do you want to engage in sex, or do you want to wait until you are older? Explain why you made this decision.

Add to your letter what you promise yourself that you will do to protect yourself from contracting an STD or from a pregnancy before you are ready to be a parent. Explain how you see yourself practising responsible choices regarding sex.

Put your letter in a safe place at home where you can often see it to remind yourself of your promise to yourself. Remember this is a private letter and you can choose whether you want to show it to anyone else or not.

Summary

Key concepts

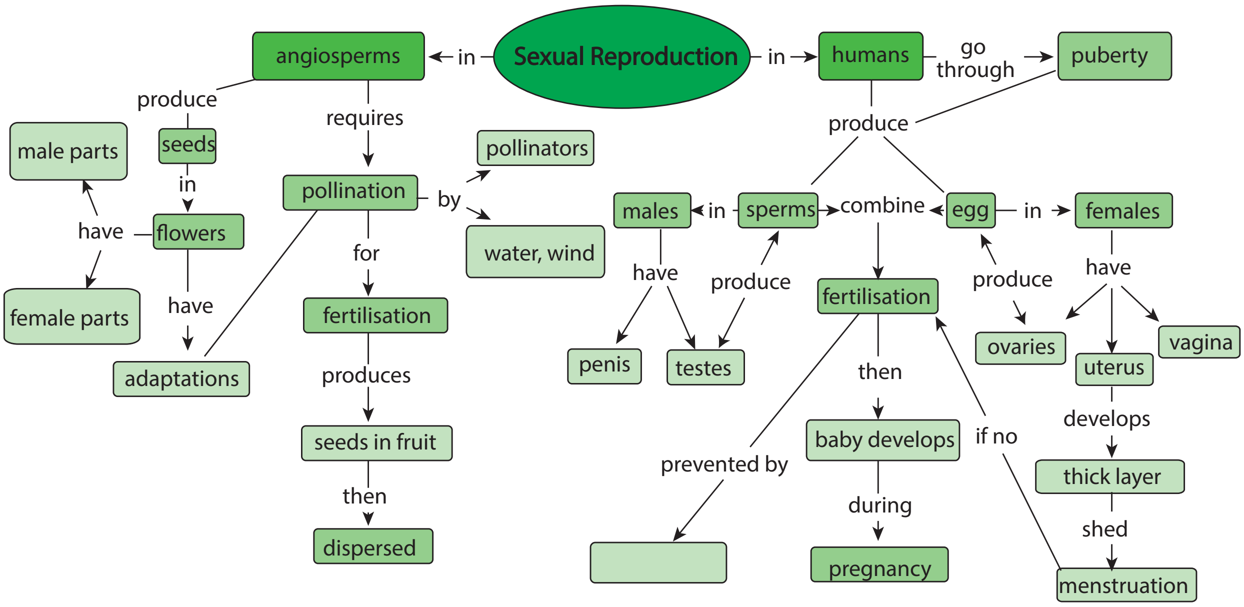
- Sexual reproduction occurs when a sperm and an egg from two people combine to make offspring which look similar but not identical to the parents.
- In angiosperm plants, seeds are produced in the flowers.
- The male structures of flowers are the anthers and filaments, making up the stamens.
- The female structures of a flower are the stigma, style and ovary, forming the pistil.
- Pollination occurs when pollen is transferred from the anther of one flower to the stigma of another flower of the same species.
- Pollination is assisted by animals (pollinators), the wind, and/or water.
- Pollinators play an important role in the production of crops for humans.
- The pollen grows a pollen tube down the style to deliver the pollen nucleus to the ovules in the ovary.
- The fertilised ovules become seeds and the ovary may swell to form a fruit.
- Seeds are dispersed in various ways by animals, the wind, water and explosive force.
- In humans the main purpose of reproduction is for the sperm and egg to fuse and develop into a baby during pregnancy.
- Puberty is the stage in the human life cycle when sexual organs mature for reproduction.
- During puberty, boys and girls experience physical and emotional changes.

The male reproductive organs include the penis and testes that produce sperm.

- The female reproductive organs include the vagina, uterus, oviducts and the ovaries.
- The ovaries produce one mature egg each month during ovulation which is then transported to the oviduct.
- If sexual intercourse takes place, the sperm travel to the egg and one will fuse with it in the process of fertilisation.
- The fertilised egg then moves to the uterus, is embedded in the lining of the uterus, and grows for approximately 9 months before the baby is born.
- If fertilisation does not take place, the egg moves to the uterus from where it is discarded in the vagina. The uterus lining is broken up and discarded through the vagina during menstruation.
- Pregnancy and STDs can be prevented mostly by wearing a male condom

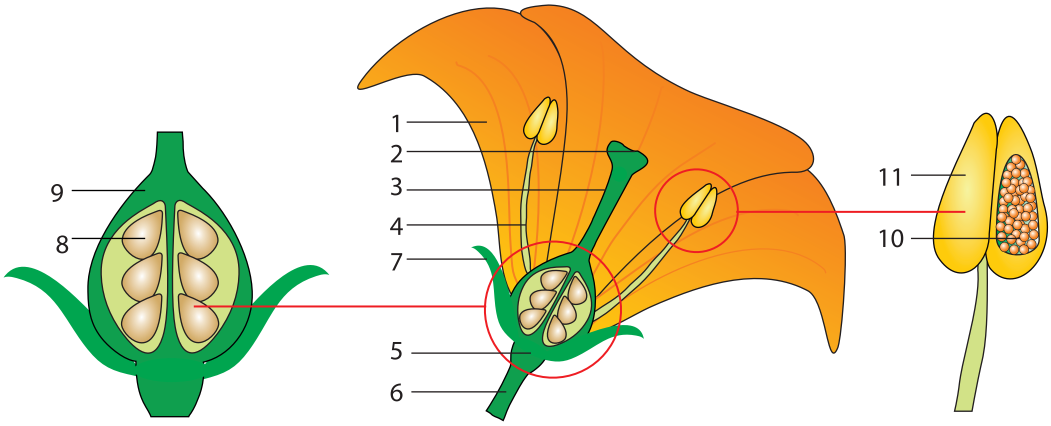
Concept map

Study the concept map below. Does it make sense to you? Are you starting to see what concept maps do? To complete the concept map below, fill in the blank spot. Look at the concept it is linked to in order to find the answer: 'In humans, fertilisation is prevented by … .'



Revision

1. Study the following diagram of a flower and the reproductive parts. Provide labels for numbers 1–11. [11]



2. Copy the table below in your books and describe the function of the following structures: [5]

Structure	Function
Petal	
Ovules	
Pollen grains	
Filament	
Recept	

3. Look at the following image of a bat busy drinking nectar from the flower. How is this flower adapted for pollination by the bat? [3]

Figure 3.33 A bat drinking nectar

4. Look at the following image of the seed. How do you think this seed is dispersed? How is this seed adapted for this kind of dispersal? [3]

Figure 3.34 A seed

5. Grade 7 learners were trying to explain the process of the human reproduction cycle, but they muddled up the order of the cycle. Write numbers 1–6 to place their sentences below into the correct order. [3]
   - The sperm arrive in the oviduct.
   - During sexual intercourse, the sperm is propelled from the penis.
   - One sperm enters the outer cover of the egg to fertilise it.
   - The fertilised egg is implanted in the uterine lining.
   - The sperm travel from the vagina, through the uterus to the oviduct.
   - The egg is released from the ovaries and travels along the oviduct.

6. Explain the difference between ovulation and menstruation. [2]

7. Once an egg is fertilised, where is it implanted or embedded? [1]

8. The reproductive organs are structured in a very specific way – to make fertilisation and pregnancy possible. Explain the function of each of these structures in the male and female bodies. [12]

Reproductive organs	Their function
Ovaries	
Oviducts	
Uterus	
Vagina	
Penis	
Testes	

9. During puberty the penis and testes develop and mature to fulfil their function in reproduction. Explain what changes occur and why these changes are necessary. [2]

10. Explain what changes occur inside the ovaries of a girl during puberty and why these changes are important for reproduction. [2]

11. Grade 7 learners were asked to define the terms puberty, menstruation, fertilisation, pregnancy, and conception. First evaluate how well they defined each of these terms and then correct or improve their definitions in each case. [10]

Term and definition	Evaluation	Improvement
Puberty: when you grow up.		
Menstruation: when a girl bleeds.		
Fertilisation: when you put stuff into the garden to make it grow better.		
Pregnancy: when the mom's stomach grows and a baby pops out.		
Conception: when the baby starts to come alive.		

Total [54 marks]

4 Variation

Key questions

- Are all dogs part of the same species if there are so many different sizes, shapes and colours?
- What about humans? What does it mean that we have different skin colours, heights and other differences if we are all part of *Homo sapiens*?
- What does 'variation' mean?
- What causes variation?
- Why is it important that we study variation?

Keywords

- inheritance
- natural selection
- variation
- litten

4.1 Variation within a species

In the last units we looked at how to classify organisms on Earth. Do you remember what the classification levels are? What is the smallest group in the classification system?

A species is a group of organisms that can interbreed with each other to produce fertile offspring. In this section you will learn why the ability to create a fertile offspring is the single most defining characteristic of a species.

Wherever organisms in a species live, they need to survive in those conditions. We say they are adapted to their environment. Those individuals within a species, that have characteristics that make them more successful at surviving, will reproduce more and pass on their characteristics to their offspring. However, environments change over periods of time. This means that the species need to change constantly over time to better survive the conditions of their changing habitat. If the organisms do not adapt to their environment, they may not survive, and the species will die out. But how do species adapt? Does it happen quickly or over a long time?

What does variation mean when we use it in Natural Sciences? Let's take a look at some animals with which we are all familiar to find out what variation means.

ACTIVITY Small, big, long-haired, short-haired, black, white, brown or spotty?!

Do you have a dog, or have you seen some dogs in your neighbourhood? Think of those dogs, and use the following image to answer the questions.

Materials

1. What kingdom of animals do dogs belong to?
2. What phylum do dogs belong to? Why do you say so? Give a reason for your answer.
3. What class do dogs belong to? Give three reasons why you would classify dogs in this class.
4. Look at the dogs in the above picture and write down some common characteristics of the animals.
5. Do you think these dogs are part of the same species? How would you know? Discuss this with your class and teacher.
6. Although these dogs share many characteristics, there are many differences between them. What are some of these differences?

Variation among horses

Another example of variation is horses. Horses all belong to the same species as they can mate and produce offspring which are fertile. This means their offspring are able to reproduce. But there are many different colours and sizes of horses.

Figure 4.1 A white horse with a brown foal.

Figure 4.2 A donkey

Horses and ponies are from the same species. But what about donkeys?

If a horse and a donkey mate, they are able to produce offspring, but the offspring are infertile. They are called mules or hinnies. Do you think donkeys and horses are the same species? Give a reason for your answer.

All living organisms that reproduce sexually produce offspring that are different from the parent organisms. Remember that we learnt about sexual reproduction in angiosperms and humans in the last unit. This allows the new organisms to be different from other organisms within the same species. We call this difference, variation. As we saw in the last activity, all dogs on Earth are actually the same species, as well as horses, but there are huge differences between all the individuals. We say there is **variation**.

Figure 4.3 Five kittens from the same litter but they all look different!

Even animals from the same litter or children from the same parents have differences. Take a look at the kittens in the box below. They are all from the same litter so they share the same parents, but they all look different.

All humans on Earth are from the same species, and yet there is huge variation among us. Look at the following photos of people from around the world.

Humans are all one species. Do you remember what the species name is for humans?

South Africa is an amazing example of diversity amongst our people. Just have a look at your class and how much variation there is between all of you in one class. Some learners may be tall and others may be shorter, some have dark hair, some have blonde or brown hair, and there is a range of skin colours in South Africa. Since you are all from the same species this is another example of variation. Let's have a look at how your class varies in height.

Take note

Do you remember how to calculate an average? You need to add up all the individual measurements, then divide by the number of learners you have measured.

ACTIVITY The height of learners in your class

Materials

- 2 m measuring tape
- pencil, table drawn on scrap paper and clipboard to work on

Instructions

1. Attach a measuring tape or similar apparatus to a wall in your class.
2. Learners who are having their length measured must be barefoot and must place their heels against the wall, standing up straight against the wall.
3. Learners who are taking the measurement must stand on a chair and place a ruler or pencil horizontally on the person's head (and flatten the hair) when taking the measurement.
4. Another learner should record the name and height of each learner.
5. Use this method to record the height of each learner in the class.
6. Draw a table to record the measurements.
7. Represent these results on a bar graph.

Use your books to record the heights of learners in your class in a table.

Take note

A correlation is a relationship between two or more sets of measurements or

Questions

1. Now use this information to draw a graph to represent the information. You will need to draw a bar graph. Think about what must go along the horizontal x-axis and what must go along the vertical y-axis. Remember, the x-axis is for the independent variables and the y-axis is the dependent variable. Give your graph a heading.
2. Who is the tallest and who is the shortest in your class?
3. What is the average height of all the learners in your class? Use your books to show your working for this calculation.
4. What is the average height of the boys and what is the average height of the girls? Use your books to show your working for this calculation.
5. As a homework activity, measure the heights of some of the adult members in your family. Record these heights in the following space to discuss with your class the next day.

6. Discuss these results with your class.
   a) Do the shorter people in your class also have shorter family members, and do the taller people in your class also have taller family members?
   b) Is there a correlation (relationship) between the heights of learners in your class and the adults in their family?
   c) What other similarities are there between family members?
   d) Write down some notes from your class discussion in your books.

4.2 Inheritance in humans

We have now seen that there is huge variation between all the people on Earth, and even in your class. But, there are also lots of similarities, especially between family members, such as height and skin colour. These characteristics (or traits) are passed down from one generation to the next in a family. We say they are inherited traits.

We say that certain traits are passed down from generation to generation over many years, from parent organisms to their offspring. This is called inheritance.

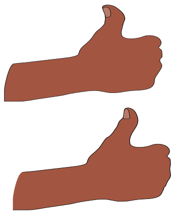
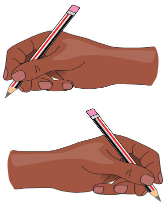
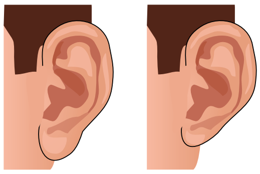
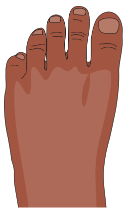
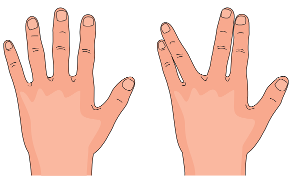
There are some traits which are very easy to see how they are inherited, such as skin colour or height. Did you know that some people are able to wink with one eye but not with both? Or that others can see only some colours but not all the colours. This is called colour blindness. Let's find out a bit more about some of these inherited traits.

ACTIVITY What is your inheritance?

1. Think about your most recent family event or family photo. Is there something that you all have in common? It can be something about your physical appearance, or your behaviour or something that you can each do. Discuss any inherited traits or characteristics that get passed down from generation to generation in your family.
2. One of the very interesting inherited traits is the ability to roll your tongue.
   Can you roll your tongue? Can your family members roll their tongues?
3. There are many other traits and abilities that are inherited from our parents, that they inherited from their parents, which they inherited from their parents, and so on. Below is a table detailing some of these traits.
4. Count how many people in your class can do each or have each of these traits or characteristics.
5. Record the number of learners in your class who have each characteristic.
6. Calculate the percentage of learners who have this characteristic.
7. When you have collected all the data and have worked out the percentage of learners that have a certain trait, draw a bar graph in your books. Remember to label your graph and to give it a heading.

Did you know?

The location of this fabulous example of natural selection was the city of Manchester in England. The first observation of a dark black Peppered Moth occurred in 1848. However, by 1895, 9,8% of Peppered Moths in the city were dark!

Characteristic	Illustration	Number of learners with the characteristic	Percentage of learners with the characteristic
Tongue rolling			
Thumb shape		Hitchhiker thumb: Straight thumb:	
Dominant hand		Right-handed: Left-handed:	
Attachment of earlobe		Attached earlobe: Unattached earlobe:	
Dimples			
Second toe length		Longer second toe:	
Vulcan sign			

Visit

10 reasons to love Science (video).
bit.ly/1bf3K5r

How does variation in a species help it to survive?

We have now looked at how variation within a species helps it to adapt to its changing environment and therefore survive. But, these changes do not happen quickly. Although small changes can happen within a few generations, big changes take a very, very long to happen – they take thousands of years.

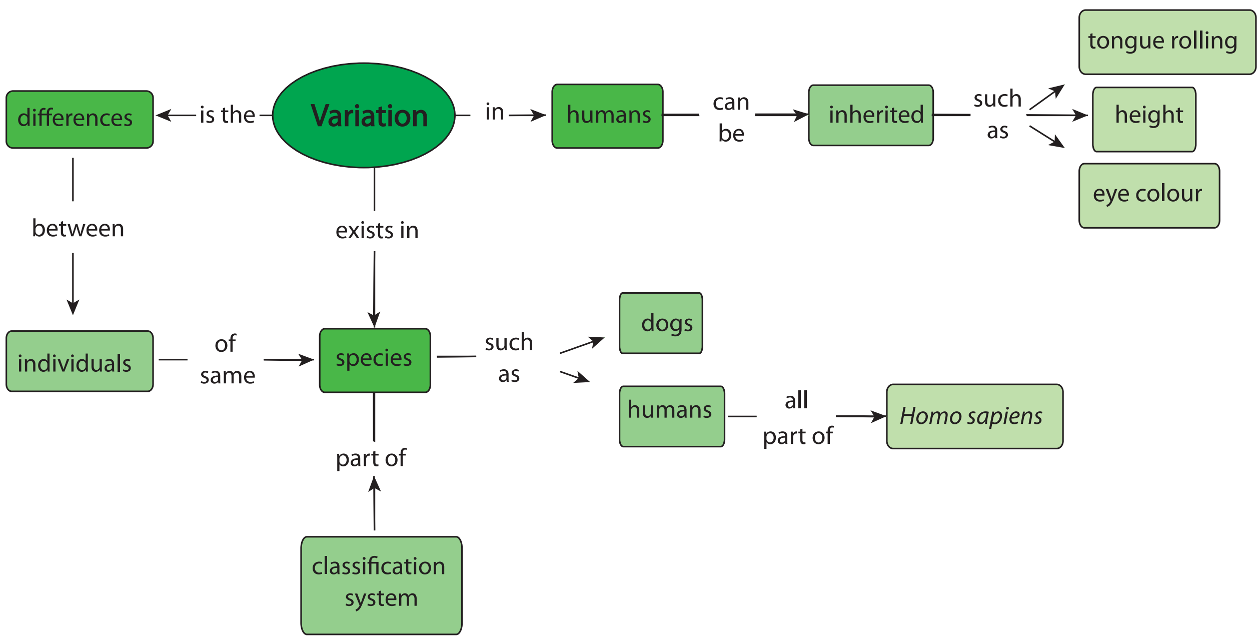
Summary

Key concepts

- A species is a category within the classification system.
- Living organisms of the same type belong to the same species.
- Organisms from the same species can reproduce sexually and produce offspring that are fertile and can reproduce.
- People belong to the species *Homo sapiens*.
- Variation is the difference between individuals from the same species.
- This variation can be passed on from one generation to the next.
- Small changes can take place in a species over shorter periods, for example from one generation to the next.
- Over very long periods these small changes can accumulate so that big changes occur over time.

Concept map

This was a short section and so we have a smaller concept map than in the previous sections.



Revision

1. Are Dobermans, terriers and bulldogs from the same species? Give a reason for your answer. [2]
2. A new breed of cat has been developed, called the Munchkin Cat. Breeders specifically tried to breed a cat with very short front legs. Explain how you think they achieved this. [2]

3. Predict whether you think Munchkin Cats would be able to hunt as well as other cats with normal-length front legs. [2]
4. Do you think it is correct for humans to breed animals in this way? Explain your answer. [2]
5. Explain in your own words what you understand by the term 'inherited characteristics'. [2]
6. Why do you think it takes a long time for a species to change and adapt to its changing environment? [2]

Total [12 marks]

Glossary: Life and Living

abiotic non-living elements of the environment such as soil, water and air

adapt/adapted to change the way that something looks or the way something is done based on the surroundings/ environment

amphibian any of a class of vertebrate animals that live on land and in water at different times in their life-cycle, are ectothermic and have a naked skin, where the larvae hatch in water and have gills, and later transforms into the adult that breathes with lungs

angiosperm a plant that has flowers and produces seeds that are enclosed in a fruit

antenna (antennae) one of two long thin parts on the head of some arthropods (such as insects and crustaceans) used for touch, smell and taste

anther the part of the male sex organ of a plant that contains the pollen

aquatic being in or near water

arthropod any of a large group of animals with a hard body, no backbone, and legs that are divided into sections

asexual reproduction reproduction of plants and fungi that doesn't require male and female sex cells to fuse in order to make a new organism

atmosphere the layers of gas that surround the Earth

biosphere the parts of the Earth's surface, water and atmosphere in which life can exist (and where plants, animals and organisms can live)

bulb a type of underground stem with one or more buds that are covered by leaves or scales such as onions and tulips

cartilage strong, flexible tissue similar to bone

cell the smallest structural unit or building block of life that can sustain the seven life processes

cellular respiration the process in living organisms by which oxygen is used to release energy from food and carbon dioxide is given off as a by-product

characteristic a typical feature or quality that makes one thing different from another class: the major taxonomic rank below phylum and above order that includes groups of vertebrate animals such as fishes, amphibians, reptiles, birds and mammals, and the invertebrate groups such as insects and arachnids

classify a systematic grouping of objects, items or organisms based on characteristics, relationships and processes

component one of the parts that something is made of

conception moment of fertilisation when the male sperm and the female gg cell fuse and a new individual is formed

cotyledon the seed leaf that is involved in the storage or absorption of food reserves

depend/dependent to need something or somebody to do their part in providing a shelter, food, air, and so on, for an organism's survival

dependent variable the variable of interest that is measured to get the results

dicotyledon a plant that has a seed with two cotyledons, nodes and internodes on its stem, a tap root, and generally, leaves on small stalks called petioles; the leaves have a net-type leaf vein

disperse spread over a wide area

diversity the number and variety of species present in an area and the location of their different habitats

ectothermic relating to animals that have a blood temperature that changes if the temperature of their surroundings change

ejaculate when a male releases sperm from the penis

embryo sac structure within the ovule that contains the egg cell; contains the newly developing plant and endosperm after fertilisation

endothermic relating to animals that have a blood temperature that does not change if the temperature of their surroundings change

environment the external surroundings, conditions, resources, stimuli, and so on, in which an organisms lives and interacts

exoskeleton the hard outer covering that protects the body of certain arthropods

fair test an experiment where only one independent variable is changed each time the experiment is repeated

fallopian tube (oviduct) a tube lying close to each ovary that receives the mature ovum (egg) and transports them to the uterus

favourable good, suitable or acceptable

fertilisation the process when a male sex cell fuses with a female sex cell to make a new, unique individual with half the genetic material from the male and half from the female parent organisms

filament the stalk-like structure of the stamen that holds and supports the anther

fuse to join or blend to form a single entity

genetic information (DNA) the inherited information coded into the cell that determines what type of cell it is and what it needs to do

gill the organ in fish and other water-breathing animals that allows them to breathe underwater

gravity the force that attracts a body towards the centre of the Earth or towards any other physical body having mass

habitat the natural place where a plant or animal lives

herbaceous a plant that has a non-woody stem and which normally dies at the end of the growing season

hormone chemical messengers that travel in the bloodstream to tissues and organs in order to effect many different reactions in the body.

hydrosphere the water on the Earth's surface, including the oceans, seas, lakes, rivers and dams

hypothesis/hypotheses a statement that is an educated guess about the outcome of the experiment; an idea that is suggested as the possible explanation for something that has not yet been proved to be true or correct

independent variables those variables that will be changed one at a time to see what effect they will cause in the dependent variable; variables that are under the control of the investigator

inheritance something that is passed on genetically from one generation to another

invertebrate an animal without a line of bones (backbone) going down its back

jointed (segmented) limbs separate parts of the legs that are covered in a hard exoskeleton with clear joints between them

kingdom refers to five major divisions of living organisms: plants, animals, fungi, protists and bacteria which in turn are composed of smaller groups called phyla

larva/larvae a stage in the development of insects and other animals where it has come out of the egg and is mainly concerned with consuming food

leaf vein little tubes that branch throughout a leaf carrying water and dissolved substances

mammary gland milk producing glands in female mammals

marine of or relating to the sea

mate come together for breeding, copulating

matter the physical substances from which all things are made, such as rocks, soil, air, water, plants and animals

maturing to become physically mature and fully developed

menstruation a recurring monthly event where the lining of the uterus breaks down and is discharged as menstrual blood

microorganism an organism that is too small to see without a microscope

monocotyledon a plant that has a seed with one cotyledon, adventitious, generally shallow roots and leaves that forms sheaths around the stem; the leaves have a parallel leaf veins

natural selection a process in which organisms with more suitable features survive and reproduce more successfully in a particular environment, resulting in more offspring that carry the same traits

order a taxonomic rank below class and above family that classifies organisms based on specific characteristics, such as diet and tooth structure, such as herbivores, carnivores and primates

organic produced by or formed from living organisms

organism an individual living thing that can react to stimuli, reproduce, grow, and so on, such as a bacterium, protist, fungus, plant or animal

ovary/ovaries the female reproductive organ in which the female sex hormones oestrogen and progesterone as well as female sex cells (ova) are produced and stored; in a flower it is the thickened part at the base of the flower that contains the ovules

ovule the part of the ovary of the flower that contains the female sex cells become the seeds after fertilisation

ovulation when a mature egg (ova) is ready and gets released (and is in the right place) for fertilisation to take place

peduncle the stalk or stem of a flower

penis the male sex organ for the transfer of sperm cells to the female

petal(s) each of the modified leaf sections of a flower that are typically coloured to attract animals

photosynthesis the process by which green plants (and some bacteria) use energy from light to turn carbon dioxide and water into food and oxygen

phylum a taxonomic rank in biological classification that is below kingdom and above class, that divides organisms according to major body similarities, such as chordates, molluscs and arthropods

pistil (carpel) the female organs of a flower containing the stigma, style and ovary

pollen a fine powdery substance that is often yellow and contains the male sex cells

pollen tube a hollow tube that develops from a pollen grain and grows into the stigma and down the style to deliver the male sex cells to the ovary of the flower

pollination the transference of pollen from the anther of one flower to the stigma of another flower of the same species

pollinator(s) an agent that carries pollen from one flower to another (bees, butterflies, birds or the wind for instance)

puberty the period between childhood and adulthood when the sex organs mature causing changes in the body that prepare the body to be able to reproduce

receptacle the place where a flower is attached to the peduncle (stalk or stem)

requirement something that you need or must have

respire to breathe

respiration taking oxygen into the body and releasing carbon dioxide; breathing

rhizome a horizontal stem underground that has both roots and shoots

roots the part of a plant that is (mostly) underground and responsible for anchoring the plant, and for absorbing water and minerals from the soil

scientific method a set way of doing / conducting a scientific investigation allowing you to gain new knowledge by collecting measurable evidence based on observation, measurement and experiment based on the formulation, testing and changing of the hypotheses

scrotum the external sac of skin that encloses the testes in males

seeds the reproductive organ formed in gymnosperms and angiosperms from which a new plant can grow; it is usually covered by a protective coat and also contains food reserves for the young plant

sepal(s) small green leaves that protect the developing bud

sexual intercourse occurs when the male sperm is introduced into a woman's body

sexual reproduction the process of producing new individuals of a species by fusing the genes of two individuals

shoot a young branch that sprouts from the main stem of a plant

sperm the male sex cell produced by the testes

spore the reproductive cell of mosses and ferns (and other organisms) that under the right conditions can develop into a new individual fern or moss

stamen the male reproductive organ of a flower containing the filament and anther

stem the long thin part of a plant that rises from the ground and from which smaller branches can grow; it supports the leaves, flowers and fruit

stigma the sticky tip of a flower pistil where the pollen is deposited during pollination

style the stalk-like slender part of the pistil joining the stigma and the ovary, and holding the stigma in a favourable position to receive pollen; the pollen tube grows through the style to deliver the male sex cells to the ovules

sustain to keep things alive or healthy

symbiotic a type of relationship between organisms in which one or both organisms benefit

tap root the main root of a plant that grows deep into the soil of a plant that has a single, dominant main stem

testes sperm producing glands of the male body

umbilical cord the cord- or tube-like structure that connects the foetus from its abdomen with the placenta of the mother; it transports nourishment and oxygen to the foetus and removes waste

uterus the hollow muscular organ in the pelvic area of female mammals in which the fertilised egg implants and develops (also known as the womb)

vagina an elastic muscular tube or canal that connects the neck of the uterus (cervix) with the external sexual opening

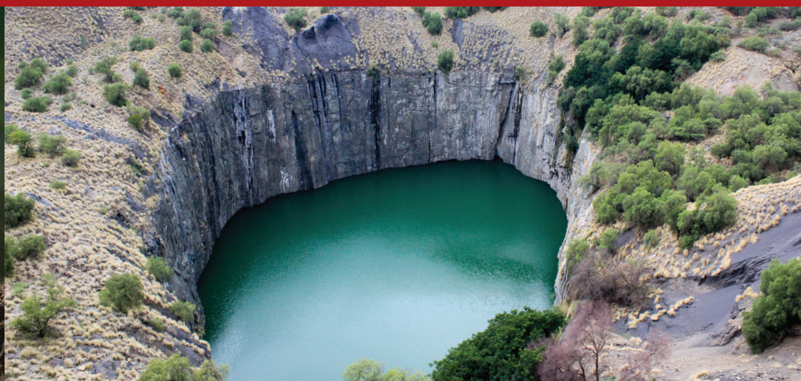
variables any factor that can affect the outcome of the investigation and can be measured, controlled or varied in some way

variation differences between living organisms of the same species

vertebrate an animal that has a backbone (spine) that holds the nerve or spinal column

STRAND

Matter and Materials



5 Properties of materials

Key questions

Which properties are important when choosing a material for a particular use?

- How can we measure the strength of a material?
- What does it mean when a liquid boils?
- How can we explain the term 'boiling point'?
- How can we explain the term 'melting point'?
- Why should we always think about the impact on the environment when we manufacture or use a particular material?

Keywords

- property
- durable
- ductile
- malleable
- flexible
- mould

We learnt in Grade 5 that the properties of a material determine what it can be used for. Can you remember what properties are?

5.1 Physical properties of materials

What are properties and why are they important?

Properties are distinctive characteristics that describe an object or material. The use of a material will be determined by its physical properties, such as strength, flexibility, boiling and melting points, electrical conductivity and heat conductivity..

Figure 5.1 The walls and roof of this house are made of sheets of corrugated metal.

Figure 5.2 Can you see some parts of a car hanging up inside a car factory? These are made of sheets of metal.

What other properties of materials do you remember? Discuss this as a class.

ACTIVITY Thinking about materials and their properties.

Instructions

Copy the following table in your exercise books and complete it by adding the names of different materials that have the properties listed.

Property	Materials
Strong	
Flexible	
Conducts electricity	
Conducts heat	

Questions

1. What does it mean when we say that a material is flexible?
2. Suggest three possible uses of flexible materials.
3. Suggest three possible uses of a material that is a good conductor of electricity.
4. Suggest three possible uses of a material that is a good conductor of heat.
5. Which of the above properties would be important if you were choosing a material for making cookware (cooking pots)?

Figure 5.3 A metal pot

Figure 5.4 These electrical wires carried by pylons are made of metal.

6. Which of the above properties would be important if you were choosing a material for making the wires used for distribution of electricity (shown in the adjacent photo)?
7. Which of the above properties would be important if you were choosing a material to make a barbed wire fence?

Figure 5.5 A barbed wire fence.

Advantages and disadvantages of materials

We have seen that strength and durability are desirable properties in some materials. We want things to be strong and to last long. Let's think of an example.

Why would plastic shopping bags need to be strong?

Why would plastic shopping bags need to be durable?

We call the desirable properties of materials advantages. Disadvantages are unfavourable features, as can be seen in the images of plastic in the environment.

Figure 5.6 A black plastic shopping bag.

Figure 5.7 A pelican about to eat a plastic bag in a river.

Figure 5.8 These plastic rings from soft-drink packaging are very dangerous in the wild as they can entangle an animal's neck.

The following activity has another example of advantages versus disadvantages.

ACTIVITY Advantages and disadvantages of materials

Can you imagine a car made of solid gold? A car like this would be very valuable!

Instructions

1. Look at the image of a gold car then answer the questions that follow.
2. Discuss some of the questions with your classmates before writing down your answers.

Questions

What are your feelings about the golden car in the picture?

1. What are the advantages of having a car made of gold?
2. Do you think a golden car would be very strong? Would it perhaps be safer in the event of an accident?
3. What are the disadvantages of a car made of gold?

Strength of Materials

How would you test how strong a material is? Let's imagine you have different types of paper. How would you test which paper is the strongest? Discuss this as a class and write some notes on the lines provided.

The strength of paper is important because we use paper for many different things.

In the next activity we are going to investigate the tearing strength of different types of paper.

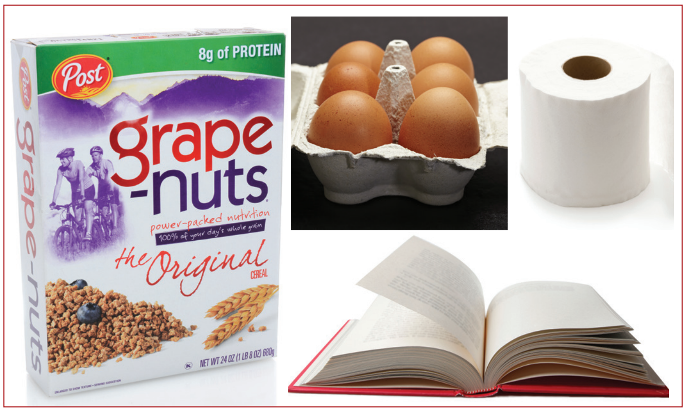


Figure 5.9 All these objects are made from different types of paper with different properties that suit the function of the object.

Investigation Which type of paper is the strongest?

Aim

To compare the tearing strengths of different types of paper.

Hypothesis

When you write a hypothesis, you must state what you think will happen in your investigation.

Materials and apparatus

- strips of different types of paper (20 cm x 5 cm)
- hole puncher
- strong paper clips
- yoghurt tub
- marbles
- string
- hand lens (optional)

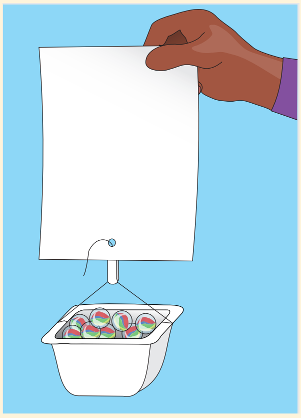
Methods

1. Punch a hole at both ends of each paper strip. This is so that you can test the paper twice on each side. Make sure that the holes are in the middle, and also at the same distance from the end of each strip. This will make it a fair test.

2. Form the paper clip into an S-shape and hang it from the hole in the paper.
3. Make a handle for the yoghurt tub, using the string.
4. Hang the yoghurt tub from the paper clip and hold it in your hand.
5. Add marbles one- by- one to the yoghurt tub until the paper tears. Count the number of marbles in the tub. (Tip: Place the marbles very gently into the yoghurt tub or the shock of dropping them in might tear the paper).
6. Repeat steps 1 – 5 using the other end of the strip and count the marbles again. Take the average of the number of marbles.
7. Repeat this using the other strips of paper, doing each twice and taking the averages.
8. If each marble has a mass of 5 grams, work out the mass in grams that was needed to tear each strip of paper and write the number in the final column of your table.
9. If you have time, you can also test different kinds of materials, such as a plastic shopping bag, aluminium foil or plastic wrap.

Tip: To calculate the **average** of a set of numbers, you add all the numbers together and then divide by how many numbers there were in the set.

In this investigation, you will add the number of marbles together for each time you tested the paper strength (this was twice for each strip of paper) and then divide by 2 to calculate the average number of marbles that each piece of paper can hold before it tears.



For example, if you had 5 marbles in the first attempt, and 3 marbles in the second attempt, the average will be calculated as follows:
5 + 3 = 8 marbles

8 ÷ 2 = 4 marbles on average Therefore, the paper type could hold an average of 4 marbles.

Results and observations

Copy the table below and record your results in it.

Type of paper	Number of marbles (Trial 1)	Number of marbles (Trial 2)	Average number of marbles	Mass of the marbles

Now answer the following questions:

1. Look carefully at the surface of one of the paper strips. Now look carefully at the torn edge. Can you see anything special? Describe what you think the paper is made of.
2. Which paper is the strongest?
3. Which paper is the weakest?
4. Arrange the different types of paper in order of increasing tearing strength. (That means from weakest to strongest.)

Analysis and evaluation

Let's now analyse and think about the results of the investigation.

1. What do you think causes one type of paper to be stronger than another?
2. How would you modify the investigation to test the strength of different types of plastic?
3. What did you do to ensure fair testing?
4. How would you modify the investigation to test the flexibility of different types of materials?
5. Why did you repeat the experiment for the same type of paper?

Conclusion

What can you conclude from this investigation?

Strength, **flexibility** (the ability to flex or bend), electrical conductivity and heat conductivity are important properties of materials that we learnt about in Grade 5 and have revised again here.

Can you think of materials that are both strong and flexible? Most people will immediately think of plastics! Most plastics can easily be melted and **moulded** into different shapes for different purposes. Why do you think plastics can be 'melted and moulded' with ease?

Keywords

- temperature
- thermometer
- heat
- melting point
- boiling point

Difference between heat and temperature

First, let's check if everyone knows that there is a difference between the words heat and temperature. The two words, heat and temperature, are connected but they do not mean the same thing:

- **Heat** is the transfer of energy from one object to another. This happens because of the difference in temperature between the two objects. The transfer of energy will be from the hotter object to the cooler object until they are the same temperature. You cannot measure heat directly, but you can detect its effect on a substance. Changes in heat can usually be detected as changes in temperature.
- **Temperature** is used to describe how hot or cold something is. Temperature can be measured directly with a thermometer.

Adding heat energy usually results in a temperature rise, so people often confuse heat and temperature. But they are not the same thing! We will look more at heating as a transfer of energy next term in Energy and Change.

As you can see in the previous diagram, a liquid can change into a gas by evaporation. For example if you leave a saucer of water out in the sun, the water will evaporate. Evaporation can take place at any temperature. But, in boiling, the liquid needs to be heated to reach its **boiling point**. Bubbles of water vapour then form in the liquid and rise up.

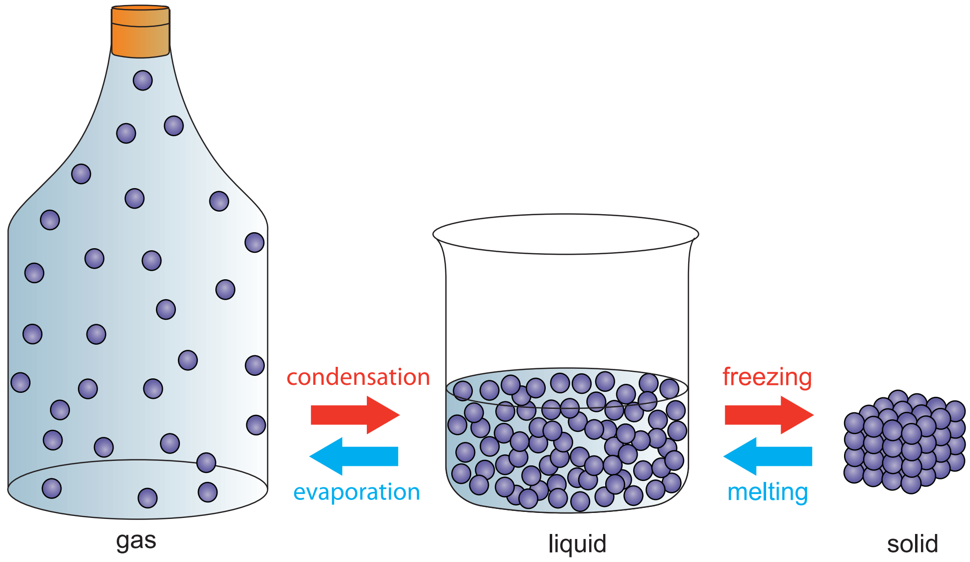
Take note

Melting point – boiling point is a temperature at which the substance changes from liquid to gas state when heat is added.

ACTIVITY Boiling and melting points

Instructions

Do you remember learning about the state changes in previous grades? We will be focusing on boiling and melting in this section. Have a look at the following diagram to refresh your memories about the different changes of state between solids, liquids and gases.



Questions

1. Melting occurs when a solid changes into a liquid. Look at this photo of a candle burning. What is happening to the wax around the flame?
2. Discuss with your partner why you think this is happening to the wax. Write your answer below.
3. Can you think of at least three different ways to boil water? Discuss this with your class and write your answer down.
4. What would happen if you tried to put the kettle into the microwave or on the stove? We will soon find out!

A burning candle.

ACTIVITY Boiling and melting

Look carefully at the picture. It looks as if something has gone wrong here!

Questions

1. Write a short story to explain what you think happened to the kettle in the picture.
2. Why do you think the person made the mistake of heating the kettle on the stove?
3. Do you think plastic is a good choice of material for making a whole cooking pot? Why do you say so?
4. Why does a plastic kettle not melt when we boil water in it?
5. Sometimes, just the handles of the cooking pot are made from plastic or wood. Why do you think this is so?

Instrument for measuring temperature

Since we have to make temperature measurements in the investigation, we are going to first check if everyone knows how temperature is measured.

Have you ever been so sick that you had a fever? Have you ever had your temperature taken?

Perhaps you have had your temperature taken with a **thermometer**. A thermometer can be used to find out how hot or cold something is. A thermometer is an instrument for measuring temperature.

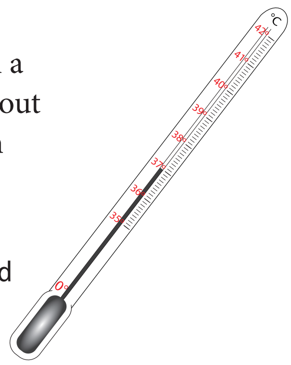


Figure 5.10 This is an example of a thermometer used to take your temperature when you have a fever.

Investigating boiling point of water.

Investigation What is the boiling point of water?

Aim

To observe boiling and to determine the boiling point of water.

Hypothesis

What is your hypothesis for this investigation?

Materials and apparatus

- two glass beakers (or small pot)
- Bunsen burner (or stove plate)
- tripod with gauze
- tap water
- thermometer
- funnel
- ice blocks

Keywords

- contract
- expand
- constant
- independent variable
- dependent variable
- altitude

Before you start, discuss the following questions in your group:

1. Discuss what you know about gases, liquids and solids: the three states of matter. Write down your ideas from your discussion.
2. What needs to happen to water to make it freeze?
3. What needs to happen to water to make it boil?
4. How do we measure temperature?
5. Can you remember the boiling point and freezing/melting point of water? If you can, write them in the space below.
6. Let's make some predictions. Read the two statements below, and indicate whether you AGREE, DISAGREE or are NOT SURE, by drawing a cross in the matching column in your exercise books:

Statement	Agree	Disagree	Not sure
Water can get hotter than 100 °C.			
Water always freezes at 0 °C.			

Take note

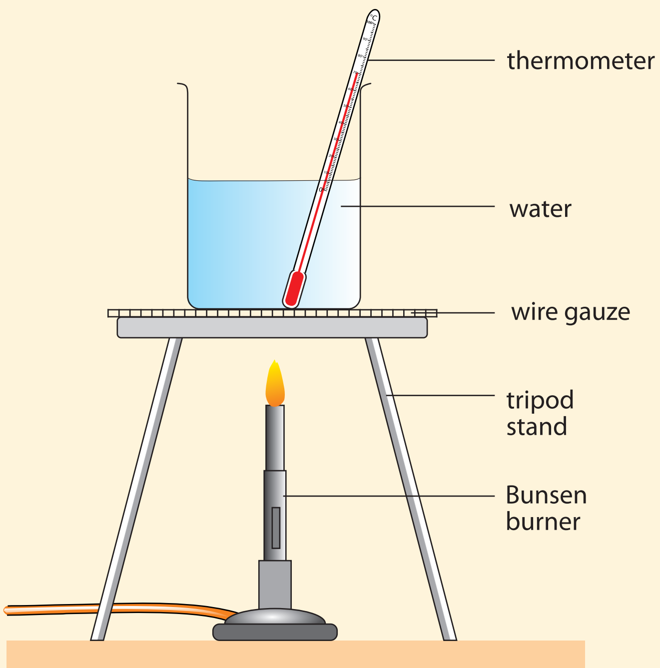
Perhaps you measured the boiling point of the water as slightly less than100 °C. This does not mean that your measurements were incorrect. The boiling point of water depends on the atmospheric pressure. At sea level (close to the ocean) water boils at 100°C. Water boils at a lower temperature at higher altitudes (for example, on a mountain) because the air pressure is less.

Safety precautions

- Your teacher will demonstrate how to handle the Bunsen burner safely.
- Remember that boiling water can cause painful burns.
- The thermometer is made of very thin glass. Hold it gently, and do not use it to stir the water. Be careful not to drop it or bump it against the bottom or sides of the beaker.

Methods

1. Set up your apparatus as shown in the image. Remember that when you want to take the temperature, the thermometer must not be touching the sides.
2. Take a measurement of the water temperature before you start heating the water. This will be your measurement at time 0.



3. Light the burner and heat the water
4. Measure the temperature of the water at regular intervals. Record the temperature in the table provided.
5. After a while you will notice that the temperature of the water becomes constant (this is when the temperature stops going up). Continue to take the temperature three more times (once every three minutes) after this happens. What do you notice about the water?

Results and observations

Copy and record your results in the table.

Elapsed time (minutes)	Temperature of the water (°C)
0	

We are now going to draw a graph of the results recorded in the table. Here are some guidelines for drawing the graph:

1. The title of your graph should be: Determining the boiling point of water.
2. The independent variable should be 'Time'. Label the axis, and use minutes as units. Remember that the independent variable should always be drawn on the horizontal axis of your graph, or the x-axis.
3. The dependent variable should be 'Temperature'. Label the axis, and use degrees Celsius (°C) as units. The dependent variable should always be drawn on the vertical axis of your graph; this is the y-axis.
4. Plot the data on a line graph on a graph paper – each data point must be marked with a small, neat cross.

Analysis

1. What did you see when the water started to boil?
2. What do you think happened to the water when it boiled?
3. Describe the shape of your graph. Is it a straight line?
4. How did the temperature of the water change over time?
5. How does the shape of the graph show the way the temperature changed over time?
6. What happened to the temperature of the water when it started to boil?
7. How long did it take for the water to start boiling?
8. At what temperature did the water boil?
9. What do we call the temperature at which the water boils? Indicate this temperature on your graph.

Take note

The boiling point of water also depends on the purity of the water. Water which contains impurities (such as salt or sugar) boils at a higher temperature than pure water. This is why orange juice or apple juice will boil at temperatures slightly above 100 °C.

Take note

Different thermometers from different batches might also give slightly different readings. This is because they might have been calibrated differently.

Take note

Ice melts at 0 °C. Water freezes at 0 °C. Coincidence, or not?

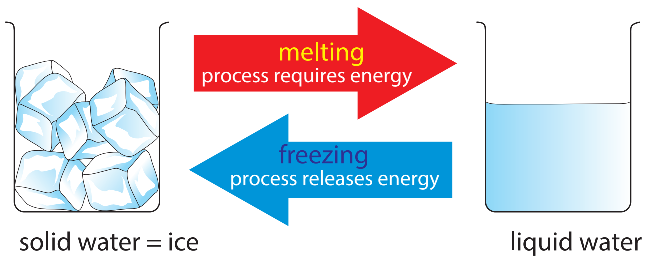
10. Suppose we used a Bunsen burner with a bigger flame.
    a) Do you think the water would boil at a temperature that is higher, lower or the same as the boiling point you just measured? Why do you say so?
    b) Do you think the time required for the water to boil would be longer, shorter or the same? Why do you say so?

Conclusion

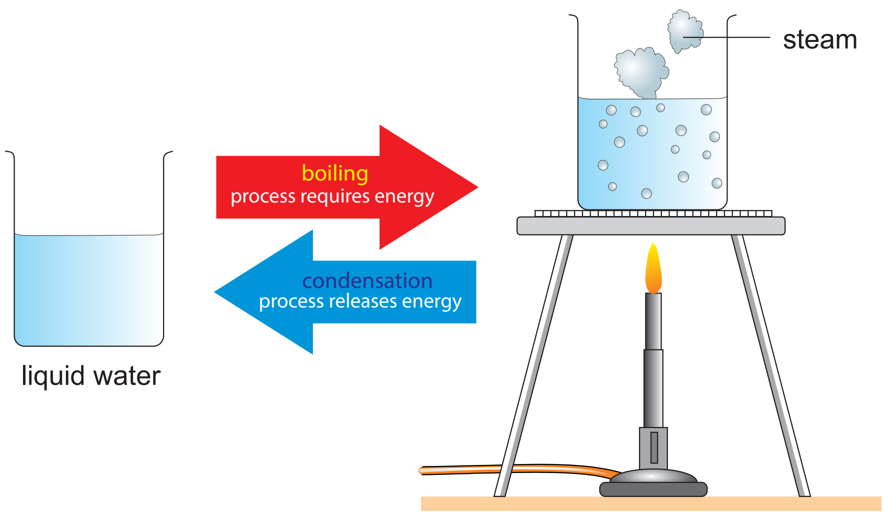
Write a conclusion for this investigation. When writing a conclusion, you must go back to look at your initial aim.

Melting Point

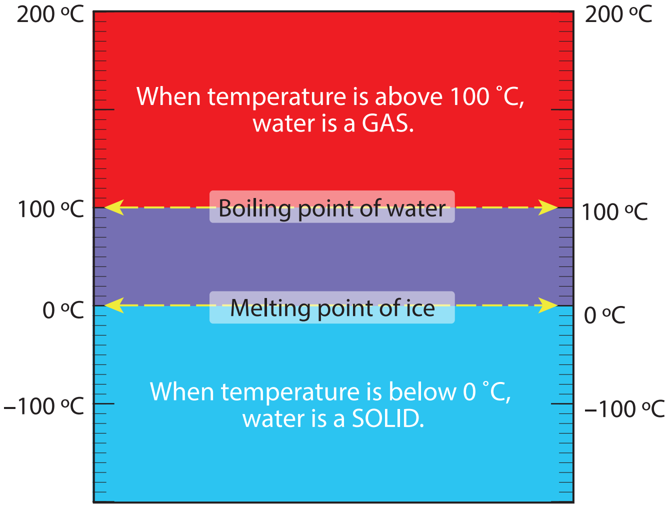
We will learn more about changes of state in Grade 8 Matter and Materials. In order to melt ice, we need to add energy to it to raise the temperature to **melting point**. However, if we want to freeze water, we need to remove (take out) energy from it until the temperature decreases to freezing point.



Does boiling have a reverse process? Boiling is when liquid water changes to water vapour or steam. The reverse process, when steam turns back to water, is called condensation. In order to boil water, we need to add energy to it. But if we want to condense the water vapour, we need to cool it down (take energy out of it).



The following diagram summarises what we have learnt so far.



Do all liquids boil at 100 °C? No, of course not! Not all substances melt at 0 °C either.

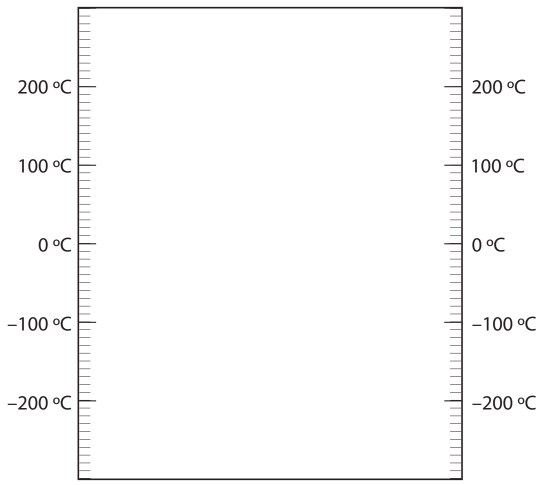
Can you think of a few substances that are solids at low temperatures, but have low melting points? (Think of things that melt easily when it is hot outside. Ice cream is an example.)

In the next activity we are going to explore the boiling and melting points of a few substances other than water.

ACTIVITY Boiling and melting points of other substances.

Instructions

1. Copy the blank template into your exercise books and record the boiling and melting points of the substances listed below. Answer the questions that follow.
2. The boiling point of nitrogen is –200 °C. Draw a green line at this temperature on the diagram and label it 'Boiling point of nitrogen'.
3. The boiling point of ethanol is 78 °C. Draw a red line at this temperature on the diagram and label it 'Boiling point of ethanol'.
4. Now draw a blue line at the boiling point of water and also label this line.
5. What is room temperature? Draw a black line at this temperature and label it.



Questions

1. What state would nitrogen be in at room temperature? Why do you say so?
2. Suppose you mix some water and some ethanol. They are mixed but they have not changed into something else. The mixture is at room temperature to begin with. Now suppose you start heating the mixture. What temperature would be reached first: 78 °C or 100 °C?

3. What do you think will happen when the mixture reaches a temperature of 78 °C? Do you think the ethanol will start to boil?
4. Will the water boil at the same time?

Keywords

- impact
- concern
- environmental concerns

5.2 Impact of materials on the environment

Earlier, we saw how some of the properties of materials may be advantages under certain circumstances, but can become disadvantages under a different set of circumstances, such as plastics and other materials which, if they end up in nature, can have serious consequences and cause harm to other animals. Every process used to produce materials for our benefit has an impact on the environment. Some processes have a small impact and others have a large impact.

We have already seen how the use of materials, such as plastics and paper, has a negative impact on our environment, but what about their production?

ACTIVITY Environmental impact of material production

Instructions

1. Look at the pictures and answer the questions that follow about the production of different materials in South Africa.
2. You will need to do some extra research for this activity. Some information about each of the processes has been provided, but you will need to research them in more detail and answer the questions that follow.

Mining:

Mining in South Africa has been one of the main reasons for our development. South Africas still one of the top gold-mining countries in the world. We also mine and produce other metals such as chromium and platinum, as well as coal and iron ore. Although this is hugely beneficial for the economy, it has devastating effects on the environment.

Figure 5.11 The Kimberly Diamond Mine.

1. This huge hole is actually a diamond mine in Kimberley. What effects do you think this has had on the environment?

In this photograph, the 2010 World Cup Soccer Stadium can be seen in the centre. In the top left are huge areas called slag piles. These are huge piles of crushed rock left over from decades of gold mining. What impact do you think this has on this area?

Figure 5.12 An aerial view of the Soccer City Stadium and surrounding area.

2. Coal mining in South Africa also has a major impact on the environment. Not only the mining, but the use of coal in power stations has negative impacts. What are some of these?

Did you know?

A major environmental concern at the moment is the proposal to start fracking in the Karoo. Fracking is a process where water is injected at very high pressures into small fractures in underground rock to crack it further and release gas and oil which are used as fuels.

Paper making:

Can you imagine your world without paper? Probably not! We use it every day of our lives. South Africa has a big paper-making industry. Although paper is important in our lives today, the production has negative impacts on the environment.

Figure 5.13 A tree plantation with trees used to make paper.

1. Huge areas of land are used to plant the trees that are then harvested to make pulp and then paper. What impact do you think this has on the environment? Hint: Also think about what you learnt about in Life and Living about biodiversity.

Figure 5.14 A paper-making factory.

2. Look at the photo of the paper-making factory. What effects does this have on the environment?

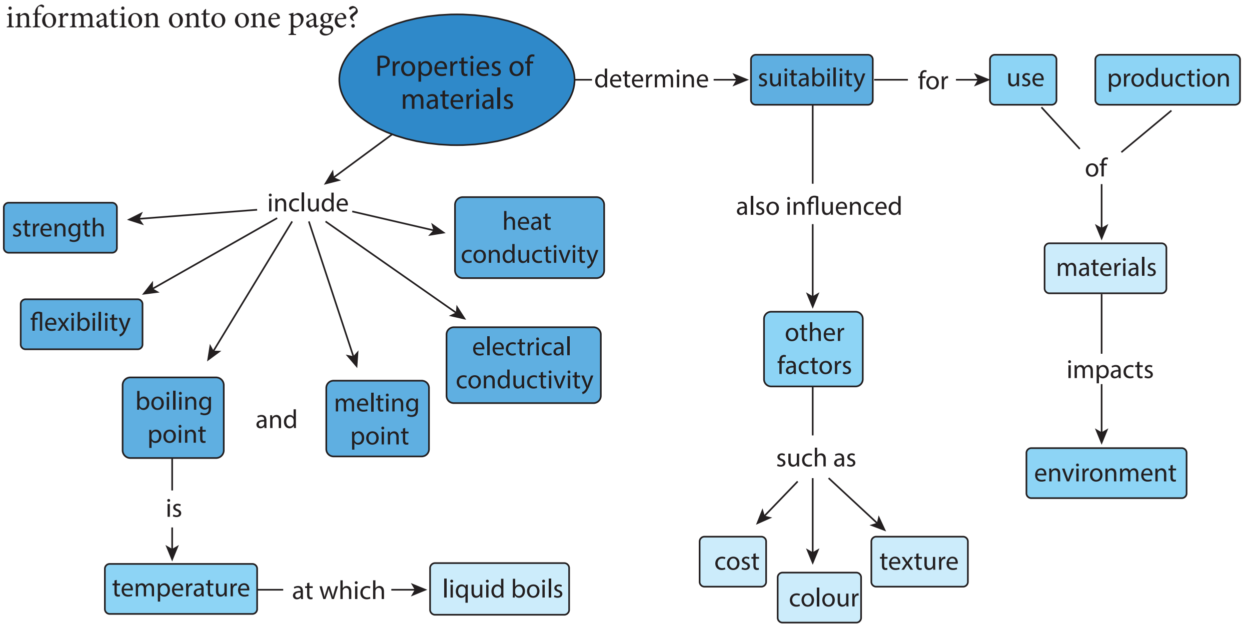
Summary

Key concepts

- The properties of a material determine the purposes for which it can be used.
- Some of the properties of materials include strength, flexibility, heat and electrical conductivity, and they have specific boiling and melting points.
- Boiling point is the temperature at which a at which a substance changes from liquid changes to gas when heat is added.
- Melting point is the temperature at which a a substance changes from solid to liquid when heated.
- The suitability of a material for a certain use is also influenced by other factors such as its cost, its colour and its texture.
- The ways we use materials and the processes we use to produce them always have an impact on the environment.

Concept map

Below is a concept map for what we have learnt about the properties of materials. We discussed several properties of materials in this unit. Can you see how we can summarise a lot of information onto one page?

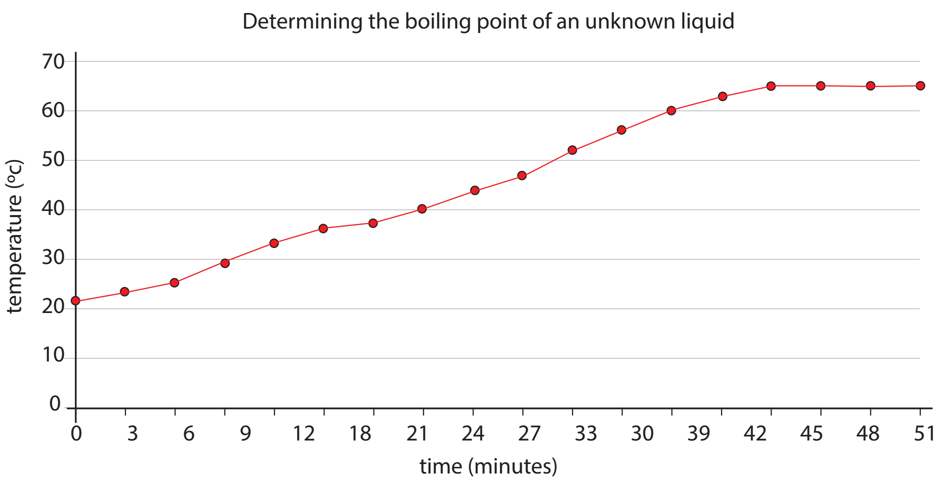


Revision

1. Below are a number of short sentences. In each case, you must complete the sentence by filling in the missing words. Write the whole sentences out on the lines provided. Fill in the missing word.
   a) The set of characteristics that describe a material are called the ________________ of that material.
   b) Materials that can be hammered into thin sheets are called ________________ (Metals have this property.)
   c) Materials that can be bent are called. ________________ (Some plastics have this property.)
   d) The boiling point of a material is ________________ at which the liquid state of that material turns into a gas.
   e) When we want to measure temperature we use a ________________.
   f) The boiling point of water at sea level is ________________.
   g) A material that conducts heat well is said to have a high ________________.
   h) If you want to create a circuit for a bulb, the material that you use in the circuit to connect the battery to the bulb must have a high ________________ [8]

2. State whether each of the following statements is TRUE or FALSE. If you think a statement is FALSE, you have to write a TRUE statement in its place.
   a) All liquids boil at 100 °C.
   b) Water always boils at 100 °C.
   c) Any given material will melt and freeze at the same temperature.
   d) When water is boiled over a bigger flame, it will boil at a higher temperature. [8]

3. A scientist wants to determine the boiling point of an unknown liquid. She places the unknown liquid in a beaker and carefully heats it on a hot plate. The scientist measures the temperature of the liquid at regular time intervals (every 3 minutes). Afterwards, she draws the following graph:



a) At what temperature does the unknown liquid boil? Show this temperature on the graph. [2]

b) How long does it take for the unknown liquid to start boiling? [1]

c) The scientist suspects that the unknown liquid is one of the substances on the following list. Use the list to identify the unknown liquid. Say why you think it is this substance. [2]

Substance	Boiling point (°C)
Acetone	56
Methanol	65
Ethanol	78
Isopropanol	83
Water	100

d) What was the temperature of the unknown liquid at the start of the experiment? [1]

Total [22 marks]

6 Separating mixtures

Key questions

Which properties are important when choosing a material for a particular use?
- How can we explain the term 'mixture'?
- What types of materials can be mixed?
- What methods can be used to separate a mixture into its original components?
- Which factors are important when choosing a method for separating a mixture into its components?
- Which materials can be recycled?
- Who is responsible for the disposal of waste materials?
- What are the negative consequences of poor waste management?

Keywords
- mixture
- suspension
- opaque
- solution
- clear

6.1 Mixtures

What does it mean to mix something? Can you mime an explanation (that means you have to explain without saying a single word)?

Is it possible to mix water? Discuss this with your class.

One substance alone cannot be a mixture. A **mixture** is made up of two or more different substances.

A mixture can contain solids, liquids and/or gases. The components in a mixture are not chemically joined; they are just mixed. That means we do not need to use chemical reactions to separate them. Mixtures can be separated using physical methods alone and that is what this unit is all about: how to separate mixtures.

There are many different kinds of mixtures. Before we learn how to separate them, it is worth looking at all the different kinds of mixtures briefly.

Different kinds of mixtures

A mixture of a solid and a solid

Figure 6.1 Soil is a mixture of different solid components.

Soil is an example of a mixture of solids. What are the substances found in soil?

A mixture of a solid and a liquid

What happens when clay or sand is mixed with water? Would you be able to see through a mixture of clay and water?

The mixture of clay or sand with water is muddy. The small clay particles become suspended in the water. This kind of mixture is called a **suspension**. Some suspensions are **opaque**; that means they are cloudy and we cannot see through them.

What happens when sugar is mixed with water? Does the mixture become muddy? Why not? The sugar dissolves in the water and the mixture is called a **solution**. Solutions are **clear**; that means we can see through them.

Figure 6.2 Can you see the difference between the suspension of sand and clay in water and a clear solution of sugar in water?

A mixture of a solid and a gas

Have you ever seen smoke from a fire? What is the smoke made of? Do you think it is a mixture?

Figure 6.3 The black smoke from a burning building.

Keywords

- emulsion
- abundant
- condense
- alloy
- pigment

A mixture of a liquid and a liquid

Milk is not a single substance, but actually a mixture of two liquids! The one liquid component in milk is water, and the other is fatty oil. The reason milk is opaque is that tiny droplets of the oil are suspended in the water. Can you remember what a mixture is called when a solid is suspended in liquid?

When some liquids are suspended in liquid, we call the mixture an emulsion. Like suspensions, emulsions tend to be opaque.

Are all liquid-liquid mixtures emulsions? (One way to recognise an emulsion is that it is opaque). Are all liquid-liquid mixtures opaque? Can you think of a liquid-liquid mixture that is not an emulsion? Discuss this with your class and give an answer.

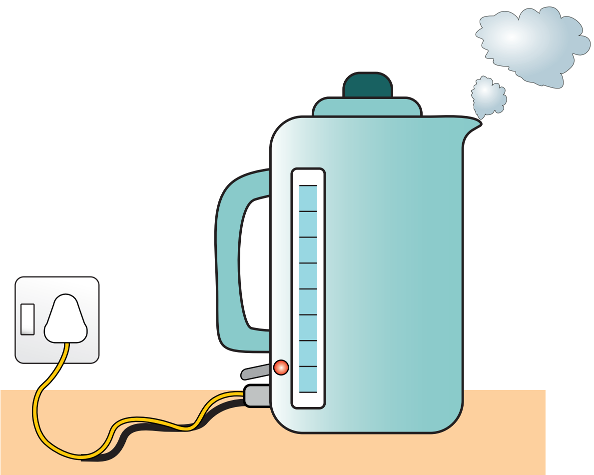
A mixture of vinegar and water is clear, and that is a clue that the mixture is a **solution**.

Solutions are special kinds of mixtures in which the particles are so well mixed that they are not separated from each other. We cannot make out separate substances any more – everything looks the same when we look with the naked eye.

A mixture of a gas and a gas

We learnt in Grade 6 Matter and Materials that the particles of gases are far apart. This means that gases can mix very easily, because it is easy for their particles to move in amongst each other. The air we breathe is not a single gas but actually a mixture of gases! Do you know what the two most **abundant** components are?

A mixture of a liquid and a gas



Do you remember that we discussed boiling in the previous unit (Properties of Materials)? What happens to a liquid when it boils?

Can you see the water vapour in the picture of a boiling kettle? Point to it with your finger. Discuss this with your teacher and classmates and when you have agreed on an answer, draw an arrow onto the picture to indicate the water vapour.

Can we see most gases? Why do you think so?

Clouds and fog or mist are all examples of tiny water droplets suspended in air.

We have learnt that mixtures can be made of substances in the same state or in different states. The following activity will help us apply our new knowledge about mixtures to more examples.

ACTIVITY Types of mixtures

Instructions

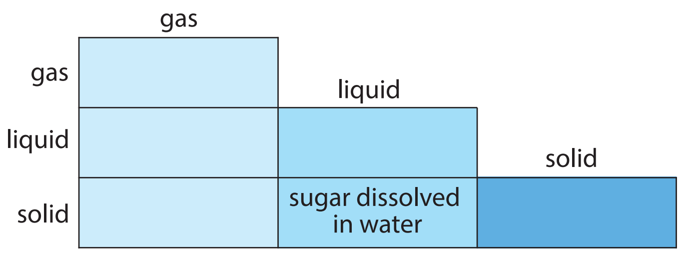
1. Look at the list of mixtures. Discuss in your group, or with your partner, what each mixture consists of.
2. Identify the type of substances (solid, liquid or gas) that are mixed in each of the examples on the list.
3. Write the name of each example in the appropriate block on the diagram.

Keywords

- filtration
- filtrate
- magnetic
- grain
- residue

Mixtures:

- air
- smoke
- hair oil (emulsion of oil and water)
- clear fruit juice (for example, apple juice)
- cloudy apple juice
- salty water
- alloys such as brass (used for coins) and stainless steel (used for rust-resistant metal items)
- foam plastic (like the material used for making mattresses and pillows)
- spray deodorant
- air freshener (aerosol type)
- paint
- dust cloud
- soil



For instance, sugar dissolved in water would go in the middle block of the bottom row, to show that it is a solid (sugar) mixed with a liquid (water).

Why do we make mixtures? Mixtures have many uses: perhaps we are mixing ingredients to bake a cake, or mixing metals to make a really strong alloy.

Many things around us occur naturally as mixtures: salty sea water, moist air, soil, compost, rocks (mixture of minerals) to name a few. Many mixtures are man made, for example; Coca Cola, paint, salad dressing and so on.

Figure 6.4 A cake is a mixture of ingredients, including flour, eggs and milk.

6.2 Methods of physical separation

Now that we know about the different kinds of mixtures that are possible, we are going to learn about some ways of separating them.

Mixtures are very useful. However, sometimes we need to separate mixtures into their components. Remember that the substances in a mixture have not combined chemically. They have not turned into new substances, but are still the same substances as before – they have just been physically combined. That is why we can use physical methods to separate them again.

How do we separate mixtures?

Suppose you were given a basket of apples and oranges. How would you sort them? You would probably pick out all the oranges from the apples by hand. The same method may not be suitable for all mixtures. You would probably not consider sorting sugar and sand **grains** by hand. Why not?

Let us look at some of the most commonly used methods of physical separation.

Hand sorting

How would you separate the mixture of beads in the adjacent picture into the different colours?

Figure 6.5 A mixture of different coloured beads.

ACTIVITY Thinking about hand sorting

1. Would hand sorting also be a practical way to sort out the mixture of rice and lentil beans in the picture alongside?
2. Would hand sorting be a practical way to sort the pebbles out of a large pile of sand?
3. Besides what we discussed in the unit, think of at least three other examples of mixtures that could be hand sorted.
4. When is hand sorting a good method for separating the components in a mixture?

Figure 6.6 A mixture of rice and lentils

Sieving

Can you think of a practical way to sort stones or pebbles from sand? Do you think picking the pebbles out by hand would work?

When we have large quantities of materials to sort and the different particles have different sizes, we can **sift** the mixture through. The smaller particles will fall through the openings in the sieve, while the larger particles stay behind.

Figure 6.7 How would you separate the pebbles from the sand in this pile?

Filtration

When the particles in a mixture are too small to be caught by a sieve and when the components of the mixture are in different states, we can separate them by **filtration** using a filter.

What type of mixture is the muddy water in the glass an example of?

Muddy water is poured through a funnel lined with filter paper to remove the small sand and clay particles.

Have you ever noticed how, when people have to work in dusty or smoky environments, they wear dust masks or smoke masks? Why do you think that is necessary?

Take note

The clear liquid that has passed through the filter paper is called the filtrate and the particles that are left behind on the filter paper are called the residue.

Figure 6.8 A firefighter wears a mask to filter out the smoke.

The following diagram shows how a gas mask works. Layers of very fine filters trap harmful substances and dust or smoke particles, so that only clean air is let through.

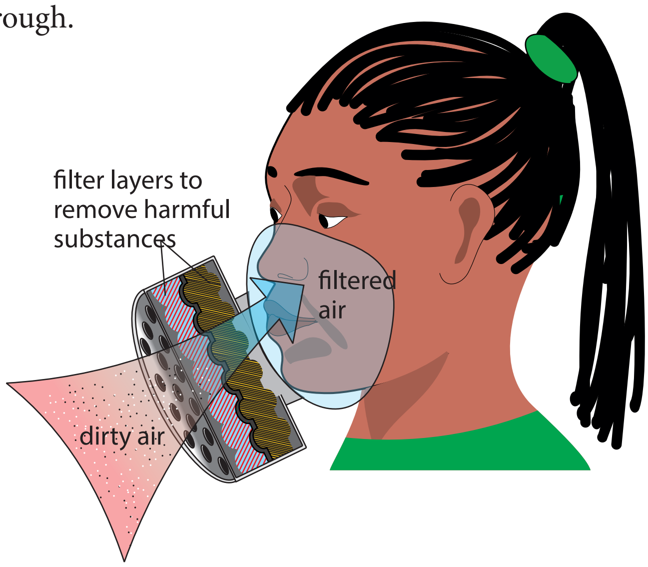


Figure 6.9 A smoke mask consists of filter layers which clean the dirty air before it is breathed into the body.

Did you know?

In ancient cultures, grain and chaff were separated by a process called winnowing. They would throw the mixture into the air and the wind would blow away the lighter chaff, but not the heavier grain.

ACTIVITY Thinking about sieving and filtering

1. Besides what we discussed in the unit, think of at least three other mixtures that could be sieved, and write them in the space below.
2. When is sieving a good method for separating the components in a mixture?
3. Nowadays most people use tea bags to make tea, but there was a time when people brewed tea from leaves and then poured the tea through a sieve or strainer into the cup. Why do you think they did this?

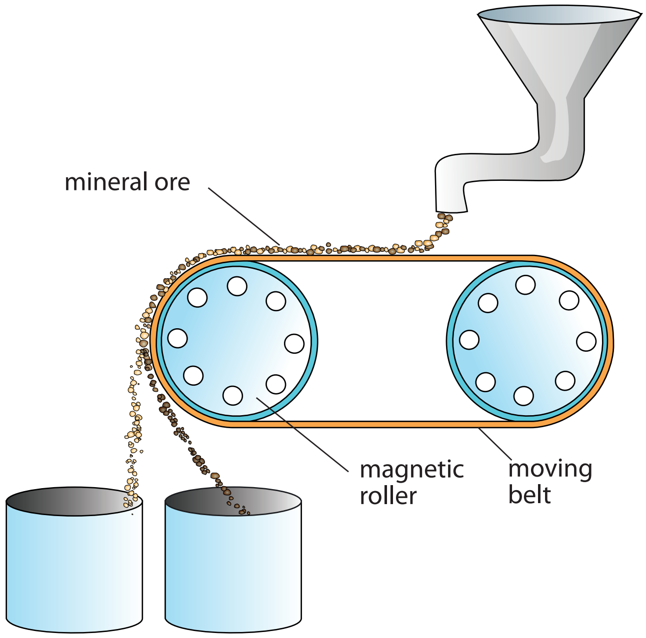
Figure 6.10 Tea leaves and other particles have collected in the sieve after pouring the tea into the cup.

4. Sometimes the particles that we want to remove from a mixture are so small that they will pass easily through a sieve (think of the example of the muddy water from before). Can you think of a way to overcome this?
5. Besides what we discussed in the unit, think of at least three other mixtures that could be filtered, and list them.
6. When is filtering a good method for separating the components in a mixture?

The **magnetic** properties of the metals allowed them to be separated in this way.

Magnetic separation

The following diagram shows how magnetic separation can be used to separate a mixture of components. In the example, mineral ore that contains two compounds (one magnetic, and the other non-magnetic) is being separated. The ore grains are fed onto a revolving belt. The roller on the end of the belt is magnetic. This means that all the magnetic grains in the ore will stick to the belt when it goes around the roller, while the non-magnetic grains will fall off the end. As soon as the magnetic grains move past the magnetic roller, they will also fall down.



In the above diagram, what colour are the non-magnetic grains and into which container do they fall? Label this on the diagram. What colour are the magnetic grains and which container do they fall into?

ACTIVITY Thinking about magnetic separation

1. Besides what we discussed in the unit, can you think of two other mixtures that could be separated magnetically? Write them in the space provided.
2. When is magnetic separation suitable for separating the components in a mixture?

How can we separate the components in a solution? Let's find out.

Keywords

- evaporation
- condensation
- distillation
- still
- chromato-graphy
- chromato-gram
- solute
- solvent

Solutions as mixtures

The substances in a solution are mixed on the level of individual particles. In a sugar and water solution, the sugar particles and the water particles are mixed so well that we could not distinguish them with the naked eye. You may think that mixtures that are so 'well-mixed' are impossible to separate! But as we shall soon see, this is not true.

Evaporation

Do you know where most of the salt that we use in South Africa comes from? South Africa gets it salt from inland salt pans, coastal salt pans and sea water. A salt pan is a shallow dam in the ground where salt water evaporates to leave a layer of dry salt.

Figure 6.11 An aerial view of salt pans in Peru.

Figure 6.12 A man is busy collecting the dried salt to be packaged and sold.

When sea water is allowed to stand in shallow pans, the water gets heated by sunlight and slowly turns into water vapour, through evaporation. Once the water has evaporated completely, the solid salt is left behind.

Do you think this is a good method for separating salt from water? Do you think it would work for a sugar and water solution?

ACTIVITY What if we want to keep both the water and the salt?

Questions

1. Do you think separation by evaporation would be a good method to separate a salt-water solution if you wanted to keep both the salt and the water? Why do you say so?
2. Can you think of a way to modify the method so that the water that evaporates is not lost? Perhaps the following diagram will help you to formulate a plan. Write an explanation.

3. What is happening in the kettle?
4. Can you say what change in state is happening inside the kettle? What is the process called?
5. What change of state is occurring on the cold surface of the metal plate? What is the process called?

Hint: The change of state from gas to liquid was covered in the previous unit, under Physical properties of materials.

6. Does the salt evaporate with the water? How would you find out?
7. What can you tell about the purity of the water after it has evaporated and condensed?

Distillation

Distillation is the separation of one substance from another by evaporation followed by condensation. The apparatus used in this technique is called a still.

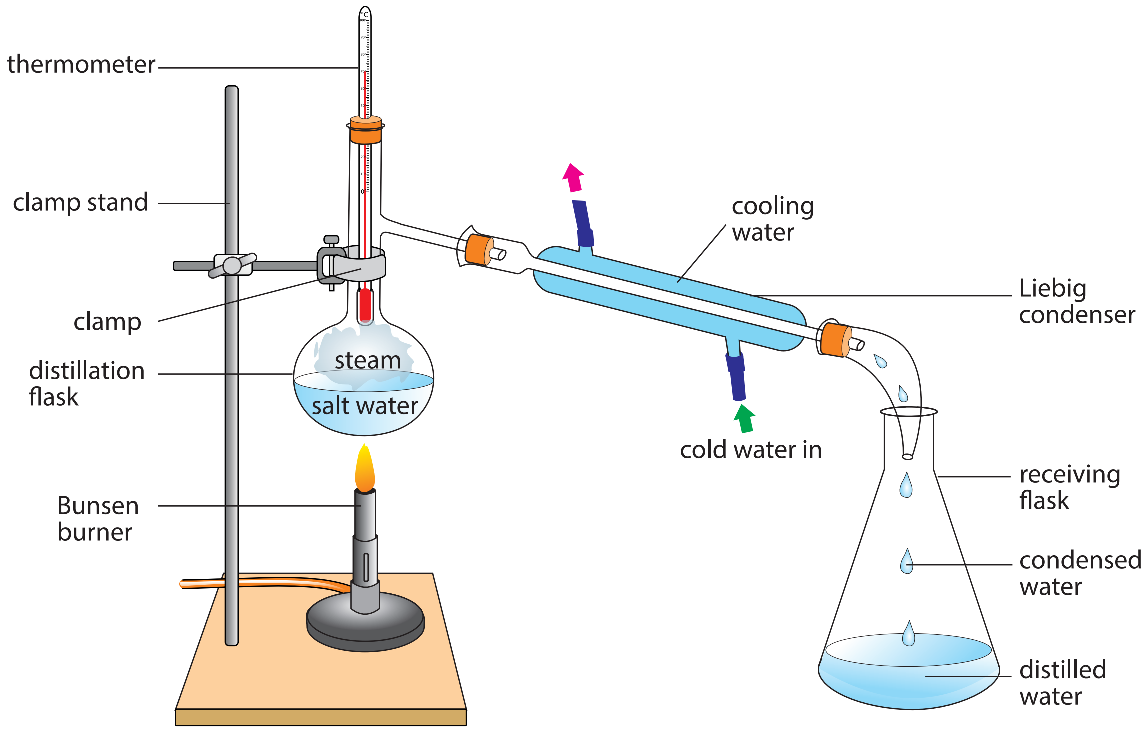


Figure 6.13 Experimental setup for distillation

Suppose we want to separate the water and salt in sea water. We would place the sea water in the round flask on the left of the picture (in the distillation flask). We would then boil the sea water to produce water vapour, or steam. The salt would not evaporate with the water, because only the water evaporates. The water vapour rises through the top of the flask and passes into the Liebig condenser.

> **Did you know?**
>
> Crude oil is separated into different components using distillation. The components are evaporated, starting with lighter fuel (which has the lowest boiling point), then jet fuel, then petroleum, then motor car oil, until only tar is left. We call the separated components fractions, and the process is called, fractional distillation.

The Liebig condenser consists of a glass tube within a larger glass tube. The condenser is designed in such a way that cold water can flow through the space between the tubes. This cools the surface of the inner tube. The water vapour condenses against this cold surface and flows into the receiving flask. Since the salt has not evaporated, it stays behind in the distillation flask.

Distillation is also the best way to separate two liquids that have different boiling points, like water and ethanol for example. Let us have a look.

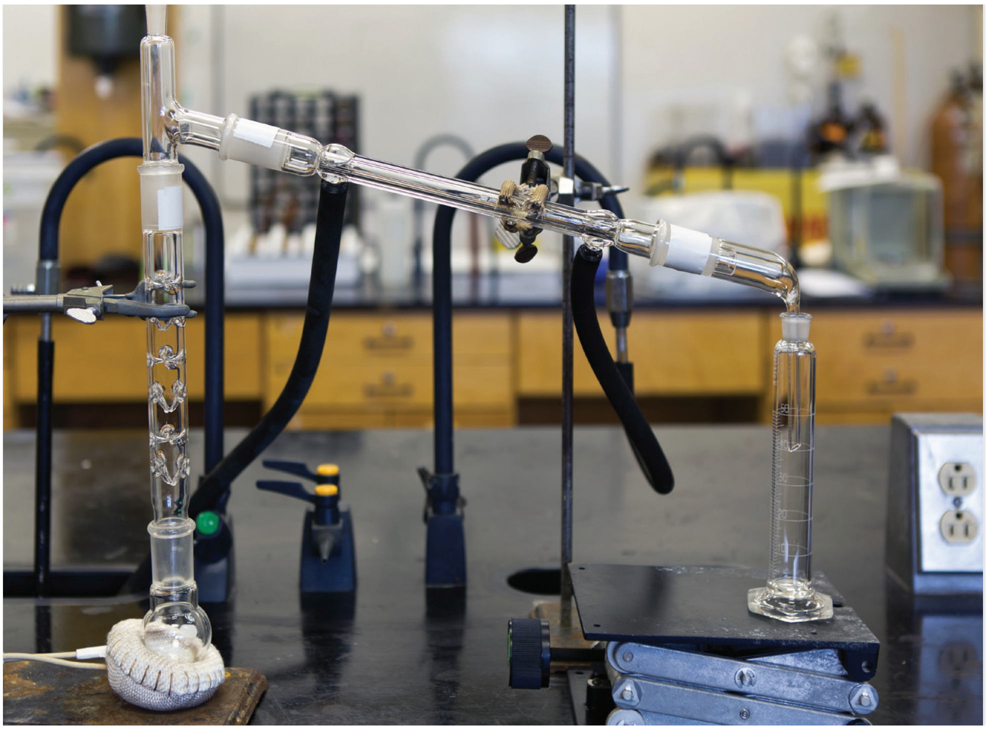


Figure 6.14 Two Liebig condensers which are used in the distillation process

ACTIVITY How can we separate two liquids with different boiling points?

Questions

1. Can you remember the temperature at which water boils? Write it down below.
2. What is this temperature called?
3. Ethanol boils at a temperature lower than the boiling point of water, namely 78 °C. Suppose you mix some water and some ethanol. The mixture is at room temperature to begin with. Now suppose you start heating the mixture. What temperature would be reached first: 78 °C or 100 °C?
4. What do you think will happen when the mixture reaches a temperature of 78 °C? Do you think the ethanol will start to boil?
5. Will the water boil at the same time?

Most inks are a mixture of different pigments, blended to give them just the right colour. A **pigment** is a chemical that gives colour to materials.

When a mixture contains colourful compounds, it is often possible to separate the different components using a separating method called chromatography. Let's have a look at this next.

Chromatography

Chromatography is a method for separating coloured substances into individual pigments. We are going to explore this in the next investigation.

Suppose it contains a third substance that we want to separate. How would you do this?

There is one more separation technique for us to explore. Have you noticed how ink on paper will sometimes 'run' when it gets wet?

In paper chromatography, liquid is drawn through the paper fibres. But, why do the pigments in the ink separate into bands of different colours?

The pigments in the ink are carried along by the liquid, but because they are different compounds, they get carried upwards at different speeds. This causes them to appear as bands of different colours on the chromatogram.

Pigments migrate at different speeds because of differences in their properties: large pigment particles tend to move more slowly. Furthermore, particles that dissolve well in the liquid will tend to stay in the liquid and be carried to the top quickly, while particles that bind well to the paper will tend to move more slowly.

Now that we have learnt about some of the different ways in which mixtures can be separated, we are going to apply what we know to separate a mixture made of many components.

Take note

Chromatography comes from the Greek words 'chroma' (meaning 'colour') and 'graphé' (meaning 'to write').

Investigation Is black ink really black?

Aim

To separate the pigment components in ink using different liquids.

Hypothesis

What do you propose the answer to our investigative question is? This is your hypothesis.

Materials and apparatus

- absorbent paper cut into strips approximately 3 cm wide and 12 cm long
- clear drinking glass or beaker
- assorted black pens and markers
- tap water
- pencil
- paper clip or clothes peg
- filter paper
- dropper
- variety of liquid solvents (ammonia, surgical spirits, methylated spirits, and nail polish remover)

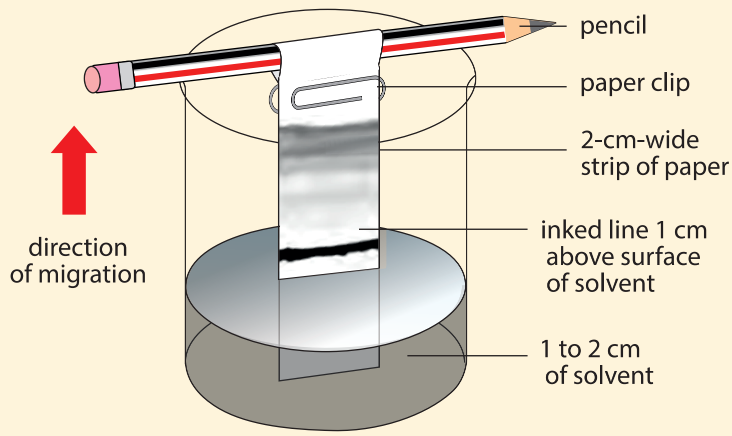
Take note

A solvent is a substance that dissolves a solute, resulting in a solution. A solvent is usually a liquid, but can also be a solid or a gas.

Methods

To make a strip chromatogram:

1. Use a black pen or marker to draw a line across one end of the paper strip, 2 cm from the end.
2. Pour tap water into the beaker to a depth of approximately 1 cm.
3. Wrap the unmarked end of the paper strip around the pencil and secure it in place with a paper clip.
4. Before putting it into the glass, adjust the strip of paper so that the height of the inked line is approximately 1 cm above the surface of the liquid by holding it against the outside of the beaker.
5. Lower the strip into the glass and rest the pencil across the top of the glass as shown in the diagram. The end of the strip should be in the water, but the inked line should be above the surface of the water.
6. Allow the liquid to soak up into the paper, rising through the inked line.

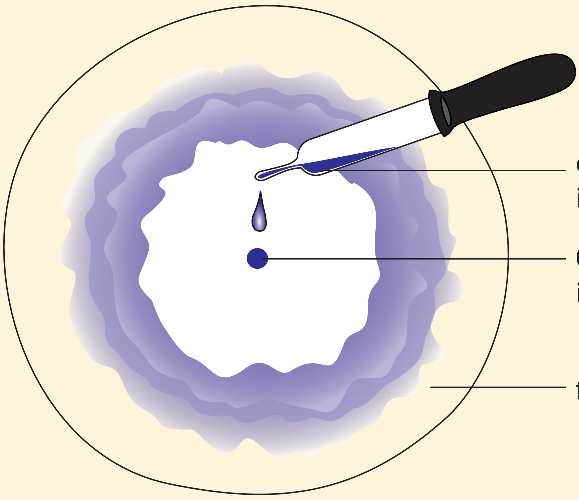


7. When the migrating pigments approach the top of the strip, near the paper clip, remove the paper strip and allow it to dry on a flat, non-porous surface.
8. Make a similar strip chromatogram for each of the black pens you have collected.
9. Compare the chromatograms. Are they the same or are they different?
10. When you have finished comparing your chromatogram with those of the rest of the class, you can either stick your chromatogram in the following space, or draw a picture of it in the space.

To make a circular chromatogram

1. Lay a large round piece of filter paper on a smooth non-absorbent surface, like the surface of your desk, for instance.
2. Use one of the coloured pens to make a 0,5 to 1 cm ink spot in the centre of the disk.
3. Lay the paper disk flat over the top of a beaker.
4. Place a drop of water in the centre of the ink spot.

5. Add another drop of water every minute or so to make the chromatogram spread toward the edges of the paper disk.



6. Repeat the experiment with one of the other solvents (ammonia, alcohol or nail polish remover).

Observations

1. Do the two chromatograms look the same or different? If they look different, and you have used the same pen, why do you think that is?
2. Which colour pigments were you able to observe?
3. Draw pictures of your chromatograms in the space in your books.

Conclusion

1. What can you conclude about the pigments that make up black ink?

ACTIVITY Chromatography

Instructions

Look at the picture of the chromatogram below.

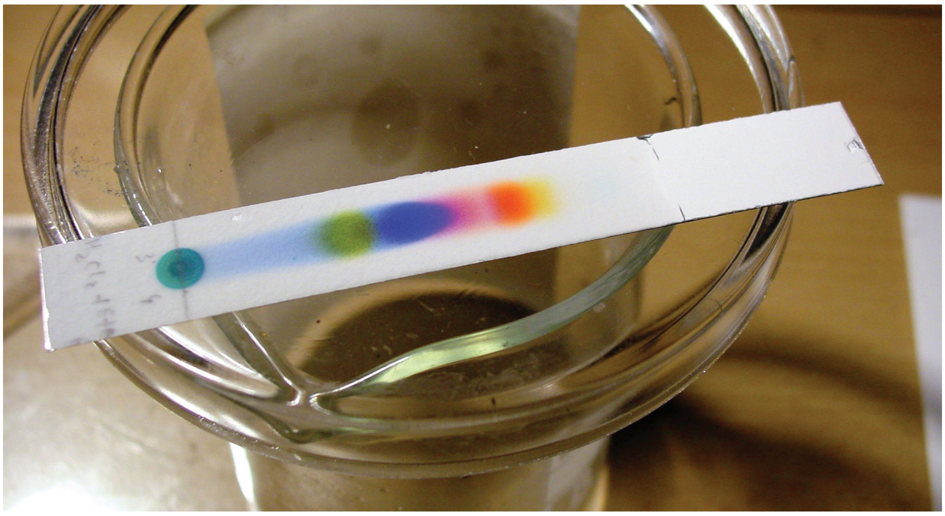


Figure 6.15 An example of a strip chromatogram

1. Which colour pigment is moving up the paper at the fastest speed? Why do you say so?
2. Which colour pigment is moving up the paper at the slowest speed?
3. Why are the different pigments carried at different speeds?

ACTIVITY Separating a complex mixture

Imagine you are a member of a team of scientists working together in a laboratory. Your team has been given an important job. You have been given a beaker that contains a mixture of substances to separate.

The mixture contains the following components:
- sand
- iron filings
- salt
- ethanol
- water.

Your job is to design a procedure for separating the mixture into its individual components. How would you do that? Your procedure should be summarised in the form of a flow chart.

Before you start, imagine what the mixture would look like. Draw a picture of a clear container and the different contents in the mixture.

To help you design your procedure, here are a few guiding questions and a template for your flow chart:
1. What is the physical state (solid, liquid or gas) of each of the components in the mixture? Copy and complete the table below in your books.

Component (substance)	State (solid liquid or gas)	Dissolved or undissolved?

2. Name the solids that will not dissolve in the mixture. These are the undissolved solids.
3. Name the dissolved solids in the mixture.
4. What would be the best method for separating the undissolved solids from the liquids in the mixture? Write the name of this method in the block numbered 1 of the flowchart below.
5. Write the names of the undissolved solids in block 2 of the flowchart.
6. What remains after the undissolved solids have been removed from the mixture? Write the names of these compounds in block 3.
7. How could we separate the undissolved solids?

   Hint: Look at the flow chart for some ideas.

   Write the name of this process in block 4.
8. Write the names of the two undissolved solids in blocks 6 and 7.

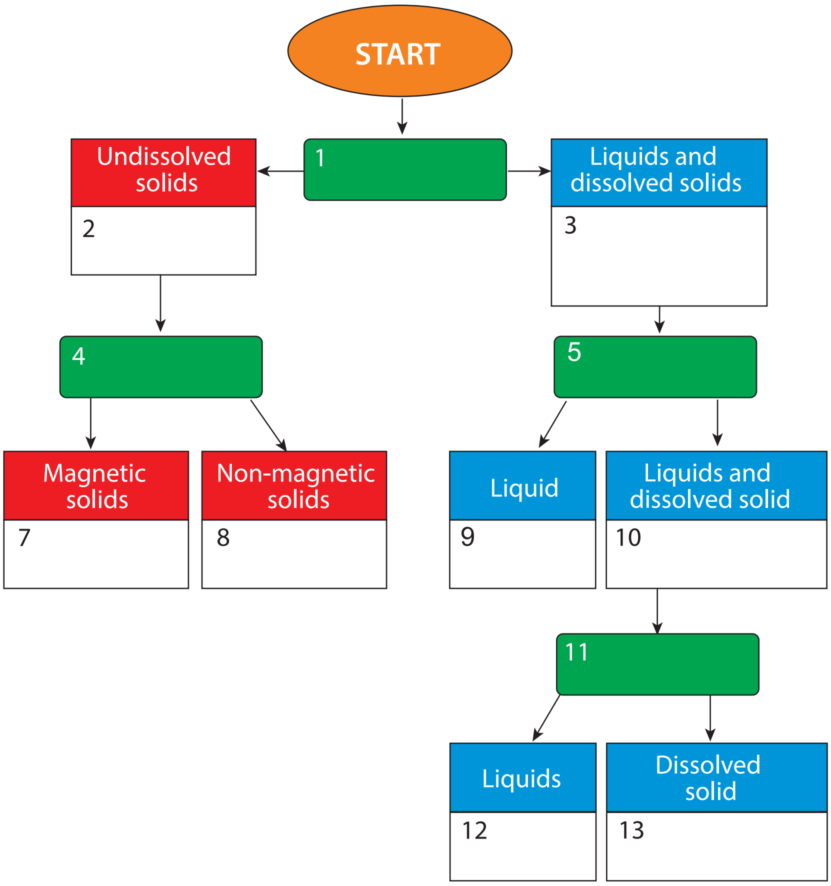
9. How could we separate the liquids from the dissolved solid? We could evaporate them, but then they would be lost. What other option is available if we want to separate the components in a solution? Write the name of this process in block 5.
10. Which liquid would be distilled first?

    Hint: Which liquid has the lowest boiling point?

    Write the name of this liquid in block 8.
11. What remains in the solution when the first liquid is removed? Write the names of these components in block 9.
12. How can we separate the liquid from the dissolved solid?

    Hint: This process is the same as the one in block 7.

    Write the name of the process in block 10.
13. Write the names of the final two components in blocks 11 and 12.



6.3 Sorting and recycling materials

Over time, some of our things get old and break and we need to throw them away. When we buy food or other items, the packaging used for wrapping these items is also thrown away. But what does 'away' mean? Does it mean these waste items just disappear? Where do you think our rubbish goes once we 'throw it away'?

ACTIVITY What happens when we throw things away?

Instructions

1. Work in groups of three to four.
2. In your group, spend 5 minutes discussing the posters and what you think they mean.
3. Get the posters.

Questions

1. Write a paragraph to explain the messages on the posters. What do you think they mean?
2. Do you think it is possible to stop throwing things away altogether?
3. Can you suggest ways to reduce the amount of trash that is thrown away in your home?

ACTIVITY Conducting a survey on waste management

How is household waste managed by local authorities?

In some suburbs, recycling is actively encouraged and special transparent recycling bags are provided for this purpose.

- Do you have recycling in your community?
- Is the recyclable waste collected from your home, or do you have to drop it off at a container or a depot?
- Did you know that some people even make money selling recyclable waste that they collect?
- Do you know which materials from household waste can be recycled?
- What are the four main categories?

Figure 6.16 Have you seen colourful bins similar to these around your school or in shopping areas? They are for recycling.

Figure 6.17 If you ever need to dispose of objects such as batteries and fluorescent light bulbs that contain harmful substances, be sure to use the correct recycling bin.

Careers in chemistry

Do you know what chemists do? Let's discover the possibilities of chemistry!

Chemists study various chemical elements and compounds, their properties and how they react with each other. We will learn about elements and compounds in the next unit. Chemists are also responsible for developing new materials with specific properties; such as new medicines; innovative materials for building buildings and other structures; materials that could be used for making fuels from renewable sources and many others.

If you study chemistry after you have finished school, you can work as a researcher, a laboratory technician, a science teacher and many other important and stimulating jobs! Be curious and discover the possibilities! Science can help us solve problems in the world around us.

ACTIVITY Careers research task

Instructions

1. Below is a list of different careers that all use chemistry in some way. Have a look through the list and then select one that you find most interesting.
   Some careers involving chemistry:
   - Chemical education/teaching
   - Chemistry researcher
   - Environmental chemistry
   - Mining industry
   - Oil and petroleum industry
   - Pharmaceuticals and drug discovery
   - Space exploration
   - Waste management

   Write down your descriptions of the career you are interested in.
2. Do an internet search to find out what the career involves.
3. Write a short description of this career. Find out what level of chemistry you will need for this particular career.
4. There are many other careers besides the ones listed here which use chemistry in some way, so if you know of something else which is not listed here and it interests you, follow your curiosity and discover the possibilities!

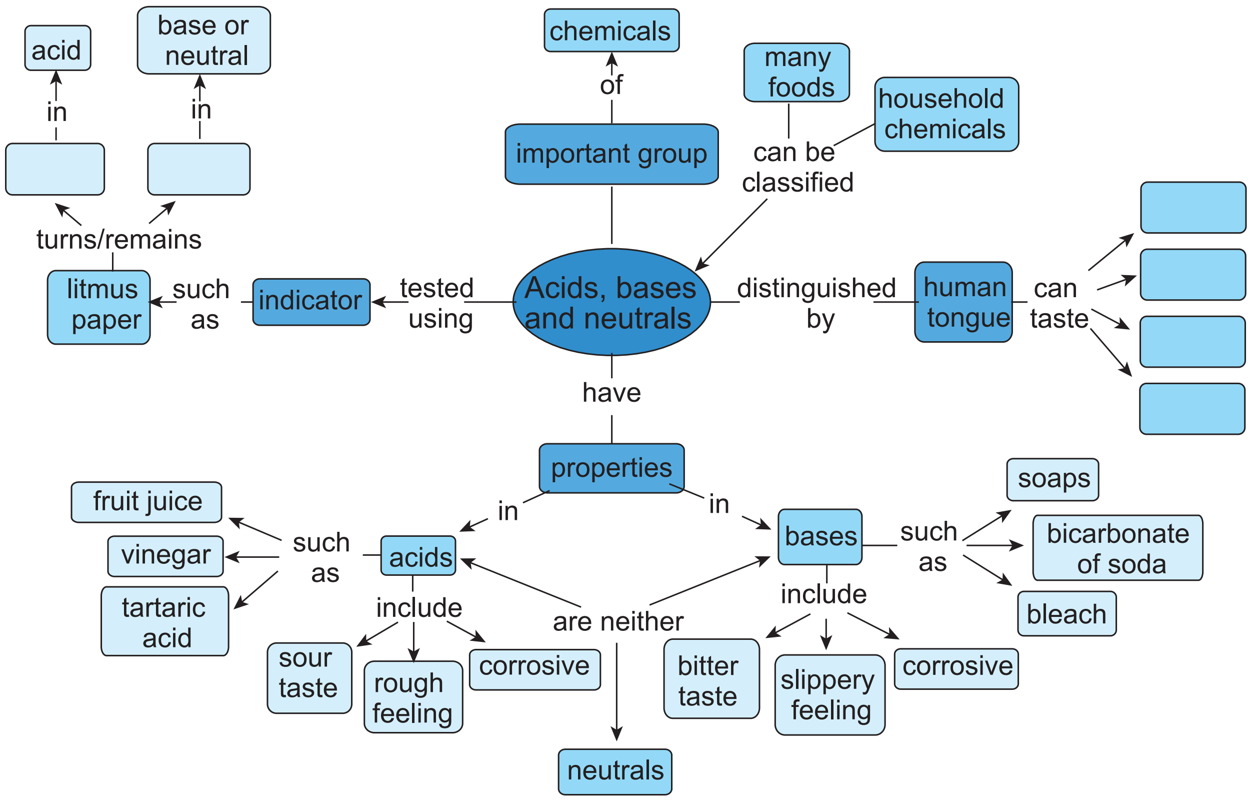
Summary

Key concepts

- A mixture consists of two or more components that have different physical properties.
- The components in a mixture are not chemically joined; they do not change their chemical identities and they retain their physical properties as well.
- When we want to separate a mixture, we can use the differences in the physical properties of the components of the mixture to separate the components from each other.
- Hand sorting is a suitable separation method for a mixture that contains a relatively small number of large items.
- Sieving is a suitable separation method when the pieces to be separated are sized differently.
- Filtration is a good method for separating an undissolved solid from a liquid.
- Components with different magnetic properties can be separated using magnetic separation.
- Evaporation is a suitable separation method for removing a liquid from a solid.
- Distillation is a suitable method for separating two liquids with different boiling points.
- Chromatography is a good method for separating coloured pigments from each other.
- Waste disposal should be managed in a responsible way so that the negative impact on the environment is as small as possible.
- Metals, plastics, paper and glass can be recycled.
- Organic waste can be turned into compost.
- Responsible waste disposal is everyone's responsibility, but it is usually managed by the local authorities, who have systems for sorting and recycling waste.
- Poor waste management leads to negative consequences for humans, animals and the environment. Some of these are:
  - pollution of the soil, water resources and the environment;
  - health hazards and the spread of disease;
  - blockage of sewers and drainage systems;
  - land wasted when it is used to dump or bury garbage (landfills); and
  - materials and other resources wasted when they could have been recycled.

Concept map

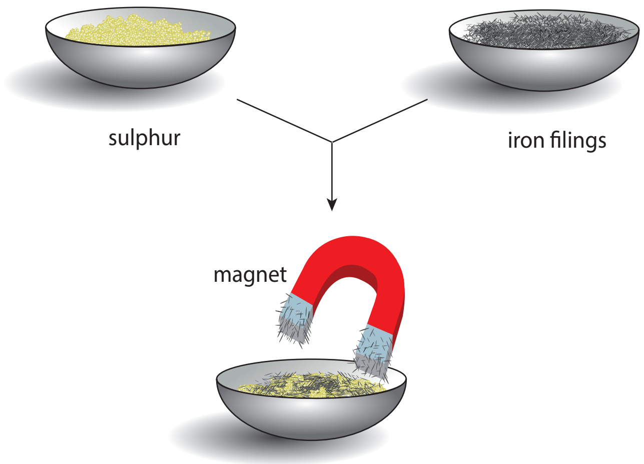
We looked at physical methods to separate mixtures and these are shown in the concept map. Give an example of the types of mixtures you could separate using three of these methods. What negative consequences does human waste have on the environment? Fill these in the concept map.



Revision

1. Two important words have been left out of the following paragraph. The missing words are chemical and physical. Rewrite the sentences and fill in the missing words in the paragraph by placing each one in the correct position: The components in a mixture have not undergone any changes. They still have the same properties they had before they were mixed. That is why mixtures can be separated using methods. [1]

2. In the diagram below, iron filings and sulfur have been mixed. Write a short paragraph (2 sentences) to explain how the mixture can be separated using magnetic separation. [2]

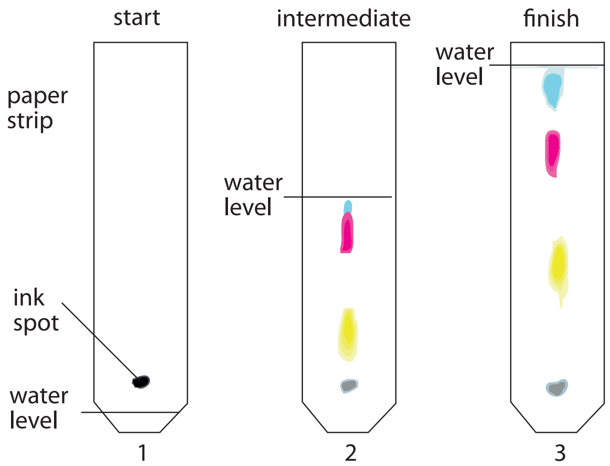


3. A vacuum cleaner creates a suspension of dust in air as it sucks up the dust on the floor. Clean air comes out of the vacuum cleaner. How does the vacuum cleaner separate the dust from the air? [2]

4. Write a short paragraph (3 sentences) to explain how salt is produced from sea water. [3]

5. Choose the correct word to complete the sentence from the following list: colours; boiling points; tastes. Write the word below. Suppose we want to separate two liquids using distillation as the separation method. This will only be possible if the two liquids have different... [1]

6. The diagram below shows a strip chromatogram that is being prepared from a spot of black ink. The strip on the left shows the chromatogram at the start of the experiment, the strip in the middle shows the chromatogram halfway through the experiment, and the strip on the right shows the chromatogram at the end of the experiment.



a) How many different pigments does the black ink consist of? Explain your answer. [1]

b) Which pigment is moving up the paper at the fastest speed? Arrange the pigments in order of increasing speed of movement. [2]

7. The table below contains a list of mixtures. In the right hand column, next to each mixture, write the best method for separating the mixture into its components in your exercise books. [8]

Mixture	Separation method
Salt and water	
Sand and iron filings	
Sand and water	
Colour pigments in ink	
Stones and sand	
Ethanol and water	
Oranges and apples	
Sugar and iron filings	

8. Name the four classes of materials that can be recycled. [4]

9. Write a sentence to say how you would dispose of each of the following non-recyclable materials: vegetable peels; old running shoes; expired medicine. [3]

Total [27 marks]

7 Acids, bases and neutral substances

Key questions

- Which tastes can we sense with our tongues?
- How does our sense of taste ensure our survival?
- What are the unique properties of:
  - acids
  - bases?
  - neutral substances?
- Which household substances are (or contain):
  - acids
  - bases?
  - neutral substances?

Keywords

- flavour
- sense
- taste buds
- chemoreceptor
- savoury
- instinct
- tongue map

Did you know?

Insects have the most highly developed sense of taste. They have taste organs on their feet, antennae, and mouth parts.

How can we tell if something is an acid, a base or a neutral substance?

What do you know about acids? Would you touch an acid? Have you ever tasted an acid? Do you think it is possible to taste an acid without burning your tongue? What do you think it would feel like when an acid burned your tongue?

Before we talk more about acids, let us first examine the human tongue. It is a most fascinating organ, and plays an important role in our sense of taste.

7.1 Tastes of substances

What is your favourite food? What do you like most about your favourite food? You will probably say that you just LOVE the taste of it! The taste of our favourite foods make us feel good. How do we taste our food?

Look in the mirror, and stick out your tongue. Look for small, round bumps. These are called papillae. Most of them contain taste buds. The taste buds are very small structures which have sensitive hairs.

Figure 6.1 We taste food with tiny structures on our tongues!

ACTIVITY Have a look at your own tongue

Materials

- mirror
- pencil
- sugar water
- lemon juice

Figure 6.2 Have you tasted a lemon before?

Instructions

1. Look in the mirror at your tongue.
2. Stick it out as far you can and try to see the papillae. Are they larger in some areas?

Close your eyes and imagine biting into a slice of lemon.

1. Can you describe the experience?
2. What does the lemon taste like? Sweet, sour, salty or bitter?

If you have sugar solution and lemon juice available in the class, taste these different substances. See if you can identify where on your tongue you taste the two different tastes.

You can sense only four different tastes with your tongue.

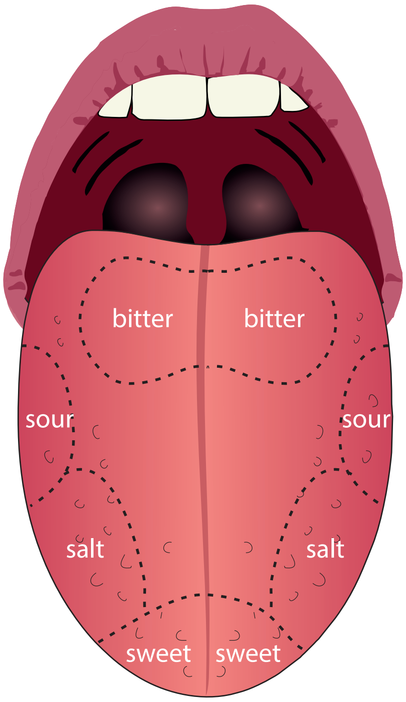


Figure 6.3 The tongue map

The four main tastes that are most common, are sweet, sour, salt and bitter. These tastes combine to make up the different flavours of our foods.

Figure 6.4 How would you classify the taste of apples? Sweet or sour? Bitter? Perhaps a combination?

Figure 6.5 Many people really enjoy the sour-salty taste of salt and vinegar chips!

There is a good reason for why we like certain tastes, but not others.

Did you know?

We have more than10 000 taste buds in our mouth. You even have taste buds on the roof of your mouth.

Take note

A flavour is a combination of tastes and smells.

Take note

When we want to say something has the properties of an acid, we use the adjective 'acidic'. When we want to say something has the properties of a base, we use the adjective 'basic'.

Did you know?

Almond nuts can be sweet or bitter, depending on the type of tree they come from. The sweet almonds (which we eat) do not contain poisonous chemicals. Bitter almonds from another tree species contain chemicals which are toxic to humans.

Did you know?

The word acid comes from the Latin word 'acidus', meaning 'sour'.

Our sense of taste protects us

Just as we like and seek out foods that taste good, our bodies have also been programmed to avoid food with strong bitter or sour tastes. This helps to protect us against poisons, which often have a strong bitter taste. 'Bitter' is also the basic taste that our tongues are most sensitive to. Spoiled food often tastes sour and it may also have a bad smell. Our instinct will be to avoid it, which will protect us from becoming ill from ingesting the organisms that have spoiled the food.

Figure 6.6 Sweet almonds, such as these, are edible as they do not contain toxic chemicals, unlike the wild bitter almonds.

Figure 6.7 Cocoa beans come from cocoa pods. Chocolate is made from cocoa, but cocoa is very bitter. Lots of sugar is added to chocolate to make it sweet.

Soon the link between the tongue and chemical substances will become clear.

7.2 Properties of acids, bases and neutral substances

In the previous section you had to imagine what it would feel like if an acid burned your tongue. In the next section we are going to learn more about acids. We will learn that they taste sour (and also why it is not a good idea to taste them!).

We will also learn about other substances that have a special relationship with acids. They are called bases. Finally, we will also learn about substances that are neither acids nor bases, but neutral substances.

Acids

Do you know the names of any acids? Think about this as a class and make a list of all the acid names you have heard.

There are many different acids. You may have already tasted an acid in class. Was it the sugar water or the lemon juice?

Figure 6.8 Do you like sour sweets, such as sour worms? The sour taste comes from fumaric acid. Fumaric acid is a natural acid with a sour taste, that is often added to foods.

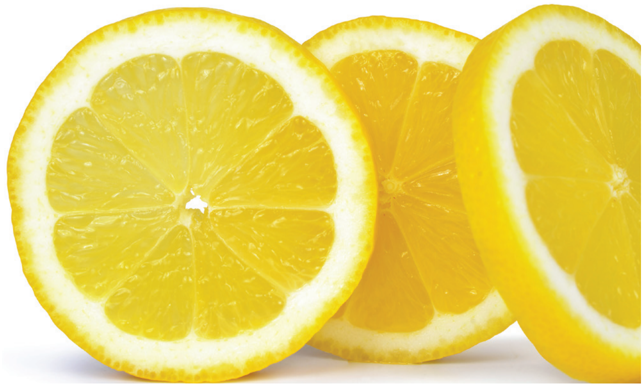


Figure 69 The juice of lemons is rich in ascorbic acid (vitamin C) and citric acid, which makes it taste sour.

All acids taste sour. Does this mean that all acids are safe to taste? Definitely NOT! Next, we will learn which acids should not be tasted under any circumstances.

Laboratory acids

Some acids are very dangerous and must be handled carefully. These acids are **corrosive**. They can cause serious burns on your skin. Scientists always wear protective clothing when handling these acids. It would be very dangerous to taste them. These acids are most often found and used in laboratories and certain industrial processes. We will refer to them as laboratory acids.

Figure 6.10 Concentrated hydrochloric acid is very corrosive and dangerous.

Keywords

- corrosive
- acid
- chemical formula
- essential
- immune system
- ascorbic acid
- citric acid
- formic acid

Figure 6.11 This scientist is handling an acid. Can you see he is wearing protective clothing, gloves, and safety glasses?

Figure 6.12 Look out for this label on bottles which contain corrosive substances, such as strong acids.

Take note

The chemical formula of a substance tells us which elements it contains.

Did you know?

You have a laboratory acid inside your body?! Your stomach contains hydrochloric acid (HCl). HCl helps breakdown the food for digestion. Your stomach has a very mucous lining which helps protect it from the strong acid.

Did you know?

Insects have the most highly developed sense of taste. They have taste organs on their feet, antennae, and mouth parts.

Name of the acid	Formula of the acid
Hydrochloric acid	HCl
Nitric acid	HNO_3
Sulfuric acid	H_2SO_4

The above table contains the names and chemical formulae of the three most common laboratory acids. Even though you have not learnt how to write chemical formulae yet, we have included them here. You should handle containers with these formulae printed on them with care.

There are many other laboratory acids that we have not listed. These are only the most common ones.

Other acids in the foods we eat are not dangerous. In fact, some are even vital for our health and well-being. Let's now have a look at acids that are safe to handle.

Natural and household acids

Not all acids are dangerous. One such acid is called ascorbic acid, or vitamin C. Vitamin C helps our immune system. Which foods contain vitamin C? Have a look at the pictures.

Figure 6.13 Kiwi fruit.

Figure 6.14 Strawberries.

Figure 6.15 Broccoli.

Figure 6.16 Bell peppers.

We will call the acids that we find in food natural acids. Many of these natural acids are found in the kitchen. For this reason they are also sometimes called household acids.

One very well-known household acid is acetic acid. Vinegar is a mixture of a small amount of acetic acid dissolved in water.

Figure 6.17 Spirit vinegar and balsamic vinegar.

ACTIVITY Acids (True or false?)

Instructions

1. Let's briefly revise some of the concepts we have learnt so far.
2. Below are some statements. You need to state whether they are true or false. If they are false, explain why.

True or false?

1. We can sense three tastes with our tongues.
2. Acids taste sour.
3. If we want to know if something is an acid, we can just taste it.
4. All acids are dangerous.
5. Vinegar is a mixture of a small amount of acetic acid dissolved in water.
6. Laboratory acids must be handled with care and using protective clothing.
7. The symbol in the illustration means you can wash your hands using this substance.
8. Formic acid is commonly referred to as Vitamin C.
9. Oranges are the food which contain the highest amount of ascorbic acid.

Did you know?

Formic acid is what gives ants their sting when they bite. 'Formic' comes from the Latin word for ant, 'formica'.

Did you know?

Many fizzy drinks contain carbonic acid.

Do you think that it would be possible for acids to lose their strength? There is one class of compounds that can make acids lose their strength. These compounds are called bases.

Bases

Bases can neutralise acids and vice versa. What does it mean to neutralise something?

Bases and acids have chemical properties that are the opposite of each other. We can think of bases as the chemical opposite of acids.

Keywords

- base
- neutral substance
- neutralise
- alkali

Take note

When an acid and a base are mixed together in the correct ratio, they will neutralise each other. This means that the solution made up of the acid and the base becomes something that is neither an acid nor a base, but neutral. In the process, both the acid and the base will lose their unique characteristics.

As with acids, there are some bases that are extremely dangerous. The same hazard symbol that is used to warn people of the dangers of acids, is also used for these bases. Strong bases react corrosively with other materials and can burn your skin. They must be handled carefully and always while wearing appropriate protective clothing, such as lab coats, gloves and safety glasses.

Other bases are mild enough to be used as cleaning materials in and around the home. This does not mean that they are completely harmless. It just means that they have been mixed with other substances so that they are not so corrosive.

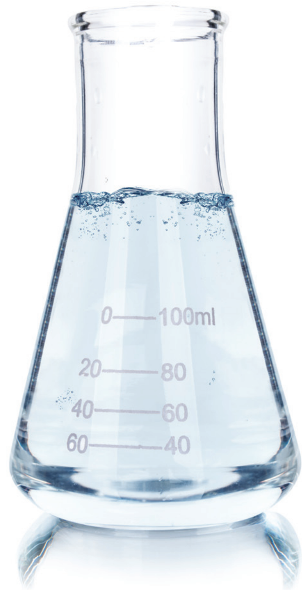


Figure 6.18 Sodium hydroxide is a strong base used in laboratories.

ACTIVITY Acids and bases in our homes

1. Bring samples of household cleaning substances (specify) page 24 CAPS. Write their names and what they are used for.
2. Next, your teacher will let you come up to feel different substances which are either bases or acids. All of these substances are safe to touch. Take note of how they feel between your fingers. Copy the table below in your exercise books and fill in your observations.


Figure 6.19 Some household products which are bases.

Substance	How did it feel between the fingers?	Is it an acid or a base?

Questions

1. What can you conclude about how bases feel?
2. What can you conclude about how acids feel?
3. What did your teacher have to do to the dry washing powder before you could feel it in the bowl? Do you know what we call the solution which forms? If so, write it down; otherwise your teacher will help you.
4. Although we have spoken about acids and bases as being chemical opposites, what property do many of them have in common?

Finally, there is a class of substances that are neither acids nor bases. They are called neutral substances. We will explore them next.

Take note

Bases that can dissolve in water are called alkalis. For this reason, the terms 'base' and 'alkali' are sometimes considered to have the same meaning. (Words that have the same meaning are called synonyms.)

Neutral substances

We have learnt that when an acid and a base are mixed (in the right amounts), they will neutralise each other. That means that, together, they will change into something that is neither an acid nor a base. So the acid will lose its properties and so will the base, and the new substance that forms from the two substances will be neither an acid nor a base. We call it a neutral substance.

Some neutral substances are formed when an acid is mixed with a base and a neutralisation reaction occurs. Other substances are neutral to begin with. They are not the product of a neutralisation reaction. The neutral substances that are the best known are: water, table salt, sugar solution, and cooking oil.

Figure 6.20 Cooking oil is a neutral substance.

We have learnt about three classes of substances: acids, bases and neutral substances. But, we cannot tell whether a substance is an acid, a base, or a neutral substance, just by looking at it. We know that acids taste sour, but we have also learnt that it is never a good idea to taste chemicals.

Let's imagine we have an unknown substance. It is colourless and looks just like water. It is also odourless (that means it has no smell). There are no physical signs to show whether it is acidic, basic, or neutral. How can we tell what it is?

7.3 Acid-base indicators

What do the indicators on a car do?

Take note

To indicate means to show.

Acids and bases can change the colour of some substances. In the next activity, we are going to investigate a substance that changes colour when we mix it with an acid or a base.

Keywords

- indicator
- litmus

Some other substances also change colour when an acid or a base is added to them. By changing their colour, they show that they have reacted with an acid or a base. That is why we call them acid-base indicators. The best known **acid-base indicator** is a substance called **litmus**.

Figure 6.22 Blue and red litmus paper.

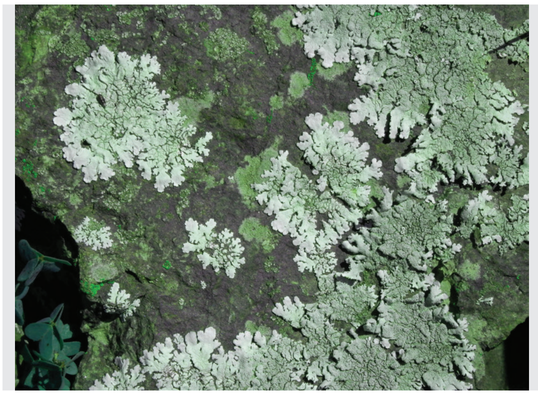


Figure 6.1 Litmus comes from pigments in the lichen which are found growing in many different places, mostly on rocks.

Litmus solution is most commonly soaked into paper. The paper is then dried and cut into strips we then call "litmus paper". Litmus paper is available in two colours: blue and red.

How does litmus paper indicate whether a substance is an acid or a base? In the next activity, we will investigate how litmus responds to some household acids and bases.

Investigation Classifying substances as acids or bases using a litmus paper.

1. Test how litmus paper responds to acids and bases (given known acids and bases).
2. Classifying household substances as acids or bases.

Aim

To determine how litmus responds to some household acids and bases.

Hypothesis

What is your hypothesis for this investigation?

Materials and apparatus

- small containers (test tubes or yoghurt tubs) filled with the following substances:
  - water
  - soda water
  - vinegar
  - lemon juice
  - sugar water (1 tablespoon dissolved in a cup of water)
  - baking soda (1 tablespoon dissolved in a cup of water)

- Handy Andy (1 tablespoon dissolved in a cup of water)
- aspirin (Disprin) (1 tablet in 2 tablespoons of water)
- dishwashing liquid (1 teaspoon dissolved in a cup of water)
- any other substances commonly used at home that are not dangerous

- litmus paper (blue and red)
- glass or plastic rods (plastic teaspoons will also work well).

Method

1. Cut a small piece (1 cm long) of blue and red litmus for each substance that you will be testing.
2. Use the plastic teaspoon or rod to place just 1 drop of water on the blue litmus. Do the same with a piece of red litmus.
3. Did the blue litmus change colour? Did the red litmus change colour? Write the new colours in your table, in the appropriate places.
4. Repeat the procedure to test all the substances you have been given. You must rinse the teaspoon or rod with water in between substances.
5. Save all your test substances, because you will need them for another investigation later.

Results and observations

Copy the table below in your exercise books and record your observations. If you did not use some of these substances, cross them out and write headings for your substances in the empty rows.

Substance	Colour with blue litmus	Colour with red litmus
Water		
Soda water		
Vinegar		
Lemon juice		
Sugar water		
Baking soda		
Handy Andy		
Aspirin		
Dishwashing liquid		

Analysis

Let us now have a look at our observations to see what we can conclude.

1. How does the litmus paper indicate when a substance is an acid?
2. Which of the substances you tested are acids?
3. How does the litmus paper indicate when a substance is a base?

Did you know?

Litmus is a coloured substance that comes from the pigments of a living organism called lichen. Pigments are coloured substances found in nature.

4. Which of the substances you tested are bases?
5. How would you describe a neutral substance?
6. How does the litmus paper indicate when a substance is neutral?
7. Which of the substances you tested were neutral?
8. Why do you think you had to rinse the glass rod or teaspoon in between testing each substance?

Conclusion

Write a conclusion based on your results in response to the initial aim for this investigation.

Extension: If you have time in class with your teacher, use your knowledge of how litmus responds to acids and bases to test some of the beverages that you drink every day. You can use litmus paper to indicate whether beverages such as Ceylon tea, rooibos tea, orange juice, milk, coffee, and fizzy drinks are acids, bases or neutrals. If you do so, record your findings.

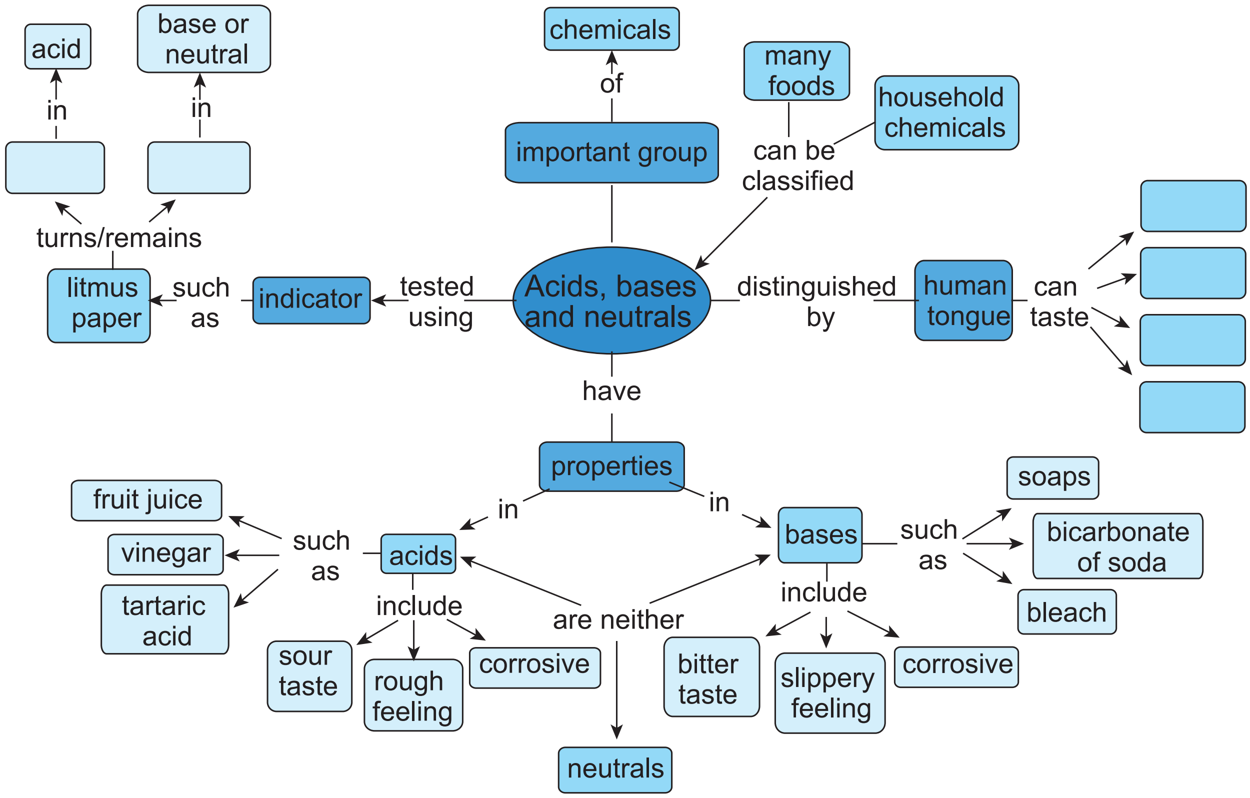
Summary

Key concepts

- Our tongues can sense four different flavours, namely, sweet, salty, sour, and bitter.
- Our sense of taste protects us from eating foods that are harmful and stimulates us to eat foods that are nutritious and energy-rich.
- Acids and bases have different chemical properties.
- Though it is not a good idea to taste chemicals, acids have a sour taste and bases taste bitter.
- When they are in solution with water, acids feel rough and bases feel slippery.
- Some acids and bases are present in foods and in household items. These are relatively safe to handle. Others are often very corrosive and should only be handled when you are wearing protective clothing.
- Substances which are neither acidic nor basic, are called neutral substances.
- When an acid is mixed with a base in the right quantities, they neutralise each other. That means they lose their power.
- Some substances change colour when they react with an acid or a base. These substances are called acid-base indicators.
- Litmus is the best known of all acid-base indicators. It does not change colour in the presence of a neutral substance, but responds to acids and bases in the following way:
  - litmus is red in the presence of an acid; and
  - litmus is blue in the presence of a base.

Concept map

The human tongue can taste four different main tastes. What are these? Copy and complete the concept map below. Can you work out how to do this? You need to fill in the colour that litmus turns (or remains) in each case, indicating either an acid or a base (or a neutral substance).



Revision

1. The box below is filled with ideas relating to acids and bases.

Words

- Sour taste
- Bitter taste
- Tartaric acid
- Bicarbonate of soda
- Feels slippery
- Feels rough
- Vinegar
- Soaps
- Lemon juice
- Citric acid
- Formic acid
- Bleach
- Turns red litmus blue
- Turns blue litmus red
- Corrosive

You must sort the words into two columns in a table. One column is labelled 'Acids' and the other is labelled 'Bases'. Write each idea inside the correct column. If an idea fits into both columns, you must write it in both. [16]

2.

Words

- Indicator
- Sour
- Bitter
- Poisonous
- Corrosive
- Neutralise
- Sweet
- Neutral
- Litmus
- Salty

3. You must use the words to complete the sentences that follow. Write out the sentences in full. Each word can be used only once. [11]
   a) The best known of all acid-base indicators is called. _________
   b) A substance that can eat away at other substances is called __________
   c) Foods that are ____________ often taste bitter.
   d) Some scientists believe the human tongue can taste 4 flavours. These flavours are _______, ________, ________, and____________
   e) An acid-base ____________ is a substance that changes colour when it reacts with an acid or a base.
   f) ____________ substances are neither acids nor bases.
   g) An acid will ____________ a base (and vice versa).

4. Give an example of a strong acid and a strong base, commonly used in the laboratory. [2]

5. Write one or two sentences to explain what is meant by the term 'neutralise'. [2]

6. Write a short paragraph to explain how laboratory acids should be handled. Your paragraph should contain the following words: corrosive; taste; clothes. [3]

7. How does our sense of taste warn us when food is not good to eat? [2]

Total [36 marks]

8 The Periodic Table of Elements

Key questions

- What is an element?
- How can we classify the elements?
- Which table helps us to make sense of the patterns we observe in the properties of the elements?
- How are elements arranged on the Periodic Table?
- What does the position of an element on the Periodic Table tell us about its expected properties?
- What information can we use to represent the identity of an element?
- What are the typical properties of the
  - metals
  - non-metals
  - semi-metals?

People have been interested in science from the earliest times. Early man discovered how to process natural ores into metals for ornaments, weapons and tools. At least 3 000 years ago, ancient people were already using embalming fluids (chemicals) obtained from plants to preserve the bodies of dead people and animals!

Mankind has been studying and experimenting with materials to try to understand matter for thousands of years. Scientists, especially, wanted some understanding of all the different substances with which they were working with.

Figure 8.1 An ancient Egyptian mummy that has been embalmed to preserve it.

Over time, many different elements were discovered by scientists all over the world. These elements make up all the materials around us. But what do we mean by the word 'element'? An element is a pure substance which cannot be broken down any further. We will find out more about elements in this unit.

Over time, our knowledge about the elements and their behaviour increased, and scientists recognised the need to organise this information. They began to observe patterns and similarities in the way some groups of elements behaved and recorded these observations. Scientists wanted some way to classify the elements according to the properties that they were observing.

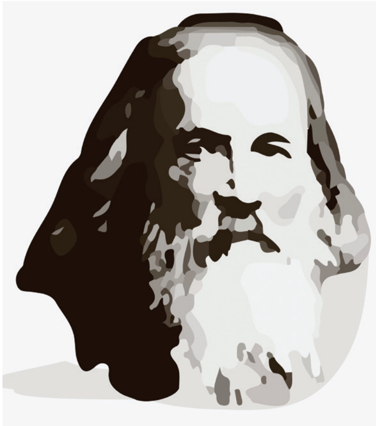


Figure 8.2 Dmitri Mendeleev

The version of the Periodic Table that we use today was first proposed by Dmitri Ivanovich Mendeleev in 1872. Mendeleev was a brilliant Russian scientist. While other scientists made many contributions to the design of the Periodic Table, Mendeleev was the one who first showed that the table could predict the existence and properties of elements that were still undiscovered at the time.

Reiben	Gruppo I. — $R^1 0$	Gruppo II. — $H^1 0$	Gruppo III. — $R^2 0^3$	Gruppo IV. RH^4 $R0^2$	Gruppo VI. RH^3 $R^1 0^3$	Gruppo VI. RH^3 $R0^3$	Gruppo VII. RH $R^2 0^7$	Gruppo VIII. — $R0^4$
1	II = 1							
2	Li = 7	Bo = 9,5	B = 11	C = 12	N = 14	O = 16	F = 19	
3	Na = 23	Mg = 24	Al = 27,3	Si = 28	P = 31	S = 32	Cl = 35	
4	K = 39	Ca = 40	— = 44	Ti = 48	V = 51	S = 32	Cl = 35,5	
5	(Cu = 63)	Zn = 65	— = 68	— = 72	V = 51	Cr = 52	Mn = 55	F0 = 56, Co = 59 Ni = 59, Cu = 63
6	Rb = 85	Sr = 87	?Yt = 88	Zr = 90	Nb = 94	Mo = 96	— = 100	Ru = 104, Rh = 104 Pd = 106, Ag = 108
7	(Ag = 108)	Cd = 112	In = 113	Sn = 118	Sb = 122	Tc = 125	J= 127	
8	Ca = 133	Ba = 137	?Di = 138	?Cc = 140	—	—	—	
9	(—)	—	—	—	—	—	—	— — — —
10	—	—	?Er = 178	?Ln =180	Ta = 182	W = 184	—	Os = 195, Ir = 197 Pt = 198, Au = 199
11	(Au = 199)	Hg = 200	T = 204	Pb = 207	Bi = 208	—	—	
12	—	—	—	Th = 231	—	U = 240	—	— — — —

Figure 8.3 Mendeleev's Periodic Table from 1872.

8.1 Arrangement of elements on the Periodic Table

The Periodic Table is a classification system for the elements that make up the matter and materials in our world. Today, there are more than 100 different elements known! Each element has its own name, symbol, atomic number and position on the Periodic Table.

Keywords

- element
- Periodic Table
- symbol (or element symbol)
- atomic number

Element names

What is your name? Perhaps it is Thando. Or David. Or Megan. Perhaps you are lucky enough to be the only person in your class with that name. Perhaps you are lucky enough to be the only person in the world with that name! That would make your name unique.

Each element has a unique name. We can think of each name as a unique 'label' we can use to identify the element. There are two other unique labels that we can use to identify elements. They are the chemical symbol and the atomic number. We will learn more about these in the next section. Each element has some of its own unique properties and later on we will see that those with some similar properties can be grouped together.

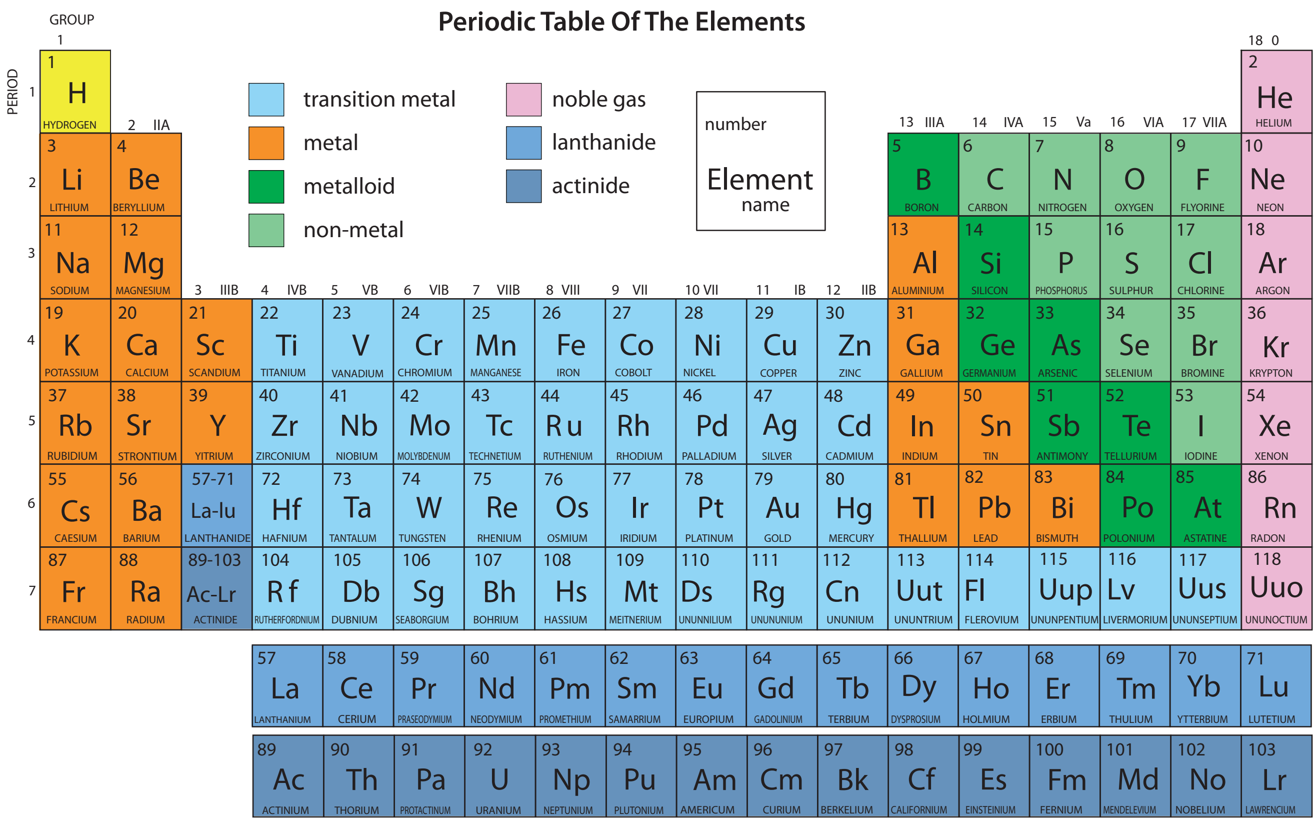


Figure 8.4 The Periodic Table of Elements as it is today.

Take note

There is a bigger version of the modern Periodic Table of Elements on the inside cover of your workbook. You can use it for easy reference.

Chemical symbols

If you are a scientist and you work with elements every day, writing out the names can become very tedious. To make writing about elements easier, scientists have given each element a short symbol. To make sure we do not become confused with different elements when we write about them, the symbol for each element must be unique, just like its name is.

The names and symbols for some common elements are shown in the following table.

Element	Symbol	Element	Symbol
Aluminium	Al	Magnesium	Mg
Bromine	Br	Nitrogen	N
Calcium	Ca	Oxygen	O
Carbon	C	Phosphorus	P
Chlorine	Cl	Potassium	K
Copper	Cu	Silicon	Si
Gold	Au	Silver	Ag
Hydrogen	H	Sodium	Na
Iodine	I	Sulfur	S
Iron	Fe	Tin	Sn
Lead	Pb	Zinc	Zn

The symbol for carbon is C, the symbol for sulfur is S, and the symbol for nitrogen is N. It is easy to see why these symbols were chosen: they simply represent the first letter of each name. This letter is always capitalised (upper case).

What happens when the different elements all start with the same letter? For example: calcium, carbon, chlorine and copper all start with the letter 'C'! To ensure that they all have a unique symbol, a second letter was added to their symbol. This letter is always a small letter (lower case).

Some chemical symbols are more difficult to understand. Na, for example, is the symbol for sodium. The Na comes from the Latin name for sodium, which is 'natrium'. These symbols were chosen very long ago, when many subjects were studied in Latin. Can you imagine how difficult that must have been?!

Some simple rules to remember when using chemical symbols:

1. Every element has its own, unique symbol.
2. The symbol is usually (but not always) the first one or two letters of the name of the element.
3. The first letter of the symbol is always a capital letter.
4. If the symbol has two letters, the second letter is always a small letter.
5. Some elements have symbols that come from their Latin names.

Atomic numbers

If you look at the Periodic Table, you will see that each element also has a unique number. This is called the **atomic number**. To properly understand what the atomic number is, we need to know what an **atom** is. We will learn more about atoms in Grade 8, but for now, let's briefly go back to our history lesson!

Did you know?

The symbol for lead (Pb) comes from 'plumbum', the Latin word for lead. For many years, lead was used to make water pipes. This is also where the word 'plumber' comes from.

Take note

You do not need to know about the atom in detail for now. We will learn more about this in Grade 8!

Take note

When things show a regular, repeating pattern, we say they are periodic. When the elements were arranged in order of increasing mass, Mendeleev observed a pattern in their properties, which allowed him to arrange the elements into rows and columns in a table, the Periodic Table. Elements in the same rows and columns in the table, have similar properties to each other.

The atomic number of an element refers to how many protons that element has in its atoms. Since each element has a different number of protons in its atoms, each element also has a unique atomic number.

Have a look at the Periodic Table.
- What is the atomic number of hydrogen?
- How many protons are there in its atoms?

The spaces marked with blank lines represent elements that Mendeleev thought existed, but they were not yet discovered at the time, so he left places for them.

Can you see how the elements are arranged so that their atomic numbers increase from left to right across the Periodic Table? This is not a coincidence!

When Mendeleev first created the Periodic Table, he arranged the 60 elements that he knew of at the time in order of increasing mass. He then saw that there was a regular pattern in other characteristics of these elements. Mendeleev then grouped them into columns and rows according to their properties. These were physical and chemical properties which the scientists had observed from doing many different experiments. This resulted in the arrangement of the elements on the Periodic Table.

The Periodic Table that we use today looks a lot more modern than Mendeleev's original version. You will notice that there are no empty blocks in the modern version of the table. That tells us that all the elements that were still undiscovered in Mendeleev's lifetime, are now known.

In the next activity, we will compare Mendeleev's original Periodic Table with the version that we use today. This will help to show us how scientific discovery is sometimes a slow process.

ACTIVITY Periodic Table treasure hunt

Your job is to follow the clues, in order to find the treasure. The instructions will help you to spell out the name of the treasure in the blocks below.

1. **Clue 1:** What is the symbol for carbon (atomic number 6)? Write this symbol in the first block above.
2. **Clue 2:** Hydrogen is the lightest element. Can you find it on the Periodic Table? Write its symbol in the second block.
3. **Clue 3:** Which element represents the gas that we breathe to stay alive? Here is a hint: It is represented by atomic number 8. Write its symbol in the third block and give the name of the element below.
4. **Clue 4:** This element is in the fourth row and the ninth column of the Periodic Table. It is a metal that is used in magnets. Write its symbol in the fourth block. Do you know its name? Write its name below.

5. **Clue 5:** This element is represented by atomic number 57. Write its symbol in the fifth block. See if you can find out the name of this element and write it down below.
6. **Clue 6:** This element is represented by atomic number 52. It is a semi-metal that is used in the manufacture of solar panels. Write its symbol in the last (sixth) block. See if you can find out the name of this element and write it down below.
7. What is the 'treasure' that you have found?

Complete the following table to see how many of the names and symbols of the elements you remember. Try to do this without referring to the Periodic Table.

Element	Symbol	Element l	Symbol
	Al		Mg
Bromine			N
Calcium		Oxygen	
	C	Phosphorus	
	Cl		K
Copper			Si
	Au	Silver	
	H		Na
Iodine		Sulfur	
	Fe	Tin	
Lead			Zn

Take note

In *Life and Living*, we looked at the classification of living organisms in our world. Now in *Matter and Materials*, we are looking at the classification system for elements!

8.2 Properties of metals, semi-metals and non-metals

The Periodic Table is an amazing tool! Did you know that the position of an element on the Periodic Table can tell a scientist what properties the element can be expected to have? This is because the elements have not just been arranged randomly! Rather, they are grouped and arranged according to similar properties. Let's find out what this means.

ACTIVITY What do some of the elements look like?

1. Your teacher will guide you through this activity. You will either look at real samples of some of the elements, or else refer to the photos below of some of the elements.
2. Identify the different elements and find their place on the Periodic Table. Copy the blank Periodic Table from the next page into your exercise books. Either stick the real samples or their photos onto their correct spaces on the Periodic Table.

Keywords

- semi-metal
- semi-conductor

Did you know?

The Periodic Table is made up of more than 100 elements, but only 90 of the elements occur in nature. The rest have been made by man.

3. Look at what the different elements look like and see if you can identify any similar properties. The questions at the end will help guide you through this.

Here are some photos of the different elements:

Figure 8.5 Aluminium foil

Figure 8.6 Carbon (graphite)

Figure 8.7 Iron

Figure 8.8 Copper

Figure 8.9 Magnesium

Figure 8.10 Sulfur

Figure 8.11 Bromine in tube

Figure 8.12 Chlorine gas

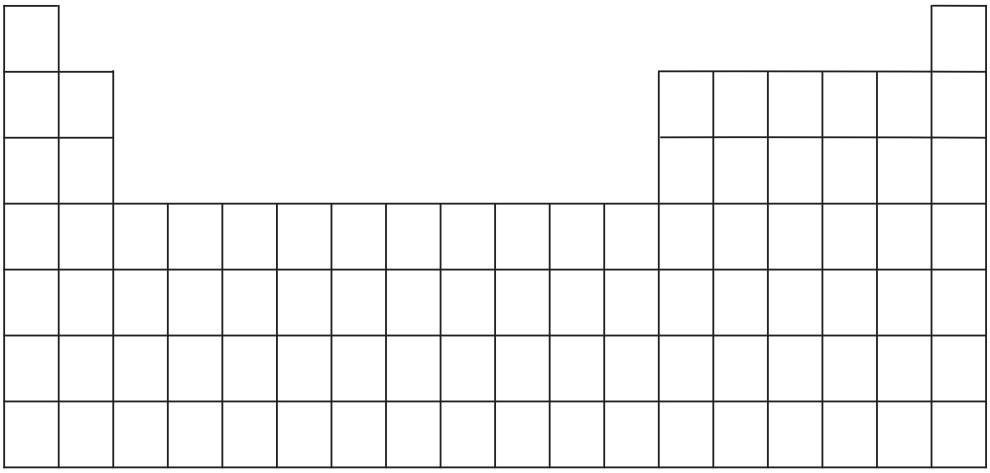
Figure 8.13 Calcium crystal

Figure 8.14 Phosphorus

Figure 8.15 Potassium

Figure 8.16 Nitrogen gas

Blank Periodic Table:



After completing this activity, answer these questions.

Questions

1. How would you describe the elements that are mostly on the left side of the Periodic Table?
2. How would you describe the elements that are mostly on the right side of the Periodic Table?

Did you know?

Francium (Fr) is the rarest element on Earth. Only 20 to 30 g exists at any one time on Earth in nature!

You probably saw from the previous activity that there is a difference in the elements on the left and right of the Periodic Table. Were you able to identify what these elements are classified as? You have learnt about them before in previous grades. They are metals and non-metals.

Let's do a quick revision of what we have already learnt about metals and non-metals in previous grades.

The properties of metals and non-metals

Metals and non-metals have distinct properties. That means their properties are unique and different from each other. Can you remember what the unique properties of metals and non-metals are? The next activity will refresh your memory.

ACTIVITY Blitz revision of the properties of metals and non-metals

Here is a block with different properties of metals and non-metals in it. They have been jumbled and are not sorted. You need to decide whether these properties describe metals or non-metals and sort them into the columns in a table. Make sure that all the properties in the block are in your table. If you can think of properties that are not listed in the block, you may also add them to the table.

Do the activity as quickly (but also as neatly) as you can, and time yourself!

Properties

- shiny
- lustrous
- dull
- brittle
- malleable
- ductile
- conducts electricity
- conducts heat
- usually a solid
- can be solid/liquid/gas
- electrical insulator
- thermal insulator
- (other)

Most elements fall into one of these two categories: metals and non-metals. We use the properties of an element to categorise it as a metal or a non-metal.

Think of chromium, for example, which is shiny (lustrous), bends easily (malleable) and conducts heat and electricity well.

1. What are the properties of chromium?
2. Based on these properties, would you categorise chromium as a metal or a non-metal?
3. Can you find chromium on the Periodic Table?

Hint: It may help to find its symbol first. What is its atomic number?

A piece of chromium.

Now think of sulfur.

Sulfur is usually a dull, yellow powder.

It does not conduct electricity or heat well, and large crystals of sulfur break easily when they are dropped.

1. What are the properties of sulfur?
2. Based on these properties, would you categorise sulfur as a metal or a non-metal?
3. Can you find sulfur on the Periodic Table?

Hint: It may help to find its symbol first. What is its atomic number?

Figure 8.5 Sulfur crystals forming on a rock wall inside a volcano.

We have now looked at the properties of metals and non-metals. But, when scientists were doing their experiments to observe the properties of the elements, they sometimes found some elements which were difficult to classify as either a metal or a non-metal.

The properties of semi-metals

Some elements are not quite metals, but they are not quite non-metals either. They just don't fit into either category! Does this sound strange to you? Let us explore.

ACTIVITY Classifying element X

Pretend that you are a member of a team of scientists that has just discovered a new element. The element has not been named yet, so it is simply referred to as 'element X'.

The team has a sufficient amount of element X to make several disks of the material. They create a file about element X. In the file, they place the following picture of one of the disks.

Figure 8.6 A disk of element X.

Look carefully at the picture. How would you describe the appearance of element X?

The team performs experiments on element X and adds the following data to the file:

1. In an attempt to bend a disk of element X, the disk shattered, like glass. The same result was observed when a second disk was dropped from a height.
2. The material is found to be a poor conductor of heat and electricity at room temperature. Element X was then cooled down significantly by placing it in a freezer. At very low temperatures, it becomes a good conductor of electricity.

Fill out the following checklist for element X by placing crosses next to each property that was observed.

Metallic properties	YES	NO
Is the material shiny (lustrous)?		
Is the material malleable and ductile?		
Does the material conduct electricity at room temperature?		
Does the material conduct heat?		
Non-metallic properties	**YES**	**NO**
Is the material brittle?		
Does the material have a dull appearance?		
Is the material an insulator?		
Additional comments (what else did you observe?):		

Questions

1. Which of the properties of element X are typical of metals?
2. Which of the properties of element X are typical of non-metals?
3. Would you classify element X as a metal or a non-metal?

Take note

Room temperature is 25 °C.

Names and symbols of the semi-metals

Name	Chemical symbol	Atomic number
Boron	B	5
Silicon	Si	14
Germanium	Ge	32
Arsenic	As	33
Antimony	Sb	51
Tellurium	Te	52
Polonium	Po	84

Now that we have looked at some of the elements and where they are found on the Periodic Table, you might have already recognised that there is a trend in where the metals, semi-metals and non-metals are positioned on the Periodic Table. We are now going to do a colouring activity to see where on the Periodic Table we will find each of the categories of elements.

ACTIVITY The regions of the Periodic Table

We are going to colour areas on the following version of the Periodic Table. This will help us identify the regions on the table where the metals, non-metals and semi-metals are located.

Questions

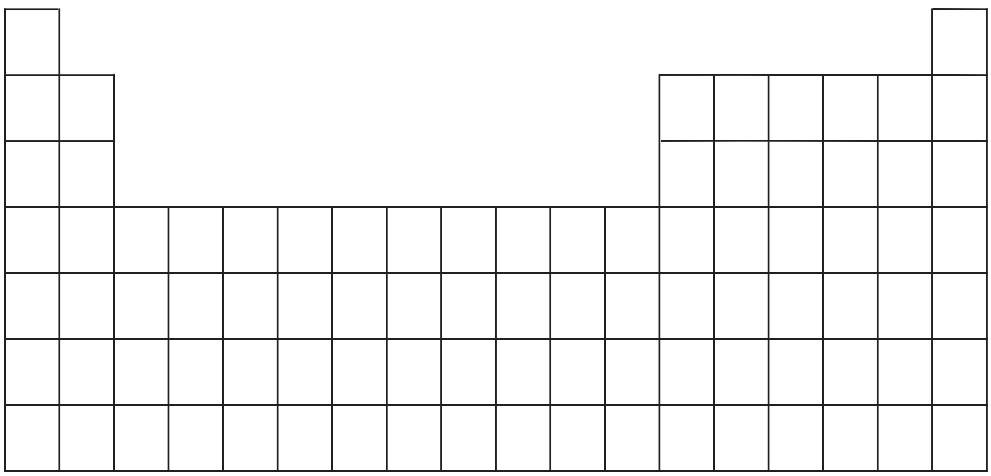
For this activity you will need coloured pencils or kokis or crayons in the following colours:

- Blue
- Yellow
- Red

Instructions

1. **Semi-metals**: Find all the semi-metals on the Periodic Table. You will need to consult the table (names and symbols of the semi-metals) to help you remember which elements are semi-metals. Colour the block representing each of the semi-metals yellow.
2. **Metals**: Colour all the blocks to the left of the semi-metals blue. Do not colour hydrogen (H), as it is not strictly a metal. All these elements are metals.
3. **Non-metals**: Colour all the blocks to the right of the semi-metals red. All these elements are non-metals. Now you can also colour hydrogen (H) red. On most versions of the Periodic Table hydrogen is placed with the metals, even though it has physical properties similar to those of the non-metals (it is a gas at room temperature). Hydrogen is placed with the metals, because it tends to behave like the other members of its column in chemical reactions.

Now answer the following questions, using your colourful Periodic Table.



Take note

The semi-metals are also sometimes referred to as metalloids.

Did you know?

Stainless steel is an alloy, meaning it is made up of a mixture of elements, including iron, carbon, chromium, and nickel.

Questions

1. Which category contains the most (biggest number of) elements: metals, non-metals or semi-metals?
2. Which category contains the least (smallest number of) elements: metals, non-metals or semi-metals?
3. State which category of material (metal, non-metal or semi-metal) each of the following elements belongs to:

Element	Chemical symbol	Category: (Metal, non-metal or semi-metal?)
Iron	Fe	
Silicon	Si	
Fluorine	F	
Titanium	Ti	
Nitrogen	N	

We have learnt that the Periodic Table can be divided into regions where metals, non-metals and semi-metals can be found. This is useful information because the elements in different regions share similar properties. Their properties help us to decide what we can use them for. For example, metals are durable, malleable and shiny so they are suitable for making jewellery, pots and pans and motor car parts.

Let's look at some more examples. Where can we find all these elements in the real world? Where do they occur, and what are they used for?

We all know that oxygen (O) is one of the elements in the air we breathe. Rings and other jewellery are often made of gold (Au), silver (Ag) or platinum (Pt). But what do we know about calcium (Ca)? And what is nickel (N) used for?

ACTIVITY Uses of the elements

1. How are properties of metals useful to us when making coins?

Figure 8.7 Our South African coins are made from various metals and mixtures of metals, such as copper, nickel, and stainless steel.

2. Why do you think we make jewellery out of the metals gold, silver and platinum, and not, for example, out of a non-metal such as sulfur?

Figure 8.8 What are the properties of these metals?

Jewellery is made from metals such as gold, silver and platinum.

3. Why do you think these electrical wires are made out of copper? What property of copper is useful in this situation?

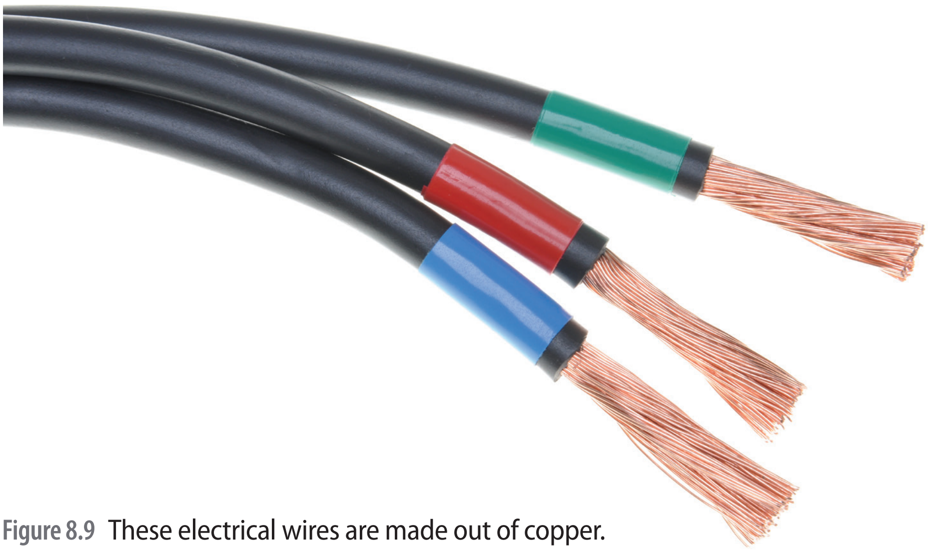


Figure 8.9 These electrical wires are made out of copper.

4. Do you think you could make electrical wires out of a non-metal such as bromine or phosphorus? Why or why not?

Uses of non-metals in everyday life

What do we use some of the non-metals for? We use carbon (coal) as a fuel, we use chlorine as a disinfectant to purify water, iodine is used as an antiseptic for wounds, and helium is used to fill balloons. Arsenic, a semi-metal, is poisonous and is therefore used as a pesticide for insects, bacteria and fungi. Another semi-metal, antimony, is used to make an alloy with lead which is very hard and has many applications. As you can see, the elements have many uses all around us!

In the final activity of this unit, we will explore some of the uses of the elements in more detail.

ACTIVITY Uses of the elements

Your teacher will divide the class into small groups. Your group must choose one element from the Periodic Table (if you are unsure, your teacher will help you choose) and research the following questions about this element:

1. Where is this element found?
2. What do we use this element for?
3. What are some of the properties of the element?

Your group must make a poster to present all the information you found about your element.

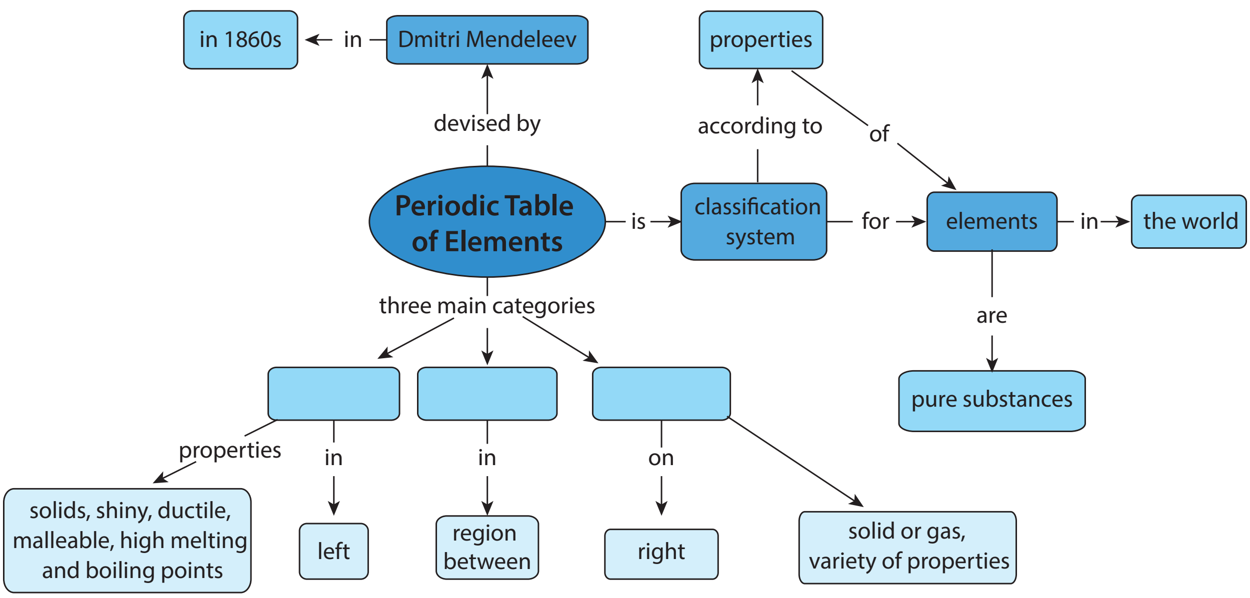
Summary

Key concepts

- All the elements that are known, can be arranged in a table called the Periodic Table.
- The discoveries of many scientists over many years contributed to the information in the Periodic Table, but the version of the table that we use today was originally proposed by Dmitri Mendeleev in the 1800s.
- Each element has a fixed position on the Periodic Table. The elements are arranged in order of increasing atomic number, with the lightest element (hydrogen: H) in the top left-hand corner.
- An element's position on the Periodic Table tells us whether it is a metal, a non-metal or a semi-metal:
  - metals are found on the left hand side of the table;
  - non-metals are found on the far right hand side of the table; and
  - semi-metals are found in the region between the metals and non-metals.
- An element can be identified in 3 different ways:
  - each element has a unique name;
  - each element has a unique chemical symbol; and
  - each element has a unique atomic number.
- Metals are usually shiny, ductile and malleable. Most are solids at room temperature, and have high melting and boiling points.
- Non-metals can be solids, liquids or gases at room temperature. They have a great variety of properties that usually depend on the state they are in.
- The semi-metals are all solids at room temperature. They usually have a combination of metallic and non-metallic properties.

Concept map

We learnt that the elements in the Periodic Table fall into three main categories. What are these? Copy and complete the concept map by looking at the concepts that come after each category.



Revision

1. What information can we tell from an element's position in the Periodic Table? In other words: [2]
   a) What does it tell us when an element occurs on the left-hand side of the Periodic Table?
   b) What does it tell us when an atom occurs on the right-hand side of the Periodic Table?

2. There are 3 unique 'labels' that can be used to identify an element. The first is its name. What are the other two? [2]

3. What is the relationship between the atomic number of an element and its place on the Periodic Table? [1]

4. Which element has the lowest atomic number? Write both its name and its symbol. [2]

5. Extension question: What does the atomic number of hydrogen tell us about it? [1]

6. Write the chemical symbols of all the elements that are in the same column as the element with the atomic number 9. (Note: The columns on the Periodic Table are called Groups.) [2]

7. The following table contains some names of elements. There is also a box of chemical symbols. You should place the chemical symbols in the right hand column of the table so that they match the names in the left hand column. [8]

Names of elements	Chemical symbols
Sulfur	
Carbon	
Nitrogen	
Sodium	
Oxygen	
Silicon	
Chlorine	
Helium	

Chemical symbols•
C
Na
Si
N
He
Cl
S
O

8. Write a short paragraph to explain what a semi-metal is. Also give an example of one semi-metal and say where in the Periodic Table the semi-metals can be found. [3]

9. Name two properties of metals and two properties of non-metals. [4]

Total [25 marks]

Glossary 2

abundant when something exists, or is available, in large quantities; plentiful
acid a substance which is corrosive, has a sour taste and feels rough (grippy) between your fingers
alkali a base that is dissolved in water
alloy a mixture of two or more metals (stainless steel is an example of an alloy)
altitude the height of a place above sea level; places that are inland, or on mountains, are said to be at a higher altitude than places on the coast
ascorbic acid a natural acid that occurs in some fruits and vegetables; also known as Vitamin C
atomic number a unique number that represents a given element and shows its position on the Periodic Table

base a substance that can also be corrosive, has a bitter taste, and feels slippery between your fingers
boiling point the temperature at which a particular material changes from the liquid to the gas state (boils)

chemical formula a representation of chemicals using symbols that tell us which elements a compound contains and in what ratio
chemoreceptor a sensory nerve cell or sense organ that detects chemical signals
chromatogram the pattern formed on the paper by the components separated by chromatography
chromatography a process in which a mixture carried by a liquid is separated into components
citric acid a natural acid that occurs in citrus fruit
clear transparent; see-through
concern (noun) something that you are worried about
condensation the process of changing a gas to a liquid
condense when particles come together; to change from the gaseous state to the liquid state
constant a variable, or physical quantity, that is constant or does not change over time
contract (verb) the physical size of an object gets smaller
corrosive a corrosive substance damages ('eats away') other materials by chemical action (the related verb is corrode)

dependent variable a dependent variable is one that we do not directly choose values for, but can measure only as we go along
disperse to spread evenly throughout
distillation a technique for separating the components of a liquid solution through evaporation and condensation
ductile the property of a material that allows it to be pulled and stretched out into thin wires
durable a material that is durable can last for a long time without breaking down

element a pure substance which cannot be broken down further
emulsion a mixture of two or more liquids that usually do not mix, such as tiny oil droplets in water
environmental concerns worries about the negative effects on habitats and ecosystems in our environment, caused by humans and their activities
essential necessary and important; required
evaporation the process of changing a liquid to a gas
expand (verb) the physical size of an object gets bigger

filtrate the liquid that has passed through a filter is called the filtrate
filtration the process of passing something through a filter
flavour the taste and smell of food in the mouth
flexible a material that is flexible will change shape easily without breaking when it is bent, and will return to its original shape when it is released
formic acid a natural acid found inside the bodies of some ant species

grain a very small piece of something

heat is the transfer of energy, from a hotter object to a colder object

immune system the biological system inside our bodies that protects us from disease and infection

impact to have an effect on something else

independent variable an independent variable is one whose values we can choose (manipulate); we still have to be able to measure it

indicator a substance that changes colour in the presence of another substance, showing that that substance is present

instinct a natural or inborn way of responding to something

litmus a well known acid-base indicator that turns red when mixed with an acid and blue when mixed with a base

magnetic a property of some materials that allows them to be attracted to a magnet

malleable the property of a material that allows it to be shaped by flattening with a hammer or squeezing it between rollers

melting point the temperature beyond which a particular material changes from the solid to the liquid state (melts)

mixture matter consisting of two or more components (substances) that retain their own properties

moulding a process that involves melting a substance and then pouring it into a specially shaped hollow container (**mould**) that will give it that particular shape when it cools down and returns to the solid state; clay can also be moulded

neutral substance a substance that is neither acidic nor basic

neutralise to make something chemically neutral

opaque something that we cannot see through is opaque; opaque is the opposite of transparent

Periodic Table a table in which the chemical elements are arranged in order of increasing atomic number

pigment a substance that gives colour to other materials

property a distinctive attribute, characteristic or quality (of a certain material)

residue the substances that are left behind in the filter after filtering

savoury refers to salty or spicy food (not sweet)

semi-conductor a material that conducts electricity only under special conditions, for instance at very low temperatures

semi-metal an element that has properties of both metals and non-metals

sense to become aware of something (specifically through our sense organs, for example, by smelling tasting, feeling, hearing or seeing something)

sieve a device with small holes through which finer particles of a mixture may be passed to separate them from coarser ones

solute the substance that is dissolved in a solvent to make a solution, for example sugar (solute) dissolved in water (solvent)

solution when a solid, liquid or gas dissolves in a liquid, we call the resulting mixture a solution; a mixture that has no cloudiness

solvent the substance that the solute is dissolved in to make a solution

soot and ash small particles of burnt material that are the solid components in smoke

still the apparatus used for distillation

suspension a mixture in which the tiny clumps and pieces are mixed in a liquid but they are undissolved; all suspensions are milky/cloudy in appearance

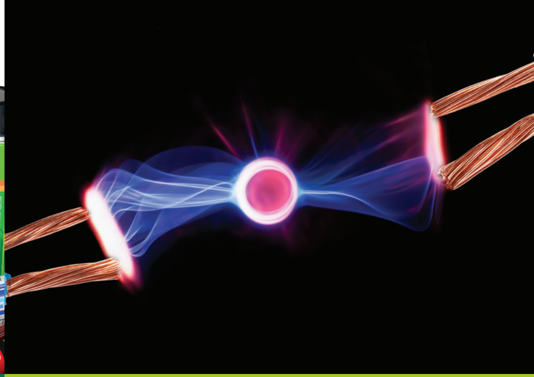
symbol (or element symbol) a unique letter (or letters) that represents a given element

taste buds taste buds are very small structures contained within papillae on the surface of the tongue responsible for taste

temperature a measurement of how hot or cold something is

thermometer a device for measuring the temperature of an object or a material

tongue map a map of the human tongue, showing which areas on the tongue are sensitive to which flavours; some scientists do not believe that the 'tongue map' is accurate




STRAND

Energy and Change












9 Renewable and non-renewable energy

Key questions

- Why do we need energy?
- What do we mean by renewable and non-renewable energy sources?
- Why should we use non-renewable energy sources?
- What are fossil fuels?

Keywords

- decompose
- renewable
- non-renewable

9.1 Renewable and non-renewable energy

All living things need energy. We learnt in Life and Living that energy is one of the requirements for life. However, it is not only living things which need energy to move and carry out various processes. The machines and appliances in our world around us also need energy to do work. Where does the energy come from?

Many substances and organisms store energy which can then be used. We call them **energy sources**. Energy sources have energy that is stored within them and can be used to make something happen, for example, energy stored in petrol can be used to make a car go. In Grade 6 you learnt about the two main sources of energy: **renewable** and **non-renewable** sources. Do you remember what these terms mean?

Renewable sources are ones which can be recycled or reused. Non-renewable sources cannot be reused, so there is a limited amount available. When that runs out there will be none left. Let's do a quick revision to see how much you remember from Grade 6.

Take note

Uranium is the source of energy for nuclear power stations

Activity Classify sources of energy

1. Study the following images which show different sources of energy.
2. Use the images to answer the questions that follow.

Figure 9.1 Natural gas – gas burning on a stove top.

Figure 9.2 Oil – An oil rig sinks a drill into the ocean floor to reach the oil deposits.

Figure 9.3 Sunlight – The Sun is a source of energy.


Figure 9.4 Biofuel – Manure decomposes to produce methane gas.


Figure 9.5 Wood


Figure 9.6 Coal – A coal mine.


Figure 9.7 Wind – Wind turns this windmill.


Figure 9.8 Uranium – Mining for uranium underground.


Figure 9.9 Hydropower – A large hydroelectric power station.

Questions

1. Draw a table in your books to classify the energy sources in the images as either renewable or non-renewable. Give your table a heading.
2. What do we mean when we say that something is renewable or non-renewable? Explain this in your own words
3. Why do you think we mostly use non-renewable energy sources?

Keywords

- consistent
- reservoir
- nuclear
- hydropower
- hydrocarbon
- biofuel
- methane
- fossil lfuel
- greenhouse gases

Let's now have a closer look at some of the most common sources of energy.

Non-renewable sources

The non-renewable energy sources most commonly used in our world today are **fossil fuels**. Fossil fuels are the non-renewable sources, oil, coal and natural gas. Why do you think they are called fossil fuels?

Fossil fuels

Where do we most often see fossil fuels in our everyday lives? Look at the following images for a clue.


Figure 9.10 Putting petrol into a car at a petrol station. Petrol is made from crude oil.


Figure 9.11 Coal is used in most of our power stations in South Africa.

Petrol and **diesel** are used mainly as fuel for cars, trucks and motorbikes. They are produced from **crude oil**, which is a fossil fuel formed from the remains of dead prehistoric animals. Crude oil contains a lot of energy which can be used. Crude oil is a non-renewable energy source because it takes millions of years to produce crude oil and so we cannot produce more when the existing reserves are finished.

Coal is most commonly used as a source of energy by power stations to generate electricity. We will learn more about this later in the term. Coal can also be burned in fires to keep warm or in coal stoves to cook our food.

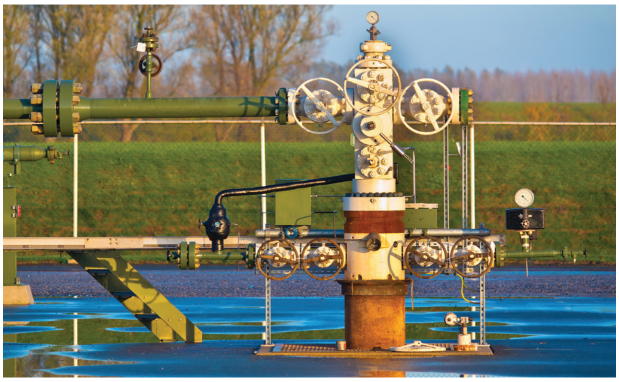


Figure 9.12 Natural gas has to be reached in underground reservoirs by drilling down wells such as these.

Natural gas is the common name used to describe a mixture of gases. Natural gas is found in deep underground rock formations and usually with other fossil fuels, such as oil and coal. The biggest part of the gas mixture is a gas called **methane**. Methane is a gas which burns easily and releases a lot of energy when it is burnt. Natural gas is used for cooking, heating and producing electricity.

Did you know?

Coal comes from the Old English term 'col', from the 13th century which meant 'mineral consisting of fossilised carbon'.

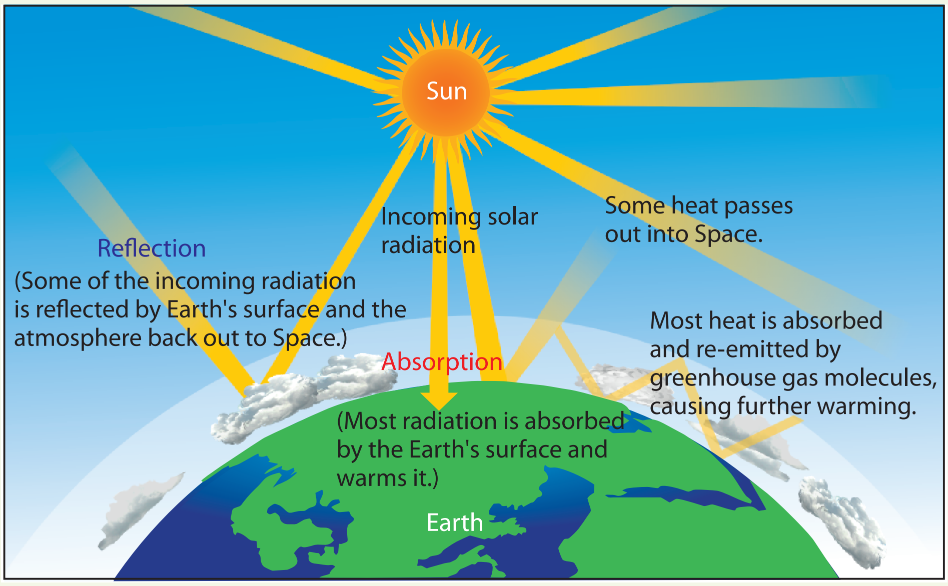
When talking about the methane component of natural gas, we are talking about non-renewable resources. Gas formed over thousands of years as organic matter decayed and the gas became trapped in wells which we now mine. However, as we will see later, methane can also be considered a renewable resource. This is when methane is produced from degrading organic matter, such as animal waste, with the help of microorganisms.

Non-renewable energy sources play a huge role in our lives and the way our world works today. However, there are some major concerns about our reliance on non-renewable energy sources. Firstly, there is only a limited supply, so these energy sources will run out one day. We will then need to find alternative energy sources. Currently alternative energy sources are being explored, and used in a small scale in some places.

For Enrichment

Another major disadvantage of burning of fossil fuels is that it releases **greenhouse gases** into our atmosphere. Greenhouse gases are present in our atmosphere and help to control the Earth's temperature. The Sun's radiation enters Earth's atmosphere. Some of the radiation is reflected by the atmosphere and Earth's surface. Most of the solar radiation is absorbed by the Earth's surface and converted to heat to warm the Earth. The Earth's surface emits heat. Some heat escapes into space, but most is absorbed and re-emitted by the greenhouse gases to warm the atmosphere and Earth's surface further. This natural process is called the **greenhouse effect**.

Do you know what an actual greenhouse is? It is normally a house made of glass, used to grow plants in. The glass also traps the Sun's energy and keeps the internal environment warm enough for the plants to grow. This has the same effect as the gases in the atmosphere.



But, our use of fossil fuels has released even more greenhouse gases, such as carbon dioxide. There is now an excess of greenhouse gases in the atmosphere. This reduces the amount of heat which escapes into Space and traps more heat within the Earth's atmosphere than before. This is causing the temperature of the atmosphere to rise, known as global warming.

Figure 9.13 A glass greenhouse traps the Sun's energy and provides a warm environment for the plants, just as the greenhouse gases in our atmosphere do.

Find out what else, besides burning fossil fuels, is contributing to an increase in greenhouse gases, and write it in your exercise book.

Nuclear fuels

Energy can be produced by nuclear reactions. Do you remember that we spoke about the atom last term in Matter and Materials? Within the atom, the nucleus is held together by very strong forces. When the nucleus is broken apart, a huge amount of energy is released. This energy can be used in nuclear power plants to generate electricity. Two different nuclei can also collide at very high speeds to form a new atomic nucleus. The energy released is also used in nuclear power plants, but on a smaller scale than when nuclei are broken apart.

Take note

When nuclei are broken apart, it is called nuclear fission. When two nuclei combine to form one nucleus, it is called nuclear fusion.

Did you know?

5% of South Africa's electricity is generated using nuclear fuels.

Figure 9.14 This is the international symbol for radioactivity.

Did you know?

There is only one nuclear power station in South Africa. It is the Koeberg power station near Cape Town. The majority of the power stations in South Africa are coal-powered and some others use hydropower, for example the Gariep Hydroelectric Plant on the Orange River near the Gariep Dam.

Some materials are better to use than others as nuclear fuels. One such substance is uranium. Uranium is an element. Find it on the Periodic Table and write its symbol and atomic number below.

There is limited supply of uranium in the world, which is why we classify it as a non-renewable source. But there is enough uranium for nuclear energy to be used for a very long time because you need only small amounts to produce lots of electricity. Therefore, many people see nuclear fuels as an alternative to fossil fuels. But there is a huge debate about this, and many people also disagree about the use of nuclear fuels. Let's find out why.

ACTIVITY Nuclear fuels - a debate

Instructions

1. You will need to do some research and extra reading to answer these questions.
2. Then you will have a class discussion about the topic.

Questions

1. What are some of the advantages of using nuclear fuels instead of fossil fuels? Write down your findings below and then add to them when you have a class discussion.
2. Find out why many people, especially environmental activists, are opposed to nuclear power. In other words, what are the disadvantages?
3. Although there are many disadvantages to nuclear fuels and power plants, many environmentalists and other people are now starting to change their minds and think that the advantages outweigh the disadvantages. This is happening as concern about climate change is increasing. Some people think that nuclear fuel is a more realistic alternative to fossil fuels than renewable energy sources, such as solar and wind power, which will not provide us with the energy to replace coal and oil. What do you think? Which side of the debate do you support? Discuss this with your class and then write down your thoughts below.

Renewable sources

Let's now take a closer look at some of the renewable energy sources that we have mentioned so far. Wind is moving air and it can be used as a source of energy. The energy from moving air particles is used to turn large turbines. The turbines are connected to a generator which produces electrical energy.

Figure 9.15 Wind turbines use wind to generate electricity.

You need a steady, strong wind blowing in order to produce a large, consistent amount of electricity. This means that wind farms cannot be put up in areas where there is not a lot of wind. Wind farms are noisy and many people do not like the look of them.

Water can also be used as an energy source. This is called hydropower. The energy from falling water is used to drive turbines in a power station. Unlike coal power stations, the water does not need to be heated and the water can be reused. These power stations must be at waterfalls or dams because there needs to be a strong flow of water to harness the energy.

Figure 9.16 Hydropower – A large hydroelectric power station.

Explain why you think we can classify wind and hydropower as renewable energy sources.

There is a lot of energy in sunlight. Solar panels are used to absorb the radiant energy from the Sun and to transform the energy from the Sun into stored potential energy. The Sun is a star, and the lifetime of a star is measured in billions of years. This means that our Sun can provide energy to the Earth for millions of years to come. Sunlight is considered a renewable energy source because it will not run out in the foreseeable future.

Take note

You will learn more about the Sun and its relationship to the Earth later in the year.

Figure 9.17 Solar panels on a rooftop.

A biofuel is any fuel which is produced from plant or animal waste. Methane can be produced by decomposing plants and animal waste. This is useful for farms as they can produce enough methane gas to help run their farms. The most common biofuels are made from maize, sugarcane and sorghum. The biofuels that are made can be used in vehicles or heating and cooling systems.

ACTIVITY A case study on biofuels

Instructions

Read the following article about biofuels and answer the questions that follow.

Dairy finds a way to let cows power trucks

27 March 2013

A large dairy farm, Fair Oaks Farms, in the United States of America has found a way to use the endless supply of manure from the cows to generate electricity. This electricity is in turn used to run the equipment that milks about 30 000 cows, three times a day.

For several years, the farm has been using the waste from the cows to create natural gas. The cow manure is swept up from the barn floors each day. The manure is then allowed to decompose in a digester and as it does so, it releases methane gas. The gas is collected and stored and used to power their buildings and barns. This gas is enough to power 10 barns, a cheese factory, a small restaurant, a gift shop, and even a 4D-movie theatre in the kids entertainment area.

Fair Oaks Farms has been doing all of this, but using only about half of the manure they swept up from the cows each day. But, they have now become even more energy efficient.

Fair Oaks Farms is now using the rest of the manure and turning it into fuel to power its delivery trucks and tractors. This is the largest group of vehicles on the roads in the US using livestock waste to power them. This is a huge saving in the amount of diesel which would otherwise be used. Gary Corbett at Fair Oaks said: "We are taking about half a million litres of diesel off the roads each year." Another advantage is that natural gas is about half the price of diesel fuel for the same amount of power.

Mike McCloskey, a co-owner of Fair Oaks, said he had first started looking into renewable energy options for the farm more than a decade ago. This was a way to become more energy efficient, and save money. He also said the smell of the manure, used as fertiliser on the fields, had started to make some neighbours complain! The leftover by-products from producing the natural gas is still spread over the fields as fertiliser, but it has much less of a smell. This shows that nothing goes to waste.

Other farmers, landfill management companies and other large industries that produce large amounts of methane-rich material are now also starting to take interest. If used, this could provide an endless supply of 'biogas', a cleaner, safer, more sustainable alternative, which also reduces greenhouse gas emissions.

Figure 9.18 A digester used to decompose manure to produce methane gas.

This has been adapted from an article which appeared in the New York Times on 27 March 2013.

Questions

1. What is the name of the farm in the article, and in which country is it based?
2. What made the owners of Fair Oaks Farms decide to use manure as a form of energy?
3. In the article, the renewable energy source referred to is an example of a biofuel. What is this renewable energy source, and why can we call it a biofuel?
4. How does the farm harvest methane from manure?
5. Why is it a good thing that the farm is taking 'about half a million litres of diesel off the roads each year'?
6. What is another advantage of using biogas to power the delivery trucks and tractors?
7. Do you think that South Africa could benefit from a setup such as the one at Fair Oaks Farms? Explain your answer.

Did you know?

Biofuels have been around as long as cars have. At the beginning of the 20th century, Henry Ford planned to fuel his cars with ethanol. But then the discoveries of huge oil deposits kept fossil fuels cheap for decades, and biofuels were mostly forgotten.

Now that we have looked at non-renewable and renewable energy sources, let's summarise the disadvantages and advantages of each.

ACTIVITY What are the advantages and disadvantages?

Instructions

1. Sit in groups of 3 or 4. Discuss, in your groups, the advantages and disadvantages of using non-renewable energy sources.
2. Discuss, in your groups, the advantages and disadvantages of using renewable energy sources.
3. Why do you believe that fossil fuels are still burnt as a source of energy? Write your own answer in your books.
4. Choose a spokesperson for your group and share your ideas with the rest of the class. Choose two of the sources of energy discussed so far in this unit. Use your school library or the internet to find more information about how they are used to generate electricity in South Africa.

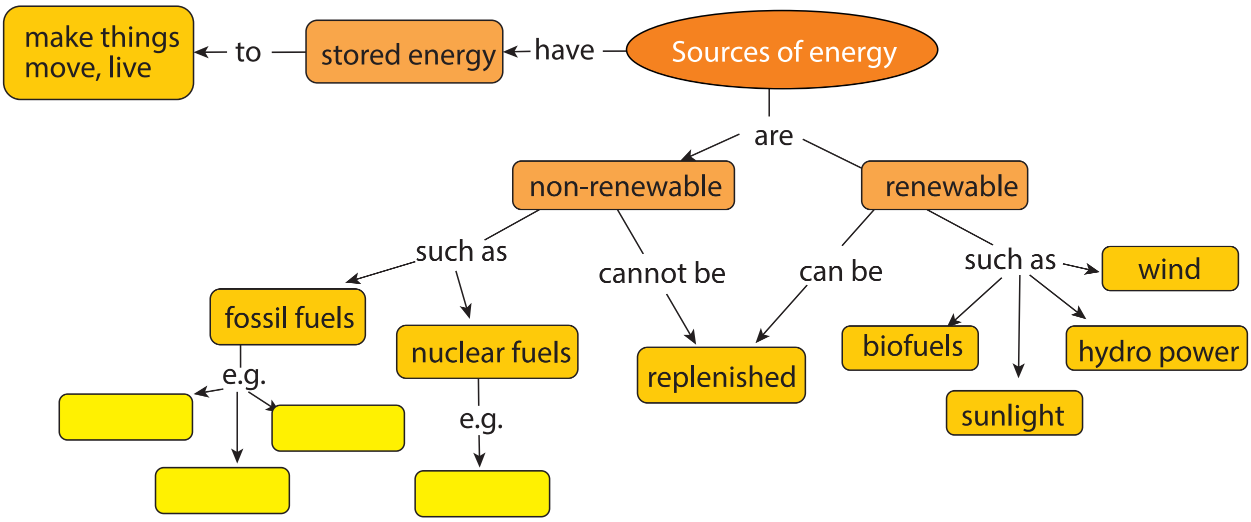
Summary

Key concepts

- Energy is one of the requirements for life on Earth.
- Energy is needed to make things move.
- Sources of energy have energy stored within them that is used to make something happen.
- Non-renewable energy sources cannot be recycled or reused. There is a limited supply.
- Examples of non-renewable energy sources are fossil fuels (coal, oil and natural gas) and nuclear fuels.
- Burning of fossil fuels releases greenhouse gases into our atmosphere.
- Renewable energy sources can be recycled or reused. There is an unlimited supply.
- Examples of renewable energy sources are wind, hydropower, solar power, and biofuels.

Concept map

This is our first concept map for *Energy and Change*. Complete it by filling in the three types of fossil fuels, and give an example of a nuclear fuel which was discussed in this unit.



Revision

1. What do we need to make things move? [1]

2. What does it mean when we say something is 'a source of energy'? [1]

3. Which of the following are sources of energy? [1]
   a) Sun
   b) waves
   c) wind
   d) coal
   e) all of them

4. What does it mean if something is a non-renewable source of energy? [2]

5. Which of these are renewable energy sources. [1]
   a) coal
   b) natural gas
   c) sunlight
   d) wind
   e) crude oil

6. Which type of renewable energy uses the movement of air to generate electricity? [1]

7. Complete the following sentences. Write them out in full on the lines provided and underline your answers. [5]

8. Coal, natural gas and oil are all examples of ________________ (renewable/non-renewable) energy resources. When they are burned, they release ________________ (energy/electricity). Coal, natural gas and oil are also known as ______________ (nuclear fuels/fossil fuels). Wind and solar energy are examples of ______________ (renewable/non-renewable) energy sources because they ______________ (can/cannot) be replaced.

9. How does the burning of fossil fuels contribute to global warming? [2]

10. Copy and complete the following table in your exercise books. [18]

Energy source	Renewable or non-renewable	Disadvantage	Advantage
Wind			
Coal			
Uranium			
Water (Hydroelectric)			
Sunshine			
Biofuels			

TOTAL: [32 marks]

10 Potential and kinetic energy

Key questions

- What is potential energy?
- What is kinetic energy?
- Where do we get energy from?
- How much energy do I need?
- Can energy be created or destroyed?
- What is a system?

Renewable and non-renewable sources are where we get our energy from, but what forms of energy do we find in the world?

All energy can be placed into two main groups:

1. Potential energy
2. Kinetic energy

So what are these different forms of energy, and what does it mean if an object has potential energy or kinetic energy? Let's investigate!

10.1 Potential energy

Keywords

- joule
- potential energy
- system

Throughout our investigation and learning about the concepts surrounding energy, we will be talking about systems and how energy is transferred within a system. A system is a set of parts that work together as a whole. A change in one part of the system will affect the other parts. This will become clearer as we see some examples throughout this term.

We are going to find the difference between potential and kinetic energy. Look at the following illustration which shows a ramp with a marble rolling down into a foam cup. The marble will knock the cup and make it move.

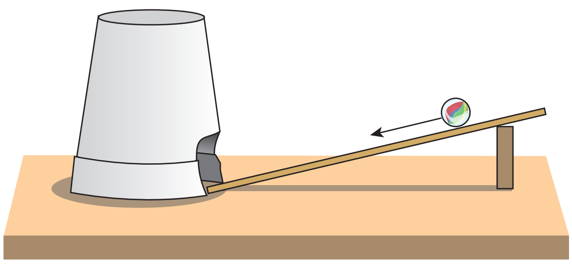


Figure 10.1 A marble rolling down a ramp.

When the marble is released, it rolls down the ramp and transfers some of its energy to the cup. This transfer of energy is what makes the cup move. But where did the marble get energy from? Do you think you can make the cup move more or less depending on how far up the ramp you start the marble? Let's do an investigation to find out.

Investigation — How can we make the foam cup move further?

Investigative question

If we roll a marble down a ramp and into a cup, how does the starting position of the marble affect how far the cup moves?

Variables

1. What will we change when performing this investigation?
2. What will we be measuring in this investigation?
3. Which things must stay the same?

Hypothesis

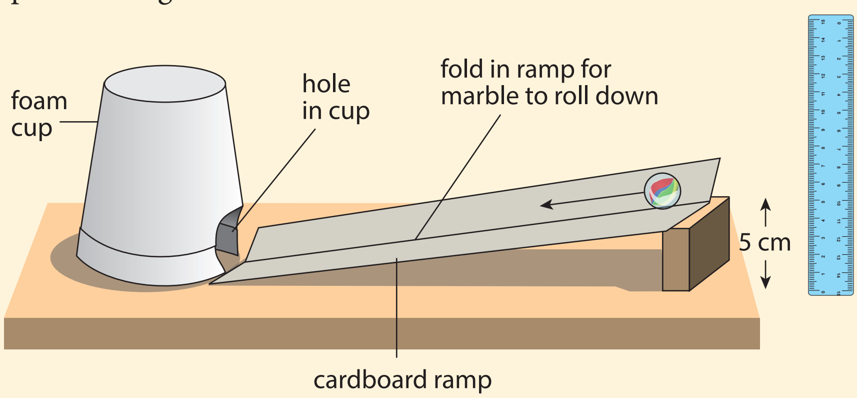
Write a hypothesis for this investigation. When you do this, you need to write what you expect to observe. It does not have to be the correct answer to the investigative question.

Materials and apparatus

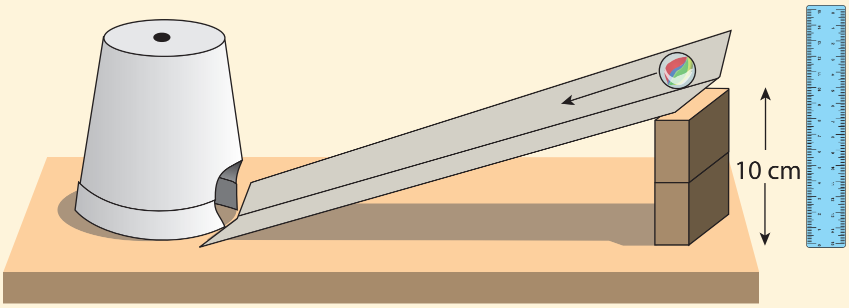
- a styrofoam cup
- a marble
- a pair of scissors
- a ramp (this can be a wooden plank or stiff card)
- books or wooden blocks to prop up the ramp
- rulers

Method

1. Work in groups of 3 or 4.
2. Cut a hole in the lip of the cup so that when you turn it over on a table, there is a hole which a marble can now fit through, as shown in the previous diagram.
3. Build the setup as shown in the following diagram. Place the cup upside down on the table surface. Place the ramp so that it ends at the hole in the cup. Prop up the ramp with blocks or books. You will adjust the height of the ramp using different books or wooden blocks. Otherwise you can just hold the top of the ramp at the specified height.



4. Practise rolling the marble down the ramp and into the cup. You can use two rulers to create a path down the ramp to guide the marble into the hole so that it does not roll off the side of the ramp, or you can bend the cardboard so that the marble rolls down the middle on the fold. You can also try a cardboard tube, such as a roller towel inner. You will need to practise to see what works best with the materials that you have available.
5. Once you have found the best way to do this, you can start the measurements.
6. First set up the ramp so that the top of the ramp is at a height of 5cm. Roll the marble from a height of 5 cm and then measure how far the styrofoam cup moves.



7. Next adjust the height of the ramp by increasing it by 5 cm each time. Each time place the marble at the top of the ramp and roll it down, measuring how far the cup moves.
8. Repeat the measurements until you have at least six recordings.
9. Record your measurements in your books under the headings in the table below and draw a graph with a line of best fit.

Results and observations

Record your results in a table like the one below.

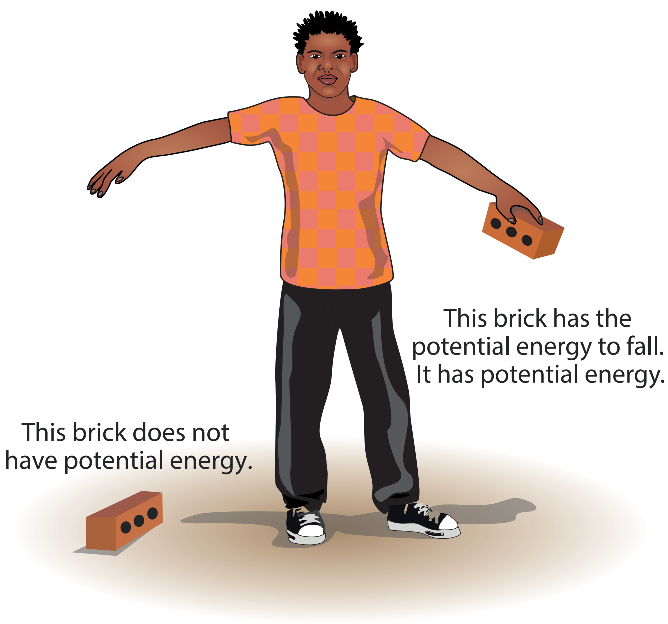
Height of marble up the ramp (cm)	Distance the cup moves (cm)

Use the information in your table to draw a graph of the height of the marble up the ramp versus the distance the cup moves. Before you draw the graph, answer the following:

1. Which is the independent variable? This is the value which you changed in the investigation. The independent variable is written on the x-axis (horizontal axis).
2. Which is the dependent variable? This is the variable you measured. The dependent variable is written on the y-axis (vertical axis).

Conclusion

1. Write a conclusion for this investigation. Remember to refer to your graph and hypothesis when writing your conclusion.
2. Was your hypothesis shown to be true or false?



When you hold the marble at a distance up the ramp, you are preventing it from rolling down the ramp. This means that the marble has the potential to roll down and knock the cup. So, YOU gave the marble **potential energy** by picking it up and holding it at the top of the ramp. When the marble hits the cup, the marble transfers energy to the cup which then moves. The cup then comes to a stop after a while. Do you have any guesses about why the cup stops after a while?

Your investigation will have shown you that the greater the vertical height of the marble, the further the cup moved. This tells us that lifting the marble to a higher position means that it has more potential energy than if it was released from a lower position.

So the higher an object is above a surface, the more potential energy it has. Think of another example of picking up a brick, as shown in the diagram. Here we are looking at a system consisting of: the arm, the brick, and the Earth that pulls on the brick.

When the brick was on the floor, it had no potential energy. But when it is lifted up, it has potential energy. Where did the potential energy come from?

The boy now let's go of the brick and it falls down to the ground and makes a hole in the sand. What received the energy of the falling brick?

Do you think the hole in the sand pit will be deeper if we drop the brick from a higher point? Why?

So what we have seen is that the energy is all still there within this system, but it is not easy to use any more. The sand is warmer but we cannot actually use that energy for anything because the temperature increase was so small. So the energy in the system has not been destroyed, but it is less available for us to use.

Let's look at another example of stored energy and energy transfers within a system.

ACTIVITY Elastic bands

1. We are going to be shooting matchboxes with elastic bands by stretching the bands and releasing them to hit the matchbox. What are the parts making up this system?
2. What is the energy input into this system?

Do you think there is a relationship between how far the matchbox travels and the energy that the hand puts in at each try? Let's find out.

Materials

- empty matchbox
- elastic band
- ruler

Instructions

1. Place the empty matchbox on a desk, and mark the spot with a piece of paper.
2. First, practise shooting the matchbox with the elastic band. Each time, place the elastic band and matchbox in the same starting position and distance from each other.
3. Once you feel comfortable doing this, stretch the elastic band by a different amount each time and measure how far the matchbox moves with each try.
4. Place a ruler next to your elastic band and first stretch it by a small amount. For example, if your elastic band is 5 cm long when held pulled tight, but not stretched, between your fingers, then stretch it to 8 cm.
5. Release the elastic band so that it hits the matchbox across the desk.
6. Measure the distance that the match box moves across the desk.
7. Record the distance in the table below.
8. Put the empty match box back in its original position on the desk.
9. Repeat the experiment several times but stretch the elastic band a bit more than before each time.

Copy the table below into your exercise books and record your measurements.

Elastic stretched (cm)	Distance moved (cm)

Questions

1. Does the distance moved by the matchbox increase or decrease as you stretch the elastic band more? State the relationship between these two measurements.
2. What did you have to do in order to stretch the elastic band and keep it stretched?

Energy is transferred from the elastic band to the matchbox and the matchbox moves. But it comes to a stop after a while. Where did the matchbox transfer its energy to?

When the elastic band was stretched it gained potential energy. We know this because your hand had to do some work to stretch the elastic band, and now the elastic band can snap back and move the matchbox. The elastic band needs energy to make the matchbox move, and it got that energy from your hand.

The further we stretched the elastic, the further it could push the matchbox. This tells us that the more we stretch the elastic band, the more energy is transferred from the elastic band to the matchbox.

Energy transfers have taken place within this system: Energy is transferred from the hand, to the elastic band, to the matchbox, to the air and the table surface. The table ends up a little warmer than it was as it now has most of the energy and the air has the rest. The energy has not gone, but again it's not available to use.

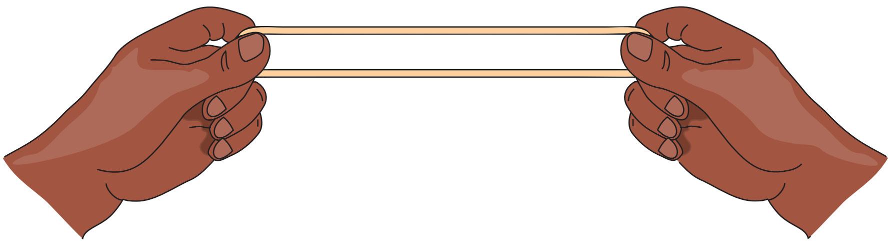


Figure 10.2 A **stretched** elastic band has potential energy.

> **Did you know?**
>
> The joule was named after an English physicist, James Prescott Joule (1818-1889).

So did you notice that both the marble and the elastic band had potential energy? But we didn't do the same thing to give them that energy. We **lifted** the marble but we **stretched** the elastic. This means that there is more than one way to give something potential energy. **Potential energy is energy that is stored within a system**.

Now that you understand a bit more about potential energy, can you think of some more examples of things which contain potential energy? Think in terms of things which have the **potential or the ability to change something or make something move**.

What about some of the fossil fuels that we discussed in the last unit, such as coal and oil? Do you think these have potential energy? Yes, they do. For example, coal is burned in power stations to generate electricity (you will learn more about this later on in the term). So, we can say the coal has stored energy which is used to generate electricity. Coal has potential energy. This is the same for other fuels as well.

Do you remember making electric circuits in Grade 6 last year? Do you remember using batteries? The batteries are the source of energy for the circuit. The batteries store energy. In other words, they have potential energy.

Figure 10.3 Batteries are a source of potential energy for electric circuits.

Where do we get our energy from? As we learnt in Life and Living, nutrition is one of the seven life processes. We have to eat food. Food is the fuel for our bodies.

Have you ever had a look at all the small writing on food packaging? The information gives us nutritional information about the food. It also gives us the amount of **energy** stored in the food. Have you noticed that this is often given in **joules**?

So what is a joule? How do we measure energy?

There is no specific measuring instrument that can be used to directly measure energy. Instead we can measure certain variables and use a formula to calculate the amount of energy that an object has.

For example, the heat transfered depends upon the change in temperature of the object. We can use a thermometer to measure the change in temperature of an object, then use a formula to calculate the heat transfered to or from the object.

The measuring unit of energy (in science) is a joule, denoted by capital letter J. For example, the heat transfered from the hot water to the air is 100 J.

Let's have a look at the energy content for some of the cereals that we eat for breakfast.

Take note

Sedentary means that you lead an inactive lifestyle and do not do any exercise.

ACTIVITY Reading a cereal box

Materials

- cereal box
- pair of scissors
- calculator

Instructions

1. Read the nutritional information on your cereal box.
2. Answer the questions that follow.

Questions

1. What is the amount of energy per 100 g for your cereal? Write your answer in kilojoules and in joules
2. The cereal boxes often indicate an amount per 100 g and then an amount per serving, which is normally less. What is the amount of energy per serving on your cereal box? Remember to include how many grams the serving is.
3. Look at the following table which gives the recommended daily amount of energy for an individual depending on your age and level of activity. This is a guideline as to how much energy you should consume in food in one day.

Take note

The joule is a measure of energy. A food joule is not different from an electrical joule, nor is it different from a joule that heats water, nor a joule that comes from the Sun.

Keywords

- kinetic energy
- transfer

Gender	Age (years)	Sedentary (kJ)	Moderately Active (kJ)	Active (kJ)
Female	9–13 14–18	8 000 8 500	8 000–9 000 8 500–10 000	8 500–9 500 9 500–10 500
Male	9–13 14–18	8 500 10 000	8 500–10 000 10 000–11 500	9 500–11 000 11 000–13 000

According to the table, what is the recommended daily amount of energy for your age and level of activity?

1. What percentage of your recommended daily energy is being supplied by one serving of your cereal? Show your calculations.
2. The following photograph shows the nutritional information on a box of cracker biscuits. Study it and then answer the questions that follow.

TYPICAL NUTRITIONAL INFORMATION

	PER 100 g	PER SERVING (2 biscuits = 15 g)
Energy	1 492 kJ	224 kJ
	356 kcal	53 kcal
Protein	8,4 g	1,3 g
Glycaemic Carbohydrate	72 g	11 g
of which Total Sugar	2,8 g	0,4 g
Total Fat	2,0 g	0,3 g
of which:		
Saturated Fat	0,4 g	0,1 g
Trans Fat	0,5 g	0,1 g
Mono-unsaturated Fat	1,1 g	0,2 g
Cholesterol	0 mg	0 mg
Dietary Fibre #	6,1 g	0,9 g
Total Sodium	589 mg	88 mg

Nutritional information above refers to the ready-to-eat product.
AOAC 991,43

   a) What is the energy content per 100 g in joules?
   b) What is the mass of one biscuit?
   c) The nutritional information gives the serving size of two biscuits, but you want to know what the energy content will be if you eat only one biscuit. Write down the answer below.
   d) You now decide that you want to eat five biscuits. What is the energy content for this serving of five biscuits?

Do you now see why we can say that food has potential energy? We need energy to make our bodies function. We get our energy from the food we eat. The molecules which make up our food have energy stored inside them. We eat the food and use the stored energy to move our muscles and perform all our bodily functions. This stored energy is potential energy.

10.2 Kinetic energy

Think back to the last activity where we used elastic bands to move matchboxes. The stretched elastic band had potential energy. When the elastic band was released, it moved and snapped back and then hit the matchbox and caused it to move. So what do we call this energy that the moving elastic band and moving matchbox have? We call it kinetic energy.

Kinetic energy is the energy that an object or system has because it is moving.

ACTIVITY Which objects have kinetic energy?

Instructions

1. Think about the definition of kinetic energy
2. Decide which of the objects (a to g) in the following table have kinetic energy.
3. Give a reason for your answer.

Object	Does it have kinetic energy? (Yes or no)	Give a reason for your answer.
 a) A lady running.		
 b) A bird in flight.		
 c) A stop street sign		
 d) A roller coaster.		

Object	Does it have kinetic energy? (Yes or no)	Give a reason for your answer.
 e) Two chairs.		
 f) An apple.		
 g) A helicopter.		

Keywords

- law
- theory
- conservation

Questions

1. Which bucket has more potential energy, the one sitting on the bottom step of a ladder, or the one sitting on the top step of the ladder?
2. Does a car travelling at 100 km/h or at 200 km/h have more kinetic energy?
3. When the wind blows, it is actually the air particles moving. What type of energy do the air particles have? Why?
4. You have a bucket full of water and you are about to tip the water out. What type of energy does the water have at this point? Explain why.
5. When you tip the water out and it falls to the ground, what type of energy does it have now?

What have we learnt so far?

- Potential energy is the energy stored in the system. In the brick activity, the brick had potential energy when it was lifted away from the surface of the Earth. The brick and the Earth attract each other so they are a system. The higher you lift the brick, the more potential energy you give it.
- We know that moving objects also have energy. We call the energy of moving objects kinetic energy.
- But, we have also seen something else. Think again of the marble activity:
  - The marble at the top of the ramp has potential energy.
  - When the marble was released, it rolled down the ramp and knocked the cup, causing it to move.

- The marble therefore **transferred** energy to the cup.
- We also saw this in the matchbox activity:
  - The stretched elastic band had potential energy.
  - When the elastic band was released, it moved and snapped back and then hit the matchbox and caused it to move. This means that the matchbox now had energy.
- Energy was therefore transferred from the stretched elastic band to the matchbox.

So, the potential energy in the elastic band is not lost. It is transferred to the matchbox. This brings us to our next section.

10.3 Law of conservation of energy

The **Law of Conservation of Energy** states that energy cannot be created or destroyed, it can only be transferred from one part of the system to other parts. This means that we keep recycling all the energy in the universe all the time!

Why are we talking about laws in science? Did you think laws were just for lawyers? Well, you would be wrong. In science we talk about **laws** and **theories**.

Scientific laws predict **what** will happen in a particular situation. The law has been tested repeatedly (often) and the results do not change. A law does not explain **why** something happens, it just says what **should** happen. Theories explain **how** or **why** things happen. Theories are also tested over and over again to make sure that they are valid.

Now that we know about the Law of Conservation of Energy, this matches our own observation that the energy in the elastic and matchbox example was not lost. Rather it was transferred from the elastic to the matchbox. We can say that the elastic band and matchbox form a system. This is also true for the marble-and-cup example. Remember, a system is made up of different parts that work together or affect each other. Let's now look at some more examples of how energy is transferred within systems.

10.4 Potential and kinetic energy in systems

Remember, energy cannot be created or destroyed. It is transferred from one part of the system to other parts. When it is transferred it can be stored or used to make something move, and so potential energy can be transferred to kinetic energy in a system.

We can look at how energy is transferred within different systems to show that energy is conserved. There are many different types of systems that we can look at to see how energy is transferred through the systems.

Mechanical systems

A mechanical system is one which is based on mechanical principles and the different parts interact in a mechanism. A mechanical system usually involves movement of some kind. It is often a group of simple machines working together.

Take note

Scientific laws and theories are not set in stone; they are just the best explanation for how the world works based on the information we have now. Scientific knowledge is constantly growing and changing as new discoveries are made.

Do you remember the elastic bands pushing the matchboxes? Do you think that was a system? You are right. It is a mechanical system. The hand, elastic band and matchbox all form part of a mechanical system. Your hand transfers potential energy to the elastic band; this is the input energy. The potential energy of the elastic band is transferred to the matchbox as kinetic energy. No energy has been created or destroyed. We experienced the Law of Conservation of Energy without even realising it.

Another simple example is a pulley and rope system, such as at a construction site, where the builders want to lift heavy objects up to a higher floor. The construction worker will pull on the rope which goes up over a pulley in order to lift the heavy object higher.

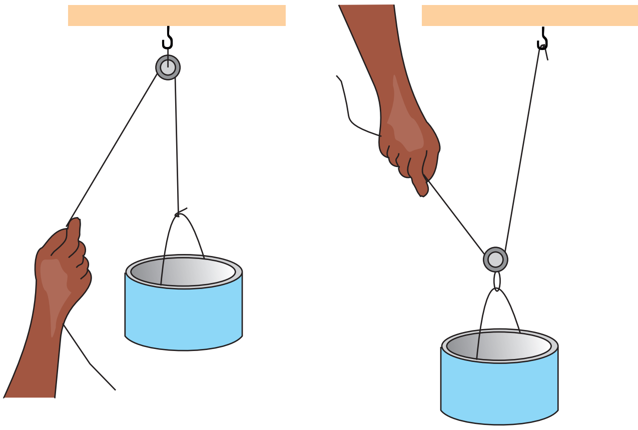


Figure 10.4 A pulley system is an example of a mechanical system.

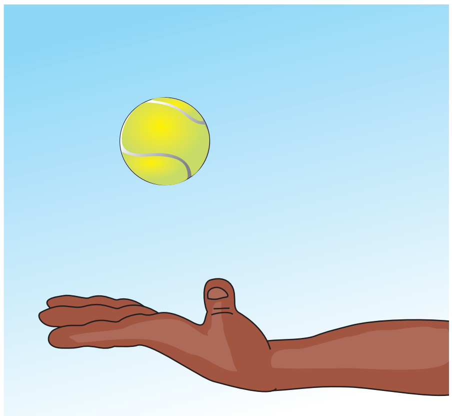
- What is the input energy in this system?
- What are the different parts making up this mechanical system?
- What is the input energy transferred to within this system?

A swing or a seesaw are examples of mechanical systems.

Figure 10.5 A swing is a simple mechanical system.

Did you realise when you were swinging on the park swings that you were a part of a mechanical system? When you are at the top of the swing's arc, you and the swing have potential energy because the Earth is pulling you and you are going to start moving down. The **potential energy** becomes **kinetic energy** as you swing through the arc.

What about when you throw a ball up into the air? Do you think this is a mechanical system?



When you throw a ball upward it slows down as it moves upwards, stops for an instant and then speeds up as it falls back down to your hand. Your hand moves to throw the ball and transfers energy to the ball, which allows it to move upwards. Does this also follow the Law of Conservation of Energy? Yes, it does. No energy was created or destroyed. The kinetic energy was transferred from your hand to the ball, which then starts to move. As the ball moves upwards, kinetic energy is transferred to potential energy as it moves further away from the ground.

As the ball moves back down again, the potential energy is transferred to kinetic energy.

1. What are the parts involved in this mechanical system?
2. What is the input energy in this mechanical system?
3. When does the ball have the most potential energy?
4. When does the ball have kinetic energy?

Let's have a look at some more examples.

ACTIVITY Identifying energy transfers in mechanical systems.

Mterials

- a piece of wire

We are first going to perform a simple demonstration to identify the energy transfers within mechanical systems. Take a length of wire and touch it to your lips. How does it feel?

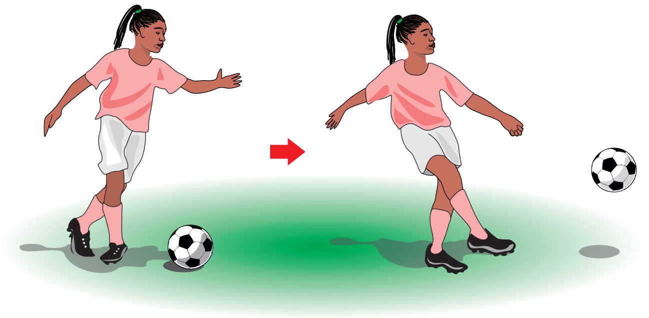
Then, bend the wire into a U-shape and quickly bend it back and forth 10 times. Now, feel the temperature again at the bend. How does it feel?

This is an example of a mechanical system. We can describe the transfer of energy as the potential energy within your arms, which is transferred to kinetic energy as you move them back and forth. This is transferred to kinetic energy in the wire, which is then transferred to the lips as heat.

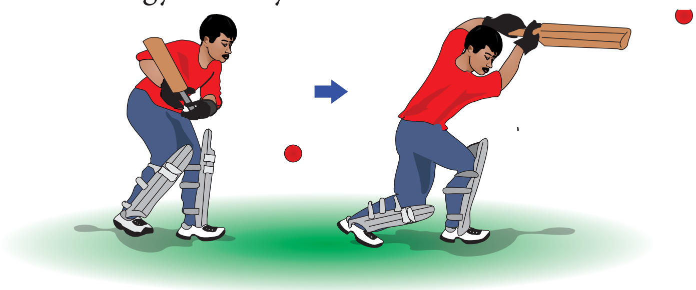
Instructions

1. Look at the following pictures of different mechanical systems.
2. Identify the different parts in the system and then how energy is transferred from one part to another. Discuss this with your partner.
3. Then write a few sentences to describe the energy transfers within each system.

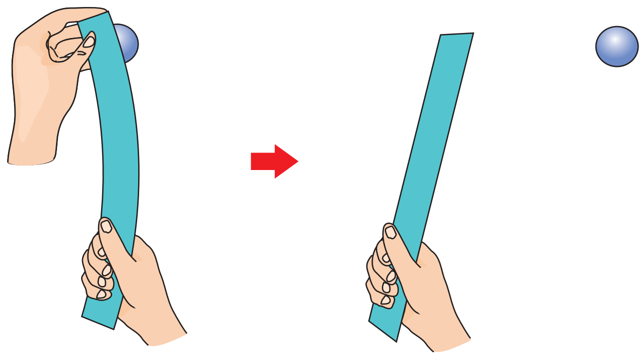
Questions



1. The girl uses the energy in her muscles and pulls her leg back. When her leg is at its highest point, what energy does it have?
2. As she swings her leg back down towards the ball, describe the transfer of energy.
3. When her foot hits the ball, and the ball moves off, describe the transfer of energy in the system.



4. The muscles in the cricketer's arm pull the cricket bat upward. Describe the transfer of energy.
5. Describe the transfer of energy as the bat swings down and then hits the moving ball.



6. Now that you have had practice with the other examples, use the following space to describe the transfer of energy within the above system as a ruler is pulled back and then flicks a pellet across the room.

Thermal systems

Did you know that the particles that make up a substance or object, such as atoms or molecules, also have kinetic energy? Particles which have more kinetic energy will move faster than particles which have less kinetic energy. When the particles are moving very fast, we feel the substance and say 'That's hot!'. This is because the temperature of a substance depends on the kinetic energy of the particles.

The thermal energy can be transferred from one object to another in a thermal system. When thermal energy is transferred, this is called heat. We will look more at this in the next unit, but for now let's look at some simple examples of energy transfers within thermal systems (heating).

Investigation: The energy transfers when boiling water.

Investigative question

What happens to the temperature of water when it is heated over a flame?

Variables

We will be measuring the change in the water temperature over time.

1. Which quantity/variable are you in control of? This is the independent variable.
2. Which variable are you measuring in response to the independent variable? This is the dependent variable.
3. Which variable are you keeping constant?

Hypothesis

Write a hypothesis for this investigation. (Hint: What do you think will happen to the temperature of the water. Will it go up or down?)

Materials and apparatus

- 150 ml or 250 ml beaker
- tripod
- gauze
- Bunsen burner
- matches
- thermometer
- stopwatch
- retort stand
- clamp

Safety Precautions

- Do not touch the heated beaker with bare hands.
- Do not play with the matches.
- The person working with the matches should wear safety coat.
- Handle the thermometer with care

Method

1. Pour 200 ml of water into a beaker.
2. Place the beaker onto the wire gauze on the tripod.
3. Carefully place the thermometer into the water. When you take the readings, the thermometer should not be touching the sides of the beaker. Alternatively, if you have a retort stand and clamp, the thermometer can be clamped in the stand with the bulb in the water.

4. Light the Bunsen burner.
5. Measure the temperature of the water every 30 seconds until the water starts to boil.
6. Once the water starts to boil, take 3 to 5 more readings.
7. Write down your observations in the table.
8. Once finished, turn off the Bunsen burner and leave the beaker of water to stand.
9. Plot a graph showing the relationship between the time and the temperature.

Results and observations

Copy the table below into your exercise books and record your observations:

Time (seconds)	Temperature (°C)
30	
60	
90	
120	
150	
180	

10. Draw a line graph for your results.
    a) First, think about what will go on your horizontal *x*-axis? This is what you changed.
    b) What will go on the vertical *y*-axis? This is what you measured.
    c) The temperature of the water kept increasing, until it started to boil. At what temperature did the water boil?
4. What did you observe about the temperature when the water started to boil?

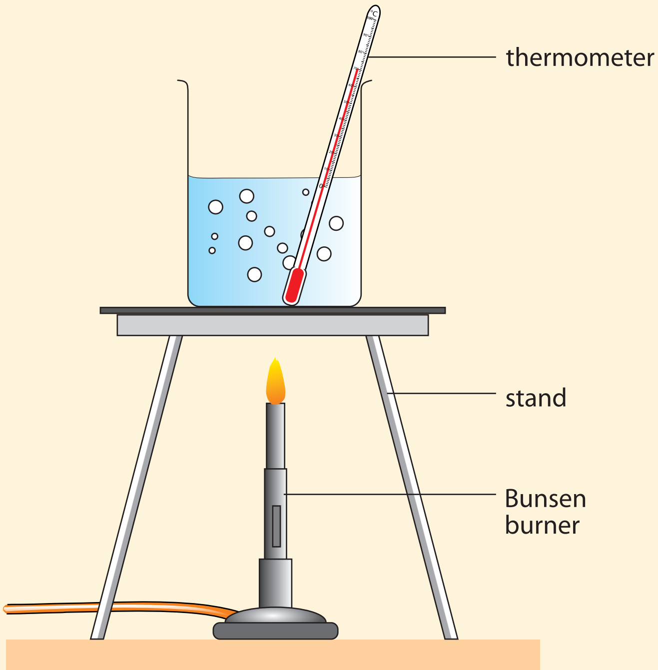
Conclusion

1. What can you conclude from your results?
2. Can you accept or reject your hypothesis?

Questions

1. In order for the water to boil, the thermal energy of the water must increase. Where do you think the energy came from to make the water boil?
2. Describe the transfer of energy within this thermal system as the water was heated.
3. After the water had boiled, and you turned off the Bunsen burner, what happened to the water in the beaker?

4. What do you think happened to the thermal energy of the water? Describe the transfer of energy.
5. A Grade 7 learner is conducting the investigation and read the temperature off the thermometer as it is set up in the diagram below. What is wrong with this set-up? What is your advice to the learner?

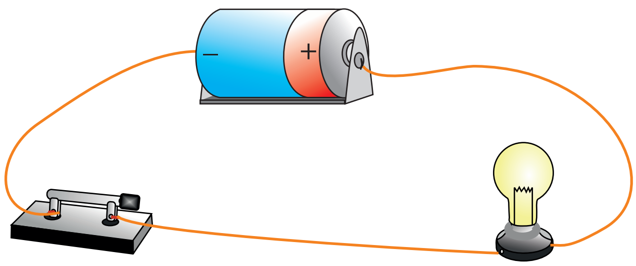


So, what have we discovered? The temperature of the water increased. This means that the water particles must have been given more **kinetic energy**. The energy must have come from the Bunsen burner flame. The flame is there because we are burning gas so the energy must have been stored in the gas. If it is stored energy then it is **potential energy**.

So, we have discovered that the potential energy stored in the gas has been transferred to the water particles as kinetic energy. No energy has been **created** it has been **transferred** from the gas to the water. The energy of the system has been **conserved**.

Electrical systems

Do you think an electric circuit is a system? Look at the following image and discuss this with your partner. Write down whether you think it is a system or not, and why.



What is the source of energy in this electric circuit? In other words, what is the input energy in this system?

What is the result of the energy transfer in the system? In other words, what is the energy output?

Let's look at another example of an electric circuit, which makes a motor turn, to see the different energy transfers within the system.

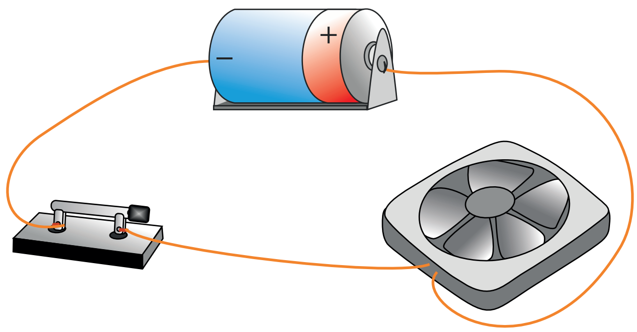
ACTIVITY An electric fan system

Materials

- small electric fan or motor
- conducting wires
- battery
- switch

Instructions

1. If possible, make the following circuit in class. However, if you do not make the actual circuit, study the image and answer the questions.
2. To make the circuit, attach a small fan or motor to a battery using the conducting wires.
3. Attach a switch in the circuit as shown in the image. You can make your own switch using a piece of board and pressing two metal pins into it. Then, bend a metal paper clip and attach it to one of the drawing pins as shown below.
4. Close the switch and observe what happens to the fan.



Questions

1. What are the parts making up this electrical system?
2. Which part of the system provides the input energy to the system?
3. What happens to the fan or motor when you close the switch?
4. What type of energy does the fan now have?
5. Using your answers to the previous questions, copy and complete the following flow diagram, which describes the energy transfers within this electrical system. You need to fill in the type of energy at each step.

Input energy in the battery is ________	transferred to →	electrons in the wires as ________	transferred to →	fan and output is ________

Biological systems

Do you know that we also get biological systems? You have come across these types of systems before in Life and Living, but now we are going to talk about them in terms of how the energy is transferred within these systems, and conserved.

Do you remember learning about photosynthesis and food chains in Life and Living? This is an example of a biological system. Let's find out why.

A plant uses the radiant energy from the Sun to make its own food through the process of photosynthesis. The energy from the Sun is stored as potential energy in plants, mainly as starch. Have a look at the following image to remind you.

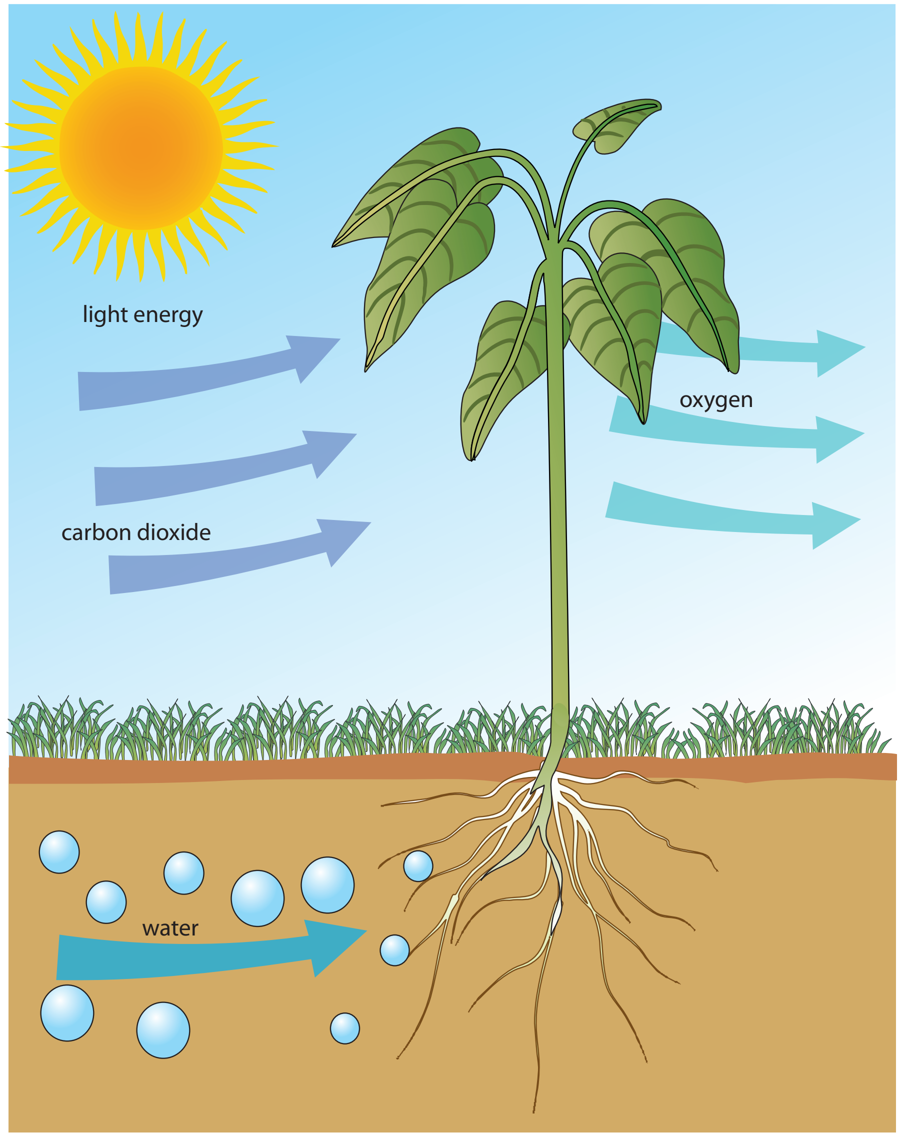


Figure 10.6 What process is being shown in the diagram? Write a sentence to describe the requirements for this process.

When an animal eats the plant it uses the potential energy in the food which is released during respiration. This is then used by the animal to move and for all its life processes. So the potential energy in the food which the animal eats is transferred to kinetic energy. Energy has been transferred from the Sun to the plant to the animal.

Figure 10.7 An impala eats the grass and stores the energy in its muscles. When the impala runs, the stored energy becomes kinetic energy.

Figure 10.8 Our food provides the input energy for our bodies to work and move. The food contains potential energy.

When we eat plants or animals we are able to use the stored potential energy to make our bodies function.

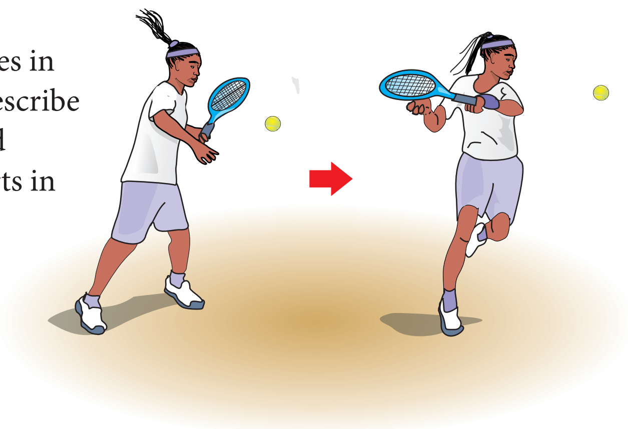
Is the energy conserved in a biological system? Yes, it is! The plants change the Sun's energy into **potential** energy, which it stores inside itself. Animals then eat the plants and the stored potential energy is transferred to them. The animals use the stored energy to enable them to move. This means that the potential energy within the animal has been transferred kinetic energy. As the animal moves and performs its functions, this kinetic energy is transferred to the surroundings. No energy has been created or destroyed; it has just been transferred from the Sun to the plant to the animal.

Let's revise the energy transfers within some systems by studying and drawing flow diagrams.

ACTIVITY Flow diagrams for energy transfers

Instructions

1. Study each of the following diagrams which show different systems.
2. Draw a flow diagram, similar to the one you did for the electric fan in your exercise book.
3. Then write a few sentences in your exercise books to describe how energy is transferred between the different parts in each of these systems.
4. The first one has been done for you.



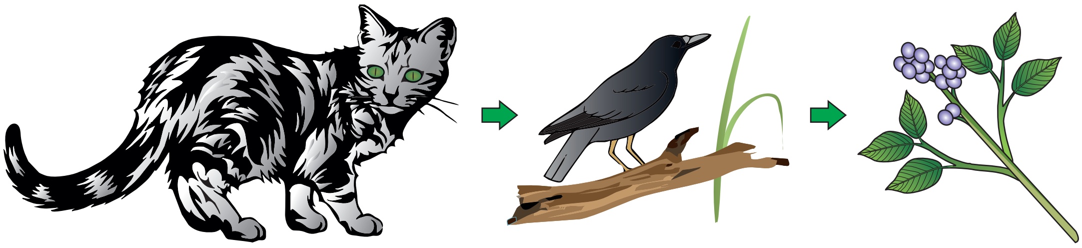
This flow diagram describes the transfers of energy.

potential energy in raised arm and raquet → transferred to → **kinetic energy** in girls arm as she swings → transferred to → **kinetic energy** in tennis raquet → transferred to → **kinetic energy** in ball

The tennis player's arm and raquet have potential energy as they are raised. As the girl swings her arm, this potential energy is transferred to the tennis raquet as kinetic energy. The tennis raquet transfers energy to the ball as kinetic energy which enables the ball to move through the air.

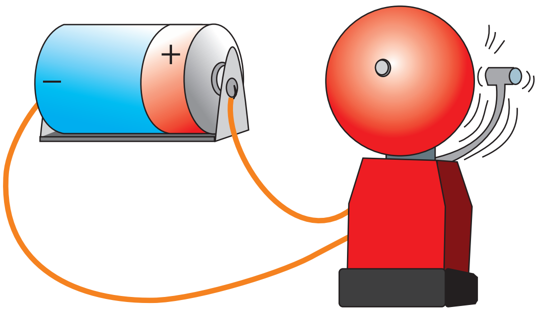
Questions

1. This drawing shows a food chain.



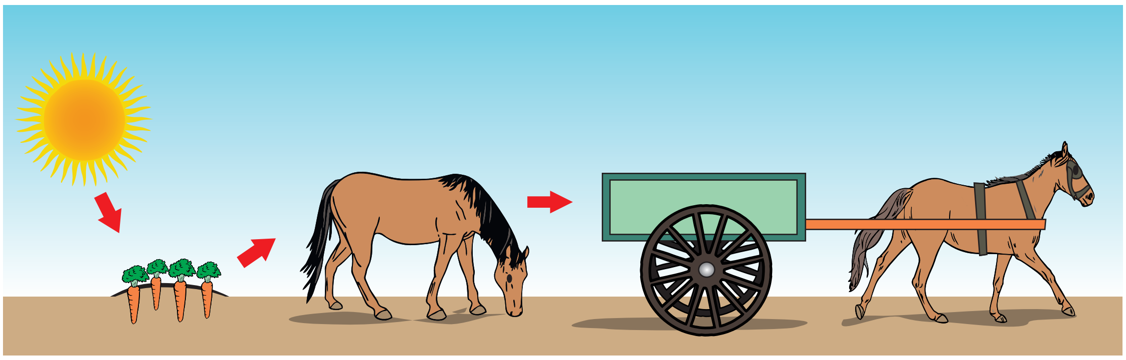
Draw a diagram showing the energy transfers in this biological system.

2. Write a description of the energy transfers below.



Draw a diagram showing the energy transfers in this electrical system.

3. Write a description of the energy transfers below.



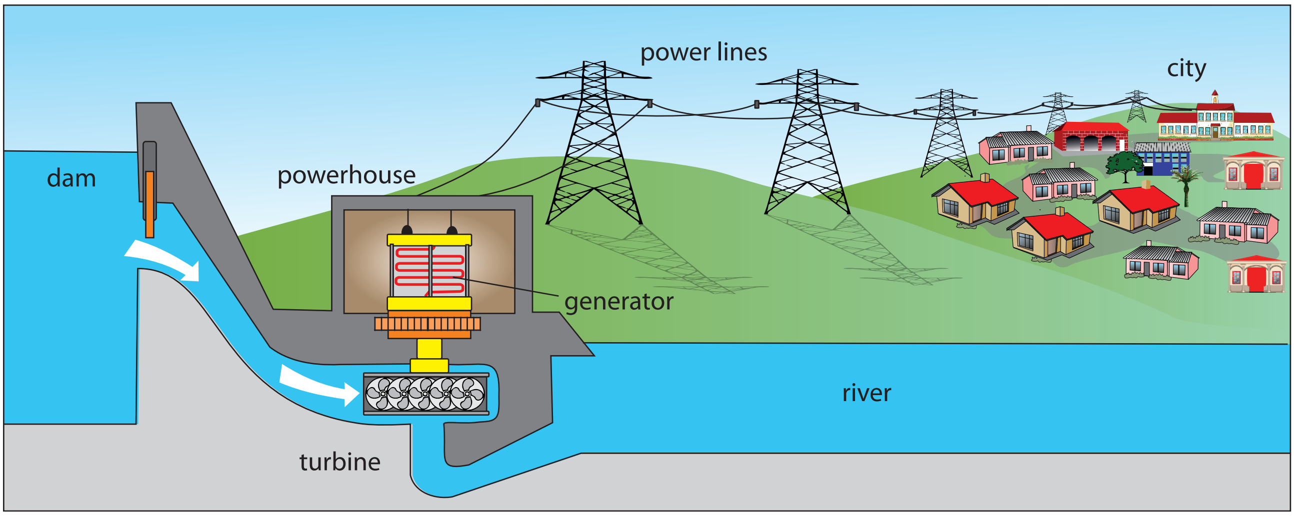
4. In the previous example showing the berries, the bird and the cat, we saw an example of a food chain. Do you remember learning about food chains in Grade 6? A food chain only shows the transfer of energy between organisms, and does not include the Sun. So, it always starts with a producer. Is the image below an example of a food chain? Why or why not?

Take note

We will learn more about food chains and the interactions between organisms next year in Grade 8 *Life and Living*.

a) We can rather call this an energy transfer sequence. Draw a flow diagram to explain the energy transfers in this biological and mechanical system.
b) Write a description of the energy transfers below.

5. Let's now look at a more complex system which involves many different parts working together. Do you remember learning about hydropower as a source? Is it renewable or non-renewable?
6. Study the following diagram which shows a hydropower plant at the edge of a dam. Then answer the questions that follow.



a) The water in the dam on the left is high up. It has the ability to fall down. What kind of energy does the water have?
b) As the water flows down the outlet from the dam, describe the transfer of energy.
c) The flowing water then turns the turbine. This is a mechanical system. What energy does the turbine have?
d) The generator then transfers the energy between two systems. The kinetic energy in the mechanical system is transferred to kinetic energy in the electrical system as it generates electricity. What parts make up the electrical system in the diagram?
e) What is the output from this whole system? In other words, what does the city get?

Take note

We will study the national electricity grid in more detail at the end of the term.

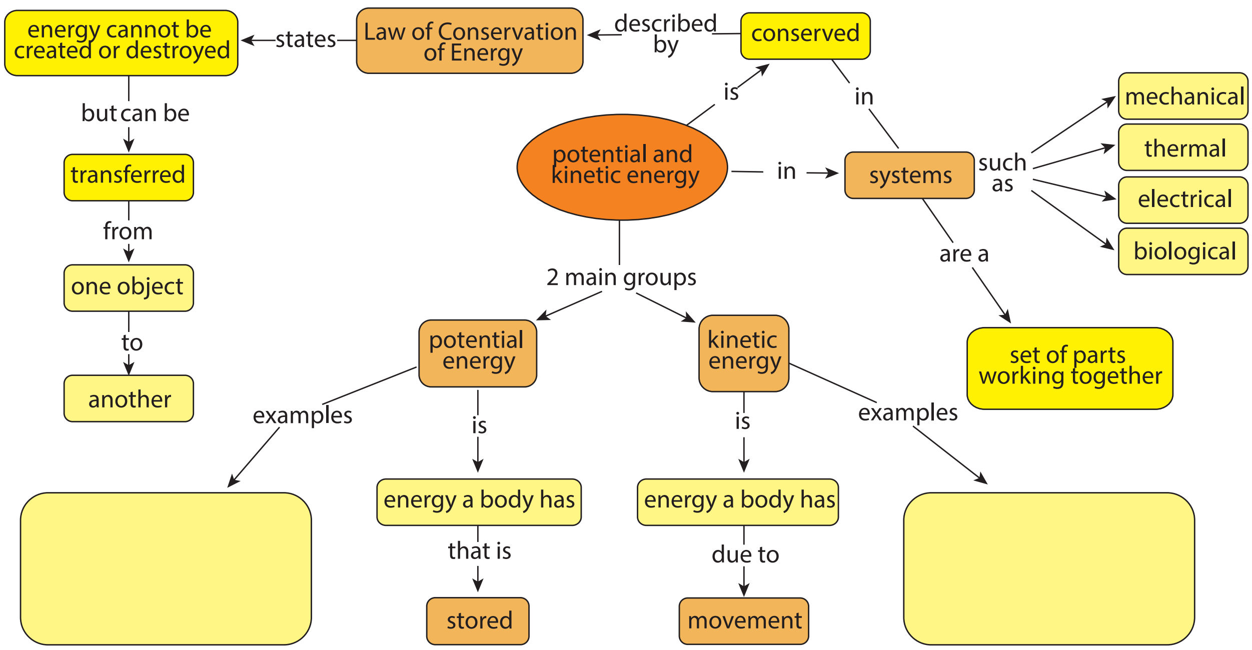
Summary

Key concepts

- Potential energy is energy which is stored in a system.
- Kinetic energy is energy which an object has because it is moving.
- Energy is measured in joules (J).
- Energy cannot be created or destroyed. It can only be transferred from one part of a system to another. This is the Law of Conservation of Energy.
- Energy is transferred within systems. The input energy is transferred through the system and energy is conserved.
- There are various energy systems, such as:
  - mechanical systems
  - thermal systems
  - electrical systems
  - biological systems
- Energy is also transferred between different systems.

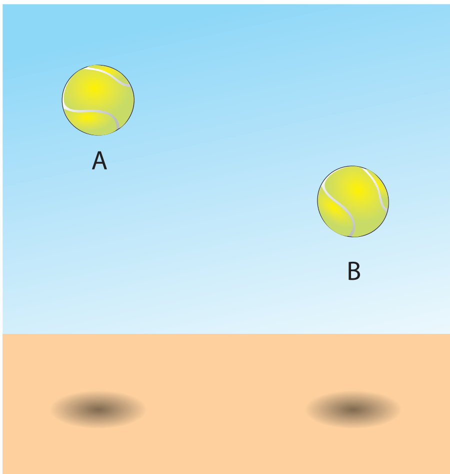
Concept map

Complete the concept map below by filling in some examples of objects with either potential energy or kinetic energy that you have learnt about in this unit.



Revision

1. What is potential energy? Give two examples of systems which have potential energy [3]
2. What is kinetic energy? Give two examples of systems which have kinetic energy? [3]
3. What does the Law of Conservation of Energy state? [1]
4. Look at the picture below.



   a) Which ball has the most potential energy? [1]
   b) Explain your choice. [1]

5. Complete the sentences by filling in the missing words. Write the sentence out in full and underline your answers.
   a) A plant receives energy from ______________ and uses the energy to make ______________. The plant then changes some of the sugar into ______________ and stores it in leaves, fruit and other parts. The plant has ______________ energy, which you can get when you eat the plant. [4]
   b) When a plane carries skydivers high into the sky, it is giving them ______________ energy. When they jump out and free-fall, they have ______________ energy. [2]

Figure 10.9 These skydivers have just jumped out of the back of a plane.

6. Draw an energy transfer flow diagram to show how energy gets from the Sun into your food and then to you. [3]

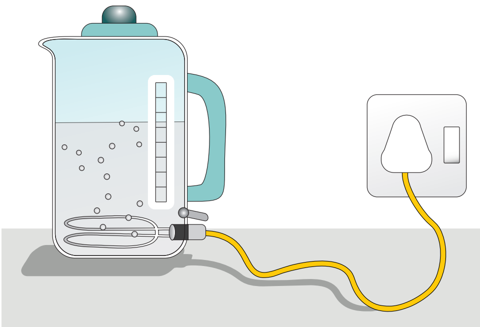
7. A high jumper starts running. As she approaches the bar, she pushes off the ground and lifts her body off the ground and flies over the bar. She then falls down into a large pad like a mattress on the ground.

Figure 10.10 A high jumper going over the bar.

Think about her jumping, from the moment her feet leave the ground. She goes up in the air, she almost stops as she goes over the bar, and then she comes down again.

a) Where does she have the most potential energy? [1]
b) Where does she have the most kinetic energy? [1]
c) Does she have some potential energy and some kinetic energy at any point in her jump? If you say yes, name one point where it is true. [2]

8. Which type of energy does each of the following systems contain (kinetic or potential or both types)? [6]



a) A mountain biker at the top of the mountain.
b) Petrol in a storage tank.
c) A racing car travelling at its maximum speed.
d) Water flowing down a waterfall before it hits the pond below.
e) A spring in a pinball machine before it is released.
f) A running refrigerator motor.

9. Study the following illustration and answer the questions.

a) There are two systems involved in this image of heating water in a kettle that is plugged in. What are they? [2]
b) Describe the energy transfers within and between these two systems. [2]

Total [32 marks]

11 Heat: Energy transfer

Key questions

- What is the difference between heat and temperature?
- How does a heater warm up a cold room?
- Why can the Sun make us warm?
- Why does my cold drink become warm?

Keywords

- thermal
- heat
- temperature

11.1 Heating as a transfer of energy

In the last chapter we looked at thermal systems. The **thermal** energy of an object is the amount of energy it has inside of it, in other words, its internal energy. In a thermal system, thermal energy is transferred from one object to another. Heat is the transfer of thermal energy from a system to its surroundings or from one object to another. This transfer of energy is from the object at a higher temperature to the object at a lower temperature.

It is very important to know that, in science, heat and temperature are not the same thing.

Heat is the transfer of thermal energy from a system to its surroundings or from one object to another as a result of a difference in temperature. Heat is measured in joules (J). This is because heat is a transfer of energy.

Temperature is a measure of how hot or cold a substance feels and it is measured in degrees Celsius (°C). Temperature is a measure of the average kinetic energy of the particles in an object or system. We use a thermometer to measure the temperature of an object or substance.

Complete the following table to summarise the differences between heat and temperature

	Heat	Temperature
Definition		
Unit of measurement		
Symbol for unit		

Heat is the transfer of energy. During energy transfer, the energy moves from the hotter object to the colder object. This means that the hotter object will cool down and the colder object will warm up. The energy transfer will continue until both objects are at the same temperature.

There are 3 ways in which thermal energy can be transferred from one object/substance to another, or from a system to its surroundings:

- Conduction
- Convection
- Radiation

Let's have a look at these in more detail.

11.2 Conduction

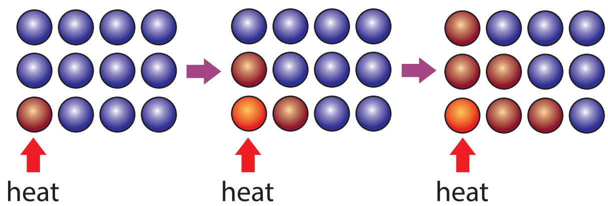
Keywords

- conduction
- conductor
- insulator

Have you noticed that when you put a cold, metal teaspoon into your hot cup of tea, the teaspoon handle also warms up after a while? Have you ever wondered how this warmth "moved" from the hot tea to the cold teaspoon and warmed it up? This is one way in which energy is transferred, and it is called conduction. Let's find out how it works.

Figure 11.1 How does the handle of the metal teaspoon become hot when in a cup of tea?

When energy is transferred to an object, the energy of the particles increases. This means that the particles have more kinetic energy and they start to move and vibrate faster. As the particles are moving faster they "bump" into other particles and transfer some of their energy to those neighbouring particles. In this way, the energy is transferred through the substance to the other end. This process is called conduction. The particles conduct the energy through the substance, as shown in the diagram.

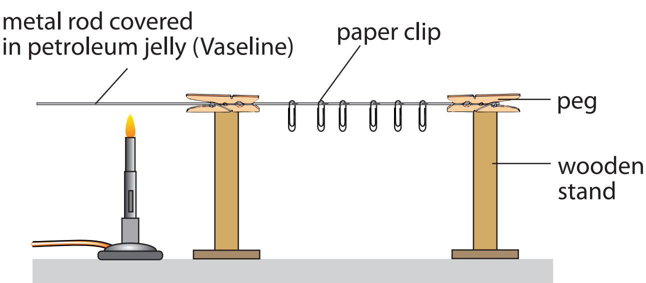


Let's demonstrate this practically.

ACTIVITY Conduction through a wire

Instructions

1. Your teacher will set up the demonstration as in the diagram below.
2. Observe what happens to the pins or paper clips as the Bunsen burner is lit and heat is applied to one end of the metal rod.



Questions

1. When the Bunsen burner is lit, what happens to the rod just above it?
2. Which pin or paperclip dropped off the metal rod first? The one closest to or furthest from the Bunsen burner?
3. What does this tell us about the way in which heat is conducted along the wire?

Let's think about the teaspoon in the tea again. The tea is hot and the metal spoon is cold. When you put the metal teaspoon into the hot tea, some of the thermal energy from the tea is transferred to the metal particles. The metal particles start to vibrate more quickly and collide with their neighbouring particles. These collisions spread the thermal energy up through the teaspoon. This makes the handle of the teaspoon feel hot.

Conduction is the transfer of thermal energy between objects that are touching. In the teaspoon example, the particles of the tea are touching the particles of the metal spoon, which in turn are touching each other, and this is how heat is conducted from one object to the other.

Do all materials conduct heat in the same way? Let's find out.

Investigation — Do all materials conduct heat in the same way?

In this investigation, we will be placing an ice cube on a plastic block and on an aluminium block and observing which ice cube melts the most quickly.

Aim

To investigate which materials are the best conductors of heat.

Hypothesis

Write a hypothesis for this investigation. Which block do you think will melt the ice cube the most quickly?

Materials and apparatus

- a plastic block
- an aluminium block
- ice cubes
- a plastic ring to keep the ice cube in place on the block

Method

1. First feel the plastic block and the aluminium block. Describe how they feel.
2. Place an ice cube onto each block and observe what happens.

Observations

3. Which ice cube starts to melt first and the fastest?
4. Is this what you thought would happen? Refer back to your hypothesis.

Conclusion

What can you conclude about which material (the plastic or the metal) is the best conductor of heat?

So how does this work? This is to do with **thermal conductivity**, the rate at which heat is conducted from one object to another.

When you originally felt the blocks, you felt that the plastic block was warmer. But, what we observed is that the aluminium or metal block melted the ice cube more quickly. This is because the metal block is conducting the heat faster to the ice cube more quickly. The plastic block is a worse thermal conductor, so less heat is being transferred to the ice cube, so it does not melt as quickly.

Why, then, does the aluminium block feel colder than the plastic block?

This is because the aluminium conducts heat more quickly away from your hand than the plastic does. Therefore, the aluminium block feels colder and the plastic block feels warmer. When you touch something, you do not actually feel the temperature. Rather, you feel the rate at which heat is either conducted away from or towards you.

Let's think of another example. Imagine you have just finished baking a cake in the oven at 180 ˚C.

Figure 11.2 A cake baking in the oven in a metal tin.

When you remove the cake from the oven, which is more likely to burn you more, the metal cake tin, or the cake?

Do you think the cake and the tin are at the same temperature when you remove them from the oven? Why?

What we have seen here is another example of thermal conductivity. The tin will conduct heat to your hand much more quickly than the cake, so the tin will burn you, but the cake will not, even though the tin and the cake are at the same temperature.

So what have we learnt? Metals conduct heat better than non-metals.

Take note

Remember, just because a material feels colder, does not mean it has a lower temperature. It may just be that it is conducting heat away from your hand more quickly.

There are substances that allow thermal energy to be conducted through them and so they are called **conductors**.

There are substances that do not allow thermal energy to be conducted through them and so they are called **insulators**.

Now that we know that metals are good conductors of heat, do you think all metals conduct heat equally well? Let's investigate which metals are better conductors.

Investigation: Which metals are the best conductors of heat?

We are going to see which metal is the better conductor of thermal energy. To do this we will see which metal becomes hot first.

Aim

To identify whether some metals are better conductors of heat than other metals.

Identify variables

Read through the method and look carefully at the diagram for the investigation to identify the different variables required.

1. Which variable are you going to change?
2. What do we call the variable that you are going to change?
3. Which variable are you going to measure?
4. What do we call the variable that you are going to measure?
5. Which variables must be kept the same?
6. What do we call the variables which must be kept the same?

Hypothesis

Write a hypothesis for this investigation.

Materials and apparatus

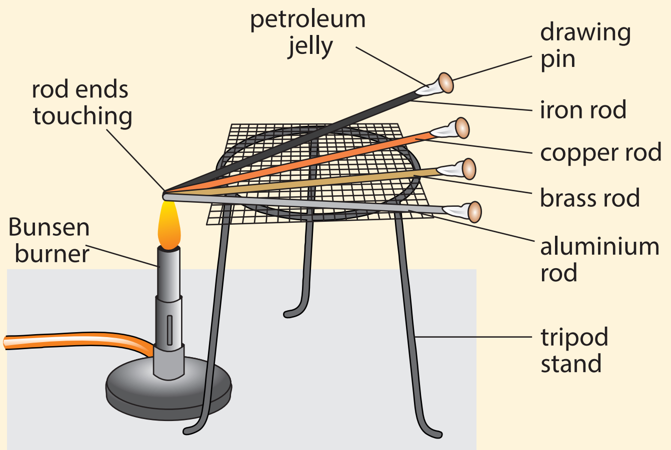
- Bunsen burner
- Vaseline
- copper, iron, brass and aluminium rod
- stopwatch
- drawing pins
- tripod
- cardboard or paper
- matches

Safety Precautions

- Do direct touch the heated metals
- Do not play with fire or the matches
- Ask for the teacher's assistance to adjust the Bunsen burner
- Leave the apparatus for at least 5 minutes to cool off after using them before removing them

Method

1. Stick the flat end of a drawing pin to the end of each of the metal rods using the Vaseline. Try to use the same amount of Vaseline for each drawing pin.
2. Place the cardboard on the tripod.
3. Balance the metal rods on the cardboard so that one end of each is over the Bunsen burner.
4. Light the Bunsen burner.
5. Using a stopwatch, measure how long it takes for each of the pins to drop off.
6. Record your results in the table.
7. Draw a bar graph to illustrate your results.



Results and observations

Copy the following table into your exercise books and record your results.

Type of metal	Time taken for pin to drop off (seconds)
Iron	
Copper	
Brass	
Aluminium	

Now draw a bar graph to show your results. Do not forget to give your graph a heading to describe what it represents.

1. Which variable should be on the horizontal x-axis?
2. Which variable should be on the vertical y-axis?
3. Why do you think that a bar graph is suitable for this investigation?

Analysis

1. Which bar on your graph is the longest?
2. Which bar is the shortest?
3. Write down the materials in order of how fast they conducted heat, from the quickest to the slowest.

Keywords

- convection
- convection current

4. Why does the Vaseline melt?
5. Why do you think it was necessary to place the piece of cardboard or paper on the tripod stand underneath the metal rods? Hint: The tripod stand is also made of metal.
6. Why do you think it is necessary to use the same amount of Vaseline on the ends of each rod?
7. Do you think we could have performed this investigation if our rods had been of different lengths? Why?

Evaluation

It is always important to evaluate our investigations to see if there is anything we would change or improve on.

1. Is there anything that went wrong in your investigation that you could have prevented?
2. If you were to repeat this investigation, what would you change?

Conclusion

Write a conclusion for this investigation about which metal is the best conductor of heat.

In this section we looked at how heat is conducted through metal rods and other objects. These were all solid objects. How is energy transferred through liquids or gases? Let's find out in the next section.

11.3 Convection

Think of a pot of water on a stove. Only the bottom of the pot touches the stove plate, but all of the water inside the pot, even the water not touching the sides, becomes warmer. How does the energy transfer throughout the water in the pot? The transfer of energy is because of convection.

Let's do an activity that will help us to visualise how convection occurs.

ACTIVITY Convection in water

Materials

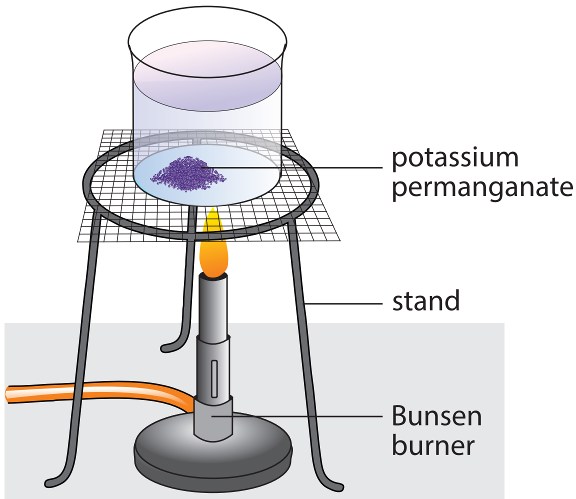
- 200 ml glass beaker
- potassium permanganate
- Bunsen or spirit burner, tripod stand, wire gauze

Safety precautions

- Use a spatula to add potassium permanganate
- Do not use a Bunsen burner without a teacher's supervision
- o nor play with fire
- Do not touch heated beaker

Instructions

1. Half fill the beaker with cold tap water.
2. Carefully put a small amount of potassium permanganate on one side of the beaker. DO NOT STIR.
3. Heat the water directly under the side of the beaker with potassium permanganate with a Bunsen/spirit burner and observe what happens.
4. Set up a control experiment and place a few grains of potassium permanganate into the bottom of a beaker filled with water. Do not heat this beaker, and observe what happens.



Instructions

1. What did you see as the water started to warm up in the beaker that was heated? Draw a picture to show what you saw.
2. What is happening to the potassium permanganate in this beaker?
3. Can you explain the pattern you saw?
4. Compare this to the beaker which was not heated. What did you observe in this beaker?

Take note

We then say that the heated liquid or gas is less dense as the same particles are now taking up a larger space. We will learn more about density next year in Grade 8.

Let's now explain what we observed in the last activity. Convection is the transfer of thermal energy from one place to another by the movement of gas or liquid particles. How does this happen?

As a gas or liquid is heated, the substance expands. This is because the particles in liquids and gases gain kinetic energy when they are heated and start to move quickly. They therefore take up more space as the particles move further apart. This causes the heated liquid or gas to move upwards and the colder liquid or gas moves downwards. When the warm liquid or gas reaches the top it cools down again and therefore moves back down again.

In the last activity, the water particles gained kinetic energy and moved apart from each other, therefore taking up more space. This water then moves upwards as it is less dense than the cold water, meaning it is lighter than the cold water. We were able to observe this as the potassium permanganate dissolved in the water and moved with the water particles, and then moved downwards again as the water cooled.

This movement of liquid or gas, is called a **convection current**, and energy is transferred from one area in the liquid or gas to another. Have a look at the illustration which shows a convection current.

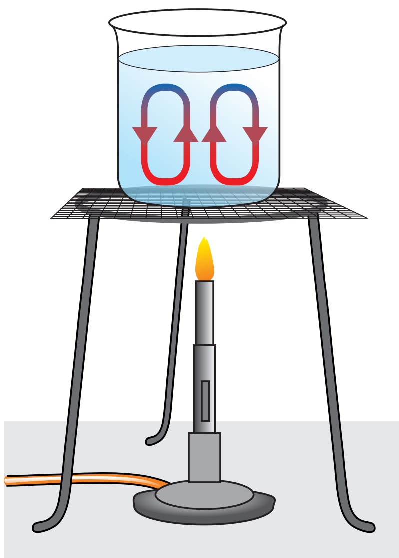


Figure 11.3 Illustration of a convection current.

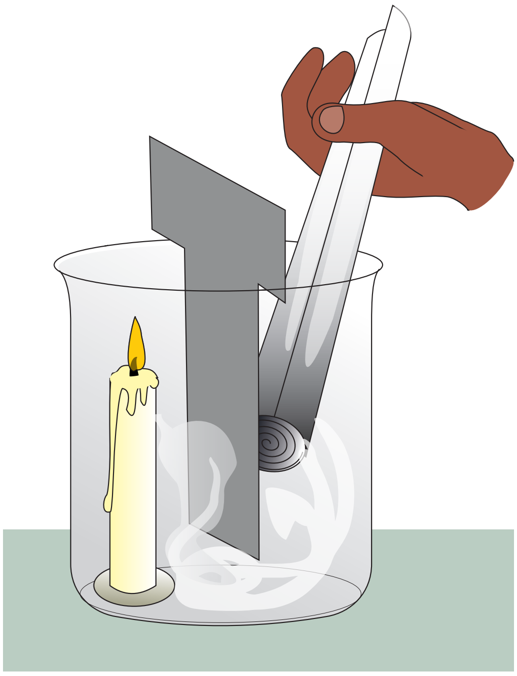
Did you know?

The blobs in a lava lamp move up and down in the lamp as they first heat and expand, and then reach the surface and cool, at which time they move back down again.

ACTIVITY Does smoke move up or down?

Materials

- T-shaped piece of cardboard
- candle
- twist of paper or splint
- beaker
- box of matches



Instructions

1. Light the candle and place it inside the beaker, to the side of the beaker.
2. Put the T-shaped piece of cardboard into the beaker so that there is a small gap between the bottom of the beaker and the cardboard.
3. Light the twisted roll of paper and hold it in the beaker on the opposite side to the candle, as shown in the diagram.
4. Observe what happens to the smoke.

Questions

1. What happens to the smoke from the paper?
2. Why do you think the smoke moves in this way?

In the last two activities, we have observed convection currents in a liquid and in a gas. Convection currents can form only in gases and liquids as these particles are free to move around. They are not held in fixed positions as they are in a solid. Solid particles are held together too tightly for them to move when heated. Solid particles will vibrate more quickly only when heated, but will not move from their positions.

Now that we have learned about convection, how can we apply this in the world around us? It is interesting to learn about concepts and theories in science, but it is even more interesting when we discover how this has an influence in our daily lives.

Figure 11.4 The blobs in a lava lamp move up and down, showing us the convection currents as the lamp provides the source of heat at the bottom.

ACTIVITY: Installation of air heating and cooling systems.

Imagine that your teacher has been given a heater and an air-conditioning unit for your classroom. The heater will warm your classroom in winter and the air-conditioner will keep you cool in summer. You need to help your teacher to decide where each item should go in the classroom. Should they go on the wall near the ceiling or near the floor? Should they go next to a window?

Figure 11.5 This is a photo of an air-conditioner.

Instructions

1. Get into groups of 2 or 3.
2. Discuss where in your classroom you would place a heater so that it can effectively heat up the room. Draw a diagram to explain your choice.
3. Discuss where in your classroom you would install the air-conditioner so that it can effectively cool the room. Draw a diagram to explain your choice.

Keywords

- radiation
- matt
- reflect
- absorb

Try to find an air-conditioner or heating specialist whom you can interview. Ask them to explain the best way to install the air-conditioner and a heater.

We have now looked at how energy is transferred through different materials, whether they are solids (conduction) or liquids and gases (convection). But, what about if there are no particles to transfer the thermal energy? Is there still a way for energy to be transferred?

Take note

Radiation comes from the Greek word radius, meaning, a beam of light.

11.4 Radiation

Have you ever wondered how the Sun is able to warm us even though it is so far away? The energy is transferred from the Sun to everything on the Earth. The Sun does not need to be touching the Earth for the energy to be transferred. Also, there is space in between the Earth and the Sun. The energy from the Sun is able to warm us without the Sun ever touching us.

This transfer of energy is called **radiation**. It is different from conduction or convection as it does not require objects to be touching each other, or the movement of particles.

We can also see how heat is transferred by radiation here on Earth, and not just between the Sun and the Earth. Let's demonstrate the difference between radiation and convection using a candle.

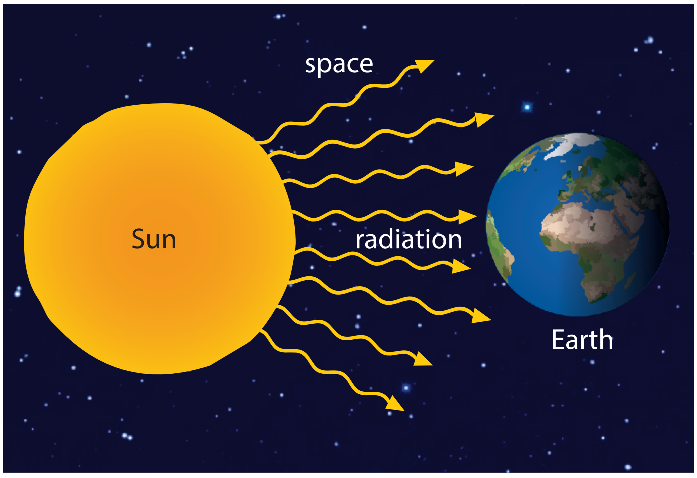


Figure 11.6 The Sun radiates heat in all directions. Energy is transferred through space to Earth.

ACTIVITY Radiation from a candle

Materials

- candle in a holder
- metal spoon or metal rod
- matches

Safety precautions

- Do not touch the fire
- Do not bring hand too close to the candle flame, it may burn you.
- Do not play with fire or the matches

Instructions

1. Light a candle and place it in a holder. Your teacher may do this and get groups of you to come up at a time to the demonstration.
2. First hold your hand above the candle.
3. Then hold your hand on the side of the candle.
4. Answer the following questions.

Questions

1. We know now that heat from a candle will be transferred to the air around it. These will warm up. Where will this air move to?
2. What is this called?
3. So, when you hold your hand above the candle, what do you feel, and why?
4. But, what about when you hold your hand on the side of the candle? Could you also feel warmth from the candle?

5. This is not convection, as the air particles do not travel sideways when they warm up from the flame. So, how is energy transferred to your hand when you feel the warmth on the side of the candle?
6. Lastly, if your teacher placed a metal spoon in the candle flame and you felt the end, how would it feel after a little while?
7. How was the energy transferred from the flame to the end of the spoon?
8. The photo shows different forms of how heat is transferred.

As we saw in the last activity, energy is transferred through convection, conduction and radiation. Have you ever stood next to a huge fire? You will feel the radiating heat even though the air may be very cold. This is because the energy is transferred to you by radiation through the spaces between the particles in air.

What about if you touch a black wall or a white wall? Do you think there is a difference in how different surfaces absorb and reflect radiation? Let's find out by doing an investigation.

Investigation Which surfaces absorb the most radiation?

We are going to investigate which surfaces absorb the most heat, using dark-coloured paper, light-coloured paper and shiny paper, such as aluminium foil. We will use the temperature inside an envelope made from each kind of paper as a measure of the amount of heat the paper absorbed. Why do you think we can do this?

Investigative question

Which surfaces will absorb the most radiation from the Sun and therefore increase in temperature most quickly?

Variables

1. Which variable are you going to measure?
2. What do we call the variable you have measured?
3. Which variable are you going to change?
4. What do we call this variable?
5. What must be kept the same for all the different materials?

Hypothesis

Write a hypothesis for this investigation.

Materials and apparatus

- matt black paper
- white paper
- aluminium foil
- three alcohol thermometers
- stopwatch or timer
- glue or adhesive tape

Method

1. Fold each piece of paper and aluminium foil into the shape of an envelope.
2. Put a thermometer into each of the envelopes and record the starting temperature.
3. Put all the envelopes outside in the Sun.
4. Check the temperature on the thermometers every 2 minutes for 16 minutes.
5. Record your results in the table.
6. Draw a line graph for each envelope on the same set of axes.

Results and observations

Record your results in the following table.

Draw a line graph for each of the envelopes. Do not forget to give your graph a heading.

Time (minutes)	Temperature in black paper envelope (°C)	Temperature in white paper envelope (°C)	Temperature in aluminium foil envelope (°C)
0			
2			
6			
8			
10			
12			
14			
16			

Analysis

1. What do you notice about the shapes of the graphs you drew? Are the graphs straight lines or curves?
2. Which line on your graph is the steepest? What does this tell us?
3. Compare your results for the white paper and the shiny surface. What does this tell you?

Evaluation

1. Did the investigation run smoothly? Or is there anything you would change?
2. Did you get any results which did not seem to fit the overall pattern?

Conclusion

Write a conclusion for your investigation. Remember to refer back to the investigative question that we wanted to answer.

Did you know?

It takes light about 8 minutes to travel from the Sun to Earth.

Take note

Radiation from the Sun is essential to life on Earth, but ultraviolet radiation from the Sun can also be very damaging to our skin. Remember to wear sun cream and a hat when outside, and avoid being in direct sunlight between11 am and 2 pm.

The investigation showed that the dark envelope showed the biggest increase in temperature. The lighter-coloured envelope showed a smaller increase in temperature. The envelope made out of a shiny material showed the smallest increase in temperature.

So what have we learnt? Dark colours seem to absorb more of the Sun's radiation than light or reflective colours. So, if you want to stay warm on a cold day, dark clothing will absorb more of the available warmth from the Sun's radiation than light colours.

The average summer temperature in Hotazel, a town in the Northern Cape, is about 34 °C. If you lived in Hotazel and needed to buy a new car, would you buy a light- or dark-coloured car? Explain why.

You have the option of getting the car sprayed to make the surface shinier. Do you think this will help keep the car cool in hot, summer months? Explain why.

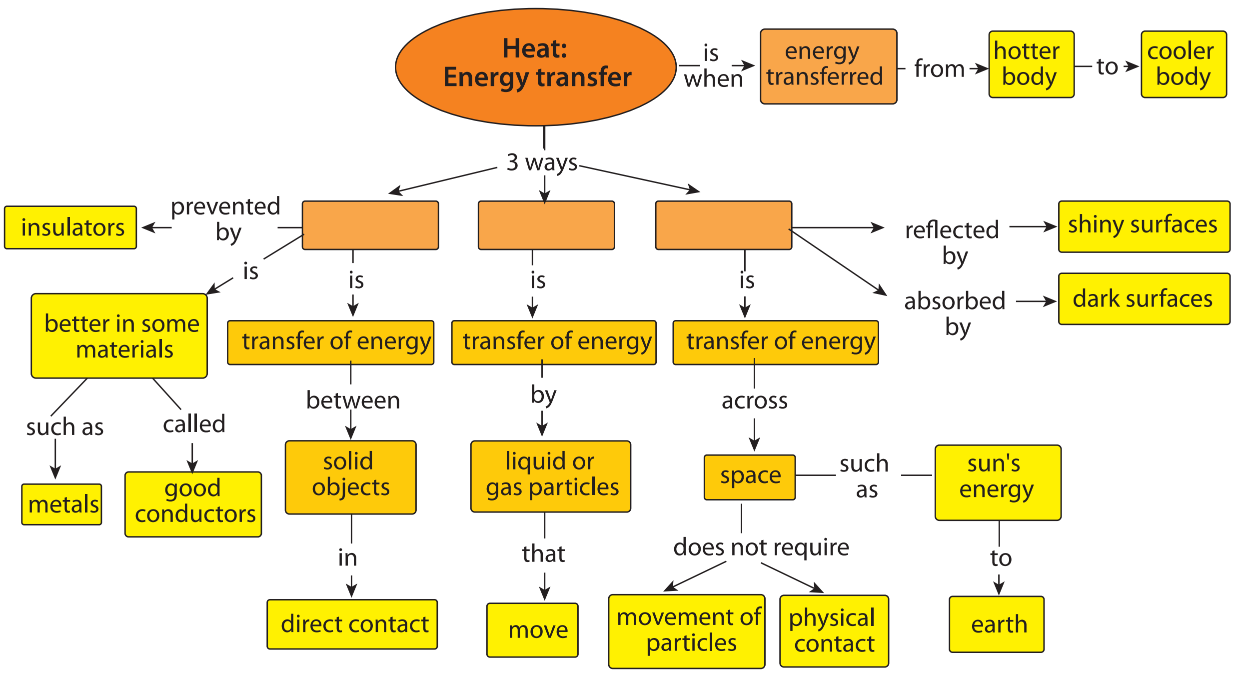
Summary

Key concept

- Heat is energy that is transferred from a hotter to a cooler object.
- Temperature is a measure of how hot or cold a substance feels.
- Heat (energy transfer) occurs in three ways: conduction, convection or radiation.
- During conduction, the objects must be touching each other for energy transfer to take place.
- Some materials, such as metals, conduct heat well. They are called conductors of heat.
- Some materials, such as plastics and wood, slow down or prevent conduction. They are called insulators.
- Convection is the transfer of energy within liquids or gases.
- A convection current refers to the movement of a liquid or gas during energy transfer. The liquid or gas moves upwards from the heat source (as it expands) and then downwards when the liquid or gas cools (as it contracts).
- Radiation is the transfer of energy where objects do not have to be physically touching. Radiation does not require a medium and can take place through empty space.
- The Sun's energy is transferred to Earth by radiation.
- Dark, matt surfaces are good absorbers of radiant heat
- Light and shiny surfaces are poor absorbers of radiant heat. Light, shiny surfaces reflect more radiant heat than they absorb.

Concept map

Below is a concept map showing how the different topics about heat link together. You need to fill in the three different ways that energy can be transferred, as discussed in this chapter, but you cannot just put any one into any box. You need to study the concepts which come after each box and explain each way of transferring energy during heating.



Revision

1. How is energy being transferred in the following photos showing different heating processes? Write down conduction, convection or radiation. Some illustrations may show more than one form. [4]

a) The heat from the Sun travels to Earth.

b) Cooking food on a braai or fire.

c) Boiling water in a metal pot.

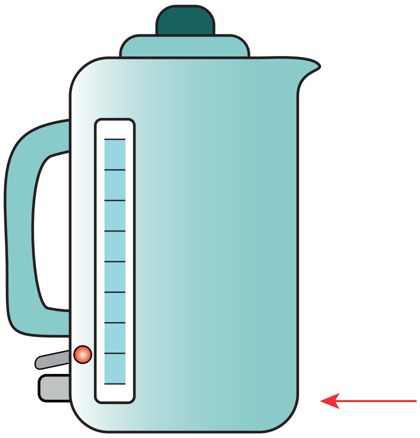
d) A heater in a room.

2. In each of the following situations, identify the method of energy transfer taking place (conduction, convection, radiation).
   a) A fireplace has a glass screen in front of it. The person sitting in a chair next to the fireplace chair feels hot due to ____________________. [1]
   b) When you stir your tea with a metal spoon the handle gets hot because of ____________ [1]
   c) When you are lying on the beach your skin feels hot because of __________________. [1]

3. Draw energy transfer flow charts for the following: You buy a cup of hot chocolate and hold it in your hands on a cold winter day. [2]

4. Your parents have a metal hot-water cylinder (geyser) and they are complaining about the amount of energy needed to keep the water hot. What can you recommend your parents could do to prevent energy loss from the geyser? Explain your answer. [4]

5. Explain why the heating element for a kettle is at the bottom and not at the top. [3]



6. Explain why you think the water boils throughout the kettle pot and not just at the bottom? [2]

7. Explain why you think take-away coffee is sold in styrofoam cups rather than ceramic cups. [2]

8. Explain why you think two thin blankets can sometimes be warmer than one thick blanket. [2]

9. Explain why birds fluff up their feathers to stay warm, especially in winter. [2]

10. Why should you place an air conditioner at the top of a room, near the ceiling, rather than at the bottom near the floor? [2]

11. Imagine you want to build a small enclosure for some chickens on your property. You have an outside area for them that is made from barbed wire, and you have made a small covered enclosure for them inside out of bricks and cement which you would like to paint. You know that it can get quite cold in winter in your area so you want the house to be as warm as possible for the chickens. What colour paint are you going to choose to paint the outside of chicken house? Will it be a dark-coloured paint, such as brown or black, or a light-coloured paint, such as white or yellow? Explain your choice. [4]

Total [30 marks]

12 Heat insulation and energy saving

Key questions

- How can you keep your tea warm?
- Can you use the same materials to keep your house warm in winter and cool in summer?
- How do insulating materials assist with saving energy?

Keywords

- insulator
- conductor

12.1 Why do we need insulating materials?

Heat is the transfer of energy by conduction, convection or radiation, as we learnt in the previous chapter. Often, we want this energy to be transferred for heating. For example, when you place a heater in a room, you want the energy to be transferred through convection and radiation to the room so that the room becomes warmer.

In other situations, you want to prevent energy transfer. For example, on a cold winter's day, we need to minimise heat loss from the house, so that it stays warm. Other objects, such as electric geysers, need to prevent energy transfer to the surroundings so that the water inside stays warm. Materials which are insulators can slow down or prevent energy transfer.

An example of where we want the transfer of energy to take place in some parts of the system, but prevent it in other parts, is in a solar water heater. The use of a solar water heater helps to save energy. This is not only because the system is efficient at warming water, but we also use solar power which is free, whereas we pay for electricity from the national grid and it puts further demands on top of the national demand for electricity.

We use different materials in different situations depending on whether or not we want energy transfer to take place. Let's find out why, and discover how a solar water heater works.

ACTIVITY How do solar water heaters work?

Instructions

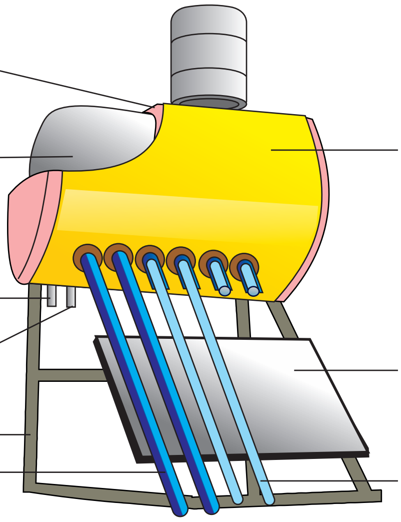
1. Study the following diagrams, which show how a solar water system works.
2. Answer the questions which follow.

There are several different types of solar water heaters. We will be looking at the most efficient heater, which uses evacuated tubes.


Figure 12.1 A solar water heater on top of a corrugated iron house.


Figure 12.2 A close up photo of a solar water heater.

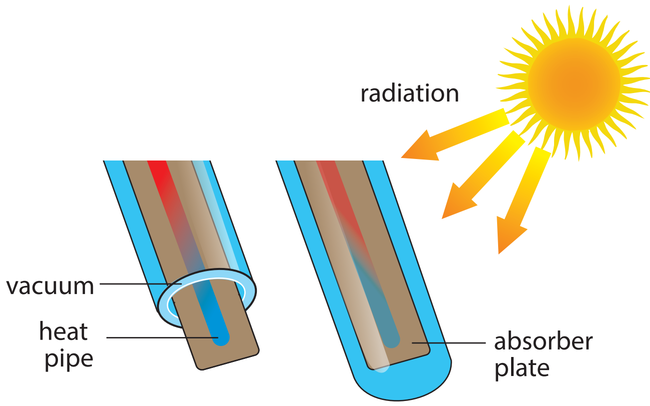
The following diagram shows the different parts of the solar water heater to which we will be referring. Cold water flows into the cold water intake pipe and then down the long tubes, called **evacuated tubes**. The water warms up due to energy transfer from the Sun and it then flows into the storage tank at the top. When someone wants hot water in the house, the hot water flows out of the hot water output and down into the house.



Questions

1. Is solar power an example of a renewable or non-renewable energy source?
2. When the cold water flows down the tubes, energy is transferred to the water from the Sun. What type of heating is this?
3. In the tubes part of the system, we want energy transfer to take place, so specific materials are used to make energy transfer as efficient as possible. There is a shiny surface underneath the tubes called a reflector. How does this help to increase the amount of energy that the water in the tubes receive?
4. Do you see that there is a tank at the top to store the hot water? In this part of the system we want to prevent energy transfer to the outside. This tank consists of an inner tank and an outer case. If there were just these two layers, made of metal, how could heat loss from the hot water to the external environment occur?

5. However, something has been done to help prevent this transfer of energy. What have they done to help keep the water warm while it is stored?
6. Let's now take a closer look at the evacuated tubes in a solar water heater. Study the following diagram. The water runs down the central heat pipe. There is an absorber plate below each pipe and this is enclosed within two layers of tube.



Can you see that there is an inner and an outer tube? Between these tubes there is a vacuum. This means that the Sun's energy can still pass through to warm the water. However, when the energy is transferred to the water, and it warms up, the vacuum prevents energy from transferring back out by conduction or convection. Why is this so?
7. Underneath the heat pipe there is a plate which helps to absorb radiant energy from the Sun and transfer it to the heat pipe. Why is it made of a dark material and not a light material?
8. Do you see that the water at the bottom is cooler, indicated by the blue colour, and the water at the top of the tube is warmer, indicated by the red colour? When the cooler water moves to the bottom and the warmer water moves to the top, what is this called?
9. This movement of water helps to move the hot water out of the tubes and into the tank so that cold water can replace it.
10. Do you think the solar water heater is an energy efficient system? Why?

Now that we have looked at how different materials are used in different situations depending on whether we want to prevent energy transfer or allow it to take place, we are going to take a closer look at how we use those materials that prevent energy transfer.

12.2 Using insulating materials

Before we start, write down your own definition for an insulator of heat.

Which materials work well as insulators of heat? Let's first do a fun activity.

ACTIVITY Keep your coffee hot and your cold drink cold

Materials

- kettle
- two identical mugs, metal or ceramic
- tea or coffee
- alcohol thermometer
- various insulating materials
- timer or stopwatch

Instructions

1. Get into groups of three or four.
2. Design a method to keep a cup of tea warm for as long as possible. You may use any materials that you have at home or provided by your teacher.
3. Make your design.
4. Write a hypothesis for your planned design.
5. Fill your insulated cup with boiling hot tea.
6. Measure the temperature with a thermometer.
7. Keep the thermometer in the cup and time how long it takes to reach room temperature (approximately 25 °C)
8. Fill the uninsulated cup with boiling hot tea and time how long it takes to reach room temperature.
9. Repeat this activity using a cold drink in the cups.

Qusetions

1. What materials did you use to keep your tea warm?
2. Why did you choose those particular materials?
3. How did you attach the materials to the mug?
4. Draw a labelled diagram of your design to keep your tea warm.
5. How long did it take your tea to reach room temperature (25 °C)?
6. What materials did you use to keep your cold drink cold?
7. Why did you choose those particular materials?
8. How did you attach the materials to the mug?
9. Draw a labelled diagram of your design to keep your cold drink cold.
10. How long did it take your cold drink to warm up to room temperature (25 °C))?
11. Why did you also time the uninsulated cups?
12. Was your hypothesis shown to be true or false?

What have you learnt from your attempts at keeping your hot drink warm and your cold drink cool? Some materials trap heat really well and others do not. Let's now do a more formal investigation of some of the different materials to find out which is the best insulating material.

Investigation Which is the best insulating material?

Aim

Write down an aim for this investigation.

Materials and apparatus

- four beakers or tins
- four alcohol thermometers
- aluminium foil
- fabric
- newspaper
- plastic
- kettle
- timer or stopwatch

Method

1. Wrap one beaker with newspaper, one beaker with plastic, one beaker with aluminium foil, and the fourth beaker with fabric.
2. Boil water in a kettle.
3. Pour 250 ml of boiling water into each beaker.
4. Put a thermometer in each beaker.
5. Measure the starting temperature of the water and then measure the temperature of the water every 5 minutes for half an hour.
6. Write the measurements in the table in the results section.
7. Draw a graph representing the data you have collected.

Results and observations

Record your results in the following table.

Time (minutes)	Temperature of aluminium foil beaker (°C)	Temperature of newspaper (°C)	Temperature of plastic (°C)	Temperature of fabric (°C)
0				
5				
10				
15				
20				
25				
30				

Draw a line graph for each type of material. You must plot each graph on the same set of axes.

First, we need to think about which data is put on each axis.

1. What will you plot on the horizontal x-axis? This is the independent variable.
2. What will you plot on the vertical y-axis? This is the dependent variable.
3. How are you going to show a difference between the lines for each type of material on one graph?

Analysis

1. Which of your graphs has the steepest curve?
2. What does the steepness of the curve tell you about how quickly the material allows heat to leave the water?
3. Arrange the materials in order from very good insulator to poor insulators of heat.
4. Which material was the best conductor of heat? Explain your choice.
5. Which material was the best insulator of heat? Explain your choice.
6. If you had to keep a bottle of water cold for as long as possible, which of the 4 materials would you choose? Explain your choice.

Figure 12.3 Here are some different fabrics.

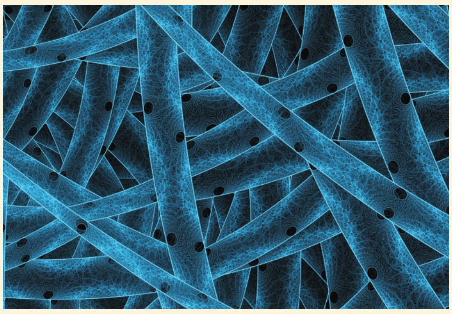


Figure 12.4 And here is a close up of the fibres making up the fabric

Fabric is not generally used to keep our hot drinks warm. In fact, most take-away cups are made from Styrofoam. Styrofoam is a good insulator of heat. It is made from polystyrene which has had air pumped through it. This makes Styrofoam extremely light and the air pockets make it a very good insulator.

Very useful applications of the use of insulating materials are the cooler box and the hot box.

Figure 12.5 A cooler box.

Look at the following photo of a cooler box. Cooler boxes are used to keep food cold. You need to put ice blocks in with the food to do so. The cooler box is made from a thick layer of plastic. How does this help to keep the contents cool inside?

A hot box works in a similar way, but can be used to keep food warm for long periods of time. There are many ways to construct a hot box.

ACTIVITY Building a hot box

Instructions

1. Depending on your teacher, he or she will either make a hot box as a demonstration in class, or else you are required to design and make your own hot box.
2. The hot box needs to keep a pot of rice and water brought to boiling point hot enough so it finishes cooking.
3. If you are designing and making the hot box yourself or in a group, you need to think about which materials will be the best insulators for the hot box.

Questions

1. Draw a labelled diagram of the hot box design that either you, your group, or your teacher made.
2. Why did you or your teacher use the specific materials to make the hot box?
3. Why did you put rice with the water boiling, instead of cold water, into the hotbox?
4. If you had something cold and you wanted to keep it cold, could you use your hotbox? Explain your answer.

Keeping our homes warm in winter is also very important, and there are different ways to do this. Let's look at how our homes are insulated.

ACTIVITY Keeping our homes warm

The following image shows how heat is lost from a house, using a colour scale to represent how much heat is lost. Red represents areas of high energy transfer, yellow is medium, and green and blue are areas of low energy transfer.

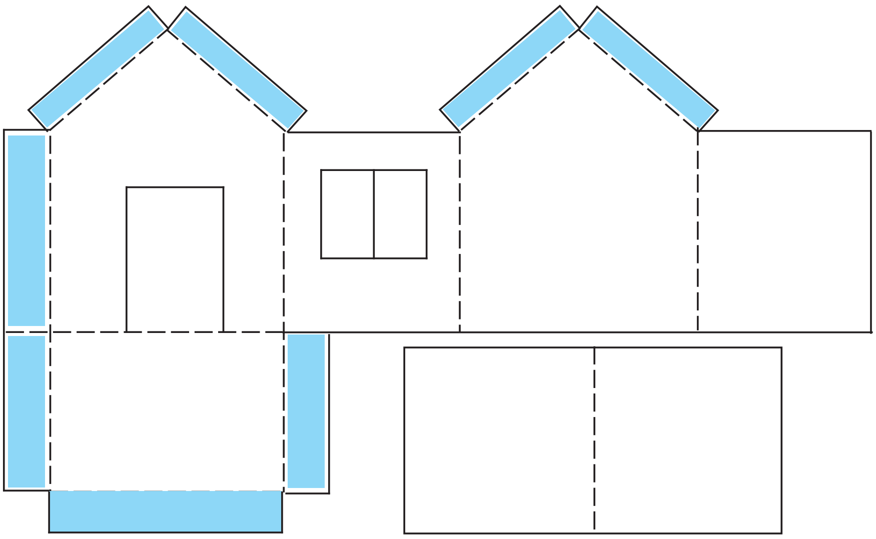
1. Which parts of the house lose the most heat?
2. How is heat lost through these places?

Convection also cools down a house. Cold air is drawn in through gaps in doors and windows and is circulated through the house. Some of the heat is lost by radiation through the walls, roof and windows. Let's now make our own model houses to see how we can prevent heat loss.

Materials

- model house template
- paper and cardboard
- glue
- sellotape
- pieces of fabric or cotton wool
- punch for making holes
- pair of scissors
- thermometer
- lamp (to simulate sunlight)
- timer or stopwatch

Instructions



1. Your teacher may provide you with a large model house template for you to cut out. If not, copy the following template onto a large piece of cardboard or design your own template for making a house.
2. Cut a small hole in the roof using the punch. This is for the thermometer.
3. Choose the number of windows you would like your house to have.
4. Cut out the windows. Use sellotape across the hole to act as glass.
5. Cut out a piece of fabric for the floor.
6. Glue the fabric to the floor of your model house.
7. Fold along the dotted lines and then glue the shaded flaps together to make the house. Place the roof on top.
8. Insert the thermometer through the roof.
9. Set up the lamp so that it is shining directly onto your model house. An alternative is to put the houses in a sunny place. This will depend on the weather.
10. Take temperature readings every 5 minutes for half an hour.
11. Switch off the lamp, or bring your model out of the Sun, and measure the temperature as the house cools down. Measure every 5 minutes for half an hour.

Time (minutes)	Temperature (°C)
0	
5	
10	
15	
20	
25	
30	
35	
40	
45	
50	
55	
60	

Draw a line graph of temperature versus time. Do not forget to include a heading for your graph.

Questions

1. Why did your model house warm up when the lamp was shining on it, or when it was placed in the Sun? Use your knowledge of radiation, conduction and convection in your explanation.
2. Why did your model house cool down when the lamp was switched off, or you brought your model back inside out of the Sun? Use your knowledge of radiation, conduction and convection in your explanation.
3. What could you have changed in your model house in order to slow down the energy transfer so that the house would not be too hot or too cold?
4. Think about your own home. What do you think you could do to improve the insulation of your home in winter?
5. Will the suggestions you made in the previous question also work for summer? Explain your answer.

In the previous unit you learnt that dark, matt surfaces are good absorbers of radiation. Light, shiny surfaces are poor absorbers and they can reflect some radiation. These properties are very important when choosing an insulating material. In extremely hot climates, such as Greece, the local people paint their houses white because the walls do not absorb as much heat during the day and therefore stay cooler inside. The position of the house in relation to the rising and setting of the Sun is also considered. For example, people will build their houses facing away from direct sunlight if they live in very hot areas.

Figure 12.6 Houses are painted white in Greece to keep them cool in the hot summers.

Let's look at how some of the indigenous houses in Southern Africa make use of insulating materials in the house structure.

Indigenous homes

The indigenous people of South Africa have many different ways of insulating their homes. Here are some pictures of different homes from different indigenous groups.

Figure 12.7 A thatched Zulu house.

Figure 12.8 An Ndebele house.

Did you notice that the houses do not have windows, or the windows are very small? Windows allow a lot of heat to escape a building and so these designs rather leave those out. The roofs are made from thatch, which is a poor conductor of heat. We know that most of the heat of a home is lost through the roof and so by using an insulating material in the roof it helps to minimise the heat loss in cold weather and heat gain in hot weather.

The roofs also extend further over the walls creating an overhang. The overhang helps to shade the walls in summer but the winter sun can still reach under the overhang. The walls are also very thick. How do you think this helps?

We have now seen how our knowledge of insulating materials can be applied in the world around us to come up with solutions for preventing heat loss. Remember, be curious to discover the possibilities.

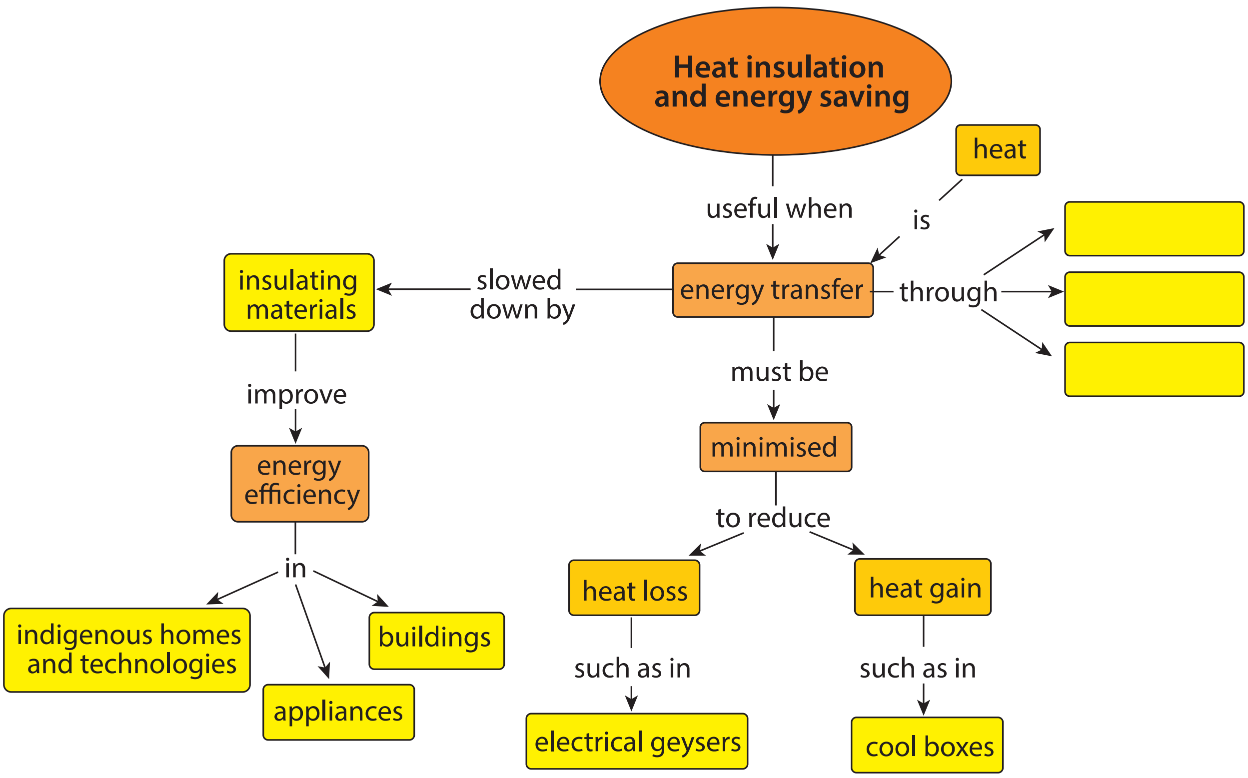
Summary

Key concept

- Heat is transferred by conduction, convection and radiation
- In some cases, heat transfer is advantageous, for example from a heater to the air in a room.
- In other systems, heat transfer needs to be minimised or prevented.
- Insulating materials are used to minimise heat loss or gain from systems.
- Metals are good conductors of heat. Non-metal materials are good insulators of heat. Non-metals are used as insulating materials.
- We use insulators to keep our homes warm in winter and cool in summer. This helps to conserve energy and electricity.
- Indigenous homes in Southern Africa make use of insulating materials to be energy efficient in our climate.

Concept map

Complete the following concept map by identifying the three ways in which energy is transferred.



Revision

1. What is an insulator? [1]

2. Are the following statements true or false? If they are false, explain why:
   a) A tea cosy keeps the cold out. [2]
   b) Space is empty and so it is impossible for energy to transfer between the Earth and the Sun. [2]
   c) On a cold day, insulating clothing reduces the energy transfer from your body to the surroundings. [2]

3. A man is building a wooden house. He lives in a very cold area, especially in winter. He has space for one window. He has two choices. He can put in a large window with a single pane of glass or he can put in a smaller window which has 2 panes of glass separated by a small air space trapped in between them. Which window do you think he should use? Why did you choose that window? [3]

4. Take-away coffee is often served in paper cups with a corrugated cardboard layer on the outside. Why are these materials used? [4]

5. You have designed a new material for insulating coffee cups. You're hoping to make money from this new material but you have to test that it works better than other materials. You arrange a blind test to convince a group of people who might invest in your new company so you can develop it.

6. The scientist who is performing the test is given 4 different materials, labelled A, B, C and D. One of the 4 materials is your new material you have developed, but she does not know which one it is. This is called a blind test. She takes 4 beakers and wraps each one in a different material. She pours hot water into each beaker. She measures the temperature of the water at the start of the experiment and again 30 minutes later. The following table shows the results of her experiment.

Time (minutes)	Material A (°C)	Material B (°C)	Material C (°C)	Material D (°C)
0	70	70	70	70
30	34	30	50	48

   a) What is the independent variable for this experiment? [1]
   b) What is the dependent variable for this experiment? [1]
   c) Draw a bar graph of the material collected. Show the starting temperature and end temperature for each material as separate bars. [8]
   d) After the experiment the results show that your material is the best insulator. Based on the results, which material (A, B, C or D) is yours? [2]
   e) How do you know? [2]

7. How does a thick woollen jersey help to prevent heat loss? [2]

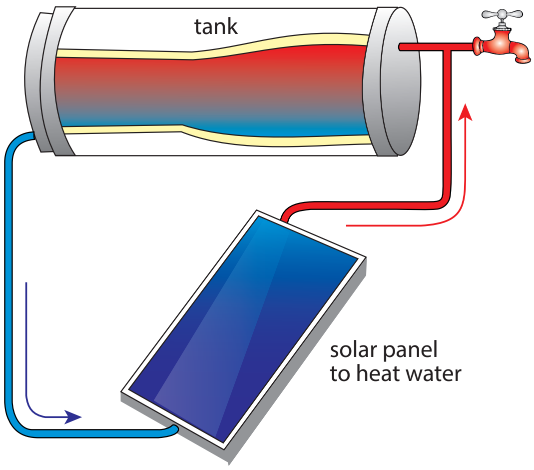
8. Look at the following photo showing the inside of a ceiling in a house being constructed. Do you see the pink material?

Figure 12.9 The ceiling in a new house being built.

a) What do you think this is for? [1]
b) How will it work? [2]
c) What type of climate do you think this house is being built in? Why? [2]

9. Marathon runners are often given thermal blankets at the end of a long race which are made from plastic and have a shiny surface. This very thin, light blanket does not look very warm at all.
a) How do you think it works? [2]
b) You might think that a wool blanket would be better for this purpose. Why do you think the race organisers preferred to use these plastic blankets? [2]

10. Study the following diagram showing the parts that make up a solar water heating system. This is a different type from the one we looked at in the beginning of the chapter. In this solar water heater, instead of evacuated tubes, there is a flat solar panel, called a collector.



a) What are the parts that make up this system? [3]
b) Why does it make sense to have the outlet pipe for the tank to go to the solar panel at the bottom of the tank? [2]
c) Why do you think the tap is at the top of the tank? [2]
d) What sort of covering do you think this tank should have to make it the most efficient system? [2]

Total [48 marks]

13 Energy transfer to surroundings

Key questions

- What sort of useful energy output do some systems produce?
- What is meant by 'wasted' energy?
- What is a Sankey diagram?
- How do we draw Sankey diagrams?

13.1 Useful and wasted energy

This term we have been looking at energy transfers within systems. Systems have an input energy and an output energy. Systems such as appliances, tools, vehicles and machines provide us with a useful output. Let's look at some examples to identify what these outputs are in some systems.

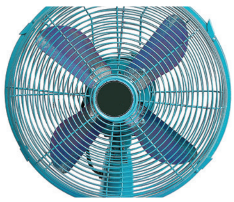
Keywords

- Sankey diagram
- input
- output

ACTIVITY Useful outputs from energy systems

Instructions

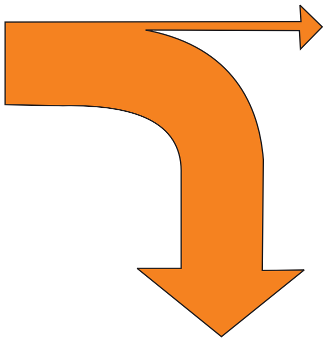
1. Look at each of the photos and identify what is useful to use from this system. Write the answers in your exercise books.

System	What useful output does it provide us with?
 A light bulb.	
 An electric fan.	
 An electric iron.	

2. What was the input for each of these systems?

Whenever we use an appliance or a machine we are transferring energy from one object to another. Not all the energy is transferred where we want it, a lot of it is transferred to the surroundings where it does not help us achieve our aims. The energy which is transferred to the surroundings is '**wasted**'.

We can use a **Sankey diagram** to show how the energy is transferred in a system. This gives us a picture of what is happening, and shows the input energy and how the output energy is made up of useful energy (arrow at the top) and wasted energy (arrow going to the bottom). Have a look at the following general example.



The width of the arrows tell us something in these diagrams. The input energy is the width of the original arrow. The width of both the output energy arrows (useful and wasted) add up to the width of the input arrow. Why do you think this is so? Think back to what you learned about energy within systems in Unit 2.

Did you know?

Sankey diagrams are named after the Irishman, Captain Matthew Sankey, who first used this type of diagram in 1898 in a publication on the energy efficiency of a steam engine.

Sankey diagrams are drawn to scale so that the width of the arrows gives us a visual idea of how much energy is useful and how much is wasted. In the diagram above, you can see that only a small part of the input energy was useful and a large amount of the input was wasted by being transferred to the surroundings. An efficient system is one where the useful output energy is only slightly smaller than the input energy. An inefficient system has a lot of wasted energy. Do you think this is an efficient energy system? Why?

This brings us to our next point of how efficient an energy system is. If the wasted energy is much larger than the useful energy output, then the system is not energy efficient. The above Sankey diagram actually shows the energy transfers for a light bulb. You identified the useful energy output as light in the last activity. What do you think the wasted energy output is? Where does it go?

Figure 13.1 A fluorescent light bulb.

Do you see that an incandescent light bulb is actually not a very efficient system? This is because a lot of the energy is lost as heat as energy is transferred to the surroundings. Is there something more efficient? Look at the photo of a fluorescent light bulb.

A fluorescent light bulb is much more efficient than incandescent light bulbs which use a heated wire to produce light. Most of the energy is lost as it is transferred to the surrounding air from the metal filament.

In a fluorescent light bulb, less energy is lost to the surroundings and more energy is transferred to useful light energy. Use this information to draw a Sankey diagram for a fluorescent light bulb.

Let's look at another example.

Look at the woman in the photo using an electric drill. The electrical energy from the drill is transferred to the drill bit as kinetic energy. The drill bit turns and drills into the metal. But the drill also makes a lot of noise. Energy is used to make sound and the drill bits get hot, so some of the energy is converted into thermal energy. This means that some of the electrical energy has been transferred to the surroundings as sound and thermal energy. This is energy that has been 'wasted' because the sound and thermal energy are not useful to us.

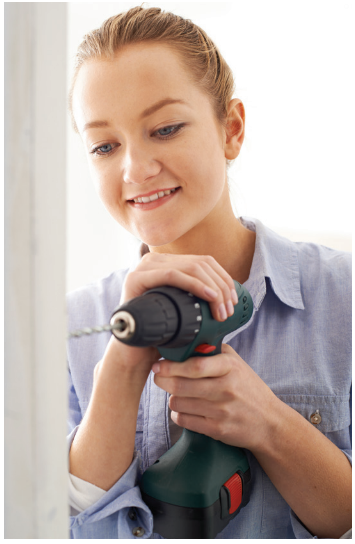
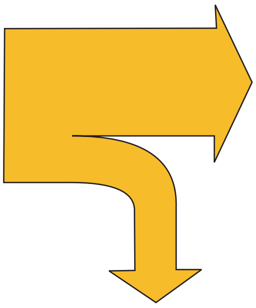


Figure 13.2 Using an electric drill to make a hole.

Complete the following Sankey diagram by writing in what the energy input is, and then the energy outputs.



In order to draw a Sankey diagram you need to think carefully about the input energy and how the input energy is transferred to the surroundings. Let's practice this a bit more in the following activity.

ACTIVITY Energy transfers in systems

Instructions

1. Look at the following photos of appliances.
2. Copy and complete the table below to show the energy transfers for each photo.

Energy INPUT	Useful Energy OUTPUT	Wasted energy OUTPUT

Figure 13.3 Filament in a light bulb.

Figure 13.4 Burning candles.

Figure 13.5 An electric beater.

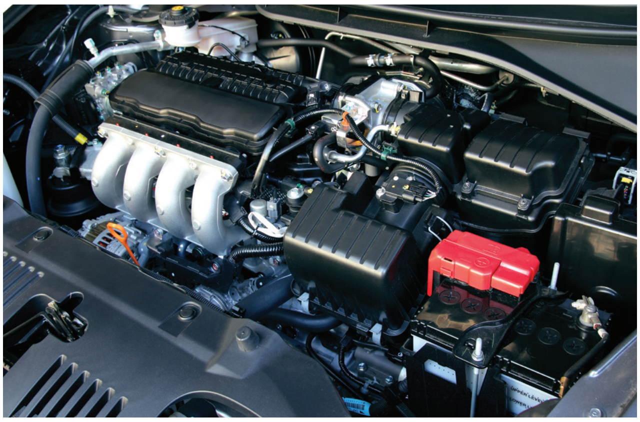


Figure 13.6 A car engine.

Figure 13.7 Welding metal together.

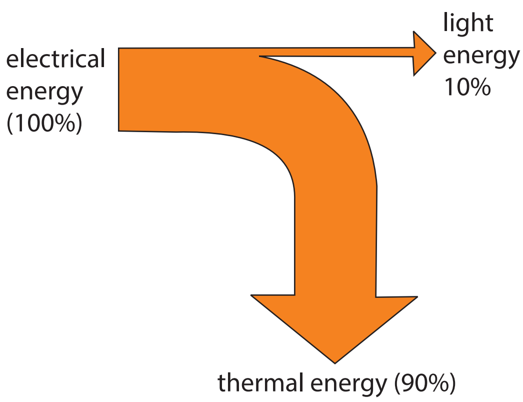
Figure 13.8 Athletes running.

Figure 13.9 A television.

Now that we have identified the energy transfers in each system and the input and output energy, let's practise drawing some more Sankey diagrams.

ACTIVITY Drawing Sankey diagrams

Let's look at the example of a filament light bulb to draw a Sankey diagram. A filament light bulb only uses about 10% of the input energy to generate light, the rest is 'wasted' because it warms up the surrounding air without producing any light. This means that our Sankey diagram must split into two parts: one for the light and one for the thermal energy which is transferred to the surroundings (heat). The thermal energy arrow must be 90% of the width of the input arrow and the light arrow must be 10% of the width of the input arrow.



Instructions

1. Now draw a Sankey diagram for some of the appliances from the previous activity, which are listed below.
2. A description of the energy transfers has been provided for each appliance.
3. Concentrate on showing how the input energy is split between useful energy and wasted energy. Remember that the width of the arrow must show how much energy is transferred. A thick arrow means a large amount of energy; a thin arrow means a small amount of energy.
4. Show the various input and output energies and the percentages.
   - **Electric beater:**
     The electric beater transfers 70% of the input energy to kinetic energy to beat the food, and 30% is wasted output energy in the form of thermal energy and sound.
   - **Car engine:**
     The car engine transfers only 30% of the input energy to move the car, and 70% is wasted as sound and thermal energy.
   - **Television:**
     The television uses 80% of the input energy to create the images on the screen and sound, and 20% is wasted as thermal energy.

Questions

1. Which is the most efficient system in the above three examples? Why?
2. Which is the least efficient system in the above three examples? Why?

Take note

In our previous Sankey diagrams, we just had one arrow for wasted energy output, but it can split into more than one arrow to represent the different ways in which energy is wasted. There could also be more than one arrow for the useful energy. For example, in the photo of the TV above, light and sound are both useful and could be represented by two arrows.

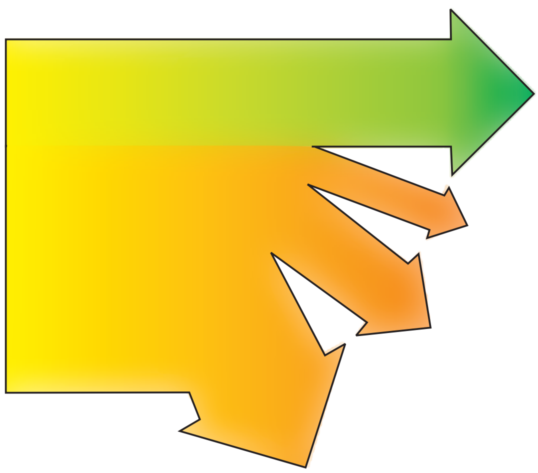
Most of our everyday activities require some form of electrical energy. Electricity is produced by burning fuels and transforming the chemical potential energy into kinetic energy to generate electricity. Fossil fuels, such as coal, store huge amounts of energy but we can only harness a small percentage of that energy. A lot of the energy is transferred to the surroundings in the form of heat, sound and light.

Take note

Remember, energy is measured in joules (J).

ACTIVITY Researching energy transfers

In the last activity we looked at the energy transfers in a car engine. However, we used only one arrow to represent the wasted energy. We can show a difference between the ways in which energy is wasted in a Sankey diagram.



Copy the Sankey diagram into your exercise book, then use the following information to label it:

- The input energy in a car engine is supplied by the combustion of petrol.
- Only 30% of the energy is transferred to useful output energy as movement.
- About 70% of the energy is transferred to the surroundings in the form of thermal energy and sound. Some of the energy is lost in cooling down the engine.
  - 40% is lost as thermal energy to the surroundings.
  - 20% is lost in cooling the engine.
  - 10% is lost as sound.

ACTIVITY Researching energy transfers

In a power station, energy is transferred through the system in order to produce electricity. During the transfer of energy through the system, some of the energy is wasted.

1. Use the internet or other resources to find the different ways in which energy is transferred to the surroundings as wasted energy during the production of electricity in a power plant.
2. Write a short paragraph to explain the energy transfers; how the input energy is transferred through the system, and where the wasted energy is lost?
3. Draw a Sankey diagram for the energy transfers.

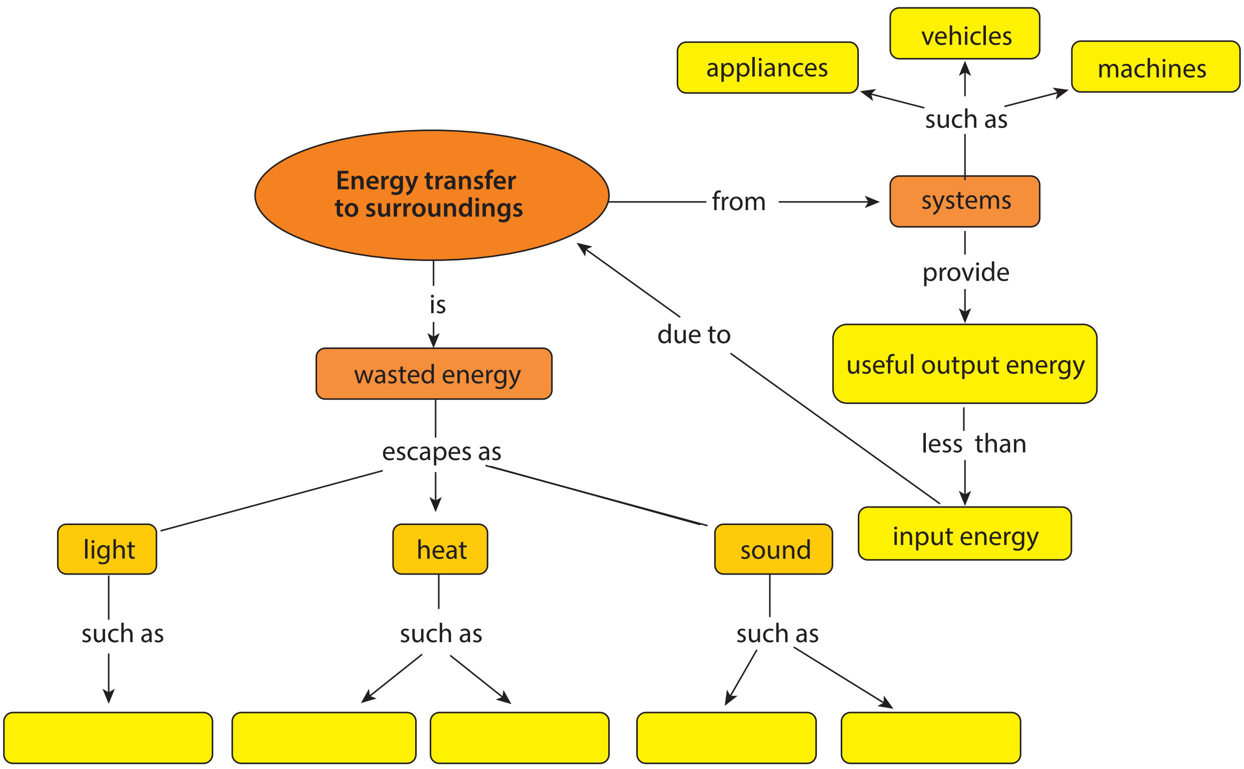
Summary

Key concepts

- Energy entering a system is called the input energy.
- The energy is transferred in a system to provide a useful output energy.
- Tools, appliances, vehicles and machines all provide useful energy outputs.
- Not all of the input energy is transferred to a useful output. Some of the energy is wasted or lost. The useful output is therefore less than the input energy as some of the output energy is wasted.
- An example is a light bulb, where the input is electricity and the useful output is light. However, a large amount of the energy is lost to the surroundings as thermal energy.
- The efficiency of a system is determined by how much of the input energy is transferred to useful output energy. The greater the wasted output energy, the less efficient the system.
- A Sankey diagram is used to show the energy transfers in a system.
- In a Sankey diagram, the arrows represent the portion of the input energy which is transferred to useful energy output and the portion which is transferred to the surroundings and wasted.

Concept map

Complete the concept map by giving two examples of systems where energy is transferred to the surroundings and 'wasted' as sound and thermal energy, and one example of where the wasted energy output is light.

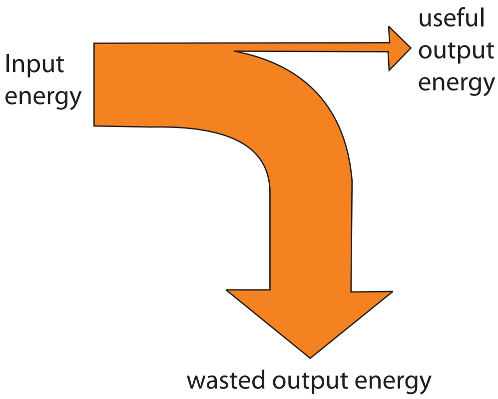


Revision

1. What is meant by 'wasted' energy? [2]

2. Draw a simple Sankey diagram to show the energy transfers in a system where the wasted energy output is more than the useful energy output. [4]

3. For each of the following situations, draw a labelled Sankey diagram to show the amount of input energy, useful energy and wasted energy.



a) An electrical torch converts 100 joules (J) of electrical energy to 10 J of light energy and 90 J of thermal energy. [3]

Figure 13.10 An electric torch.

b) A television has an energy output of 500 J. 400 J is in the form of light. 50 J is in the form of sound and 50 J is thermal energy. [3]

Figure 13.11 A television set.

c) A hair dryer converts 300 J of energy into 150 J of kinetic energy, 100 J of thermal energy and 50 J of sound energy. [3]

Figure 13.12 A hair dryer.

4. Write a description of the energy transfers in each of the situations in question 2. [6]

5. What is the difference between a filament light bulb and an energy-saving light bulb? [2]

6. Why is an energy-saving light bulb better at saving energy than a filament light bulb? [3]

7. In the last unit we looked at insulating materials and how they help reduce energy transfer. Use this knowledge, and what you have learned in this unit about input energy, useful output energy and wasted energy, to explain why an electric geyser should have an insulating layer on the outside. [4]

8. In the electric geyser, the heating element is placed near the bottom of the geyser. Why is this? [2]

Total [32 marks]

14 The national electricity supply system

Key questions

- How does Eskom produce electricity?
- What energy is transferred during electricity generation?
- How does the electricity reach our homes?
- Can we use as much electricity as we like?
- How can we save electricity?

Keywords

- national electricity grid
- Eskom
- turbine
- generator
- dynamo
- solenoid
- geyser
- transformer
- pylon
- consumption

14.1 Energy transfers in the national grid

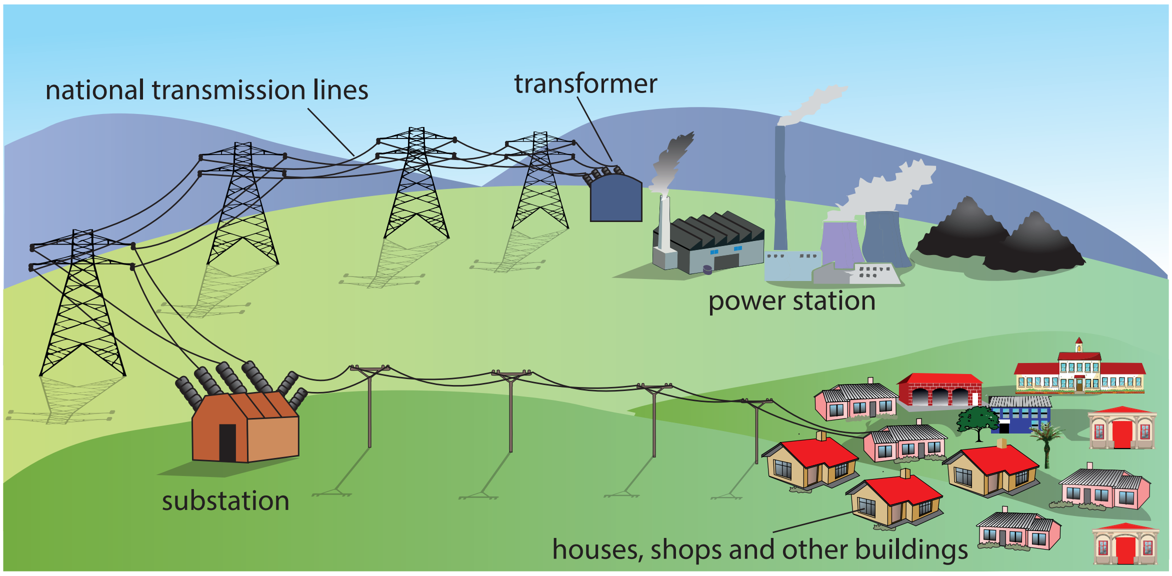
Do you remember learning about the mains electricity supply in Grade 6 Energy and Change? We learnt that the electricity that is used to power our homes, schools, shops and other buildings is generated in power stations and delivered to us in the **national electricity grid**. In this unit we are going to be looking in more detail at how electricity is generated and delivered to the consumers.

The national grid is a system

Let's look at the different parts of the national electricity grid.

ACTIVITY Overview of the national electricity grid

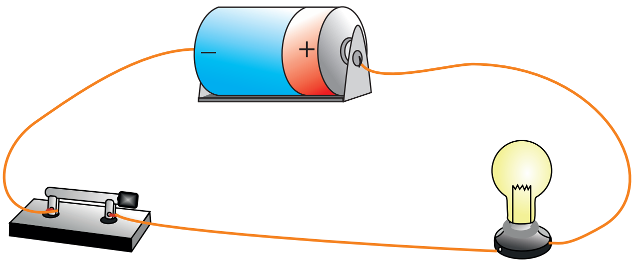
The following is a diagram of the national electricity grid. This gives you an overview of the process and different steps that we will be discussing.



Questions

1. Write your own definition of a system.
2. What does the Law of Conservation of Energy tell us about the energy in a system?

3. Look at the diagram of the national electricity grid. Do you think it is a system? Why?
4. The national electricity grid is actually a big electrical circuit. Look at the following diagram of a simple electric circuit that you might have made in class and the diagram of the national grid. We can draw similarities between this circuit and the national electricity grid to understand it.



The battery is the source of potential energy in the simple circuit. What generates electricity in the national electricity grid?
5. In the simple circuit, the conducting wires transmit the electricity in the circuit. What does this job in the national electricity grid?
6. In the simple circuit, the useful output energy is to make the light bulb light up. What are some of the useful outputs in the buildings where the electricity is delivered to in the national electricity grid.
7. In Unit 9 of this term, we discussed sources of energy. What is the source of energy for the power station in the diagram?
8. Is this a renewable or non-renewable energy source? Why?
9. We can divide the national electricity grid up into 4 main stages. These are:
   A: Generation (this is where electricity is generated)
   B: Transmission (the electricity enters the power lines of the national grids and is transmitted)
   C: Distribution (the electricity is distributed at substations to various towns and areas)
   D: Consumers (this is where the electricity is transferred to useful energy outputs)
   Use this information to write the letters A, B, C and D on the diagram of the national electricity grid in order to label these stages.

Take note

In the simple circuit, the circuit is completed as the wire goes from the bulb back to the battery. We cannot see this in the national electricity grid, but there are also power lines which connect back to the station to complete the circuit.

Let's now take a closer look at the first stage in the national electricity grid, namely how electricity is generated.

How electricity is generated and supplied

Do you remember that in Unit 10 we looked at another renewable way that electricity is generated using a hydropower plant? The water in the dam was used to turn the turbine to generate electricity. What energy did the water have when it was at the top in the dam?

What was this energy transferred to as the water fell and turned the turbine?

In South Africa most of the power stations use coal for fuel. We are therefore going to learn more about how coal-powered power stations work. The coal is mined out of the earth. It is then transported to the power station in large trucks or trains.

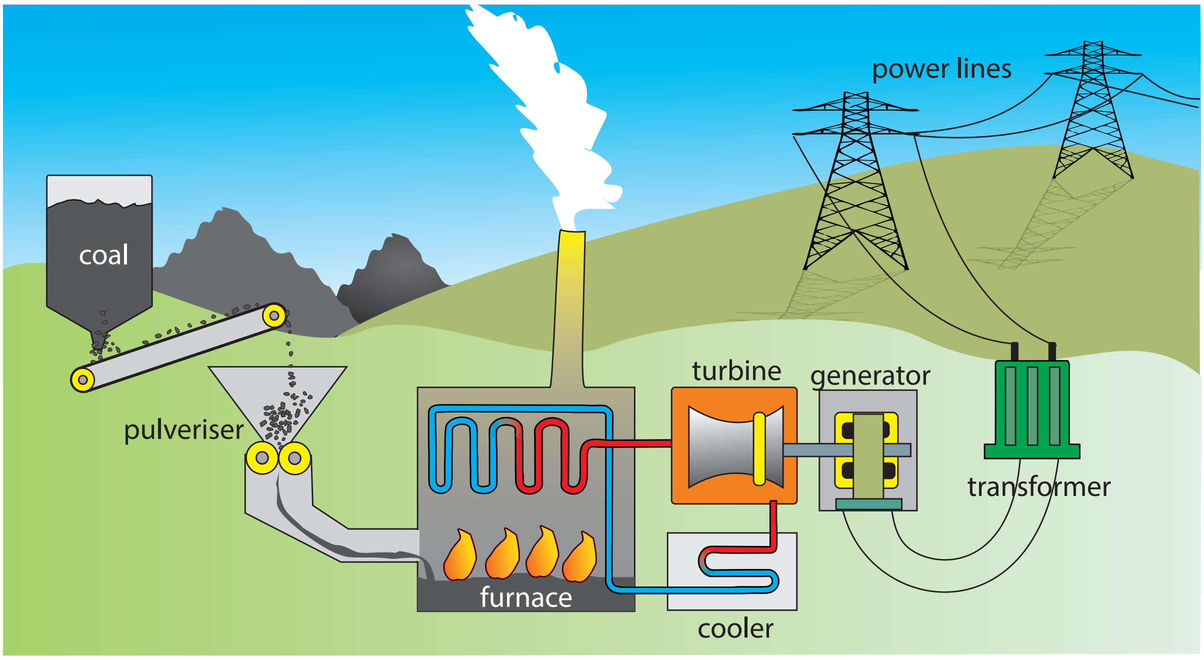
Did you know?

The cooling tower on the left in the photo is covered in the largest mural painting in South Africa.

Figure 14.1 This is the Orlando Power Station in Soweto which served Johannesburg for 50 years from 1951. It is not used any more. The painted cooling towers are seen most prominently.

Figure 14.2 A coal-powered power station.

Let's take a closer look at what happens inside a power station. Have a look at the following diagram.



Take note

We will learn about how coal is formed next term in *Planet Earth and Beyond.*

1. The large chunks of coal are first crushed into a fine powder. This is called pulverisation.
2. The coal is then transported to a **furnace**, where it is burnt.
3. The thermal energy from the burning coal is used to boil water and **generate steam**.
4. The steam pushes the blades of the **turbine** and so the turbine spins.
5. The turbine is connected to the shaft of the **generator** which then turns large magnets within wire coils, ad generates electricity.
6. The **electric current** is sent through the **power lines** to businesses and homes.

Now that we know the basic process for producing electricity, let's look more closely at how energy is transferred from one part to another in the system.

Energy transfers in the national grid

In a coal-powered power station, the potential energy stored in the coal is used to boil water to produce steam.

The thermal energy in the steam is transferred to a turbine. This allows the turbine to turn, which means that the turbine now has kinetic energy. Can you see how energy is transferred from a thermal system to a mechanical system?

Figure 14.3 A steam turbine with the outer case removed.

How does the steam make the turbine turn? Let's make a simple turbine (pinwheel) and see how it works.

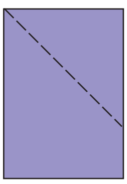
ACTIVITY Turning a pinwheel

Materials

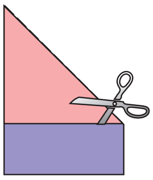
- sheet of A5 paper
- stiff cardboard
- pair of scissors
- straw
- pin
- kettle

Instructions

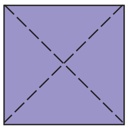
1. Start with a piece of paper. Fold the rectangular A5 page into a square.



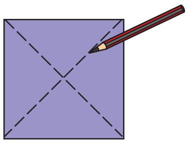
2. Use the scissors to cut off any excess paper.



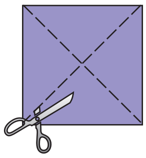
3. Fold the square corner to corner and then unfold so that you have diagonal crease marks.



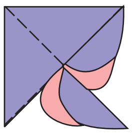
4. Make a pencil mark about a third of the way from the centre along each diagonal line.



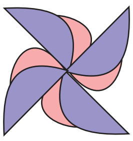
5. Use the scissors to cut along the fold lines and stop at the pencil mark.



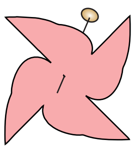
6. Bring each point to the centre of the square and stick a pin through all four points.



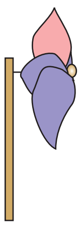
7. The head of the pin forms the centre of the pinwheel.



8. Turn the pin wheel over and make sure your pin goes through the exact centre.



9. Stick the pin into a thin stick or straw. Make sure that the pinwheel is free to turn. You can also place a small bead in between the pinwheel and the stick to make sure it spins easily.



Take note

We have mostly looked at coal-powered power stations, but other energy sources, such as hydropower or nuclear power, can also be used to transfer energy to the turbine.

10. Boil a kettle. The kettle must be full and boiling rapidly.
11. Hold the pinwheel over the spout of the boiling kettle and watch it.

Questions

1. What happened to the pinwheel when it was held in the steam from the boiling kettle?
2. Why did the pinwheel turn? Explain the energy transfers which are taking place.

The turning turbine is attached to the axle of a generator. The turning turbine turns the generator. So the turbine transfers its kinetic energy to the generator.

A generator consists of a very large solenoid with a large rotating magnet. The solenoid is made up of thousands of coils of conducting wire. When the magnet is turned inside the coil, the generator produces electricity. The electricity is then sent to our homes through the national grid power lines. We use the energy in our homes to make our appliances work.

Take note

We will learn more about electromagnets next year in Grade 8.

Figure 14.5 The national power lines transmit electricity across the country from the power stations.

ACTIVITY Energy transfers

Instructions

1. Use the information given in this unit about how electricity is produced to draw a flow diagram of the energy transfers which take place in the production of electricity in a coal power station.
2. Start with the burning of coal and end with the transmission of electricity in the power lines.

Take note

A dynamo is a type of generator, but a generator is not necessarily a dynamo.

Dynamos

Eskom produces electricity by using large generators, but we can produce electricity on a smaller scale using a dynamo. A dynamo is a type of generator and they are considered to be the device that came before and led to the development of the modern-day electrical generators that are used now all over the world. However, dynamos are still used in some places where a low current is needed.

A bicycle light is powered by a small dynamo. A bicycle dynamo has a small magnet which is turned inside a metal coil. The magnet is turned by the motion of the bicycle wheel.

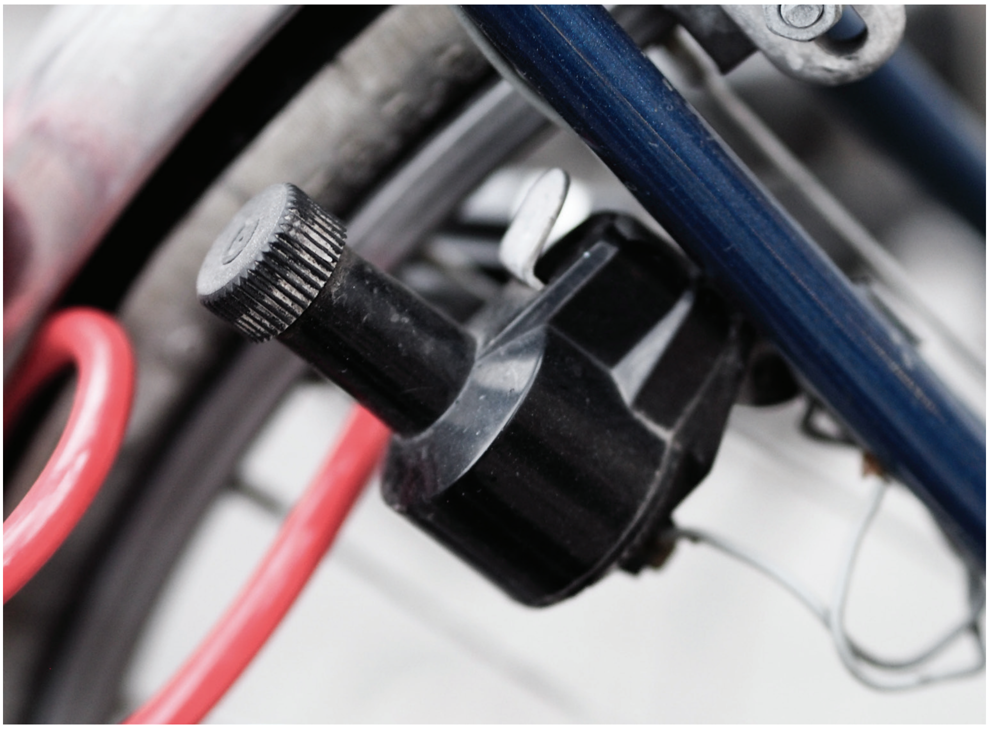


Figure 14.6 A dynamo on the wheel of a bicycle.

Do you see the cog which turns at the top as the wheel goes around? This turns the magnet enclosed in the dynamo. Explain the transfer of energy in this system.

What is the advantage of having a dynamo on the bicycle, rather than a battery, for example?

Dynamos are also used in mining helmets and wind-up torches and radios. If a miner's light on his helmet goes out, he can just wind up the dynamo again to generate electricity for the light. This is very useful when miners are deep underground and they cannot afford to have no light. A battery-powered light has the risk of running out and there is no way to recharge it when underground.

Electricity is very expensive to produce and, in South Africa, we rely heavily on non-renewable sources of energy such as coal. The burning of fossil fuels releases greenhouse gases into the atmosphere, causing damage to our environment. We therefore need to conserve electricity.

14.2 Conserving electricity in the home

Keyword

- conserve

In South Africa, electricity is produced by Eskom and sent to our homes through the wires of the national grid. Eskom charges us for the electricity we use. In order to save money and to preserve our environment, we need to make sure that we use as little electricity as possible.

There are many ways to cut down on the amount of electricity we use in our homes, simple things such as switching off lights when you leave a room, or using extra blankets to keep warm rather than a heater. Air-conditioners also use a lot of electricity, so using them only when really necessary will also help to save electricity.

Figure 14.7 An electric oven.

There are several common household appliances which use a lot of electricity. The elements of an electric stove and ovens use a lot of electricity in order to stay hot enough to cook food. Electricity can be saved by making sure that the oven is switched off as soon as the food has been cooked.

An electric stove usually has several different sizes of heating elements. In the photo there are two large plates and two smaller ones. It is important to use small pots on small elements and large pots on larger elements. Why do you think this is?

ACTIVITY Geyser blankets and solar geysers

Any appliance that produces heat requires a lot of electricity. A geyser is an appliance which uses a lot of electricity. A geyser is a cylindrical tank which is used to warm and store hot water for people to use in their homes. It takes a lot of energy to warm the water and a great deal of electricity is needed. A lot of the energy transferred to the water is wasted because the air around the geyser gets warmed up as energy leaves the water and is transferred to the air. The geyser has to keep warming the water to keep the temperature constant.

One way to help reduce the energy transferred to the surrounding air is to use a geyser blanket. Geyser blankets are usually between 50 mm and 150 mm thick and are often made from fibreglass and other insulating materials. They are covered with a reflective aluminium layer.

Solar geysers do not use electricity from the national grid for their energy needs. We have already learnt about how they work.

Questions

1. Use your knowledge of insulating materials to explain how a geyser blanket could help reduce energy loss from the water to the surroundings, and therefore conserve electricity.
2. How does installing a solar geyser contribute to relieving demand placed on the national grid?

Let's look at some more ways to conserve electricity.

ACTIVITY Conserving electricity

Instructions

In your exercise books, copy and look at the grid below. If the instruction helps to SAVE electricity, colour it in BLUE. If the statement WASTES electricity, colour it in RED.

Turning off appliances when on holiday	Leaving lights on in an empty room	Using an electric blanket	Using fluorescent light	Using filament lights
Wearing jerseys and warm clothes in winter	Leaving outside lights on during the day	Using an electric toothbrush	Running full loads in the washing machine	Switching off the geyser during the day
Boiling a full kettle	Using a gas heater	Hanging clothes outside to dry	Turning the TV off when no one is watching	Using a geyser blanket
Running half-loads in a dishwasher	Leaving the oven on when nothing is cooking	Using an electric can opener	Running an air-conditioner with the windows open	Using a tumble dryer

Look at all of your red blocks. Rewrite each statement so that it changes from a waste of electricity to a method of saving electricity.

Questions

1. Make a list of the electrical appliances in your home. Walk through your home and make sure to count every item. What could you do, in your home, to help your family conserve electricity?
2. Our country relies heavily on fossil fuels for our energy supply. Eskom power stations use coal, which is a non-renewable energy source. How can saving electricity in our homes help to reduce our negative impact on the environment?
3. What renewable energy alternatives could your family use in your house to reduce your use of electricity supplied by coal-powered stations through the national electricity grid?

ACTIVITY Writing a letter to your local newspaper

You have just found out that there are plans to build a new coal-powered power station just outside your home town. Your local community is upset about this because of the effects of the pollution on the environment. Your community also feels that greater measures are needed to change the way we rely so heavily on non-renewable sources. We should rather be looking at alternative ways of generating electricity. You decide to do some research about the best possible solution for a power station, other than one which uses fossil fuels.

Instructions

1. You decide to write a letter to your local newspaper explaining your findings, your community's concerns, and your alternative suggestion.
2. Use your knowledge from this term's work and think about the best possible solution for your area. For example, perhaps there is a dam nearby which could be used for a hydroelectric power plant? Perhaps there is a windpower farm close by which could be expanded?
3. You need to think critically and present a constructive solution to the problem.
4. Write your letter in your exercise books.
5. Reference any sources you use.

Careers in electricity

There are many different careers in the field of electricity generation. Engineers, both mechanical and electrical, are needed to help design and run the processes of electricity generation. Technicians and artisans are needed to build and maintain the power generators. Research scientists are also needed to help test and develop new technologies.

ACTIVITY Career research

Instructions

Choose an electricity-related career which you find interesting and research the career. You can do this by searching on the internet or in books. Some careers to find out about are those in the field of electricity generation, including engineers, scientists, artisans and technicians.

What does a day in the life of this career involve?

Did you know?

'Citizen science' means that the general public takes part in and conducts scientific research.

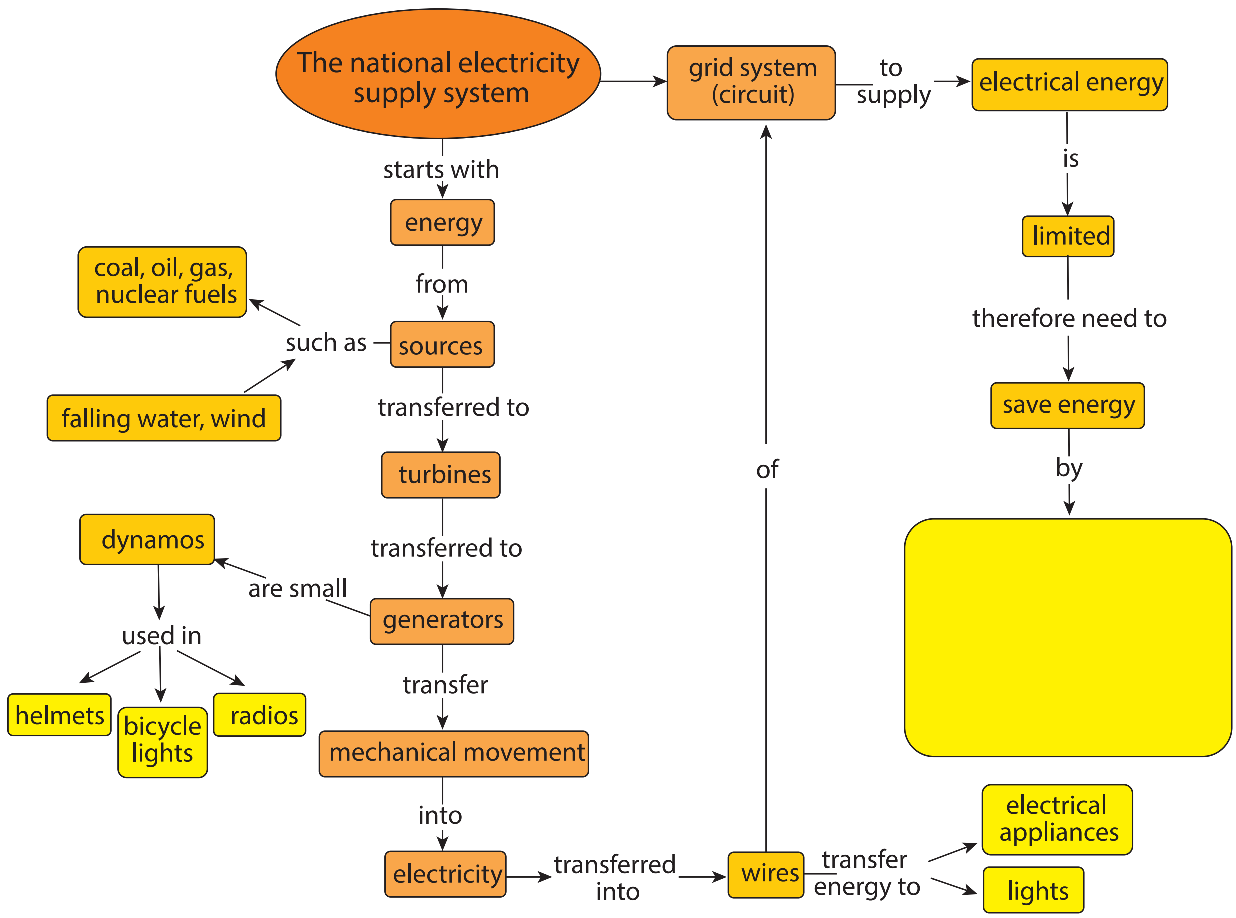
Summary

Key concepts

- The national electricity grid is a system in which the energy is conserved. It makes a complete circuit.
- In a coal power station, the coal is burned and steam is produced. The steam turns a turbine. The turbine turns a generator which produces electricity. This is transferred to the powerlines in the national grid.
- Eskom uses coal-powered stations and generates electricity using generators.
- Dynamos are a type of generator that can be used to produce small amounts of electricity, such as a for a bicycle lamp.
- Electricity is expensive and we need to conserve electricity to reduce our household costs.
- Fossil fuels are burnt to generate electricity. When fossil fuels are burnt they release greenhouse gases into the atmosphere. We need to reduce our electricity consumption in order to reduce pollution.
- There are many practical ways to conserve electricity within our homes.

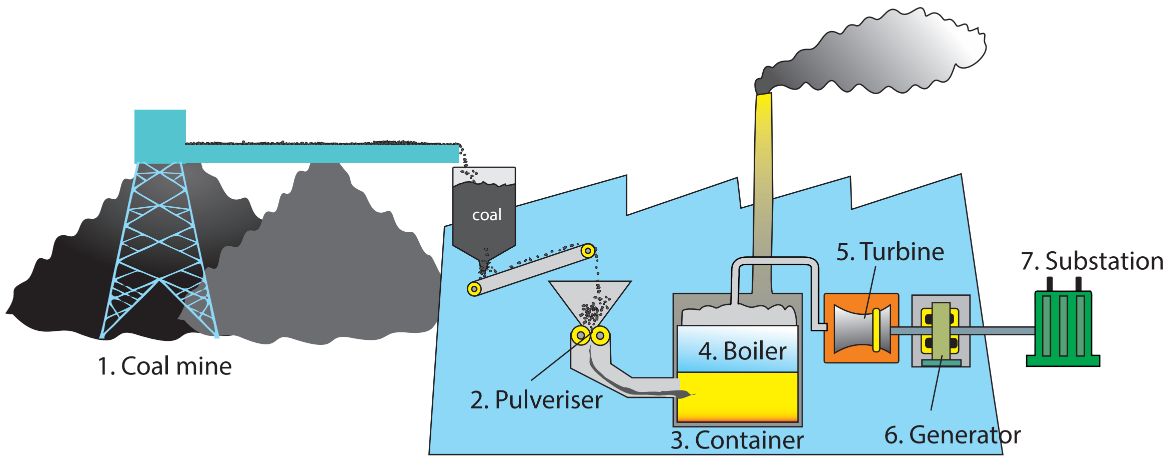
Concept map

Complete the concept map below by filling in some of the ways to save energy.

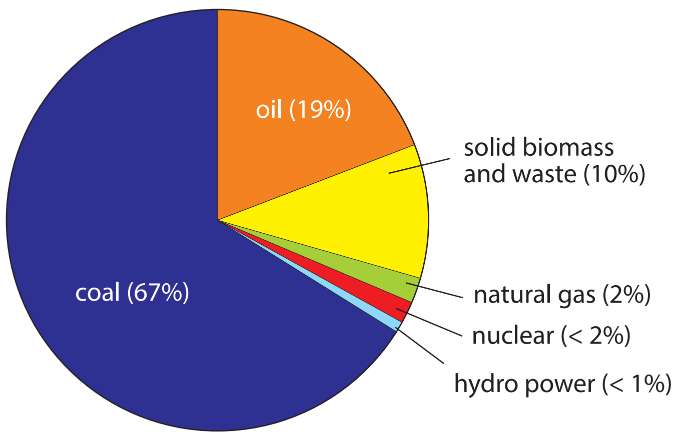


Revision

1. Why do you think we refer to the national electricity supply as a grid? [2]
2. What is the main source of energy for power stations in South Africa? [1]
3. What is Eskom? [1]
4. Look at the diagram of a power station. Write a paragraph to describe the process by which electricity is produced in a coal power station. [7]



5. We have mostly looked at coal power stations and how energy from coal is transferred to the turbine. What other energy sources can be used? [3]
6. The following graph shows the energy supply in South Africa from the various sources of energy. These percentages include the electricity production, consumption and export for each source in 2010. Answer the questions that follow.
   a) What type of graph is this? [1]
   b) What do all the percentages add up to in this type of graph? [1]
   c) What percentage of our energy supply comes from coal, as shown in 2010? [1]
   d) What percentage of our energy supply came from fossil fuels in total in 2010? [2]
   e) Does South Africa rely more on renewable or non-renewable energy supply? [1]
   f) What energy source is the smallest supply in South Africa, as in 2010? [1]
   g) What is the impact of our country's reliance on non-renewable energy sources? [3]
7. Use the chart to draw a table showing this data. [6]



8. Why does a miner need a dynamo instead of a battery for his helmet light? [2]

9. List 3 ways in which you could save electricity in your home. [3]

10. The following table shows the amount of energy used by some kitchen appliances in one hour.

Appliance	Kilojoules
Coffee machine	2 400
Electric stove	10 800
Electrical frying pan	4 500
Hot plate – large	8 600
Hot plate – small	4 600
Kettle	6 800
Microwave oven	4 400
Toaster	3 600
Snackwich	4 300
Food processor	600

a) Use the table to draw a bar graph. [5]
b) Which appliance uses the most electricity? [1]
c) How could you conserve electricity by continuing to cook your food in another system, once it has warmed up? Hint: You might have made one of these in a previous activity! [1]

Total [42 marks]

Glossary 3

absorb to take in

biofuel a fuel made from biological materials such as soya, maize or sugar cane; examples of these fuels are biodiesel and methanol

conduction the transfer of energy between objects that are in direct contact with each other

conductor a substance which allows heat, sound or electric charge to pass through it easily; a good conductor allows free passage while a poor conductor allows partial passage

conservation a quantity stays constant; something is not lost or destroyed

conserve to make something last longer by using it carefully

consistent reliable and predictable

consumption using up a resource

convection current the movement of liquid and gas particles as the substance warms up and rises and then cools and moves down again to form a current

convection transfer of energy through a liquid or gas by the movement of liquid or gas particles

dynamo a small generator that can be used for powering a bicycle light, a mine helmet or a wind up torch

fossil fuel non-renewable energy sources, namely coal, oil and natural gas

generator a machine used to convert mechanical energy into electrical energy

geyser a cylindrical tank that is used to warm and store hot water

greenhouse gases gases in the atmosphere that contribute to the greenhouse effect; these gases include carbon dioxide and methane

heat heat is the energy transferred between two objects as a result of the temperature difference between them; it also refers to when energy is transferred between a system and the environment as a result of the temperature difference between them; it is measured in joules (J).

hydrocarbon a molecule which consists of hydrogen and carbon atoms bonded together

hydropower the energy harnessed from a moving water source, such as a river or a waterfall

input something that enters a system and is altered by the system to produce an output

insulator a substance which resists the movement of heat, sound or electric charge through it

joule the standard, international unit of measurement for energy

kinetic energy energy that a body has when it is moving

law in science, a law is a statement of what happens and it is based on repeated experiments and observations

matt not glossy or shiny

methane a colourless, odourless gas which is often called natural gas

national electricity grid the network of cables, pylons and transformers which transfer electricity throughout the country

non-renewable a resource, such as coal, that cannot be replenished or there is a limited supply of it

nuclear the type of energy released when a large atomic nucleus breaks up or two smaller ones combine

output the end result of a process

potential energy energy that is stored in a system

pylon a large vertical steel tower which supports electrical power cables

radiation the transfer of energy from a source that does not require physical contact or movement of particles

reflect to throw back heat, light or sound without absorbing it

renewable something which is continuously replenished or there is an unlimited supply of it

reservoir a large container or space in which a gas or liquid can be stored

Sankey diagram a Sankey diagram is used to show the difference between input and output energy

solenoid a current carrying coil or coils of conducting wire

system a system is any set of parts working together to carry out a particular function

temperature a measure of how hot or cold a substance feels; it is measured in degrees Celsius (°C).

theory in science, a theory is an explanation of why or how something happens

thermal relating to heat

transfer to move from one object or place to another; in an energy system, we say energy is transferred from one object to another

transformer an electrical device to transfer energy between two parts of the circuit in the national electricity grid

turbine a set of curved blades on a central, rotating spire

STRAND

Planet Earth and Beyond

15 Relationship of the Sun to the Earth

Key questions

- Why do we have night and day?
- Why do we experience seasons on Earth?
- Do other planets have seasons too?
- How does the Sun influence life on Earth?

Keywords

- sphere
- axis
- rotation
- revolution
- day
- orbit

The Sun is our closest star. It is a huge ball of very hot gas in space which radiates heat and light in all directions. All the planets, including our home, the Earth, travel around the Sun in orbits. As we will see in this unit, the Sun is incredibly important: it provides us with light and warmth, and its apparent motion across our sky causes day and night and the passage of the seasons.

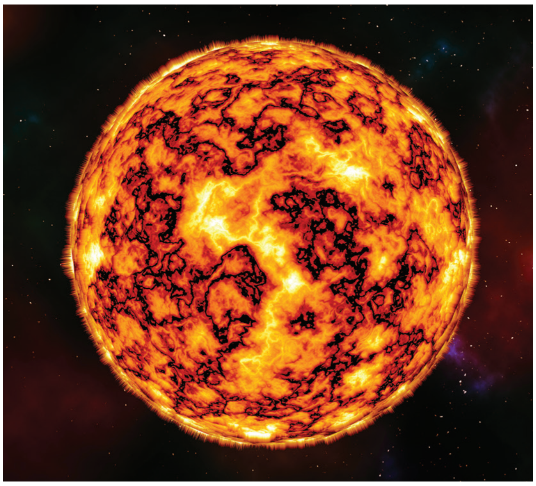


Figure 15.1 Our Sun.

Did you know?

Different planets take different amounts of time to make one complete rotation on their axis and so they have different lengths of days. Venus is the most sluggish rotator of all the planets in our solar system – it takes 243 Earth days to complete one rotation. A Venus day lasts longer than 200 days on Earth!

15.1 Solar energy and the Earth's seasons

Earth's rotation

Let's start off with seeing what you can remember learning about day and night in Grade 6.

ACTIVITY Day and night revision exercise

Instructions

Answer the questions in the table below.

Questions

1. In which direction would you have to look to see the Sun rising?
2. In which direction would you look to see the Sun setting?
3. At what time is the Sun at its highest point in the sky?
4. At midnight, where is the Sun in relation to your position on the Earth?
5. How long does it take the Earth to complete one rotation on its axis?

If you follow the path of the Sun during the day you will see that it rises in the east and sets in the west. The Sun reaches its highest point at noon (midday). Why do you think it looks as though the Sun moves across the sky during the day?

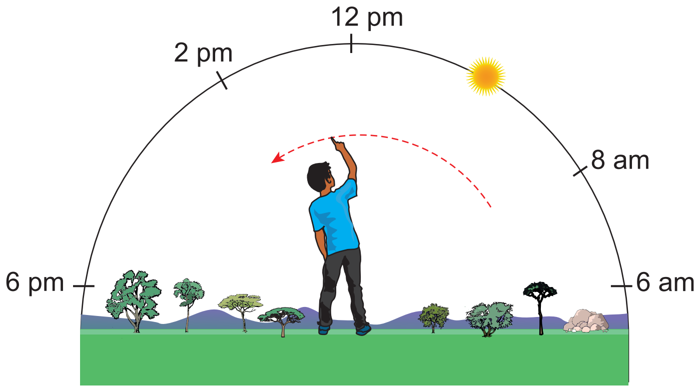


Figure 15.2 The Sun is at different positions in the sky during the day. But is it the Sun that is moving?

Let's do an activity to find out!

ACTIVITY Movement of a classroom Sun

Materials

- yellow round balloon or ball which can be hung from the ceiling
- string for hanging the ball or balloon

Instructions

1. Hang up the balloon or ball from the ceiling using the string close to one of the corners in your classroom. Make sure that the balloon/ball is high up and visible from the back of the classroom. The balloon/ball represents the Sun.
2. Stand up in your classroom and face the balloon/ball.
3. Now slowly turn on the spot in a clockwise direction keeping your head still, completing two or three turns.
4. Repeat the activity but this time turn in an anti-clockwise direction.

Questions

1. As you turned clockwise what direction did the hanging balloon/ball appear to move?
2. As you turned anti-clockwise what direction did the hanging balloon/ball appear to move?
3. Did the hanging Sun actually move?
4. Why do you think we see the Sun move across the sky?

As you can see the hanging Sun is not really moving, it just appears to move because you are turning. This is also true for the real Sun in the sky. The Sun does not really move, it just appears to move because the Earth is turning on its axis. So, it is the Earth's rotation that causes the apparent movement of the Sun across the sky during the day.

ACTIVITY Daytime and night time

Materials

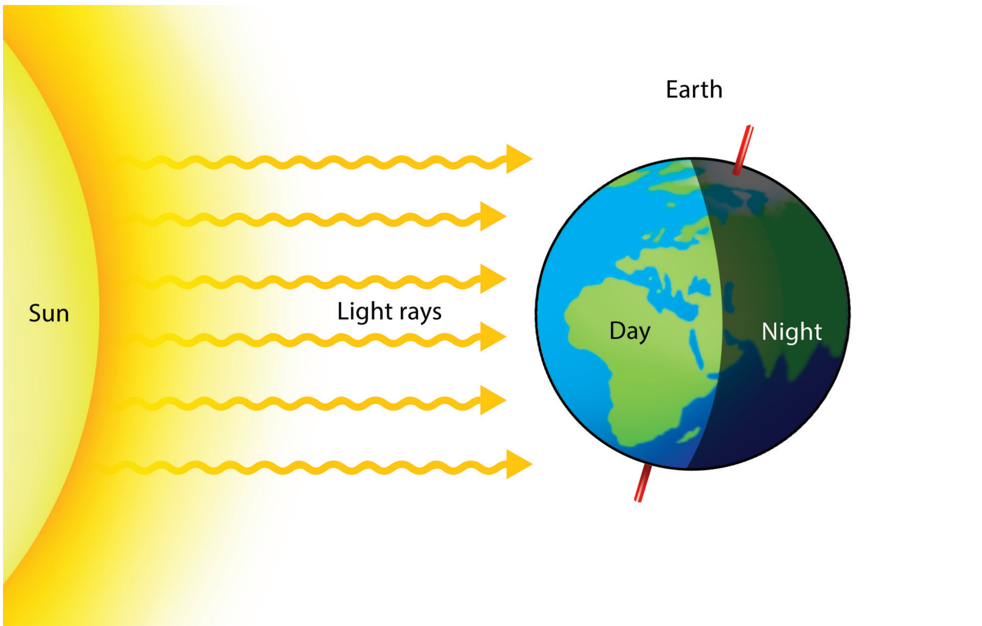
- a globe (or a ball/balloon with the shapes of the continents drawn on it) which can be hung from the ceiling
- string for hanging the globe
- non-permanent marker or sticker
- desk lamp or torch
- black bin bags or curtains to darken the room

Take note

It is incorrect to talk about the Sun 'burning'. The Sun is not 'burning' in the way a fire does. Remember, a fire burning on Earth requires oxygen and there is no oxygen in space. Rather, the gas is very hot and glows as a result.

Instructions

1. If you do not have a globe, you can make a model of the Earth yourself in class. Use any ball. Draw the Equator and mark the North and South Poles.
2. Mark with a dot/sticker your position on the globe.
3. Hang the globe from the ceiling near the middle of the class. It should be at about eye level height. The globe represents the Earth.
4. Darken the room.
5. Shine a desk lamp or torch on the globe facing Africa and keep the lamp/torch steady in this position. The torch represents the Sun.
6. Walk around the globe so that you can see all of it. Is it all lit up by the torch? How much of it is lit and how much is dark?
7. The lit area represents daytime and the dark area represents night time. Is your dot/sticker in daytime or night time?
8. Now turn the globe anti-clockwise, half a turn. Is your dot/sticker in daytime or night time?
9. Where is it now daytime?
10. Keep turning the globe anti-clockwise until your dot/sticker is back in its original position and lit again. How long would it take on the real Earth for the dot to complete one rotation like this?



So, now you can see how the Earth's rotation about its axis causes day and night. When one half of the Earth is lit up by the Sun, the other half is in darkness. It is daytime in the lit half and night-time in the dark half. As the Earth spins you move from light to shadow and back to light again over the course of one day (24 hours).

During the night you cannot see the Sun move across the sky, but if you look carefully you will notice that the stars move across the sky, just like the Sun does. It takes the Earth 24 hours to make one complete turn (called a rotation) on its axis, so an Earth day is 24 hours long.

Figure 15.3 This picture of the SALT telescope near Sutherland was taken at night with the camera shutter left open. You can see the star trails due to the Earth's rotation.

You now know that the Earth rotates on its axis completing one turn every 24 hours. But which way does it turn? Let's see if you can figure it out.

ACTIVITY Which way does the Earth rotate?

Materials

- a ball or balloon
- string for hanging the ball

Instructions

1. Hang up the balloon or ball from the ceiling using the string close to one of the corners in your classroom. Make sure that the balloon/ball is high up and visible from the back of the classroom. The ball represents the Sun.
2. Stand up in your classroom and face the balloon/ball.
3. Now slowly turn on the spot in a clockwise direction keeping your head still, completing two or three turns. Are you turning to your left or right? Note what happens to the hanging balloon or ball.
4. Now repeat the activity, but this time turn in an anti-clockwise direction. Are you turning to your left or right? Note what happens to the hanging balloon or ball.
5. What do you notice about the direction that you turn (left or right) and the direction that the hanging Sun appears to move?
6. Which direction does the Sun appear to move across the sky, east to west or west to east? Given your answer to question 5, which way do you think the Earth is really turning?
7. Look at the following picture showing the Earth from space. Using your answer to question 6, is the Earth spinning in a clockwise or anti-clockwise direction? Draw the direction on the picture below.

Did you know?

The only planet that rotates on its side like a barrel is Uranus. The only planet that spins backwards relative to the others is Venus.

Keywords

- solar energy
- intensity
- oblique
- direct
- indirect
- equator
- equinox
- hemisphere
- tilt
- season
- solstice

Figure 15.4 This colour image shows North and South America (green and brown continents) as they would appear from space.

Earth's revolution

The Earth revolves around the Sun in an almost perfect circle, completing one **revolution** (**orbit**) around the Sun per year (or $365\frac{1}{4}$ days to be precise). As the Earth revolves around the Sun it also rotates (spins) on its axis at the same time. Having two words both beginning with 'r' relating to movement can be confusing! Let's check now that you know what they mean before we continue.

In your own words explain what is meant by the Earth's **rotation**.

In your own words explain what is meant by the Earth **revolving**.

Different planets take different amounts of time to make one complete revolution around the Sun and so their years have different lengths. The planets further from the Sun will have bigger orbits, as shown in the diagram, and therefore take longer to revolve around the Sun.

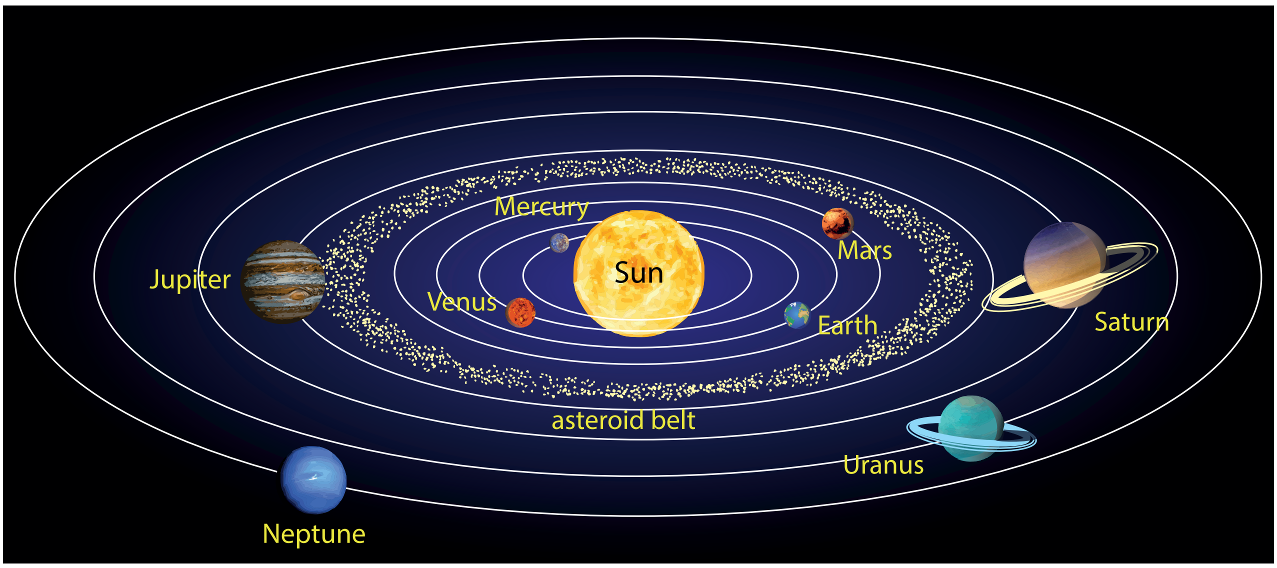


Figure 15.5 Our solar system.

Why do we have seasons?

As the Earth travels around the Sun it receives **solar energy** in the form of light and heat, emitted from the Sun. Do you remember that in *Energy and Change* last term, we spoke about how heat is transferred from the Sun, to Earth through space? What is this called?

We are very lucky to have our Sun! If the Earth did not receive any energy from the Sun the Earth would be cold and lifeless. Have you noticed that the average temperature is not the same all year round? We experience the **seasons**: winter, spring, summer and autumn. It is generally much warmer in summer and cooler in winter. Why do you think that is?

Let's first make sure that we know some of the terminology about Earth before continuing.

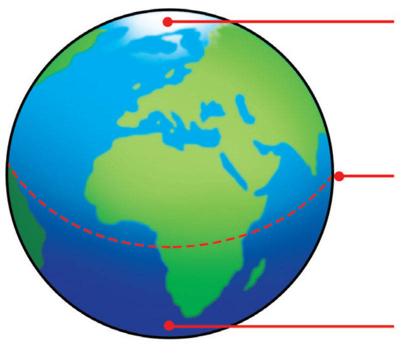
Did you know?

Mercury has a year of just 88 Earth days, and Neptune has a year of 164 Earth years.

ACTIVITY Label the Earth

Instructions

Using the word bank, label the diagram of the Earth below.



Word bank

- Northern Hemisphere
- Southern Hemisphere
- Equator
- North Pole
- South Pole

Take note

The amount of solar energy the Earth receives is called 'insolation' which comes from the words: 'incoming solar radiation'.

You may already have some thoughts about why we get different seasons throughout the year.

ACTIVITY What causes the seasons? Guesses!

Instructions

Which of the statements in the table do you think are true and which do you think are false? Copy the table and write your answers in the right-hand column.

Statement	True or False
We experience winter because the Sun emits less energy in winter.	
We experience summer because we are closer to the Sun during summer.	

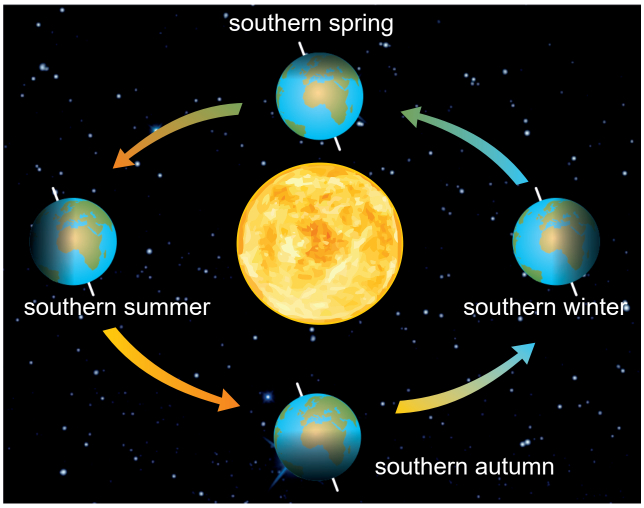
Statement	True or False
If it is winter in the Northern Hemisphere it is winter in the Southern Hemisphere too.	
Daytime is longer in the summer because the Earth spins more slowly in the summer months.	

ALL the statements in the 'What causes the seasons?' activity are false! The amount of energy emitted by the Sun is the same all year round. Also the Earth spins on its axis at the same rate all year. When it is summer in Cape Town it is winter in Paris, and when it is spring in London it is autumn in South Africa. The seasons are reversed in the Northern and Southern **Hemispheres**. If it can both be winter and summer on different parts of the Earth at the same time, the seasons cannot be caused by our distance from the Sun. If that were the case, then the whole of the Earth would experience summer and winter at the same time.

Figure 15.6 Springtime in the Northern Cape, when the flowers are out in bloom.

Figure 15.7 Winter time in the Northern Cape. In Sutherland, temperatures can go below 0°C and it often snows.

Let us now find out what causes the seasons. The seasons don't just divide up the year into quarters; they tell us where the Earth is in its path around the Sun. Have a look at the following diagram which shows how the Earth revolves (orbits) around the Sun and the different seasons experienced by the Southern Hemisphere.



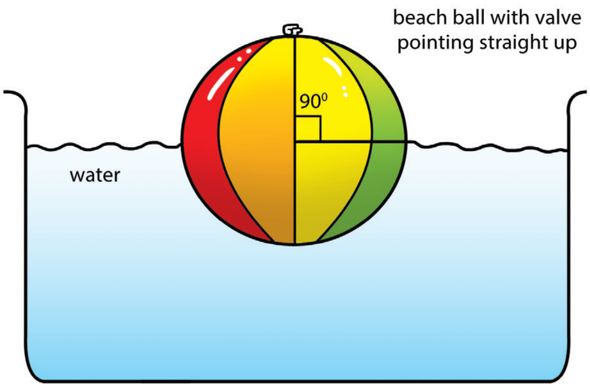
Look at the picture showing the position of the Earth as it orbits the Sun during a year. The Earth travels around the Sun in an almost perfect circle. If you look closely, you can see that the Earth's axis is not pointing straight up, but is slanted, or tilted in the picture. This is because the Earth is actually tipped over slightly relative to the plane of its orbit. The Earth's axis always tilts in the same direction in space: the North Pole points towards the star Polaris.

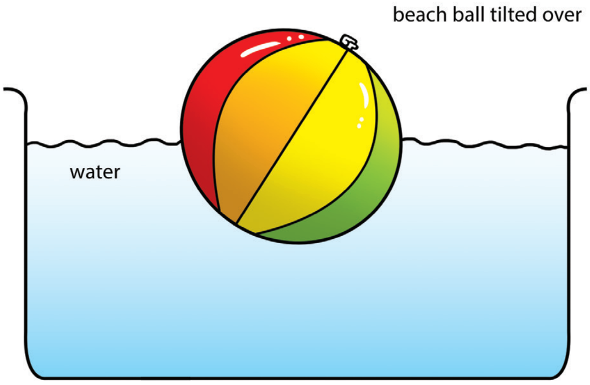
Figure 15.8 The relative positions of the Earth and Sun during the course of a year. It takes one complete year for the Earth to revolve (orbit) around the Sun. It takes six months for the Earth to travel halfway around the Sun.

What do we mean when we say that the Earth's axis is 'tilted relative to the plane of its orbit'? A **plane** is a flat surface, for example a flat piece of card or the surface of still water. The plane of the Earth's orbit is an imaginary flat surface that contains the Earth as it revolves around the Sun.

Imagine that the Earth is a beach ball floating on the surface of water in a swimming pool with half the ball submerged so that you can only see the top half of the ball poking out of the water. Now imagine that the ball is moving around in a circle on the surface of the water but it is not moving up or down. This is what we mean when we say that the Earth travels in a circle in a plane. In this example the Earth's orbital plane is the surface of the water. In space there is no surface of water. The plane is just an imaginary flat surface!

Now imagine that the valve where you blow up the beach ball is pointing straight up towards the sky. This valve represents the Earth's North Pole. In this case the valve and the plane are **perpendicular** to each other and the angle between them is 90°.





However, if you push the ball over slightly so that the valve no longer points straight up, then the valve (representing the Earth's North Pole) and the water surface will not be perpendicular to each other.

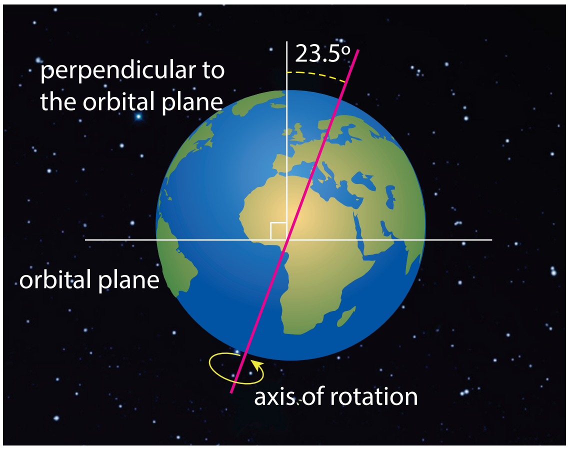


Figure 15.9 The Earth's rotation axis is tilted by 23. 5° from the vertical as it orbits the Sun.

The Earth's rotation axis is tilted over by an angle of 23,5 degrees (23,5°) from the vertical. As the Earth travels around the Sun its North and South Poles constantly point in the same direction in space.

Let's model the Earth's tilt.

Take note

The relative position of the Earth around the Sun is not drawn to scale. If it was drawn to scale, the Earth would not fit on this page!

Take note

The Earth's orbit is actually very slightly elongated but very close to a circle, called an ellipse.

Did you know?

By pure luck, in the Northern Hemisphere the North Pole points to the star Polaris, which allows astronomers to find north easily! Unfortunately, there is no 'south star' in the Southern Hemisphere.

ACTIVITY The Earth's tilt

Materials

- globe or ball/balloon
- non-permanent marker or stickers
- card and tinfoil to make a star
- string
- scissors
- glue

Instructions

1. Mark on the globe the position of the North and South Pole with a marker or stickers. If using a ball or balloon mark the positions of two points directly opposite each other on the surface of the ball/balloon which will be used to represent the North and South Poles of the ball/balloon.
2. Using the scissors, cut the card into the shape of a star.
3. Cover the star in foil, using the glue if necessary to stick it to the card.
4. Hang the star up from the ceiling using the string. Make sure it is high up and clearly visible from the whole of the class.
5. Sit in a circle with the rest of your class, your class teacher should sit or stand in the middle of the circle representing the Sun.
6. Select one member of your class in the circle to start the activity and pass the globe to them.
7. Tilt the globe away from the vertical, pointing the North Pole towards the hanging star.
8. Pass the globe around the circle keeping the North Pole pointed in the same direction towards the hanging star. Remember to keep the globe spinning on its axis as it is passed around!
9. Note how as the globe moves around the circle, sometimes the Northern Hemisphere is tilted more towards the Sun, sometimes the Southern Hemisphere is pointed more towards the Sun and sometimes neither hemispheres are tilted towards the Sun.

Questions

1. For roughly what fraction of the orbit did the Southern Hemisphere point towards the Sun?
2. For roughly what fraction of the orbit did the Northern Hemisphere point towards the Sun?
3. What length of time do these fractions correspond to for the real Earth's orbit around the Sun?

Let's see now what effect this tilt has on the Earth.

ACTIVITY Direct and indirect light

Materials

- A4-sized or larger piece of black card, one per pair
- torch, one per pair
- bin bags to darken the room if necessary
- pencil or pen, one per pair

Instructions

1. You will need to work in a pair for this activity.
2. Place the card flat on a desktop or table.
3. Darken the room using curtains or bin bags.
4. One person should hold the torch about 25 cm above the card, pointing straight down onto the card. Shine the light onto the card.
5. Look at the beam shining on the black card and note its size. The person in the pair not holding the torch should draw around the edge of the beam with a pen or pencil.
6. Swap places and point the torch towards the card at an angle of 45°, keeping it at the same distance from the card as before. Shine the light onto the card.
7. Look at the beam shining on to the card, draw around the edge of the beam with a pen or pencil.

Questions

1. In which case is the light more concentrated? (direct or indirect)
2. In which case is the light more spread out? (direct or indirect)
3. If the light is more concentrated, does this mean that the energy from the torch is more concentrated or spread out?
4. In which case did the light look brighter? Why is this?

The energy is spread out over a larger surface area when the light is shone at a slanting (oblique) angle relative to the card than when it is shone directly onto the card. Similarly, when light from the Sun hits the Earth directly, the solar energy is spread over a smaller surface area and is more intense (concentrated) than when light hits the Earth indirectly. Do you think this has an effect on the temperature? Let's investigate.

Investigation Direct and indirect light and its effects on temperature

Scientists often use models to recreate the real world in a laboratory. In this investigation, you will use a model to simulate how sunlight strikes the surface of the Earth. You will use a torch to represent the Sun. You will change the angle at which light strikes a flat surface and see what effect this has on the heating of the surface. This will model how sunlight strikes the surface of the Earth at different angles.

Investigative question

Does direct light heat an area more quickly or more slowly than indirect light?

Hypothesis

What do you think will happen?

Identify variables

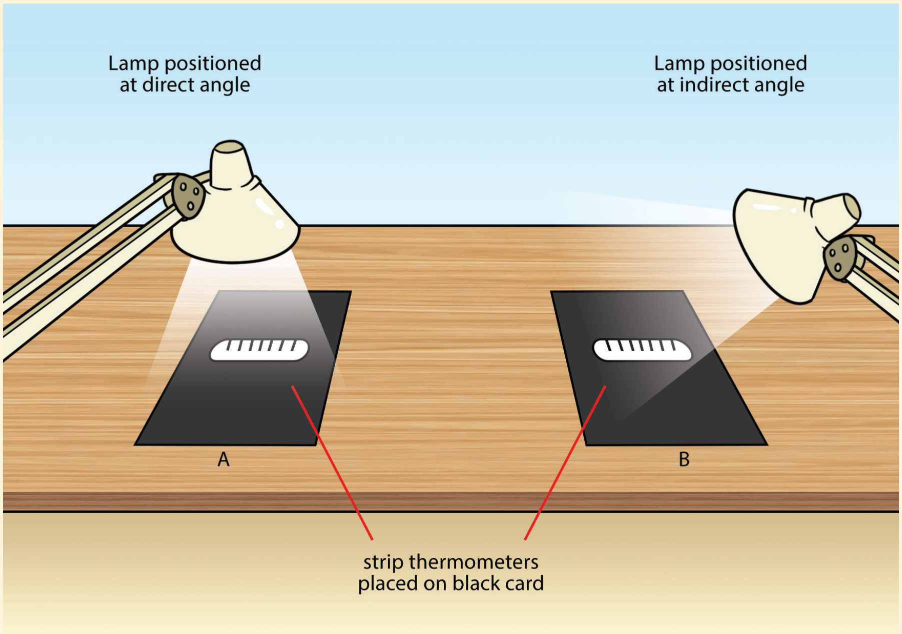
1. What are you keeping constant in this experiment?
2. What are you changing in this experiment?
3. What are you going to be measuring in this investigation?

Materials and apparatus

- two desk lamps
- two pieces of black card/paper
- two strip thermometers
- watch or clock
- marker pen and/or sticker to label the cards

Method

1. Place the two desk lamps on a table or desk about 1 metre apart from each other.



2. Point one of the desk lamps directly downwards towards the table, at a height of about 30 cm.
3. Place the black card under the light and label it 'A'.
4. Place the thermometer strip in the centre of the black card. The light bulb should be directly above the thermometer strip.
5. Adjust the second desk lamp so that it is at the same height as the first one, but instead of pointing it directly down at the table, tilt it slightly to one side (left-right direction).
6. Place the second piece of black card under this lamp and label it 'B'.

7. Place the second thermometer strip in the centre of the black paper. This light should shine indirectly over the thermometer.
8. Copy the following table in your exercise books and record the temperature of both thermometers.
9. Turn on both lights at the same time. Wait for about 30 seconds and then record the temperatures of the thermometers in the table below.

Results and observations

Card	Initial temperature (°C)	Final temperature (°C)	Temperature difference (°C)
Card A (direct light)			
Card B (indirect light)			

1. Is light hitting the card from lamp A direct or indirect light?
2. Is light hitting the card from lamp B direct or indirect light?
3. Which card has the hottest final temperature? Why is this?

Evaluation

How could you have improved this experiment?

Conclusion

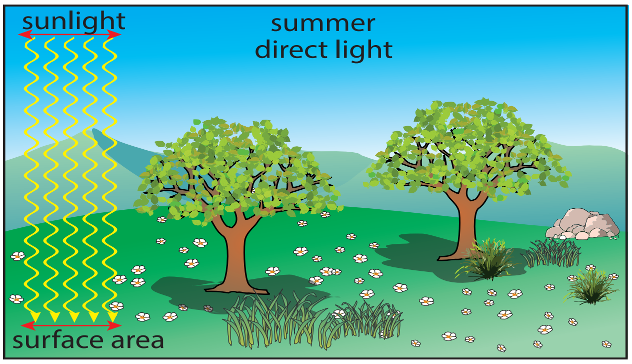
1. What do you conclude about the heating effects of direct and indirect light?
2. Why do you think this is the case?

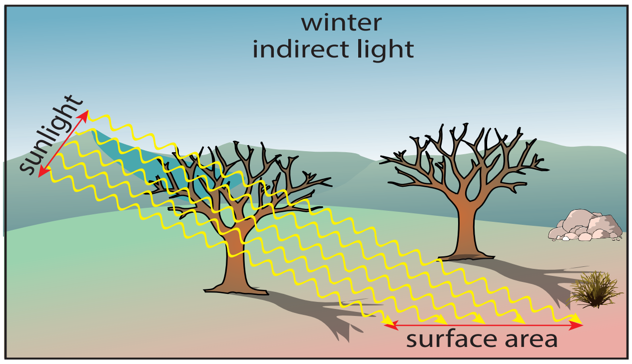
Questions

Imagine that the lamps represent sunlight and the cards represent the surface of the Earth.

1. What season on Earth do you think corresponds to case A, and why do you think this?
2. What season on Earth do you think corresponds to case B, and why do you think this?

Areas of the Earth that are hit by direct sunlight are therefore warmer than areas that are hit by indirect sunlight. In the summer, the Sun is high in the sky and we receive more direct sunlight than in winter when the Sun is lower in the sky and we receive more indirect sunlight. This explains why summer is warmer than winter.





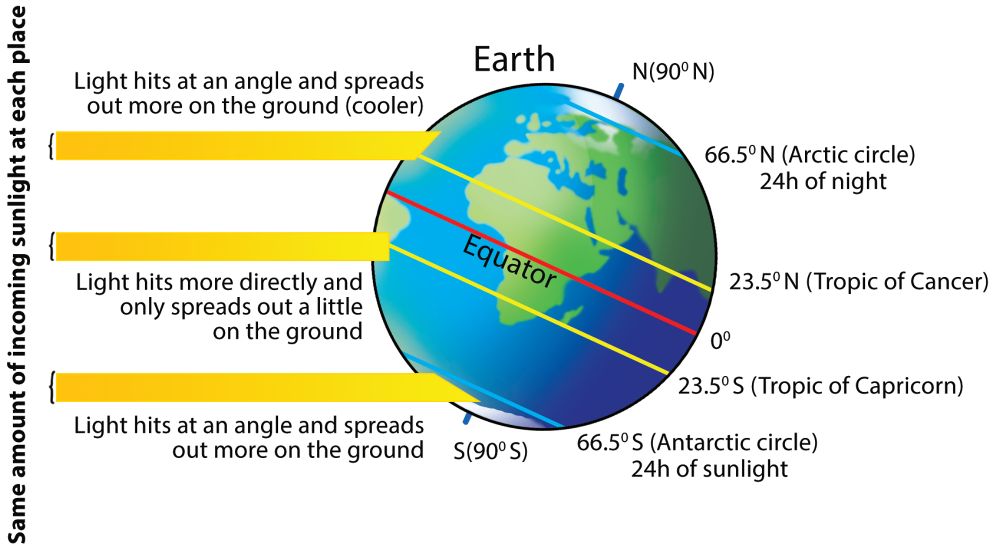
> **Did you know?**
>
> Different cultures around the world have various celebrations and holidays around the winter and summer solstices, the equinoxes, and the midpoints between them.

But why do we receive more direct light in summer? And why is it always warmer at the equator than at the North and South Poles? Let's do an activity to find out.

ACTIVITY Looking at sunlight hitting the Earth

Instructions

1. Look at the example picture below. It shows sunlight hitting the Earth.
2. Look at the Sun's rays and see how the angle at which they hit the Earth's surface changes at different points along the surface of the Earth because of its curved shape.
3. Answer the questions below.



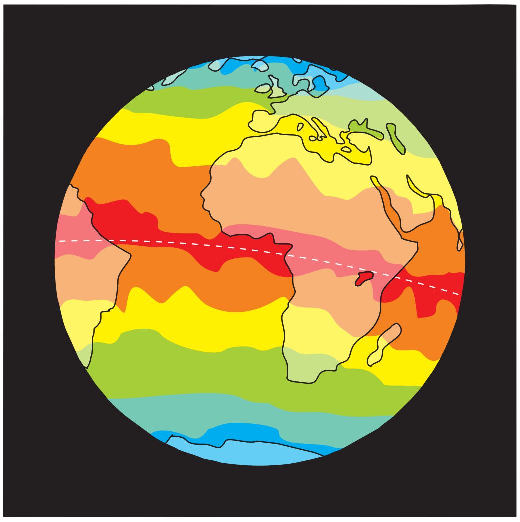
> **Take note**
>
> Another way to say that the light falls indirectly is to say 'obliquely'. Oblique means it is not at a right angle (90°), but slanted.

Questions

1. Does the equator receive more or less direct light than the poles?
2. Which hemisphere receives more direct light in the picture? Why is this?
3. Which hemisphere in this diagram receives more indirect light? Why is this?
4. Why do you think it is warmer at the equator than at the poles?
5. Is it summer or winter in the Southern Hemisphere in this example?
6. Is it summer or winter in the Northern Hemisphere in this example?
7. What would happen to the seasons if the Earth was tilted in the opposite direction, with the Northern Hemisphere tilted towards the Sun instead?

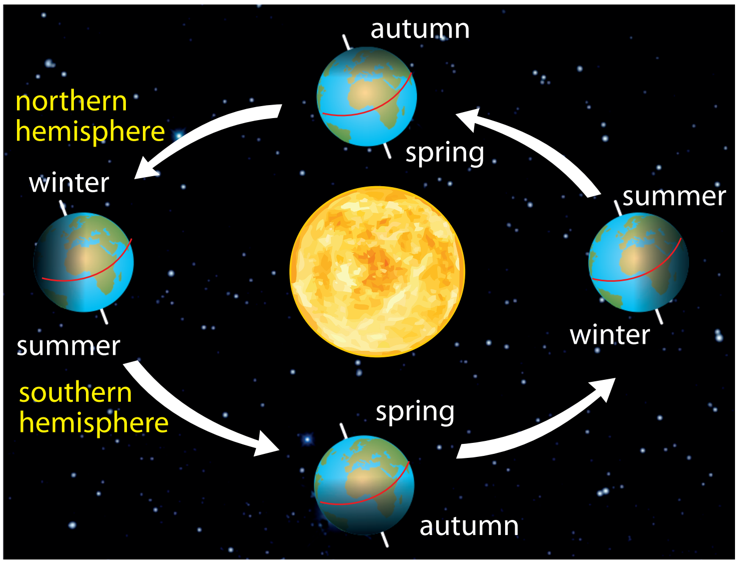
The light falling on the Equator always hits at angles very close to 90° (almost direct), so it stays almost the same temperature all year round.

The areas around the Equator are warmer than at the poles throughout the year, as light falls almost directly on the Earth's surface between the Tropic of Cancer and Tropic of Capricorn.



Areas that are hit by indirect sunlight are cooler because the Sun's energy is spread out over a larger area than at the equator. The poles are always hit by indirect sunlight which explains why it is cold at the North and South Poles.

We experience the different seasons because of the varying amount of direct and indirect sunlight we receive. When the Southern Hemisphere is tilted towards the Sun it receives more direct sunlight (more radiant energy) and temperatures increase: it is summer in the Southern Hemisphere.



The opposite hemisphere is tilted away from the Sun and receives less direct sunlight, it receives less energy and temperatures decrease, so it is winter in the Northern Hemisphere. When the Northern Hemisphere is tilted towards the Sun we have the opposite case, and it is summer in the Northern Hemisphere and winter in the Southern Hemisphere.

The seasons as the Earth revolves around the Sun

In the picture above you can see the Earth travelling around the Sun in its orbit. The Earth's axis always points in the same direction in space. Because of this, sometimes the Southern Hemisphere is tilted towards the Sun and sometimes it is tilted away from the Sun. Let's follow the path of the Earth around the Sun as it completes one revolution from points 1 to 4.

At position 1 the light falls directly on the Tropic of Capricorn (23,5° S). This occurs when we, in the Southern Hemisphere, are having summer, and is called a **solstice**. The day of the summer solstice is the longest day in the year. In the Southern Hemisphere, this is usually around 21 December. At position 3, the light falls directly on the Tropic of Cancer (23,5° N). This occurs during our winter, while the Northern Hemisphere is having summer. This is called the winter solstice in the Southern Hemisphere and occurs around the 21 June. The winter solstice is the shortest day of the year.

At position 2 and 4, the equator receives direct sunlight. This is called an equinox. An equinox occurs twice a year, around 22 March (when our autumn equinox occurs at position 2) and 22 September (when our spring equinox occurs at position 4).

Take note

The term 'equinox' comes from the Latin words 'aequus' (equal) and 'nox' (night), because around the equinox, night and day are about the same length.

ACTIVITY Earth's seasons summary

Instructions

1. Refer to the previous diagram showing the Earth's seasons.
2. Fill in the blanks in the sentences below.
3. Write out the paragraph in full and underline your answers.

Questions

1. At position 1, the Southern Hemisphere is tilted towards the Sun and experiences summer. This is called the summer _________ in the Southern Hemisphere and occurs around the date_________. The Northern Hemisphere is tilted _____________ from the Sun and experiences winter. This is called the winter _________ in the Northern Hemisphere.
2. At position 2, _____________ months later, neither hemisphere is tilted more toward the Sun. Direct sunlight hits the Earth only near the _____________, and indirect sunlight hits nearly everywhere else. This is called an ___________. This causes mild temperatures in the north and south away from the equator.
3. Six months later, the Southern Hemisphere is tilted __________ from the Sun and experiences __________. This is called the winter _____________ in the Southern Hemisphere and occurs around the date, _________. The Northern Hemisphere is tilted _____________ the Sun and experiences _____________. This is called the summer _________ in the Northern Hemisphere.
4. Nine months later, neither hemisphere is tilted more toward the Sun. Direct light hits the Earth only near the ________________, and indirect light hits nearly everywhere else. This causes mild temperatures in the north and south away from the equator.
5. The Earth is now back to its starting point again, having completed one revolution of the Sun in __________ months.
6. Why do you think it is important to know about the seasons? Think about how people used to use the knowledge of the seasons to organise their lives and mark the passage of time. Discuss this with your class and take some notes below.

So you now know that temperatures (and therefore the seasons) on Earth are determined by the angle at which sunlight hits the Earth. In summer, the Sun is high in the sky and sunlight hits the Earth directly. In winter, the Sun is low in the sky and the Sun's rays strike the Earth indirectly at an oblique (shallow) angle. The seasons occur because the Earth's axis is tilted relative to the path of its orbit around the Sun and not because the distance between the Earth and the Sun vary as the Earth revolves around the Sun.

Viewed from the Earth's surface, the Sun appears higher in the sky in summer. As the Sun travels higher in the sky it takes more time to travel across the sky from sunrise to sunset. Therefore, daytime is longer in summer than in winter. The change in the length of daytime during the year also occurs because of the tilt of the Earth's rotation axis in space.

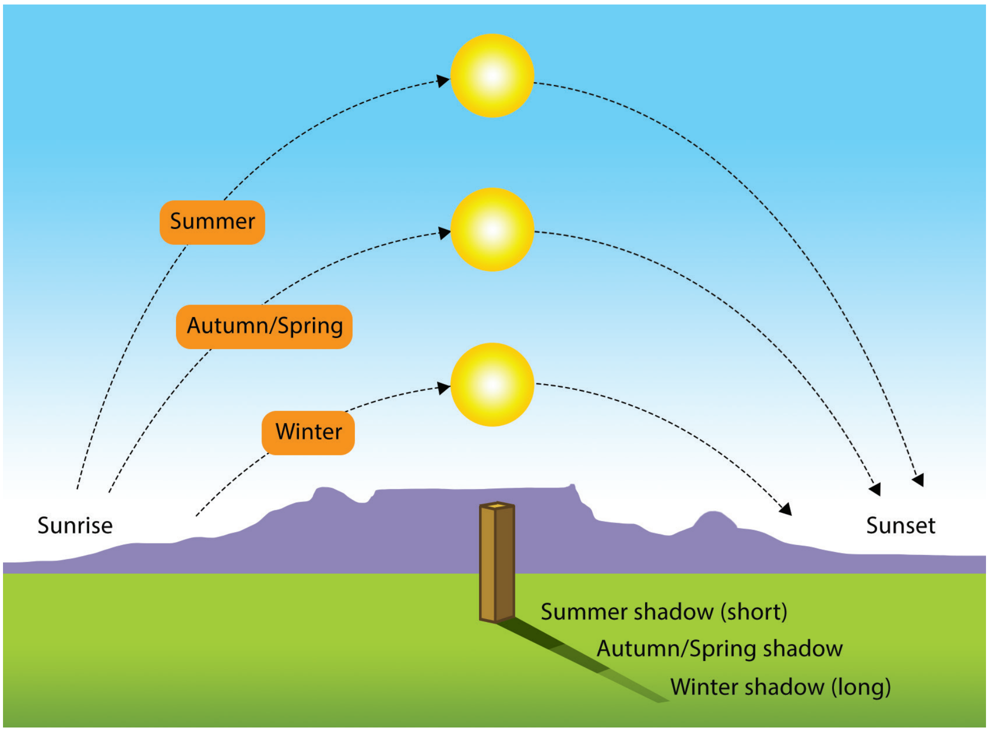


Figure 15.10 The apparent path of the Sun across the sky in winter and summer. The Sun travels higher and further across the sky in summer, and so days are longer.

What do you think would happen to the seasons if the Earth were not tilted by 23,5°, but instead were pointed straight up relative to the path of its orbit?

The Southern Hemisphere receives the greatest amount of solar energy around the 21st of December each year. However, the hottest days of the year are generally a month or so afterwards. Why do you think this is?

Seasons on other planets

Do you think that other planets experience seasons too?

Yes, they do! Every planet in the solar system has seasons, but they are nothing like the seasons we experience on Earth. Seasons pass very quickly on some planets like Venus, yet last decades on others like Uranus. Unlike the Earth's seasons, which are caused only by the tilt of the Earth's axis in space, seasons on other planets can be caused by:

1. The tilt of the planet's rotation axis.
2. The variable distance of the planet from the Sun during its orbit. This is because some planets have extremely oval-shaped orbits around the Sun unlike Earth.

Take note

Remember that it is NOT actually the Sun that moves, but Earth's rotation which makes it look as though the Sun moves across the sky.

The planets Venus and Jupiter have very small tilts compared with Earth. Their rotation axes are tilted only by 3° compared with the Earth's 23,5° tilt so Venus's and Jupiter's seasons are hardly noticeable. Venus does have interesting weather, however! Venus's surface is a whopping 460 °C all year round because Venus has an atmosphere made of dense acidic clouds which trap sunlight leading to a runaway greenhouse effect.

Mars's tilt is 25°, very close to the Earth's 23,5°. Because of this tilt, Mars has seasons, just like the Earth. As Mars takes two Earth years to orbit the Sun, the seasons on Mars are twice as long. The rotation axis of Mars does not point toward Polaris, our North Star, but points towards the star Alpha Cygni. Because of this, Martian seasons are out of step with the seasons on Earth. Mars also has a distinctly oval-shaped orbit. When Mars is further away from the Sun in its orbit it is cooler, which leads to long, extreme southern winters. The northern winters are not so long and extreme because they occur when the planet is closer to the Sun.

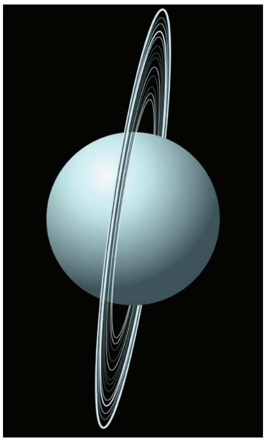
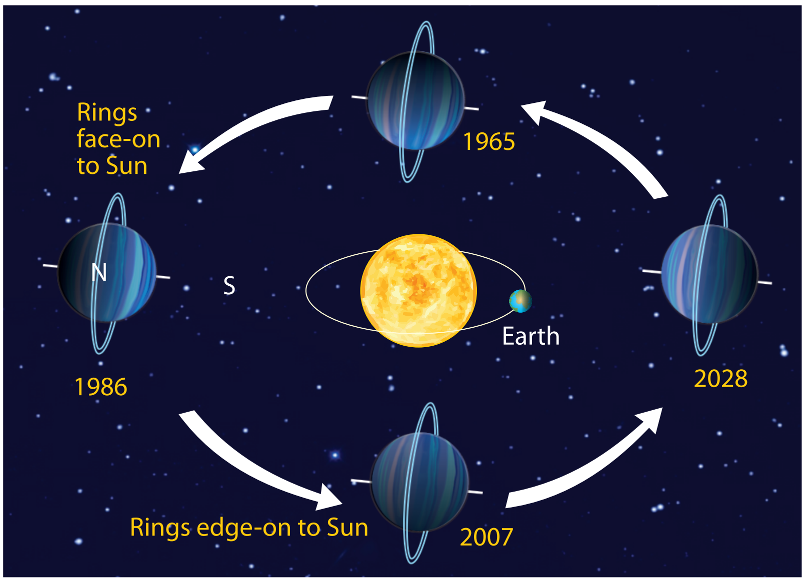


Figure 15.11 Uranus.

The planet with the most extreme seasons in the solar system is Uranus. Like Earth, the orbit of Uranus is nearly circular. However, Uranus's rotation axis is tilted by a massive 98°. Uranus is on its side! Uranus completes one revolution around the Sun every 84 Earth years, giving rise to seasons which last 21 years each! For two of the seasons, one pole is pointed directly at the Sun and the opposite hemisphere does not see the Sun because Uranus spins on its side. The hemisphere facing away from the Sun experiences a long (around 21 years!) dark, bitterly cold winter and doesn't see the Sun until the planet has travelled on in its orbit, to a point in its orbit where Uranus's rotation axis no longer points directly at the Sun.



The seasons on Uranus:

In 1986 the South Pole was facing the Sun and so its Northern Hemisphere was in total darkness. In 2028 the North Pole of Uranus will face the Sun and the Southern Hemisphere will be in total darkness. At present, neither pole is facing the Sun directly.

15.2 Solar energy and life on Earth

So far this term you hve learnt about how the Sun and Earth interact to form day and night, and the seasons. In this section we are going to look further at how important the Sun is for us on Earth, and more specifically at how the energy from the Sun is essential for life on Earth.

In Grade 6 you learnt how plants produce food through the process of photosynthesis. Plants absorb light energy from the Sun and use the energy to make food. In this way the Sun's energy is captured and stored so that it can be used later on.

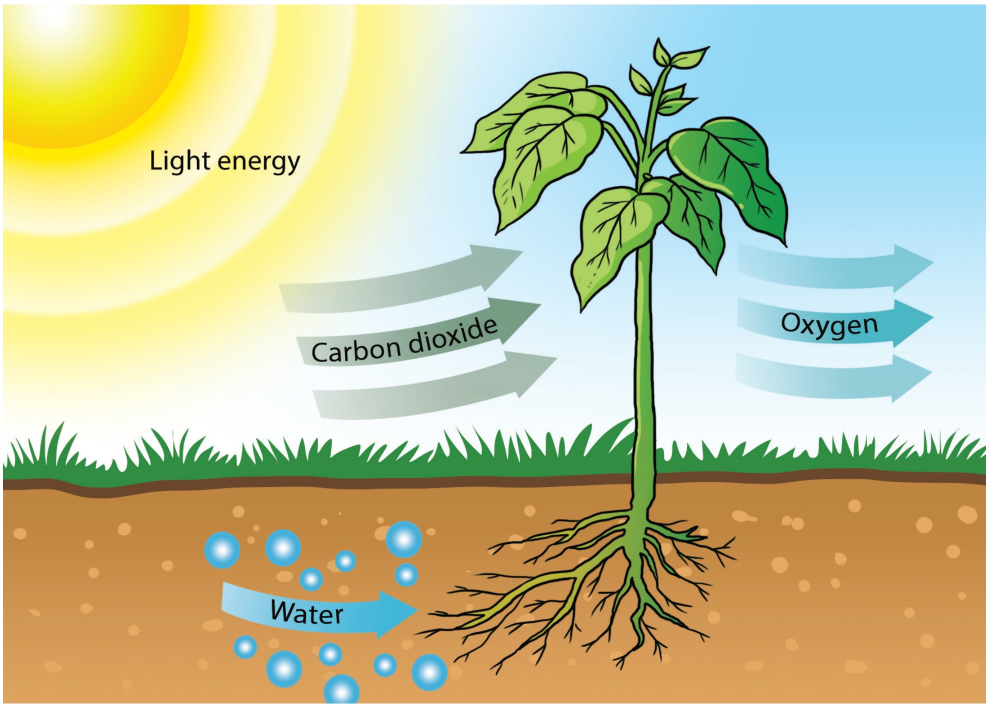


Figure 15.12 The process of photosynthesis to produce carbohydrates which are stored in the plant.

In photosynthesis the energy from the Sun is used to change carbon dioxide and water into **carbohydrates** (for example **cellulose**, **starch** or **glucose**). The carbohydrates are stored in fruits, leaves, wood or bark. When we eat the plant, for example an apple, our bodies are able to release the energy stored in carbohydrates. In the same way animals, for example cows, use the Sun's energy when they eat the grass.

Keywords

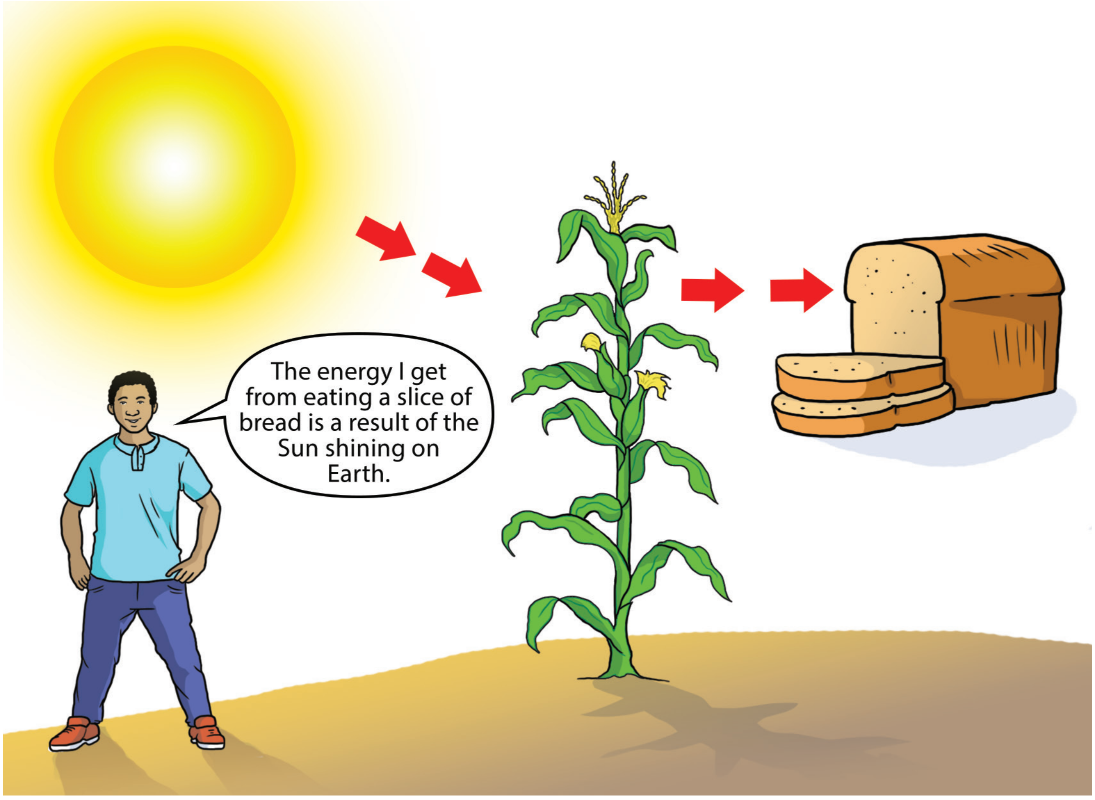
- solar energy
- photosynthesis
- cellulose
- glucose
- starch

Take note

Plants also take up minerals from the soil, which are necessary for their functioning.

ACTIVITY Capturing the Sun's energy

Study the following flow diagram and answer the question below.



Questions

A boy says: 'The energy I get from eating a slice of bread is a result of the Sun shining on Earth.' Do you agree with this statement? Use the flow diagram provided, and write a paragraph to explain why you agree or disagree with the statement. Use the words in the word bank in your explanation.

Word bank

- capture
- release
- store
- energy
- photosynthesis
- Sun
- wheat
- bread

All plants and animals depend on photosynthesis for their energy. In previous grades, you learnt about energy transfer between producers, for example grass, and consumers, for example a buck or lion. You used food chains and food webs to show how energy is transferred. Plants play a vital role in life on Earth as they form the basis of food chains. Without plants, life on Earth would not survive. Plants are completely dependent upon the Sun for survival and would die out without its energy which allows them to photosynthesise. Let's investigate this in the following activity:

ACTIVITY What would happen if the Sun's rays were blocked from reaching Earth?

Imagine a world without the Sun. How can this happen? It has happened before in Earth's history.

Dinosaurs lived on Earth millions of years ago. They were the dominant terrestrial vertebrates until about 65 million years ago, when there was a massive extinction. There are several theories about what caused this mass extinction. The most strongly supported theory is that a massive asteroid hit Earth. It entered Earth's atmosphere with a brilliant flash of light and crashed into a shallow sea. Huge pieces of red-hot rock and steam exploded into the sky, causing raging fires which destroyed everything in their path. The asteroid's impact also caused giant waves, called tsunamis, which swept across the coastal lands. Scientists think that the impact could have started a series of volcanic eruptions. This sent huge clouds of ash and dust into the atmosphere, blocking the sunlight. These huge clouds of ash, dust and steam quickly spread all over Earth and blocked the warm rays of the Sun. Scientists hypothesise that this cold, dark environment could have lasted for months, or even years.

Much more recently in Earth's history, there was a super volcanic eruption at the present site of Lake Toba in Indonesia. This occurred about 70 000 years ago when Mount Toba erupted and sent a huge volcanic ash cloud into the atmosphere. The eruption was followed by a six-year-long volcanic winter as the ash blocked out the sun's rays, and a 1 000-year-long Ice Age. Following the eruption, mount Toba collapsed inwards, and today the site can be seen at Lake Toba.

Take note

A caldera, meaning cooking pot in Latin, is a large volcanic feature usually formed by the collapse of land after a volcanic eruption.

Figure 15.13 An artist's depiction of the asteroid impact 65 millions years ago, which scientists think is the most direct cause of the dinosaur's sudden, mass extinction.

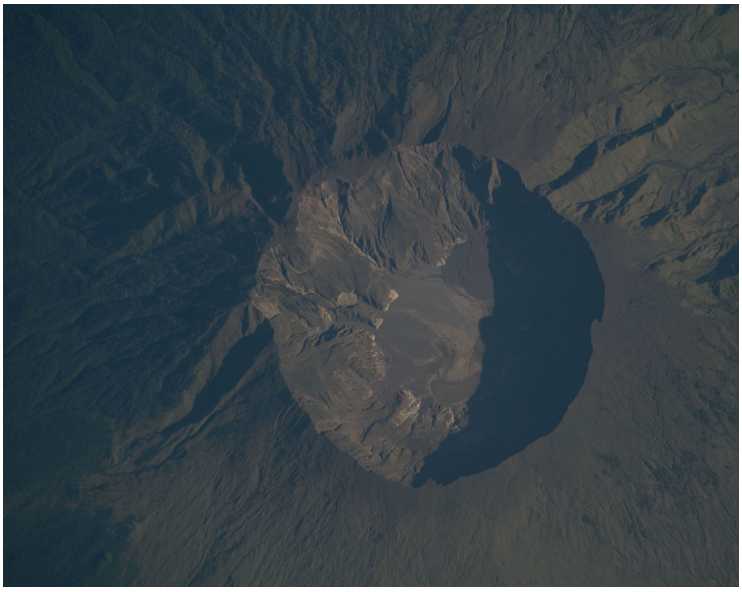


Figure 15.14 An image of Earth's largest caldera taken by a crew member on the International Space Station.

Let's now pretend that another event occurs in present day, blocking the Sun's rays from reaching Earth. What would happen to the people, animals and plants on Earth? Discuss this with a friend and then copy and complete the table by writing down the things that you think would happen if the Sun's rays were blocked from reaching Earth for an extended period.

	What do you think would happen?
On the first day	
One week later	
One month later	
One year later	

15.3 Stored solar energy

Earlier this year you learnt about **renewable** and **non-renewable** energy sources. Fossil fuels are examples of non-renewable energy sources. In this section we are looking at the relationship between the Earth and the Sun and how solar energy is stored on Earth. We have learnt that plants store the Sun's energy and we are able to use that energy later on. But what happens to the stored energy when plants die? To answer this question we need to go back in time. Millions of years back in time...

ACTIVITY Going back in time

Keywords

- fossil fuels
- coal
- crude oil
- natural gas
- renewable
- non-renewable
- vegetation

The following video tells the story of how fossil fuels were formed millions of years ago and how we are able today to use the energy captured at the time: bit.ly/19FdvrQ.

Watch the video and answer the questions below.

Questions

1. What are fossil fuels?
2. Are fossil fuels renewable or non-renewable? Give a reason for your answer.
3. What conditions are needed for fossil fuels to form?
4. How were each of these conditions met at the time when fossil fuels were formed?
5. Why are fossil fuels important?
6. Why can't we make fossil fuels today?

Fossil fuels were formed millions of years ago. Coal, crude oil and natural gas are examples of fossil fuels. The different fossil fuels were all formed in slightly different ways. Let's look at how they were formed.

Formation of coal

Millions of years ago the Earth was covered with fern-like plants. The plants captured the Sun's energy and manufactured carbohydrates through the process of photosynthesis, just like plants do today. Through changes in the conditions on Earth, the land was increasingly covered by water, forming swamps. Over time the plants died, forming a thick layer of dead **vegetation** on swamp bottoms.

As more water covered the land, sand and silt were washed in and covered the dead vegetation, enabling more and more plants to grow. These plants eventually died as well and more layers of plant material formed. Again Earth was covered with water, sand and soil. This process repeated itself for millions of years building up massive layers of dead plant material, called **peat**. The peat layers eventually became buried and compressed by further layers of sediment forming above them.

> **Take note**
>
> **Bituminous** coal is a soft coal, containing bitumen, a sticky, black tar-like substance. Bituminous coal is of a lower quality than **anthracite** coal, which is a hard, compact coal with the highest carbon content of all the coal types.

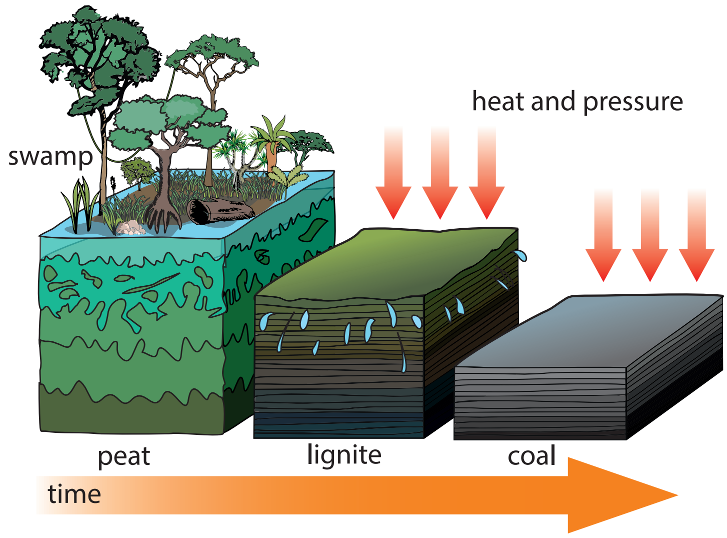


Figure 15.15 Coal was formed from the remains of ancient plants over millions of years.

Deep in the Earth the peat was subjected to pressure and heat, and turned into **lignite**, a porous type of coal. Upon further pressurisation and heating, more moisture was squeezed out of the lignite until it became soft, bituminous coal and eventually anthracite, the hardest type of coal available.

ACTIVITY Coal formation flow diagram

Instructions

1. Read the above section on the formation of coal and summarise it in a flow diagram.
2. The following tips will help you draw your flow diagram:
   a) Underline the most important key words.
   b) Write a short sentence on each event.
   c) Identify the order in which events took place.
   d) Link the sentences using arrows.

Did you know?

92% of the coal consumed in Africa, is mined in South Africa.

Coal is found in a number of different areas in South Africa. Study the map to see where the coal deposits are located in South Africa. Millions of years ago the interior of South Africa was a large swamp where many plants grew and died, eventually forming coal.

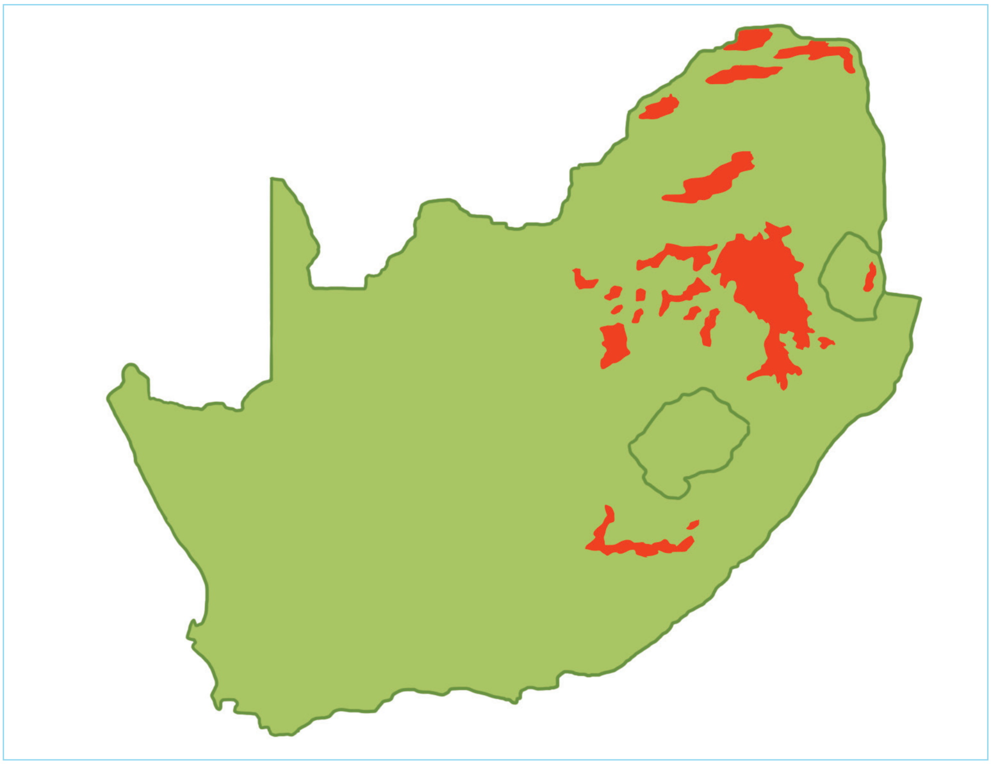


Figure 15.16 Coal deposits in South Africa.

Did you know?

South Africa is one of the seven largest coal-producing countries in the world. A quarter of the coal mined in South Africa is exported, mostly from Richards Bay.

Formation of crude oil and natural gas

Oil, also known as crude oil, and natural gas were also formed millions of years ago by processes similar to those leading to the formation of coal. Sea animals and plants died in the oceans and were deposited on the ocean floor. Over millions of years, layer upon layer of marine deposits formed and were covered by sand and silt.

Through the actions of temperature and pressure, the deposits were changed into crude oil and natural gas. Today, oil and gas are trapped under layers of rocks and sediment and have to be drilled and pumped out of the Earth. South Africa has some gas fields off the coast of Mossel Bay, but we do not have any oil reserves.

Crude oil is a thick, dark, sticky substance when it comes out of the ground. Crude oil has many uses, but has to be refined first to obtain different a number of different products. These different products have different boiling points, which is how they can be separated from each other. Do you remember that we learnt about this in Matter and Materials when looking at how to separate mixtures? What is the name of this technique where different components, which have different boiling points, are separated by evaporating and collecting them?

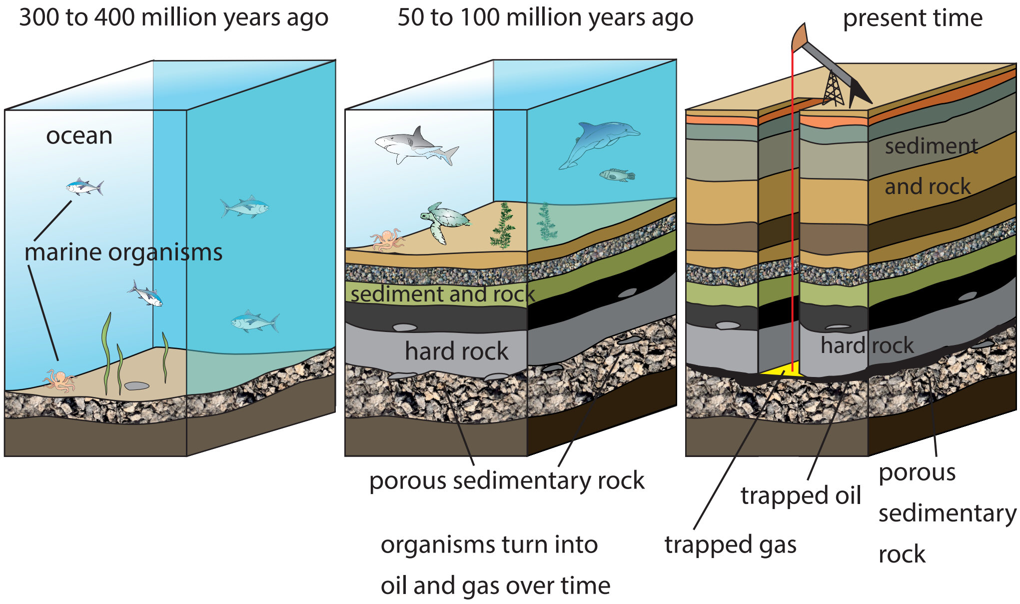


Figure 15.17 Crude oil and gas were formed millions of years ago.

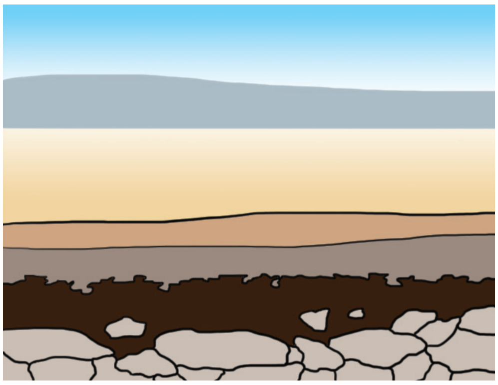
Crude oil is refined to make a number of different products such as motor oil, petrol, lighter fuel, aeroplane fuel, diesel and tar, Vaseline and other waxes. The components of crude oil are evaporated at different temperatures, starting with lighter fuel (which has the lowest boiling point), then jet fuel, then petroleum, then motor car oil, until only tar is left. When crude oil is refined, some of the raw materials extracted from this process are then used to make plastics and various chemicals.

ACTIVITY Forming coal

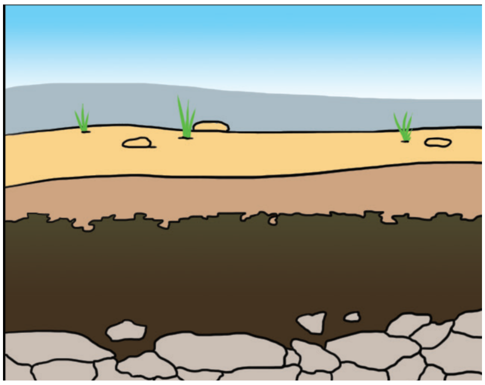
Instructions

1. The following pictures explain the formation of coal. The pictures are not in the correct order.
2. Study the pictures and list them in the correct order to show how coal is formed.
3. Write a paragraph explaining the formation of coal.

Picture 1



Picture 2



Picture 3

Picture 4

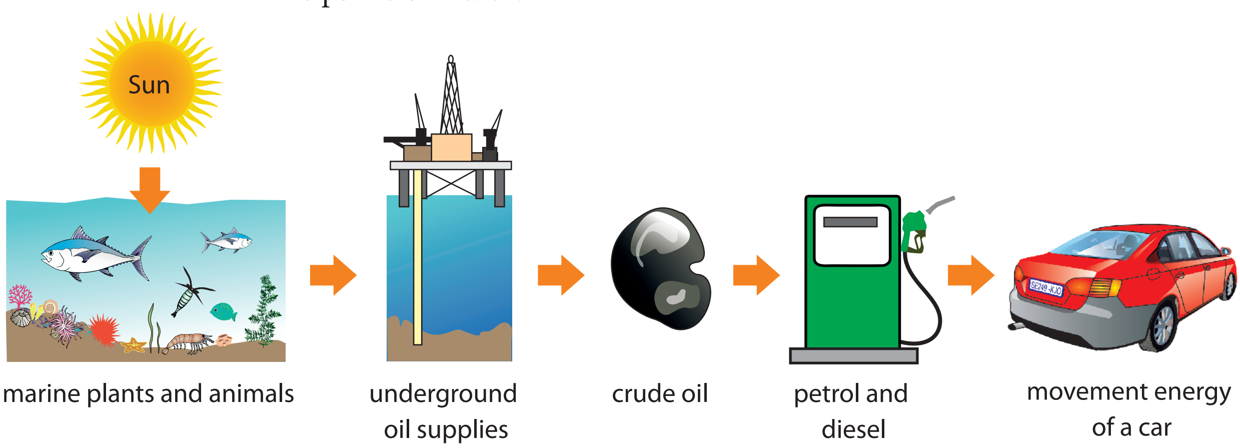
4. Fossil fuels store and transfer solar energy. What type of energy is stored in fossil fuels?

When we use fossil fuels, the stored energy is transferred to another part in the system, for example as kinetic energy. We have already seen this in Energy and Change last term when looking at how a coal-powered power station works to generate electricity. In a coal-powered station, coal is burned and used to boil water. The steam produced then turns the turbine, which in turn causes the generator to turn to produce electricity. In the next activity we will investigate how the Sun's energy is transferred through fossil fuels.

ACTIVITY Explaining the flow of energy

Instructions

Petrol is made from crude oil, a fossil fuel. Use the diagram below to answer the questions about how the Sun's energy is captured in petrol and how this helps life on Earth.



Questions

1. Using the diagram, explain how the Sun's energy is captured in petrol and used in cars.
2. What transfer of energy takes place within the system?
3. Why is petrol important in our lives?
4. Draw a labelled flow diagram to show the transfer of energy from the Sun to a fire made from burning anthracite, a type of coal.
5. For each label write a sentence explaining how the energy is transferred. Also give an example of how this energy can be used in human activity.

This stored energy is not in limitless supply. It will run out at some point so we need to be very careful how we use it, and we need to find alternatives to using fossil fuels for our energy supply. Do you think that people on Earth are using our fossil fuels wisely? Let's investigate how fossil fuels are used in our homes.

For this task, you need to find out how much your household makes use of fossil fuels in one month.

Investigation: The uses of fossil fuels in our homes

1. Make up a question that you would like to answer. Your teacher will help you formulate this. Write your question below.
2. Think about what information you need and design a table where you will gather this information.
3. Research information about fossil fuels and their uses.
4. Report the information in the format that your teacher specified (either a written report, a poster or a project):
   a) Do a write-up that clearly shows how your findings are linked to fossil fuels, and how you collected your data.
   b) What have you found? Write a paragraph on your findings.
   c) Write a conclusion. Answer the question you posed in step 1.
   d) Make some recommendations on what you have found. Does your family use a lot of fossil fuels? Is this good or bad? Why do you think so? Write your opinion in your exercise book.

Take note

We also rely on crude oil form any products besides as a source of energy, such as producing plastics, lubricating waxes and oils and other materials and chemicals.

Summary

Key concepts

- The Earth revolves around the Sun completing one orbit every 365 days. As the Earth revolves around the Sun it also spins on its axis completing one rotation in 24 hours.
- The Earth's rotation axis is tilted in space. The North Pole points towards the star Polaris and the axis is offset from the vertical by 23,5°.
- The tilt of the Earth's rotation axis is responsible for the seasons on Earth.
- Areas near the equator are warmer than areas near the poles because they receive more direct sunlight.
- The Sun's energy is captured and used by plants to produce carbohydrates, which the plant uses and stores. Plants form the basis of food chains.
- The energy stored by plants millions of years ago is available to us today in fossil fuels. The energy, however, is non-renewable.
- Coal, crude oil and natural gas was formed millions of years ago from the remains of dead animals and plants.
- Life on Earth depends on the Sun's stored energy in fossil fuels.

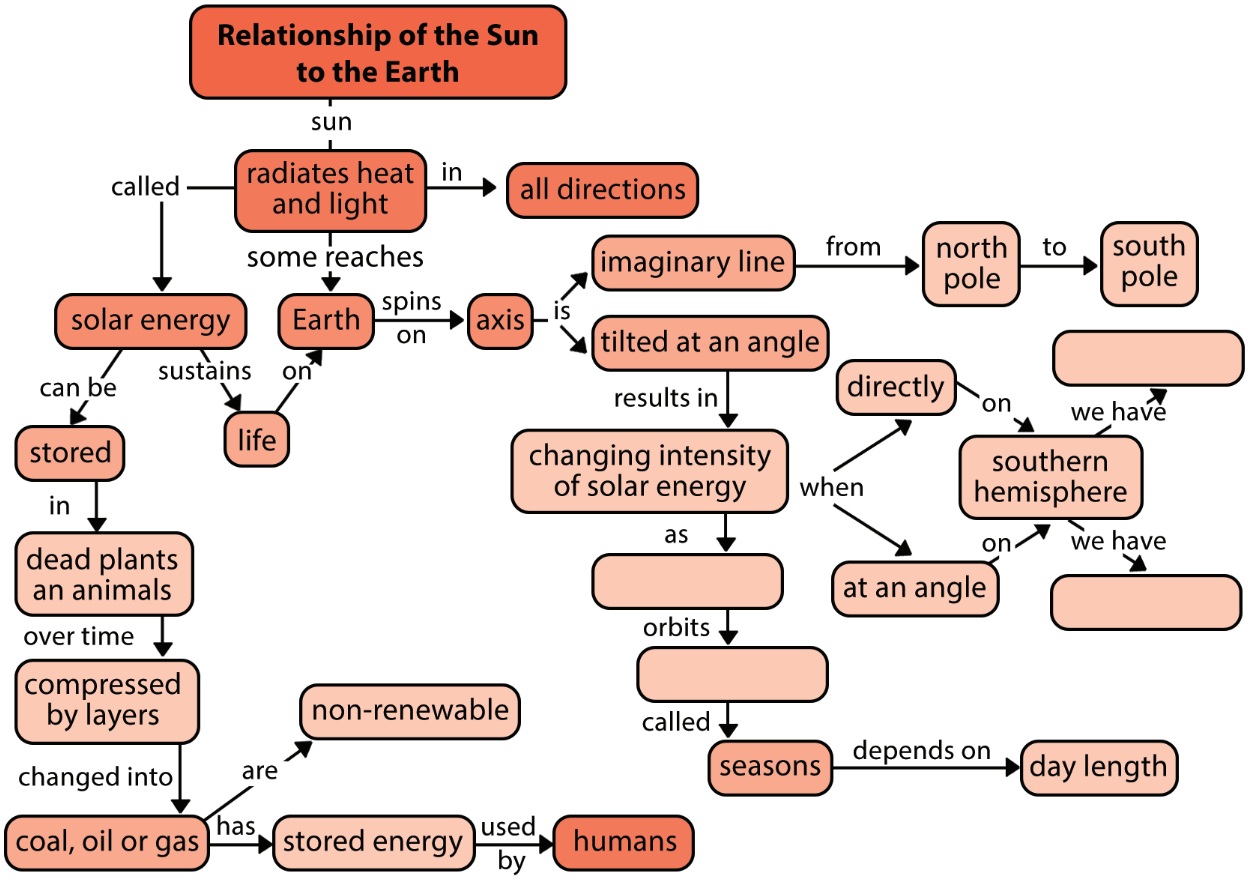
Concept map

Look at the concept map below which shows what we have learnt in this unit about the relationship between the Sun and the Earth.

Fill in the blank spaces to complete the concept map. You need to fill in two of the seasons. To do this, read the concept map and complete the sentence. For example 'when **solar energy** falls directly on **the Southern Hemisphere**, we have _______________.

There are also two blank spaces to fill in about what orbits what in terms of the Sun and the Earth.

It is important to take note of the direction in which the arrows are pointing in a concept map so that you know which way to read it. For example, below where we have:



Revision

1. What causes day and night? [2]
2. The Sun appears to move across the sky during the day moving from east to west. What is really happening? [2]
3. What is the difference between rotation and revolution? [2]
4. How long does it take the Earth to complete one rotation? [1]
5. How many days does it take for the Earth to complete one revolution around the Sun? [1]
6. Why do you think we have leap years every 4 years, when there is an 'extra day', 29 February? [1]
7. What does sunlight do for the Earth? [2]
8. Why is it hotter at the equator than at the poles? [4]
9. What causes the seasons on Earth? [5]
10. Explain why the seasons cannot be caused by the change in the Earth's distance from the Sun as it travels along its slightly oval (elliptical) orbit. [2]
11. Where does crude oil come from? [2]
12. Why are the coal deposits found mostly in the same area in South Africa? [1]
13. Compare the formation of natural gas, crude oil and coal by completing the following table. [5]

	When was it formed?	What was it formed from?	What conditions were need for its formation?	Does South Africa have this natural resource?	Renewable or non renewable resource?
Coal					
Oil					
Natural Gas					

14. Explain how fossil fuels are able to store the Sun's energy. [4]
15. The Sun's energy is essential for life on Earth. Draw a flow diagram to show how the Sun's energy is transferred through natural gas and used in gas cooker in a household. Use appropriate labels to explain the diagram. [4]

Total [38 marks]

16 Relationship of the Moon to the Earth

Key questions

- How long does it take for the Moon to orbit the Earth?
- What keeps the Moon in orbit around the Earth?
- What causes tides on Earth?

Keywords

- moon
- lunar
- eclipse

The Moon is the most obvious feature in our night sky and has captivated people for thousands of years. Ancient cultures recorded the apparent motion of the Moon through the sky and made calendars which used the phases of the Moon to mark the months. In fact some religious calendars still use a lunar – (Moon) based calendar rather than the official solar – (Sun) based calendar used today in South Africa and most of the Western world (called the Gregorian calendar). The Moon's influence on the Earth is also important to us in other ways, as you will discover in this unit.

Figure 16.1 Our Moon.

Did you know?

The Moon is actually covered in a layer of lunar 'soil' called 'regolith'. This is why you can see astronauts' footprints on the Moon. Lunar 'soil' has different properties to soil on Earth. Most significant is that terrestrials soil has organic matter in it.

16.1 Relative positions

You learnt about the Moon in Grades 4 and 6. Let's see what you can remember!

ACTIVITY Moon revision quiz

Instructions

1. Copy the following table in your exercise books and fill in the gaps in the Earth-Moon comparison, using the word bank.

Word bank

- rock, soil and water
- rock and lunar soil
- reflects
- absorbs
- Sun
- Earth
- an
- no
- larger
- smaller
- 24
- 27,3

The Earth	The Moon
Surface consists of ____________.	Surface consists of __________.
Is_______________ than the Moon.	Is ____________ than the Earth.
Is visible because it ________ light from the Sun hitting it.	Is visible because it _______ light from the Sun hitting it
Is in orbit around the___________.	Is in orbit around the____________.
Spins on its axis once every _________ hours.	Spins on its axis once every _____________ days.
Has _______________ atmosphere.	Has ____________ atmosphere.

Let's now take a closer look at the surface of the Moon.

Did you know?

Humanity got its first view of the far side of the Moon in 1959 when the Soviet Union launched the small spacecraft, Luna 3. This was the first probe to get to the far side of the Moon and photograph it.

ACTIVITY Observe the Moon!

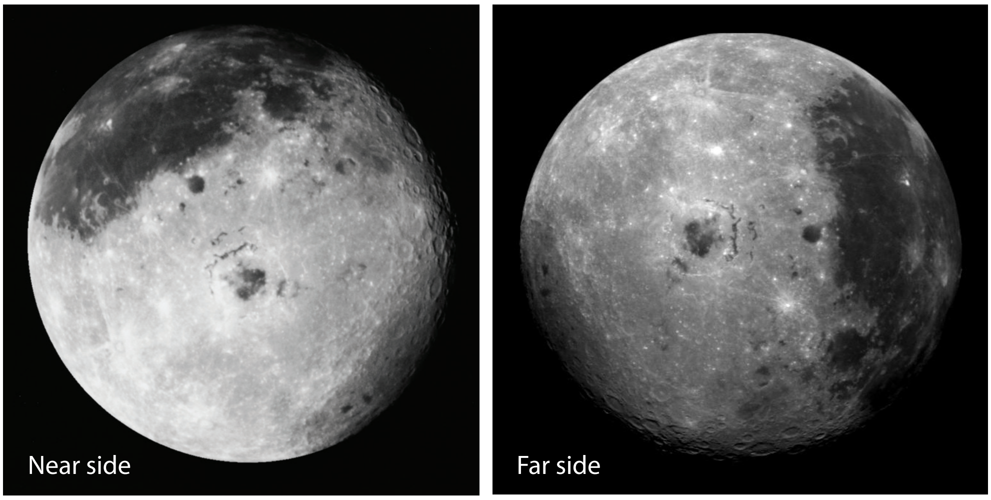


Figure 16.2 Images of the near side and far side of the Moon. Look at the difference between the two images, what do you notice?

Instructions

1. Study the images of the Moon.
2. Answer the questions below.

Questions

1. Does the Moon's surface have any oceans or lakes?
2. What do you notice covering much of the Moon's surface?
3. Some areas look dark and others look lighter, the dark areas are called 'maria' (singular mare) meaning 'seas', as astronomers initially thought that these areas were seas on the surface. The bright areas are called highlands as they are higher than the maria. On what side of the Moon (near or far) are there more dark areas (maria)?

The Earth, just like all the other planets in the solar system, travels around the Sun, completing one revolution every year. As the Earth travels around the Sun it has a companion in space: our Moon!

The Moon orbits around the Earth completing one revolution every 27,3 days. Our Moon rotates on its own axis and experiences daytime and dark night time just like the Earth does. However, the Moon spins much more slowly than the Earth does and completes one rotation on its axis once every 27,3 days. Did you notice that the Moon takes the same amount of time to spin on its axis as it does to orbit completely around Earth? This means that from the Earth, we always see the same side of the Moon (called the 'near side'). The side we do not see from Earth, called the 'far side', has been mapped during space missions to the Moon.

Viewed from above, the Moon moves in an anticlockwise direction around the Earth. The Moon's orbit is not a perfect circle, it is elliptical; so its distance from Earth varies as it revolves around the Earth. The average distance is about 385 000 km, which is about 60 times the radius of the Earth itself. For comparison, the Earth's average distance from the Sun is 149 597 871 km, or about 23 481 times the radius of the Earth. You can see now why the Moon is called Earth's close companion!

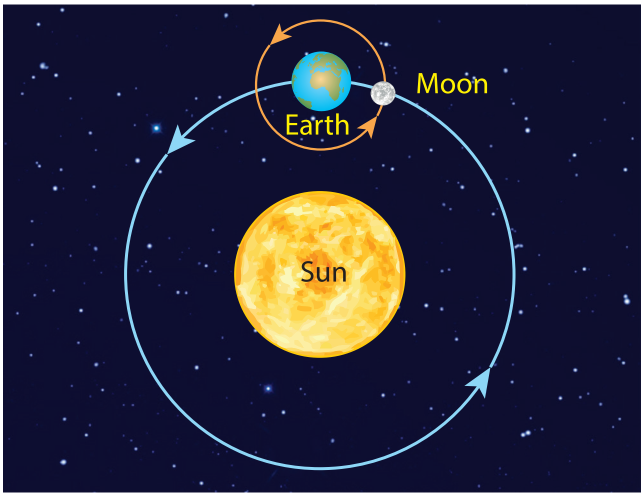


Figure 16.3 Diagram showing the Earth's motion around the Sun and the Moon's motion around the Earth.

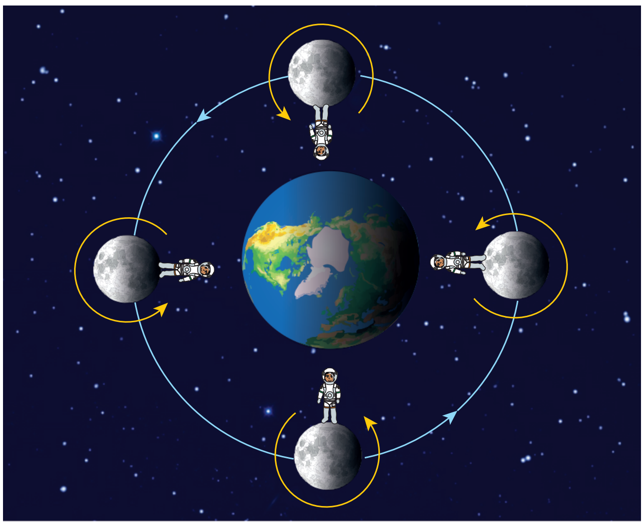


Figure 16.4 The Moon spins on its own axis at the same rate that it revolves around the Earth. As it completes one quarter turn on its axis, it also completes one quarter of its orbit. This results in the same side of the Moon always facing Earth.

Take note

The time that it takes an object to make one complete orbit around another object, relative to the stars, is called the orbital period or synodic period.

Take note

In the diagram, the Sun and Sun-Earth distance are not drawn to scale. The Sun would be MUCH larger than in this image, and the distance between the Sun and Earth would also be MUCH larger.

Figure 16.5 An image of the Earth and Moon taken from the Galileo satellite on its way to Jupiter over 6 million km away. The Moon's diameter is just under a third of the Earth's diameter. You can see the sunlit sides of the Earth and Moon. On what side do you think the Sun is?

The following table summarises some useful information about the Sun, Earth and Moon.

Characteristic	Sun	Earth	Moon
Relative position	Is at the centre of our solar system	Orbits the Sun once every 365,25 days	Orbits the Earth once every 27,3 days
Rotation	Spins on its own axis roughly once every 28 days	Spins on its own axis once every 24 hours	Spins on its own axis once every 27,3 days
Distance from orbited body		23 481 Earth radii from the Sun	60 Earth radii from Earth
Size	Diameter is roughly 100 times the Earth's diameter		Diameter is roughly times the Earth's diameter

We have now looked at the relative positions and movement of the Earth, Moon and Sun. Let's extend this knowledge to learn about a solar eclipse.

ACTIVITY Total solar eclipse

Instructions

Look at the image below. It shows a total solar eclipse which you learnt about in Grade 6. This happens when the Moon passes directly in front of the Sun and blocks the Sun's light. The bright light from the Sun is blocked, allowing us to see the very faint outer edge of the Sun's atmosphere, called the corona. We normally cannot see the corona as it is swamped by the bright light from the Sun. When you look at the size of the Moon in the sky compared with the size of the Sun in the sky you see that they are very similar. We call this the **angular size.** This is because the Moon is much closer than the Sun. The Moon appears large enough from Earth to block out the Sun's light totally.

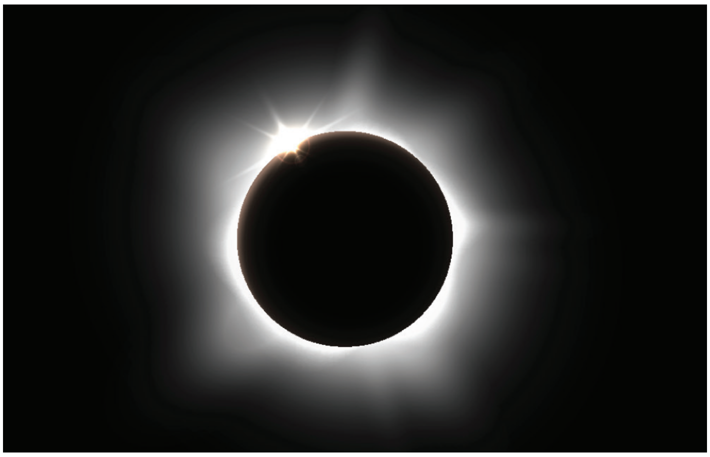


Figure 16.6 A total solar eclipse. The Moon is in front of the Sun allowing us a rare glimpse of the Sun's outer corona, with thin wisps of atmosphere extending into space.

Questions

1. Which is larger in reality, the Moon or the Sun?
2. Which is further away, the Moon or the Sun?
3. How do the angular sizes of the Moon and the Sun compare when viewed from the Earth's surface?
4. Why is this the case?

A total solar eclipse occurs when the Earth, Moon and Sun are aligned in a straight line, with the Moon placed in between the Earth and the Sun. Just by chance, the Sun and Moon are currently at distances where they have the same angular size viewed from the Earth's surface. If the angular size of the Moon were smaller, it would not be large enough to completely block the Sun and we wouldn't have a total eclipse! The picture below shows the relative alignment of the Sun, Earth and Moon during a solar eclipse.

The picture below shows the relative alignment of the Sun, Earth and Moon during a solar eclipse.

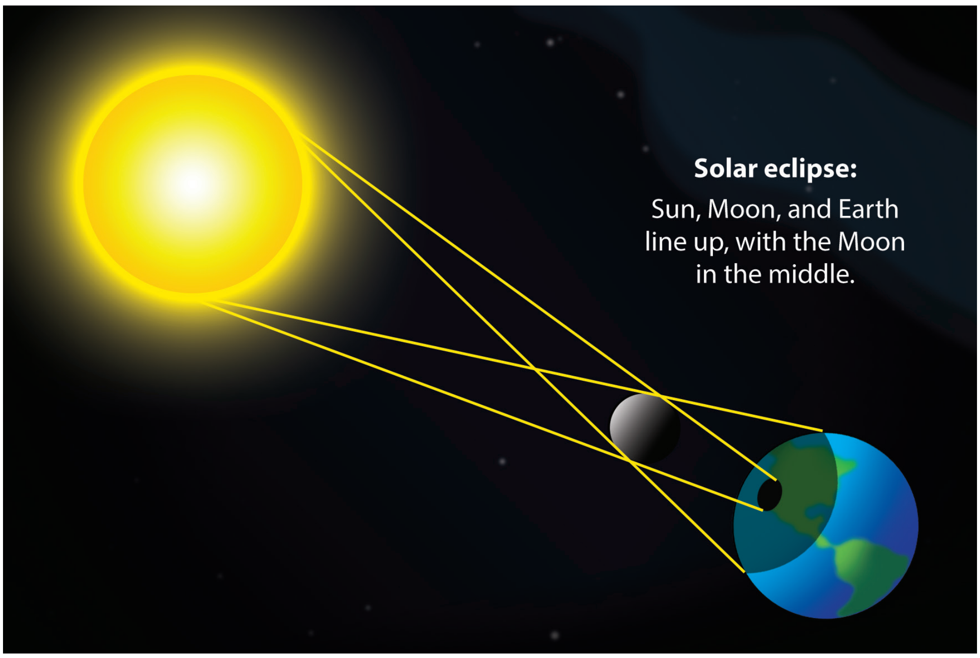


Figure 16.7 The Sun, Moon, and Earth all lined up during a solar eclipse. The black spot on Earth shows the location from where a total solar eclipse would be visible. This area is in the Moon's shadow. The grey area on Earth's surface indicates the location from where a partial eclipse would be visible.

We can also get a lunar eclipse. This is when the Sun, Earth and Moon line up with the Earth in the middle.

Figure 16.8 A series of images showing the Moon during a full lunar eclipse.

See how a lunar eclipse compares to a solar eclipse in the diagram. In this case, the Earth blocks the sunlight from reaching the Moon's surface, making the Moon appear dark in the night sky.

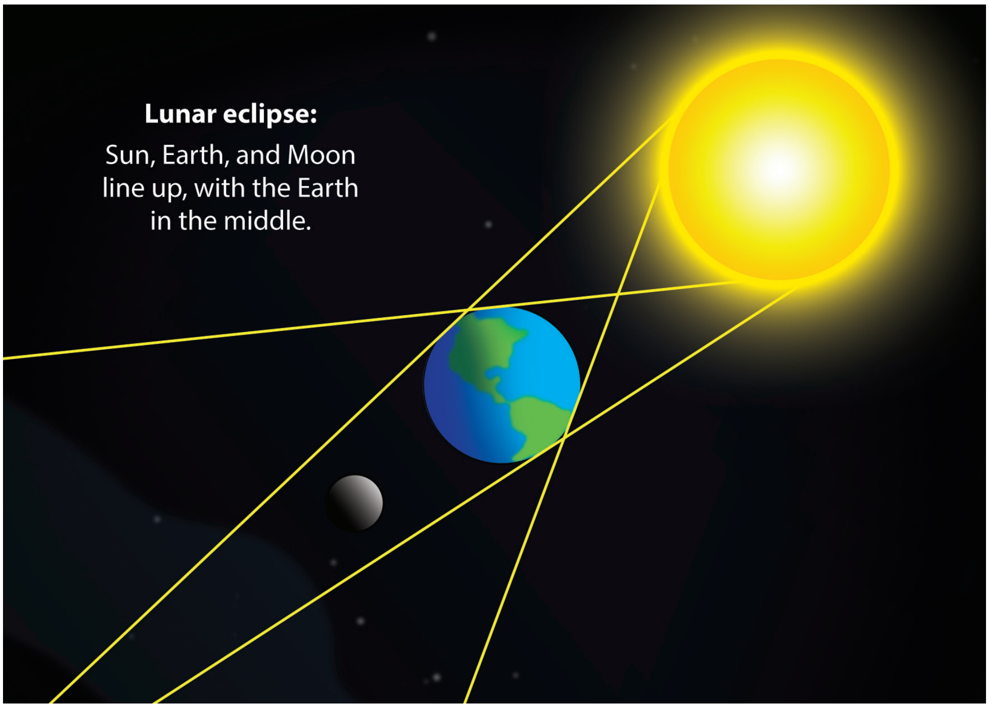


Figure 16.9 Sun, Earth and Moon line up to form a lunar eclipse.

Keywords

- gravity
- mass
- weight
- acceleration due to gravity
- gravitational force

16.2 Gravity

The word gravity is used to describe the gravitational pull (force) an object experiences on or near the surface of a planet or moon. The gravitational force is a force that attracts objects with mass towards each other. Any object with mass exerts a gravitational force on any other object with mass. So, the

Earth exerts a gravitational pull on you, the desks in your classroom and the chairs in your classroom, holding you on the surface and stopping you from drifting off into space.

The Earth's gravity pulls everything down towards the centre of the Earth, and so when you drop an object such as a book or an apple it falls to the ground. However, do you know that you, your desk, your chair, and the falling apple and book exert an equal but opposite pull on the Earth? Why do you think that these pulls don't cause the Earth to move noticeably?

Figure 16.10 The arrows show the direction of the force of gravity by the Earth on all other objects with mass. The arrows all point towards the centre of the Earth because the gravitational force is always attractive.

The gravitational force between two objects decreases as the objects move further apart. If you double the distance between two objects the gravitational force between them decreases by a factor of four. Similarly, if you triple the distance between them, the gravitational force between them decreases by a factor of nine. This explains why we are stuck to the Earth rather than the Sun. The Sun is 333 000 times more massive than the Earth and its gravity is much stronger than the Earth's. However, we are so far away from the Sun that the gravitational force the Sun exerts on us, is much smaller than the gravitational force the Earth exerts on us.

The Moon is held in orbit around the Earth by the gravitational force between the Earth and the Moon. Similarly, the Sun's gravity holds the Earth in orbit around the Sun. Let's do an activity to demonstrate the Moon's orbit around the Earth.

ACTIVITY Demonstrating the Moon's orbit around the Earth

Materials

- rope
- ball (tennis balls are ideal)

Instructions

1. Tie a ball to the end of a piece of rope. You may have to wrap the rope around the ball a few times to do this.

> **Did you know?**
>
> The Moon is slowly moving away from the Earth at a rate of 3,8cm per year (the Moon's orbit is getting larger). In about 563 million years' time its angular size on the sky will have decreased so much that it will no longer be large enough to produce total solar eclipses!

2. Hold the rope up high above your head and swing the rope around in a horizontal circle.
3. Let go of the rope and observe what happens.

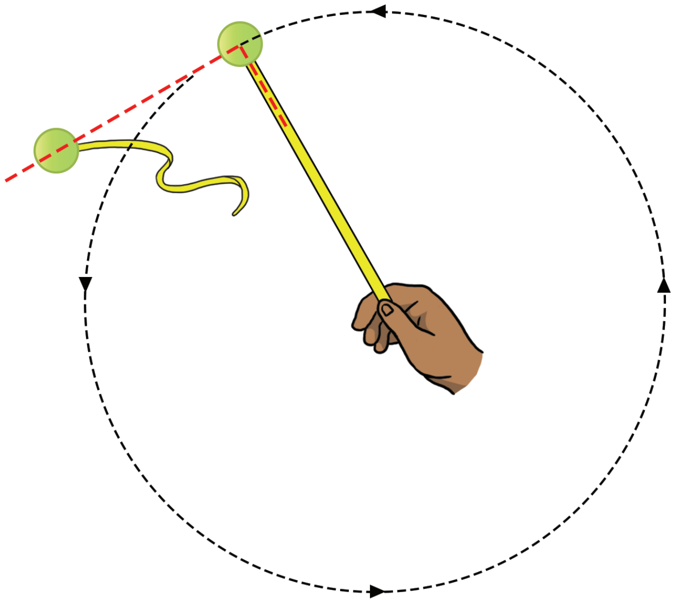


Figure 16.11 Looking down at a ball swung in a circle after it is released.

Questions

1. How can you describe the movement of the ball as you swing it around?
2. The rope pulls the ball inwards towards the centre of the circle keeping the ball moving in a circle. What force holds the Moon in orbit around the Earth?
3. What happens to be ball when you let the rope go?
4. What does this represent in terms of the Earth and the Moon?

All the components in our Universe are held together by gravity. In summary we can say:

- The greater the mass of the objects, the stronger the gravitational pull between them.
- The closer objects are, the stronger the gravitational pull between them.

Weight

The weight of an object is the force acting on it due to gravity. Weight is not the same as mass although the two words are often confused in everyday language.

The **mass** of an object is the amount of matter in the object, it tells you how many particles you have. Do you remember that we briefly spoke about atoms in *Matter and Materials*? So, for example, the mass of a wooden block tells us how many atoms there are. Mass is measured in kilograms (kg) and is independent of where you measure it. A wooden block with a mass of 10 kg on Earth also has a mass of 10 kg on the Moon.

However, an object's **weight** can change as it depends on the mass of the object and also the strength of gravity acting on it. Weight is measured in Newtons (N). For example, the Earth exerts a gravitational force of about 10 Newtons for every kilogram of mass on its surface. So, a person with a mass of 50 kg has a weight of 500 N on the surface of the Earth.

The Moon also has its own gravity. The strength of gravity on the surface of the Moon is one-sixth that of the Earth, and so you would weigh one-sixth of what you do on Earth on the Moon. On Jupiter you would weigh 2.5 times more than you do on Earth as Jupiter's gravity is 2.5 times that of the Earth's. Even though you would weigh different amounts (and feel lighter on the Moon and heavier on Jupiter) your actual mass would stay the same in both cases.

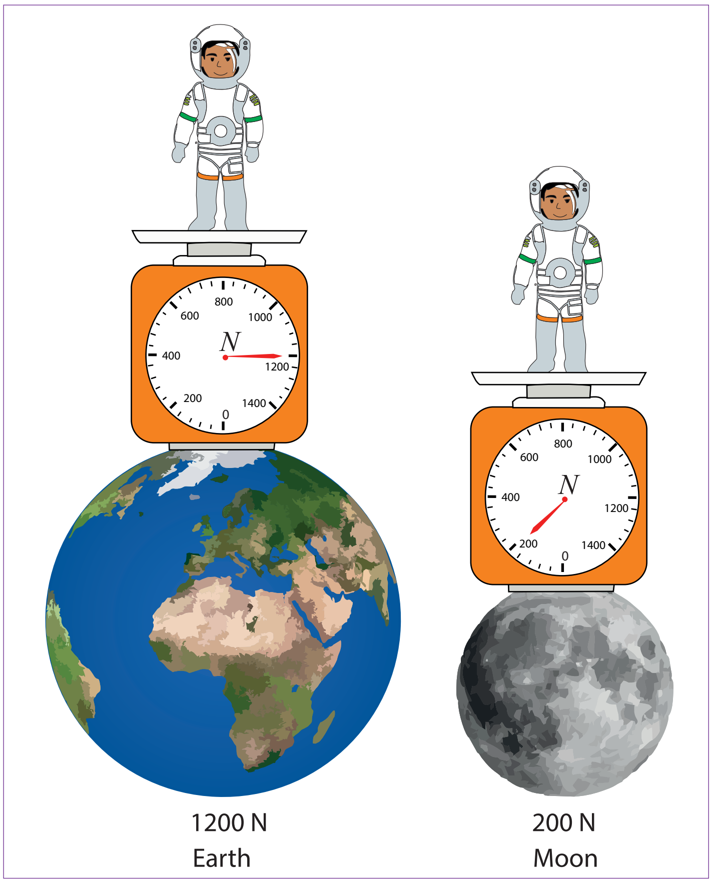


Figure 16.12 An astronaut's mass remains the same wherever it is measured. The astronaut's weight, however, depends on where you measure it. As you can see, the astronaut weighs 1200 N on Earth but only 200 N on the Moon.

Check your understanding of mass and weight with the following questions.

1. Lindiwe has a mass of 50 kg on Earth. What is her mass on the Moon?
2. Andrew has a mass of 60 kg on Earth, what is his weight in Newtons on Earth?
3. How much would Andrew weigh on the Moon?
4. Would Lindiwe feel heavier or lighter on the Moon?

ACTIVITY How much would you weigh on other planets?

Materials

- weighing scales
- calculator

Instructions

1. Measure your mass in kilograms using weighing scales. Record the value in the table below.
2. Look at the table below. It shows how strong the gravity is on each of the planets in our solar system.

Did you know?

The Moon's gravity affects humans on Earth. The tug of the Moon's gravity decreases a person's weight by the equivalent of a few grams on the surface of the Earth!

3. Calculate your weight on each of the planets and enter it into the table below.

Hint: On Earth each kilogram weighs 10 Newtons. So if your mass is 50 kg then you weigh 50 x 10 = 500 N on Earth. If the strength of gravity on a planet is half the strength of the Earth's gravity then you would weigh half of what you weigh on Earth on that planet.

Planet	Your mass (kilograms	Strength of gravity relative to Earth	Your weight (Newtons)
Earth		1	
Mercury		0,378	
Venus		0,907	
Mars		0,377	
Jupiter		2,36	
Saturn		0,916	
Uranus		0,889	
Neptune		1,12	

Questions

1. On which planets would you feel heavier than you do on Earth?
2. On which planets would you feel lighter than you do on Earth?

The Moon's gravity

Keywords

- tides
- tidal bulge
- spring tides
- neap tides

Figure 16.13 Neil Armstrong, the first man on the Moon.

As you have already discovered, the Moon, like any other planet or moon, has its own gravity. The strength of gravity on the surface of the Moon is one-sixth that of the Earth, and so on the Moon you would weigh one-sixth of what you do on Earth. Due to the weak gravity on the Moon, you would be able to jump six times higher than usual! The astronauts had to learn to walk in strange ways (such as leaping or hopping) to move about on the surface of the Moon.

As we will find out in the next section, the Moon's gravity not only affects humans walking on the Moon, but also influences the Earth.

16.3 Tides

Tides are the predictable, repeated rise and fall of sea levels on Earth. If you look closely you will notice that the height of the surf at any beach varies slowly with time. When the sea is far out and there is lots of sand exposed, it is called low tide. You can see an example of low tide in the photo.

Figure 16.14 At low tide, the water is far out and the boats are resting on the sand.

Following low tide, the water gradually comes further up on the beach until it reaches its highest level. This is called high tide. After high tide the water level gradually drops again until it goes back to low tide. This pattern repeats over and over again. You can see an example of low and high tide at the same beach in the pictures below.

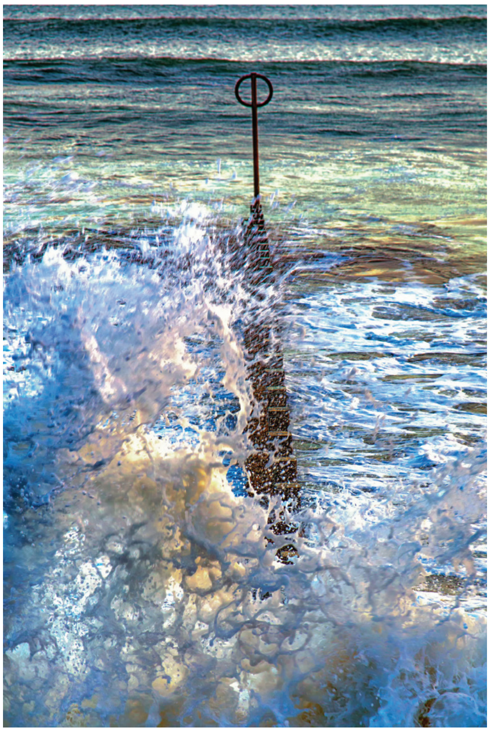


Figure 16.15 The same beach photographed at low tide (top) and high tide (bottom).

In general there are two low and two high tides per day on the sea, which can be observed on the beaches or even in estuaries. The times of high and low tides are not exactly the same every day; they occur roughly one hour later each day.

Did you know?

Some lakes and rivers also have tides!

Tides can be predicted, and low and high tide times are published in tide tables. Fishermen use this information to plan when they will fish. Surfers also use this information so they can plan the best times to go surfing as each beach has a particular time when the sea level is just right for producing excellent surfing waves.

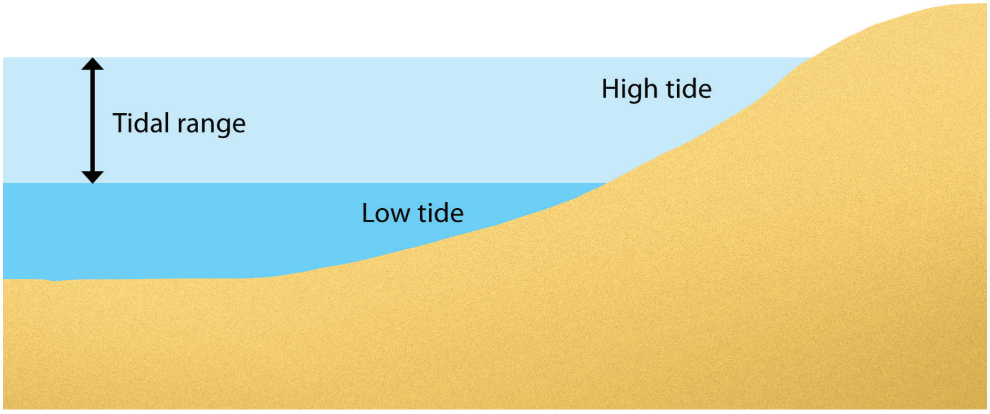
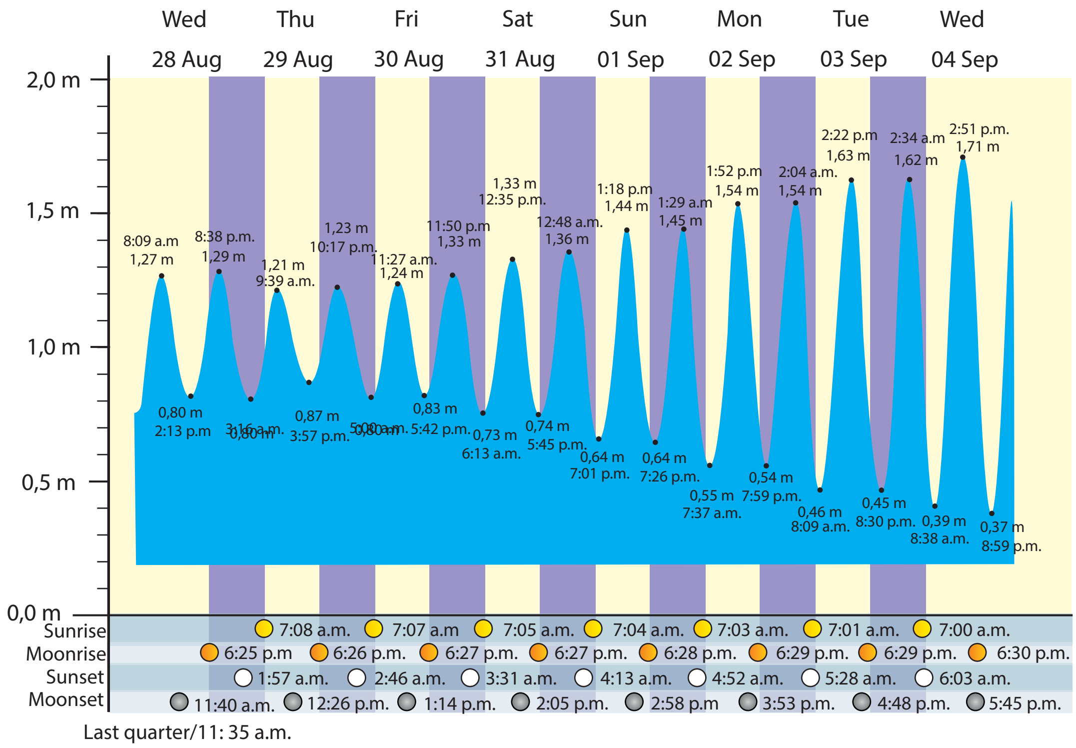


Figure 16.16 This diagram shows how the sea level differs at low and high tide at a beach. The vertical difference between low and high tide is called the tidal range.

ACTIVITY Reading a tide chart

Instructions

1. Look at the chart below. It shows the predicted times of low and high tide for one week in Cape Town.
2. The peaks represent times of high tide and the heights are listed in metres along with the time of high tide. The troughs represent times of low tide.
3. Answer the following questions.



TFigure 16.17 his graph shows the predicted tides for a period of one week in Cape Town. Although the graph includes data for only one week, the actual pattern of high and low tides repeats every day throughout the year.

Questions

1. How many peaks appear per day in the chart?
2. What do these correspond to? High or low tide?
3. How many troughs appear per day in the chart?
4. What do these correspond to? High or low tide?
5. What is the height in metres of the highest low tide during the week?
6. When does the lowest high tide occur? (date and time)
7. What height is the lowest high tide?
8. The following photo is of a small harbour in Cape Town with a boat moored. These photos were taken on Monday 29 April.

Figure 16.18 Boulders Beach in Cape Town at low tide.

Figure 16.19 The same view of Boulders Beach at high tide.

   a) What time of day was the photo taken of low tide?
   b) What time of day was the photo taken of high tide?

Figure 16.20 This picture shows a small harbour at low tide. The tide is out and the boats are stuck on the sand banks. Once the tide comes back in the boats will float on the water again.

So you now know that all seas have tides, why do you think this is? Let's do an activity to find out. ...

ACTIVITY Dance of the tides

Materials

Four (ideally blue) scarves or strips of fabric per group. Each one needs to be about a metre in length.

Instructions

1. Work in groups of six. One learner represents the Earth, four learners represent the Earth's oceans and one learner represents the Moon.
2. The learner representing the Earth: stand in an open space.
3. The four learners representing the oceans: take one scarf each and stand in a circle around the learner representing Earth. (One behind, one in front, and one on either side.)
4. The four learners representing the oceans: link scarves with your neighbours.
5. Learner representing the Moon: stand outside the circle of 'oceans' about five steps away from the 'Earth', directly in front of one of the learners representing the ocean.
6. All learners apart from the Moon: turn to face the 'Moon'. You are now going to be 'pulled' towards the Moon by the Moon's gravitational attraction! Remember that the gravitational pull exerted on an object by the Moon decreases with increasing distance to the Moon.
7. Which part of the Earth and ocean is being pulled the most by the Moon?
8. Which part of the Earth and oceans is being pulled least by the Moon?
9. Ocean learner closest to the Moon: take three large steps towards the Moon.
10. Two ocean learners standing beside the Earth and the Earth learner: take two large steps toward the Moon.
11. Ocean learner farthest from the Moon: take one large step towards the Moon. Why have you moved towards the Moon by varying amounts?
12. Note what happens to the shape the 'oceans' now make, are you still in a circle or forming an oval shape?
13. Note which sides of 'Earth's' body is experiencing high tide. (Front and back or left and right arms.)
14. Earth: spin around on the spot a few times, stopping in a random position, not directly facing the Moon. Remember that the Earth is continually spinning on its axis!
15. Note which sides of the 'Earth's' body is experiencing high tide.
16. Now imagine that there is no Moon, but only the Sun to exert a gravitational pull on the Earth. Because the Sun is much farther than the Moon, its gravitational pull is only one third of the Moon's pull. The team member representing the Moon must now represent the Sun instead.
17. Sun learner: take an additional 10 steps away from the Earth so that you are 15 steps away in total.
18. Ocean learners return to your starting circle positions.
19. All learners apart from the Sun: turn to face the 'Sun'. You are now ready to be pulled towards the Sun.
20. Ocean learner closest to the Sun: take one large step towards the Sun.

21. Two oceans learners standing beside the Earth and the Earth learner: take one normal step toward the Sun.
22. Ocean learner farthest from the Sun: take one small step towards the Sun.
23. Note what happens to the shape the 'oceans' now make, are you still in a circle or forming an oval shape? How does the shape compare with that made when you were pulled by the Moon?

Questions

1. How many sides of the Earth experience high tide at the same time?
2. Where are they positioned in relation to the Moon?
3. As the Earth spins, what happens to the position of high tides in relation to the Moon?
4. As the Earth spins, what happens to the position of high and low tides on the surface of Earth?
5. Besides the Moon, what pulls on the Earth?
6. If there were no Moon, would we still have tides?

Look at the image below. It shows how the Moon's gravity distorts the shape of the Earth's oceans into an oval shape. Do you remember how the gravitational force depends on distance? The ocean on the side of the Earth closest to the Moon experiences a greater gravitational pull towards the Moon relative to the ocean on the far side of the Earth.

This difference in gravitational pulls stretches the Earth's oceans into an oval shape. Along the Earth-Moon direction the oceans form two tidal bulges. At places in line with the Moon, where the oceans are experiencing a tidal bulge, we have high tide. At locations which are at right angles to the Moon, we have low tide.

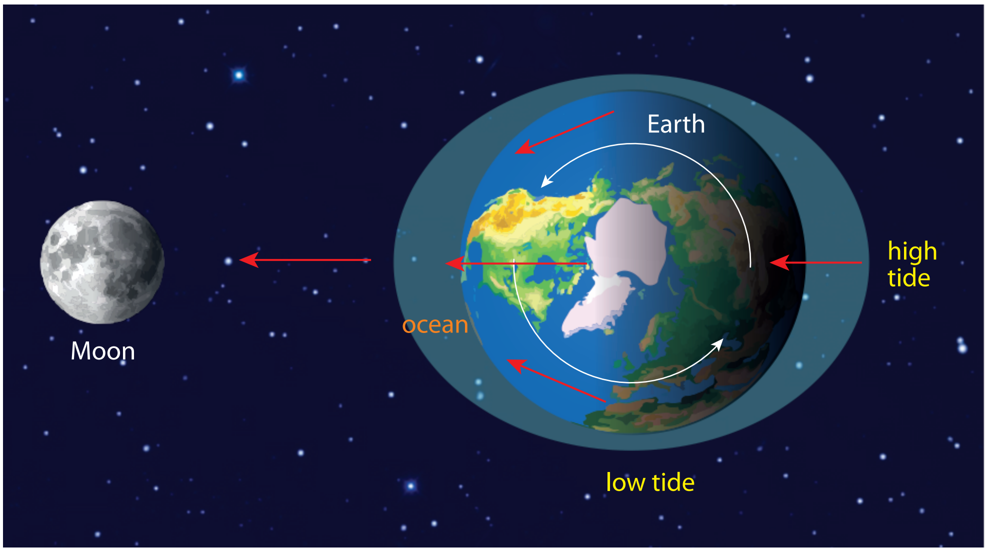


Figure 16.21 This picture shows the Earth and the Moon looking down from above. The gravitational pull experienced by different parts of the Earth towards the Moon is shown as arrows. The longer the arrow, the greater the pull. The ocean closest to the Moon experiences the greatest pull from the Moon, and the ocean farthest from the Moon experiences the smallest pull towards the Moon. The differences result in the Earth's oceans being stretched to an oval shape.

Did you know?

As well as distorting the shape of the Earth's oceans, the Moon's gravitational pull also distorts the shape of the solid Earth. The solid Earth's bulge is about one hundred times smaller than the ocean bulge, but the Earth's crust closest to the Moon actually rises a few centimetres!

Did you know?

The highest tides in the world are at the Bay of Fundy in Canada. The bay is very narrow, so water rushing in from the ocean can rise and fall by up to 20 metres a day!

Why do you think there are two low tides and two high tides at a given beach per day? Look at the diagram above again. When the Moon is directly overhead your location you experience high tide. You also experience high tide when the Moon is directly opposite your location on Earth. Remember that the Earth spins on its axis once every 24 hours and so during one day you experience two high tides at a given location: one when the Moon is directly above your location and one when the Moon is directly opposite your location roughly twelve hours later. Similarly, there are two low tides per day. This cycle continues as the Earth spins.

The height of the tides varies slightly with the phase of the Moon. This is not because the gravitational pull of the Moon is changing: the Moon has the same amount of mass and therefore exerts the same gravitational pull at all phases. Rather, the change in the heights is due to the relative alignment of the Sun and the Moon. Let's look at this further in the following activity.

ACTIVITY Spring and neap tides

Instructions

1. Look carefully at the following diagrams. They show the size of the tides at Full and New Moon (top) and at the first and third quarter phases (bottom).
2. Answer the following questions.

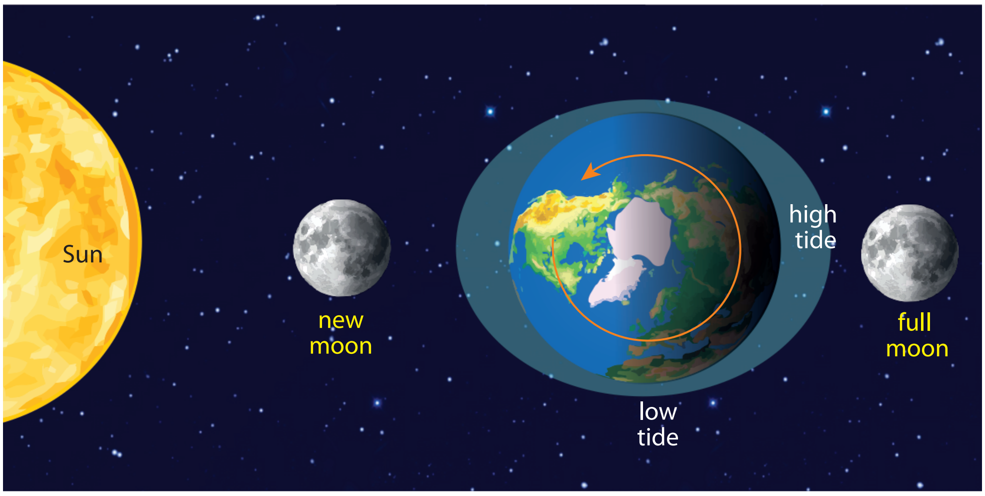


Figure 16.22 Spring tide, showing the size of the tides at New moon and Full moon.

Did you know?

Earth's only natural satellite is simply called the Moon because people didn't know other moons existed until Galileo Galilei discovered four moons orbiting Jupiter in 1610. Other moons in our solar system are given names so they won't be confused with each other.

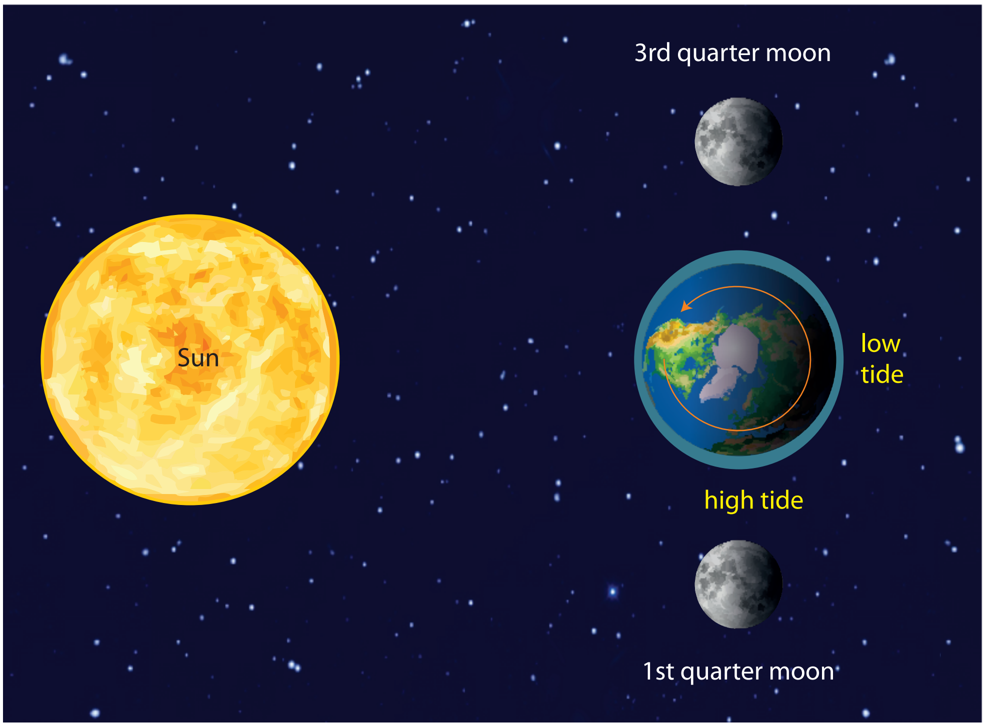


Figure 16.23 Neap tide, showing the size of the tides at first quarter and third quarter moon.

Questions

1. When the Sun, Moon and Earth are in a straight line, the Sun's gravitational pull adds to the Moon's gravitational pull. What Moon phases does this correspond to?
2. During what phases of the Moon do the Moon's and Sun's gravitational pulls partly cancel each other out?
3. During what Moon phases would you expect the highest high tides and the lowest low tides?

When the Sun, Moon, and Earth are lined up in a straight line (at the time of New or Full Moon), the pull of the Sun's gravity adds to the pull of the Moon's gravity, creating extra-high high tides, and very low tides. The difference in height between low and high tide is at its maximum at this time. These are called spring tides. When the Sun and Moon are at right angles to each other (during the first and third quarters), the Sun's gravitational pull partially cancels out the Moon's gravitational pull and produces less extreme tides. The difference in height between low and high tide is at its minimum at this time. These are called neap tides. Overall, the Moon's contribution to the Earth's tides is bigger than the Sun's contribution, because it is much closer to Earth. If there were no Moon, the Earth's tides would be about a third of their current height.

You can now see how important our closest neighbour the Moon is. The Moon's gravitational pull is responsible for the ocean tides!

Did you know?

The Moon's orbit is gradually increasing, and the Moon is slowly moving away from the Earth. Because of this, the tides used to be much higher than they are today, and they will continue to become smaller.

Keywords

- ecosystem
- intertidal zone

The effects of tides on shoreline ecosystems

The region of the beach between high tide and low tide levels is called the **intertidal zone**. The intertidal zone is a harsh environment for marine animals to live. During storms the surf can be very rough and plants and animals must be able to withstand the battering from big waves and not get washed away! Animals and plants that live here are underwater at high tide but are exposed to the air during low tide. Some organisms may stay underwater if they are in small rock pools which do not empty out when the tide goes out. Those that are exposed to air at low tide, face hot temperatures in summer and cold temperatures in winter, so they must be able to adapt to different temperatures.

Figure 16.24 The intertidal zone can be seen here between the sea and the top of the sand.

Animals exposed to the air at low tide may be soaked in fresh water when it rains and yet be soaked in salty sea water at high tide. Therefore, they must also be able to adapt to different salt concentrations as the tides come in and out.

Different animals have adapted to this tough environment in different ways. For example:

Figure 16.25 Crabs burrow into the sand to hide during low tide.

Figure 16.26 This oystercatcher takes advantage of low tide to feed.

Figure 16.27 Mussels and barnacles close their shells tightly to avoid drying out.

Figure 16.28 Kelp and other seaweeds are covered with thick slime to prevent them from drying out.

ACTIVITY The effects of tides on shoreline ecosystems

Materials

Pictures and texts about shoreline animals. (Can be textbooks, library books, or online materials, as directed by your teacher).

Figure 16.29 Seaweed, starfish and mussels in a rock pool.

Figure 16.30 Birds feeding on the rocks.

Figure 16.31 Eggs on some seaweed.

Figure 16.32 Green anemones in a rock pool.

Figure 16.33 Mussels growing on the rocks.

Figure 16.34 A crab in the sand.

Figure 16.35 A mother seal and pup in the waves in the intertidal zone.

Figure 16.36 Mudskippers – fish that can walk on land!

Instructions

Study the pictures and texts and write a summary about how two different organisms are adapted to living in the intertidal zone. You can use the internet or other resources to do some more research.

High up in the intertidal zone, water splashes only during high tide, and the rest of the time it is dry. As you go lower down the intertidal zone, down the beach towards the sea, it gets progressively wetter for longer periods of time.

Figure 16.37 Fishermen looking for big catches time their fishing activities according to the tides too. Let's investigate this further.

Figure 16.38 Harvesting seaweed during low tide.

> **Did you know?**
>
> Sea anemones look like plants with flowers, but they are actually animals. Their tentacles contain a poison which paralyses their food (small fish and shrimps) when touched.

Marine life in the intertidal zone has to adapt to the rise and fall of sea levels at the beach. But marine life is not the only kind of life that has to take note of the tides. Many people also use the low tide to collect seaweed. Seaweed has many uses, including being a food source for people. In some cultures seaweed is used for medicinal purposes and to make various woven products, such as rope, baskets and mats.

ACTIVITY How good a fisherman are you?

Background

Fish are easier to catch at times when they are feeding. The tides determine when most fish feed. When the tide is coming in or going out, the moving water stimulates feeding. The fastest part of the tide is normally around two hours before and after low and high tides. These times are the best times to go fishing.

Instructions

1. Look at the example of tide table data for one day below, and answer the following questions.

Durban – Thursday 29th August 2013

Time	Tide Height (m)	Comment
00:56		Moonrise
02:29	0,85	Low tide
06:14		Sunrise
08:41	1,26	High tide
11:42		Moonset
14:52	0,93	Low tide
17:39		Sunset
21:34	1,27	High tide

Questions

2. Thembela wants to go fishing at the best time around the first low tide of the day. What times could she go fishing?
3. Josh wants to go fishing when the Sun has set. What would be the best possible times for him to choose from?
4. Faried wants to go fishing while the Sun is up. What would be the best possible times for him to choose from?

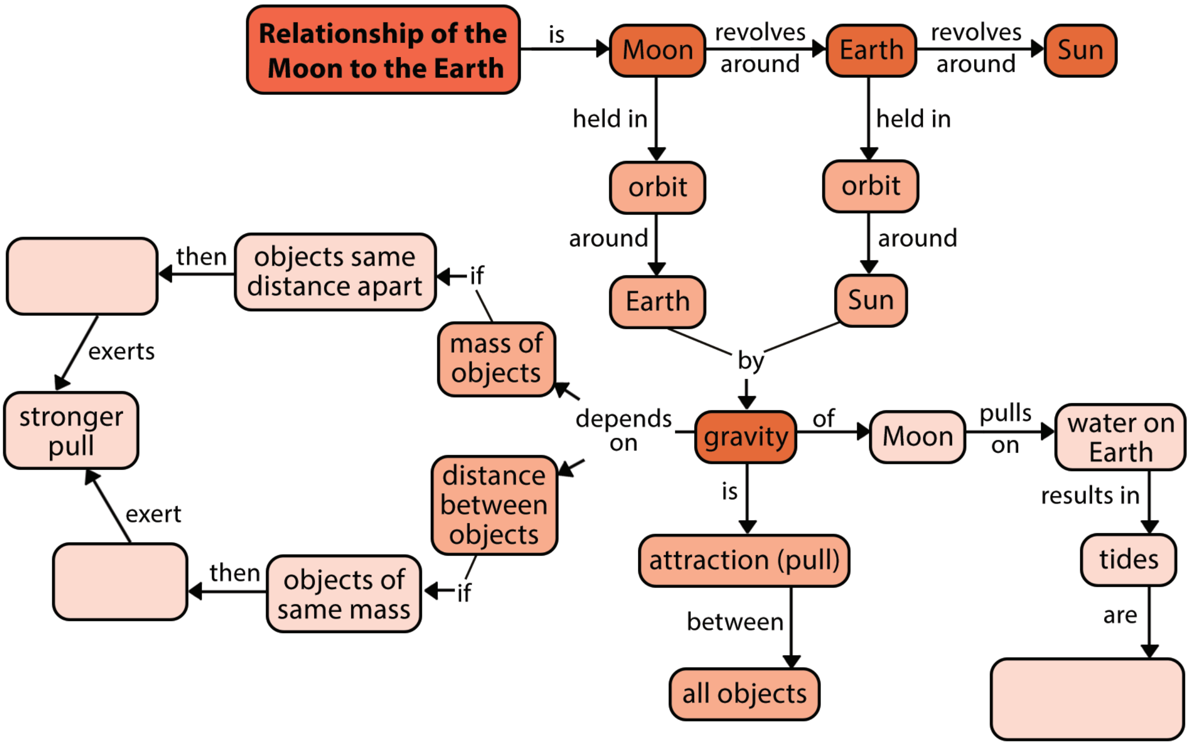
Summary

Key concepts

- The Moon orbits the Earth once every 27,3 days. The Moon also spins on its own axis once every 27,3 days. Because both of these time periods are the same, we only ever see one side of the Moon from Earth.
- Gravity is a force that acts between all objects with mass. The size of the force acting on the objects is proportional to their masses and inversely proportional to their distance from each other.
- The Earth's gravity is responsible for holding the Moon in orbit around the Earth.
- The Moon's gravitational pull is mainly responsible for the tides on Earth.
- Neap tides occur when the Sun and Moon are at 90 degrees to each other.
- Spring tides occur when the Sun and Moon are in line with each other.
- The rise and fall of the tides affects marine life living along shorelines. They have adapted to this harsh environment in many ways to prevent themselves from drying out and from being washed away by strong waves.

Concept map

Complete the concept map by filling in the blank spaces. You can do this by reading the sentence that is made in the concept map. For example, 'Gravity depends on mass of objects. If objects same distance apart, then ______________________ exerts a stronger pull.' What would the answer be? A 'bigger object' or a 'smaller object'? Fill the answer in. Also do this for the distance between objects. Would 'closer objects', or 'further-away objects' exert a stronger pull? Then give a description of tides.



Revision

1. Why do we only see one side of the Moon from Earth? [2]
2. What is gravity? [1]
3. What holds the Moon in orbit around the Earth? [1]
4. How does the gravitational force of attraction between two objects depend on their masses? [2]
5. How does the gravitational force of attraction between two objects depend upon their distance? [2]
6. If you were to stand on the surface of the Moon you would experience only one-sixth | the strength of gravity that you experience standing on the surface of the Earth. Why is this? [2]
7. What causes tides? [2]
8. Look at the following photo of boats on the sand. Do you think it is a problem that they are stuck on the sand? How will people get them into the sea?

Figure 16.39 Boats on the sand.

9. What kind of tides occur when the Moon is in line with the Sun? [1]
10. What kind of tides occur when the Sun, Earth and Moon are at right angles to each other? [1]
11. At what phases of the Moon do spring tides occur? [2]
12. At what phases of the Moon do neap tides occur? [2]

13. What would happen to the height of the tides if there were no Moon? [1]

14. Draw a diagram to show the alignment of the Sun, Earth and Moon during neap and spring tides. [4]

15. Explain why spring tides are more extreme than neap tides. [2]

16. Look at the following photo and answer the questions.

Figure 16.40 A rocky shore.

a) Do you think it is low or high tide? Give a reason for your answer. [2]

b) What is the name given to this zone on the shoreline where the tides move back and forth? [1]

c) What are the main risks to marine life living in this region? [2]

d) How is the seaweed adapted so that it does not dry out? [1]

e) What other types of animals do you think you would find in this region? Give 4 examples. [2]

Total [33 marks]

17 Historical development of astronomy

Key questions

- How did ancient astronomers use the motions of the Sun, Moon and stars for time keeping?
- How did ancient astronomers view our place in the solar system?
- Why did Copernicus think that the Earth and planets go around the Sun?
- What discoveries did Galileo make using his telescope?
- How did Newton explain Kepler's observations?

Keywords

- lunar calendar
- solar calendar
- constellation
- star lore

17.1 Early indigenous knowledge

Astronomy is one of the oldest sciences. Ancient civilisations around the world watched the night skies, noting the patterns they saw in the sky. These patterns are called the constellations. A constellation is any group of stars, as seen from Earth, that seems to form a pattern or picture in the sky. Different nations, cultures and people have given different names to the different star patterns and how they interpreted the patterns.

A well-known example is the Southern Cross. Have a look at the photos which show the stars in the night's sky and how to view the pattern making up the cross.

Figure 17.1 This pattern of stars is the Southern Cross.

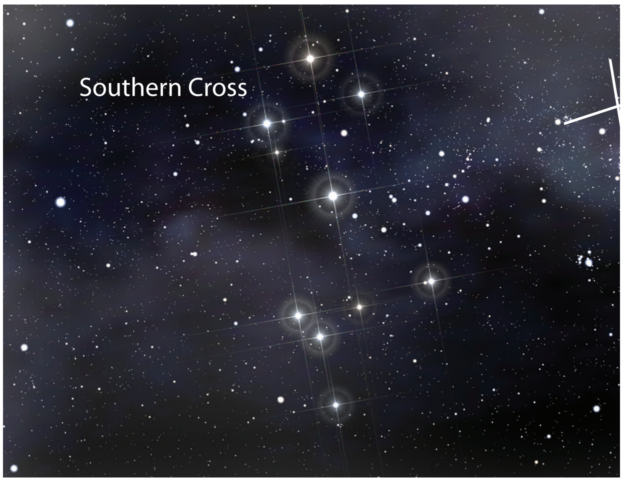


Figure 17.2 The white lines show you how to view the Southern Cross.

Take note

To find south using the Southern Cross constellation, extend the long axis of the cross four times and go straight down to the horizon.

The Southern Cross, Crux, and the two bright Pointer stars were used by farmers to mark the beginning of the planting season. According to Sotho, Tswana and Venda traditions, these stars were called Dithutlwa, meaning 'The Giraffes'. The bright stars of Crux are male giraffes, and the two Pointers are female giraffes.

Another example is the constellation Orion. It is named after Orion, a supernaturally, strong hunter in Greek mythology. This is one of the most recognised constellations around the world and many cultures have identified with it, each forming their own myths, many around a strong man or hunter.

Figure 17.3 The Orion constellation, seen here as the three bright stars in the middle making up Orion's belt and the four stars in each corner.

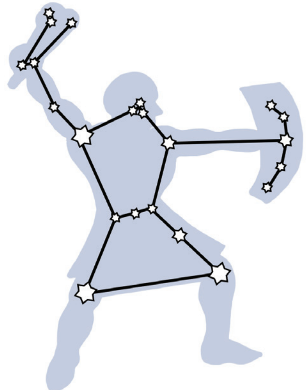


Figure 17.4 This image shows how the pattern of stars in Orion make the image of the hunter.

Did you know?

We have seven days of the week due to the seven moving celestial bodies known to the ancient people, namely, the Sun, the Moon, Mercury, Venus, Mars, Jupiter and Saturn.

People also watched the movement of the stars and planets across the sky marking the passage of time. Early cultures tended to identify the stars and planets they saw in the night sky with gods, spirits or animals. Ancient astronomers could tell the difference between stars and planets as the relative positions of the stars remain fixed in the sky, whereas planets appear to move across the sky relative to the background stars. Not all the planets were known to the ancient people; only Mercury, Venus, Mars, Jupiter and Saturn were. Uranus and Neptune were discovered only after telescopes were invented.

Did you know?

The name 'planet' comes from the Greek word 'planetes' which means 'wanderer'. Planets were called wanderers by the ancient Greeks as they move across the sky relative to the background stars.

Ancient civilisations like the Sumerians, Babylonians and Egyptians were responsible for introducing many of the constellations that astronomers use in the West today.

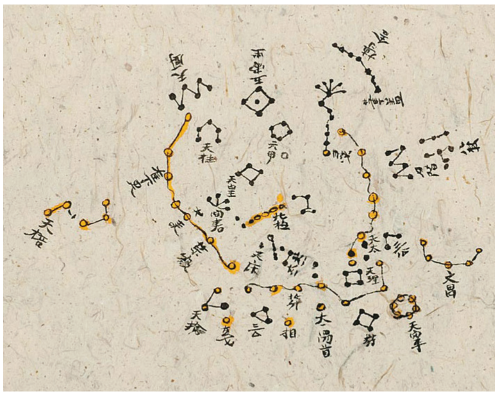


Figure 17.5 The Dunhuang Star Map from the Tang Dynasty in China (circa 700 AD) shows some of the constellations they observed.

Knowledge of these constellations were later passed on and added to by later civilisations such as the ancient Greeks, Romans and Arabs. Native Americans, Aboriginal Australians, Mayans, Aztecs, Polynesians and ancient Chinese and Japanese peoples took a keen interest in the stars and had their own constellations and stories about the stars.

Astronomy played an important role in religion at the time, and the dates of festivals and holy days were fixed by the alignment of the stars or the phase of the Moon. In fact, the ancient Egyptian and Mayan pyramids and temples were designed in such a way that the Sun, Moon, stars and planets would be visible from the top or through certain windows at important times of the year, such as solstices or equinoxes.

Did you know?

Some people believe that the builders of the ancient pyramids of Giza in Egypt placed them specifically to look the same from above as the three "belt stars" of the constellation Orion looked from Earth.

Figure 17.6 The three Great Pyramids of Giza.

Here in South Africa, early cultures also had their own constellations and stories which were passed down from generation to generation.

Early cultures used the stars for navigation. When travelling to new areas or over water they would have been unable to use familiar landmarks. When viewed from a particular location, a star always rises and sets in the same direction and follows the same path across the sky. We are familiar with this idea as the Sun is a star and we see it rise and set in the same direction every day. Early navigators learnt to use the directions of rising and setting stars to find their way.

Figure 17.7 Ancient manuscripts from Timbuktu in Mali in central Africa, documenting astronomical observations.

Take note

In a lunar calendar the time between one New Moon and the next is called a synodic month and it is 29,5 days.

Early cultures also used the observed changes in the sky for timekeeping. A day was marked by the time between one sunrise and the next, just as it is today. The Moon's regular phases made it a very convenient 'clock', and the time period between one New Moon and the next formed the basis of many of the oldest calendars.

The lunar cycle was useful because it was predictable in the same way as day and night. However, each Moon cycle was also connected to a slightly different season, with its own name and activities. Tally sticks made of bones with notches etched into them have been found dating as far back as 20 – 30 000 years ago, and are believed to mark the phases of the Moon. Today we use a **solar calendar**, a calendar in which a year is defined by the complete revolution of the Earth around the Sun, but some religious calendars still use a lunar calendar. Accurate timekeeping was particularly important for farming communities, because people needed to know when to plant their seeds and when to harvest their crops.

Figure 17.8 The Lebombo Bone was discovered in the Lebombo mountains between South Africa and Swaziland in the 1970s. It is a bone from a baboon used as a Tally Stick. It is roughly 35 000 years old. It is thought to have been used for tracking lunar cycles, because of the 29 marks on it.

The Pleiades, also called the Seven Sisters, form a bright cluster of stars. Traditional farming communities in South Africa used the Pleiades to help them plan their planting. Once the constellation was visible in the early morning in June they knew it was time to start planting their crops. The Khoikhoi call the Pleiades Khuseti or Khunuseh, meaning 'rain stars'. They are called Selemela in Sotho and Tswana, Shirimela in Tsonga, Tshilimela in Venda, and isiLimela in Xhosa and Zulu. In Xhosa the stars are called the 'digging stars'. In East Africa and Zanzibar the Pleiades are called Kilimia, which also means 'ploughing stars' or ' digging stars'. Not only were the Pleiades used in Africa to mark planting season; they were also used by the ancient Mayans in Mexico and Central America to mark the start of their rainy season.

Figure 17.9 The Pleiades or Seven Sisters star cluster. Although the constellation is known as the Seven Sisters, the star cluster actually contains hundreds of stars, although only about seven are easily visible to the human eye.

ACTIVITY The traditional and modern Xhosa calendars

In the Xhosa language, there are two ways of naming months, the modern and the traditional way. The modern names of the months are used in urban areas. However, in rural areas, in poetry, and particularly in the Eastern Cape, the old names are still used. Look at the following table which shows these names.

English	Modern Xhosa	Traditional Xhosa	Meaning of traditional name
January	uJanuwari	EyoMqungu	month of the Tambuki Grass
February	uFebhuwari	EyoMdumba	month of the swelling grain
March	uMatshi	EyoKwindla	month of the first fruits
April	uApreli	UTshazimpuzi	month of the withering pumpkins
May	uMeyi	UCanzibe	month of Canopus (Canopus is a star)
June	uJuni	Isilimela	month of the Pleiades
July	uJulayi	EyeKhala / EyeNtlaba	month of the aloes
August	uAgasti	EyeThupha	month of the buds
September	uSeptemba	EyoMsintsi	month of the coast coral tree
October	uOktobha	EyeDwarha	month of the lilypad
November	uNovemba	EyeNkanga	month of the small yellow daisies
December	uDisemba	EyoMnga	month of the mimosa thorn tree and Simba (the lion)

Questions

1. Do you see that the modern Xhosa names are derived from the English names? The traditional names for the months mostly come from the names of plants and flowers. Why do you think certain months are given specific plant or flower names?
2. Why do you think August is called EyeThupha, the month of the buds?
3. Why is June called Isilimela? Hint: Read the preceding text in your workbook.
4. What time of year does Isilimela correspond to? What does this signal to traditional farmers?
5. What month were you born in? Write down the traditional Xhosa name below.

Take note

You do not need to know the names of the months in Xhosa. This activity is for interest.

ACTIVITY Class discussion about different calendars.

The calendar we use is the Gregorian calendar and it is the most widely used around the world. It is also known as the 'Western calendar' or 'Christian calendar'. It was named after the man who first introduced it in February 1582: Pope Gregory XIII. The term 'New Year's Day' for 1 January was adopted in Western Europe in the Middle Ages. Before this, the Roman Julian calendar (named after Julius Caesar) was used.

The Islamic year begins on the first day of the month of Muharram. It is counted from the year of the Hegira (*Anno Hegirae*), when Muhammad emigrated from Mecca to Medina (16 July 622 AD).

The Jewish calendar represents the number of years since they believed the world was created. This is calculated by adding up the ages of people in the Bible. So when someone of Jewish beliefs says that the year is 5763, it means 5 763 years from the creation of Adam.

Instructions

1. Around the world, and within South Africa, there are different calendars which are in use. Do you think it would just be easier to have one calendar?
2. Discuss this as a class.
3. You could do this as a class debate with teams debating the pros and cons of the concept.

As well as their practical uses in timekeeping, stories surrounding the Sun, Moon and constellations have been passed down from generation to generation. These mythical stories are called star lore. For example, some believed that after sunset, the Sun travelled back to the east over the top of the sky, and that the stars are small holes which let the light through. Others said that the Sun is eaten each night by a crocodile and that it emerges from the crocodile each morning.

Did you know?

The Roman influence in the Gregorian calendar explains why the months of July (Julius) and August (Augustus) are named after Roman emperors.

Being the most prominent object in the night sky, the Moon also has many stories and legends associated with it. If you look closely at the Moon you can see that it has lighter and darker patches. The pattern formed by the light and dark patches had been interpreted differently by different cultures: some see a rabbit, others a buffalo, others a 'Man in the Moon'. One urban legend that some people still incorrectly believe is that the Full Moon is linked to insanity. There is no evidence to support the claims of increased birth rates, admissions to psychiatric hospitals, traffic accidents, homicides or suicides during a Full Moon.

The Khoikhoi called the Moon 'kham', or 'khab' meaning 'the Returner'. The Khoikhoi also considered the Moon to be 'the Lord of Light and Life' and would sing and dance at times of New and Full Moon. In /Xam San star lore, there is the following story:

> The Moon is a man who has made the Sun angry. The Sun's sharp light cuts off pieces of the Moon until almost the whole of the Moon is gone, leaving only one small piece. The Moon then pleads for mercy and the Sun lets him go. From this small piece, the Moon gradually grows again until it becomes a Full Moon.

What do you think the San were observing which they explained with this story?

The Xhosa considered the time of New Moon to be a time of inaction. When it reappeared as a crescent in the evening sky, it was cause for celebration. Important events were scheduled to take place around the time of Full Moon.

The Milky Way is also a prominent feature of the South African night time sky visible away from cities. Ancient peoples in South Africa described the Milky Way as a footpath across the sky, along which the ancestor spirits walked. In San starlore, the Milky Way was created by a girl who scooped up a handful of ashes from a fire and flung them into the sky. This made a glowing path along which people could see the route to return home at night.

Did you know?

'Lunacy' and 'lunatic' are derived from the Latin name for the Moon, 'Luna'.

Take note

We will learn more about our galaxy, the Milky Way, and other galaxies, next year in Grade 8.

Figure 17.10 The Milky Way seen from Sutherland, Northern Cape, by Janus Brink (SAAO/SALT).

Meteors (also called shooting stars) and comets also feature heavily in starlore around the world. In most cultures meteors and comets were regarded as signs of important events. In Tswana star lore, a very bright meteor is an indication of a good season ahead. However, the .Xu San saw a meteor as an evil spirit racing across the sky to cause mischief among people. The /Xam San, thought that a meteor announced the death of one of them. In Xhosa star lore, a comet, Uzatshoba, is associated with bad luck, wars and death. There was also a strong belief that comets predicted the death of a chief. The Sothos called comets 'naledi tsha mesela', and the Zulus called them 'inkanyezi enomsile', which means 'stars with tails'.

ACTIVITY Create your own legend

Materials

- pictures of famous constellations for inspiration

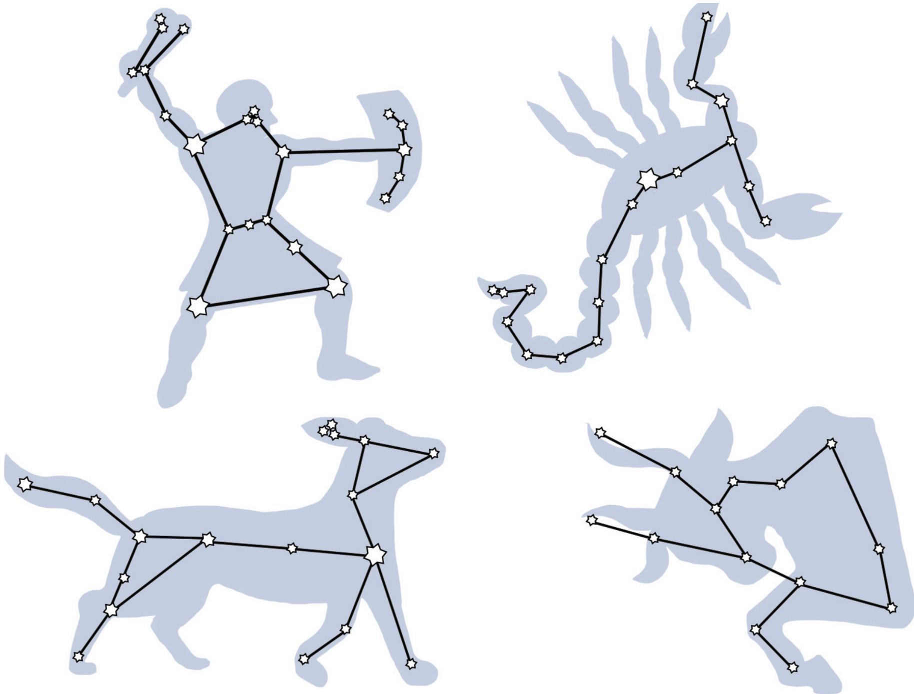


Figure 17.11 Some examples of constellations in the sky.

Instructions

1. Make up your own pattern of stars and draw them in your exercise book.
2. Make up a legend (story) to go along with your new constellation.

17.2 Modern developments

The earliest astronomers had no sophisticated observatories. They studied the stars and planets using just their eyes. This is called 'naked eye' observing. The South American Mayans, ancient Egyptians and ancient Chinese built some of the first observatories. These are special buildings used for studying the stars. These ancient **observatories** had no telescopes inside.

Nowadays modern observatories contain large telescopes with extremely sensitive cameras and instruments mounted on the telescopes. Astronomers use computers to move the telescopes and operate the instruments. As technology has progressed, we have been able to see a lot more and have learnt a lot more about the Universe.

South Africa currently has the largest optical **telescope** in the Southern Hemisphere, the Southern African Large Telescope (SALT). SALT is located just outside Sutherland in the Karoo where the skies are clear and very dark. SALT's main mirror is a hexagonal shape measuring 11 × 9 metres across, and is made up of 91 individual smaller mirrors, which are slotted together. Its mirror is as large so as it can be it can collect a lot of light from very faint and distant objects. SALT is used to study a variety of objects including asteroids, stars and galaxies.

Figure 17.11 Chichen-Itza observatory in Mexico. This ancient observatory was used by the Mayans, although it had no telescope inside.

Figure 17.12 The Southern African Large Telescope (SALT).

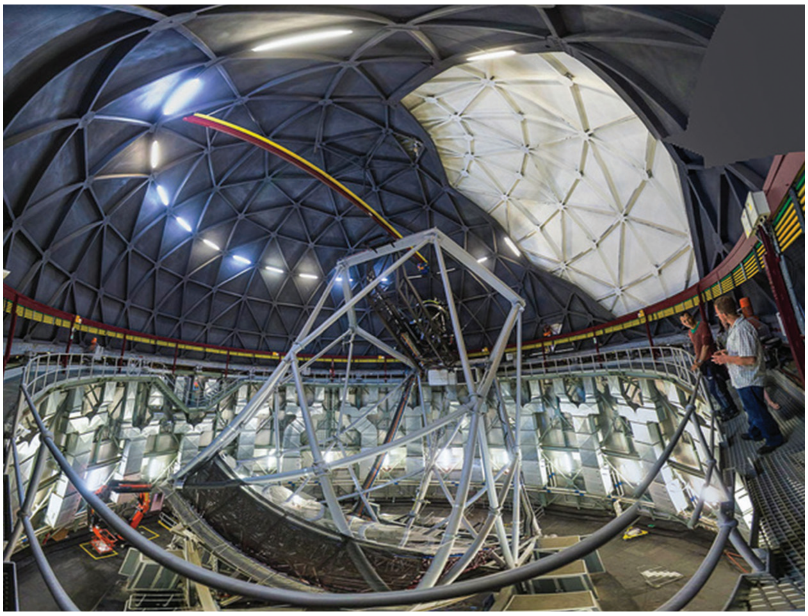


Figure 17.13 SALT's huge mirror collects light from faint distant objects.

South Africa will also be hosting part of the Square Kilometre Array (SKA), the world's largest radio telescope, scheduled to be completed in 2024. The SKA will be located in the Karoo near the town of Carnarvon, far away from big towns and cities where there is little radio interference. When complete, the telescope array will be 50 times more sensitive than any other radio telescope to date. The array will contain 3 000 radio dishes as well as other types of radio detectors.

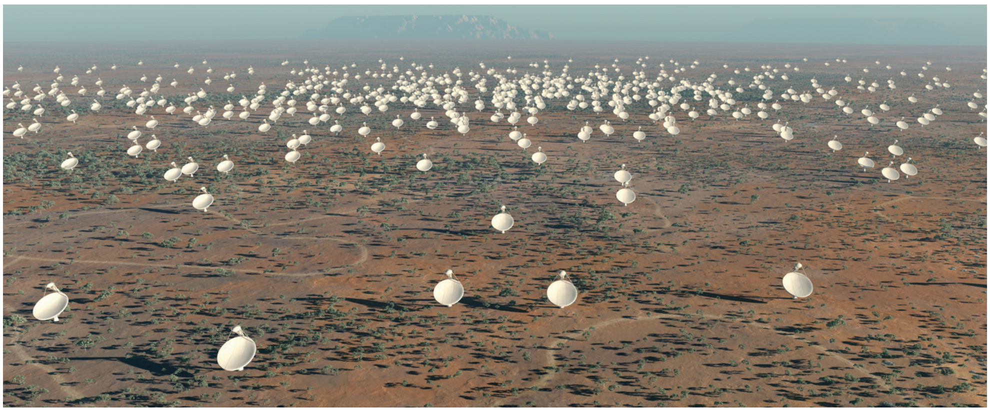


Figure 17.14 What the SKA will look like in the Karoo.

Astronomers plan to use the giant telescope to test the laws of gravity using black holes. They will also peer at some of the most distant clouds of gas in the Universe, which formed before the first stars. Astronomers will also study how galaxies form, and change over time, and perhaps also detect life elsewhere in the Universe.

We still have so much to learn about our Universe. We understand only about 5% of the content of our Universe presently. SALT and SKA will help us understand far more about our Universe, so much is still to be discovered.

Let's look at some of the highlights in our journey of scientific discovery so far.

Take note

An array means a large number of the same items. For example, when the desks in your classroom are all lined up neatly, we can call that an array of desks.

The discovery that the Sun is at the centre of the solar system and not the Earth

Early astronomers such as the ancient Greeks believed that the Earth was at the centre of the Universe, with the stars and planets orbiting around the Earth.

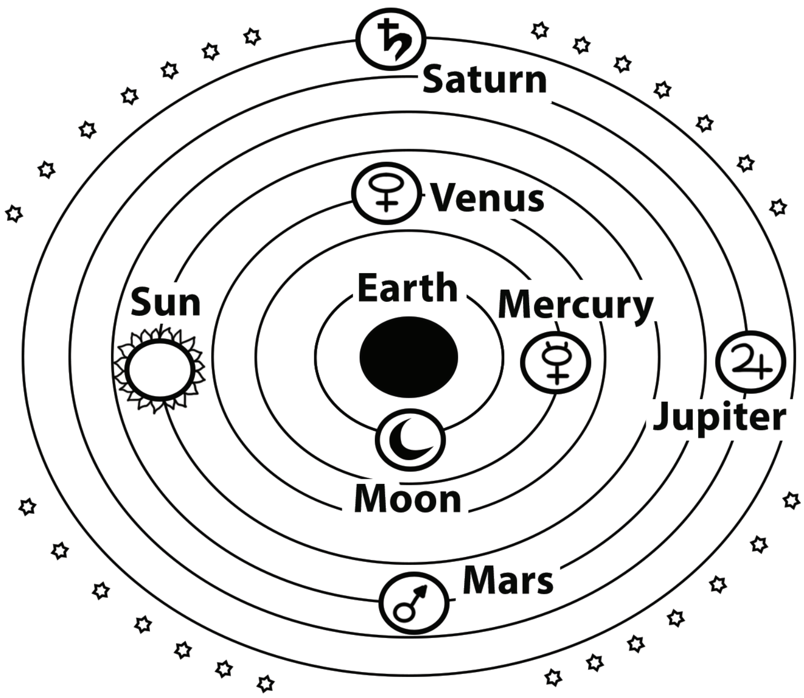


Figure 17.15 The ancient Greeks thought that the Earth was at the centre of the universe and believed that the planets, Sun and background stars all orbited around the Earth.

Take note

Motion towards the east is called direct or **prograde** motion. Backwards motion is called **retrograde** motion.

By carefully watching the motions of the planets in the sky, the Greeks saw that most of the time the planets travelled west to east across the sky relative to the background stars. However, they occasionally reversed their direction and moved backwards, from east to west relative to the background stars. The ancient Greeks' ideas about the Earth-centred Universe worked when the planets were travelling in the same direction as the background stars, but could not account for their retrograde (backwards) motion.

In 1543, Nicolaus Copernicus, a Polish mathematician and astronomer, published his book called *De revolutionibus orbium coelestium*, or in English, *On the Revolutions of the Celestial Spheres*. In it he correctly deduced that the Sun, rather than the Earth, was at the centre of the Solar system. He based his deductions on many of his own and other people's observations.

Copernicus correctly ordered all the planets known at the time in increasing distance from the Sun. In his model, all the orbits of the planets were circular, so in this way, it was similar to the model of the ancient Greeks. But how did Copernicus's new deduction solve the problem of Mars's backwards motion?

Let's do an activity to find out.

ACTIVITY Explaining the motions of Mars

Materials

- pencil/pen
- ruler

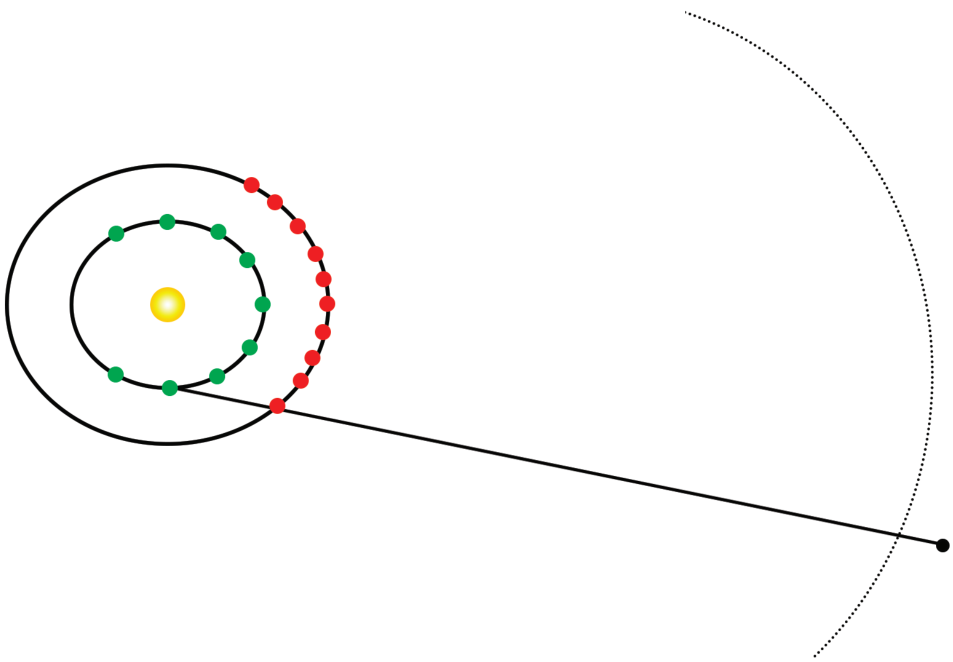


Figure 17.16 Note that the inner orbit is that of Earth (green) and the outer is that of Mars (red). The dashed line indicate the background stars.

Instructions

1. Draw a line from each Earth position through the Mars position for the same month. Extend the line approximately 1 cm past the dashed curve on the right which represents the background stars.
2. Place a dot at the end of the line and label the dots in order. If a new line crosses one already drawn, draw the new line slightly longer and place the dot slightly farther away than you did for the other lines. The line for January is already drawn as an example. The dots represent the positions where an observer on Earth would see Mars for the month indicated on the diagram.
3. Start with the dot number 1, and carefully connect the dots in order. This connecting line represents the path Mars appears to follow on the sky as viewed from Earth.
4. Answer the questions below.

Questions

1. How does Mars move around the Sun between January and August?
2. To an observer on Earth, what movement does Mars appear to experience during that time period?
3. During which months does Mars appear to be moving backward in its orbit?
4. Carefully observe what is happening to Earth and Mars in their orbits when Mars seems to loop 'backward'. What causes Mars to seem to move backward in its orbit?

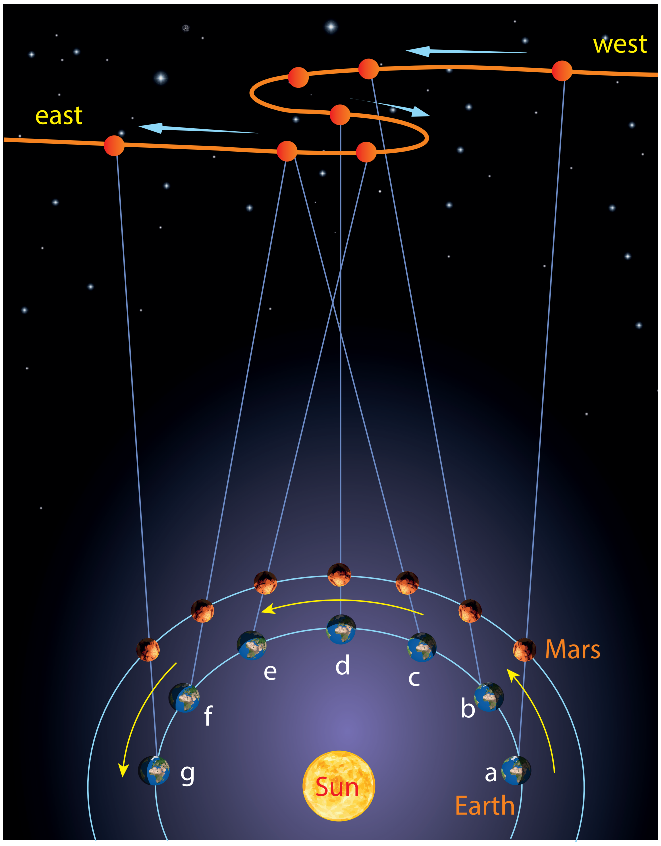


Figure 17.17 The Earth moves faster than Mars in its orbit and catches up with Mars at point (b) before overtaking Mars at point (d). As the Earth overtakes Mars, Mars appears to travel backwards on the sky, even though Mars is not really changing direction in space.

Did you know?

The idea of a Sun-centred solar system was proposed as early as about 200 BC. by Aristarchus of Samos (Samos is an island off the coast of Turkey). However, the idea did not survive long because the famous Greek Aristotle did not believe in a Sun-centred solar system.

How can objects appear to move backwards when they are not really moving backwards? Let's do a test right now. Hold your arm outstretched in front of you and hold up your first finger. Cover or close your left eye and note where your finger appears against the background. Now cover or close your right eye instead. What do you notice about the position of where your finger appears? It moved to the right didn't it? But did you really move your finger? No, it just appeared to move because of your change in perspective.

Figure 17.18 Johannes Kepler.

The discovery that the planets' orbits are elliptical

Johannes Kepler was a German astronomer and mathematician. He spent ten years trying to explain the motion of Mars across the sky in detail. He could only get his model of the solar system to fit the observations of the planets' motions if he assumed that rather than moving in a circle around the Sun, the planets all orbited in ellipses (ovals). He discovered that the true shape of the planets' orbits is elliptical.

The Earth travels faster in its elliptical orbit when it is closer to the Sun than when it is farther away. This is because the gravitational force of attraction between the Earth and Sun is stronger when the Earth is closer to the Sun. This is true of the orbits of all planets around the Sun.

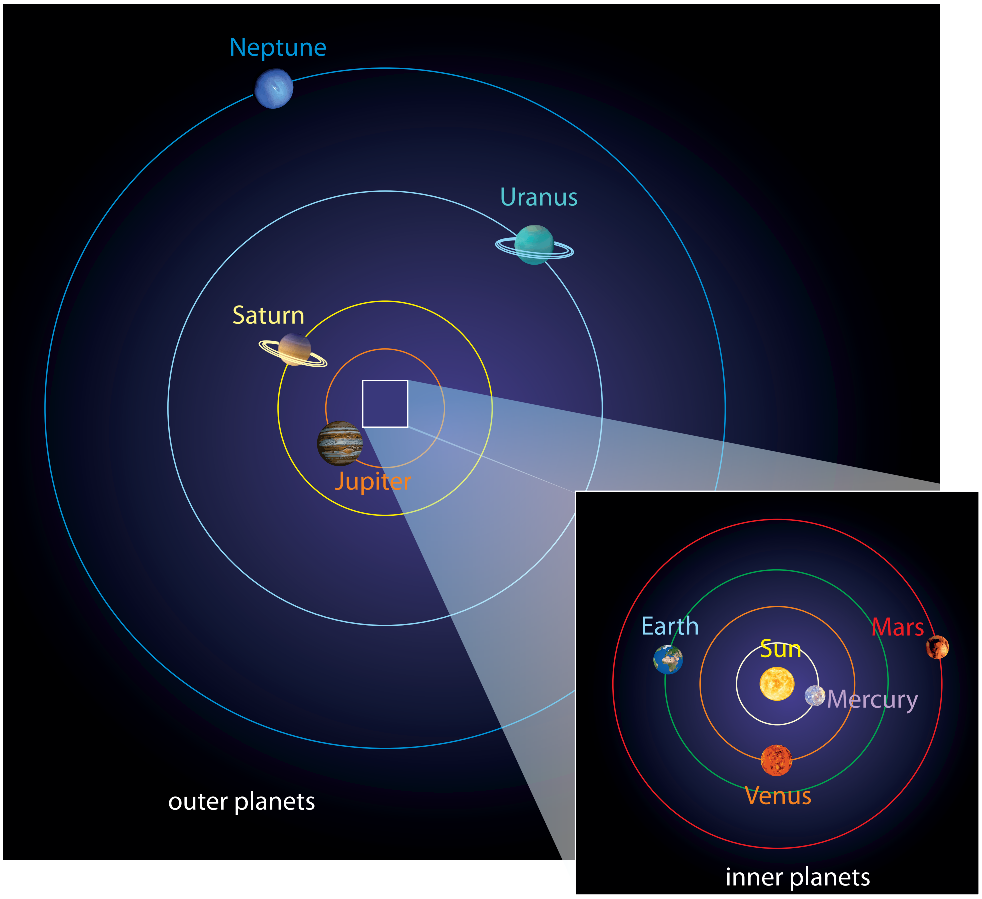


Figure 17.19 The Earth and the other planets in our solar system orbit around the Sun in an ellipse.

Galileo's discoveries using his telescope

Galileo Galilei was an Italian physicist, mathematician and astronomer. He built his first telescope in 1609 and was the first astronomer to use a telescope. In 1610 he published a book called the *Sidereal Messenger*, listing the discoveries he had made using his telescope.

Figure 17.20 Galileo displaying his telescope.

Galileo discovered the four largest moons of Jupiter (which are now called the Galilean moons). Over several nights he watched them move and realised that they were actually orbiting around Jupiter.

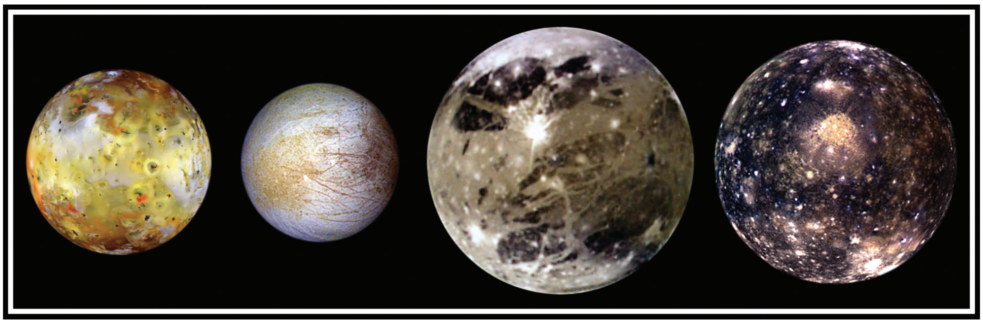


Figure 17.21 The four largest moons of Jupiter, left to right in increasing distance from Jupiter: Io, Europa, Ganymede and Callisto.

He also found that Venus has phases just like the Moon (and just like all planets). He discovered that the Moon has craters and that the Sun has dark spots which are called sunspots. These imperfections on the Moon and Sun discredited the belief held by the Catholic Church at the time that the heavens were perfect and unchanging.

The Catholic Church allowed Galileo to conduct his research, as long as he did not openly publicise his findings. In 1632 Galileo angered the head of the Catholic Church (the Pope) when he published a book in which he stated that the Earth was moving around the Sun. He was put on trial and found guilty of heresy. He was first imprisoned and later placed under house arrest.

Take note

Although Galileo wasn't appreciated during his lifetime, his experimental and mathematical approach to physics was revolutionary and way ahead of his time.

Take note

Heresy is having a belief or opinion that is against the official teachings of the church at the time.

Figure 17.22 Sir Isaac Newton aged 46.

Newton discovers gravity

Isaac Newton was an English physicist and mathematician and is considered one of the greatest scientists of all time. He derived mathematical laws to describe the motions of objects but his greatest discovery was that of the force of gravity. In 1687 he published a book called *Philosophae Naturalis Principia Mathematica*, or in English: *Mathematical Principles of Natural Philosophy*, in which he explained his ideas about the motions of objects and gravity.

There is a famous story which says that Newton was sitting under an apple tree when an apple fell on his head and he began to think about gravity and falling objects. The apple didn't really land on his head, but he did watch an apple fall and began to wonder why apples always fall down. He suggested that it was the force of gravity that caused apples to fall.

Amazingly, he made the mental leap from Earth to space and realised that it was the force of gravity that was holding the Moon in its orbit around the Earth. According to Newton, gravity is the reason that objects fall to the ground when dropped and why planets orbit the Sun and why moons orbit planets. Up until Newton no one had been able to explain what held the Moon and the planets up in their orbits.

ACTIVITY Interview with a revolutionary

Materials

- reference materials about famous historical astronomers.

Instructions

1. Work in pairs in this activity. One of you will play the role of an early famous astronomer and the other will play the role of a journalist.
2. Astronomer: Pick which famous astronomer you are going to be and answer the questions your partner asks you.
3. Journalist: Ask the 'astronomer' what they have discovered and why their discoveries are important.

Did you know?

Quotes from Sir Isaac Newton: *'I can calculate the motions of the heavenly bodies, but not the madness of people.'*

Modern day discoveries

Scientists are continually making new discoveries, and with every new discovery comes a new question.

ACTIVITY Research a new discovery, invention or scientist.

Instructions

1. Research either a recent discovery made in astronomy, or an invention used in astronomy, or about a famous astronomer.
2. You can choose to write about one of the examples provided in the text below, or you can choose your own example.
3. Your teacher will inform you how you must present your work.

Some example discoveries: See Visit boxes in margin.

Exoplanets: An exoplanet is a planet orbiting around a star other than our own Sun. The first exoplanet was discovered in 1992, when several planets were found orbiting around a small, rapidly spinning star. By June 2013, 890 exoplanets had been discovered, and more and more are being found all the time.

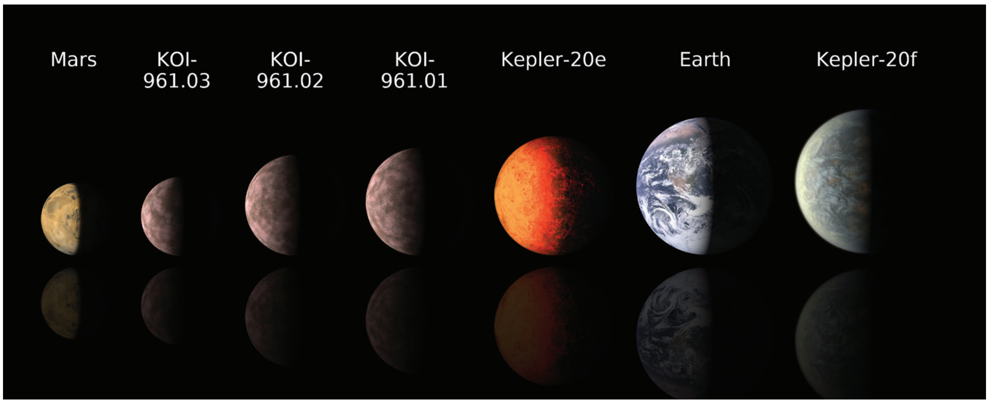


Figure 17.23 This image compares the smallest known exoplanets orbiting outside the solar system, to our own planets Mars and Earth.

Black holes: Black holes are super-dense regions in space which have very strong gravity, so strong that not even light can escape from them. Although you cannot see a black hole directly, astronomers know they exist because of their pull on objects close to them. If you were to fall into a black hole feet first, you would be pulled apart like a piece of spaghetti.

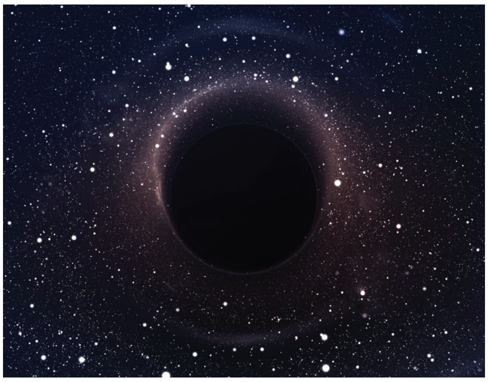


Figure 17.24 An artist's drawing concept. On the left, the yellow, sun-like star comes too close to the black hole, and is stretched (middle yellow blob), until it is ripped apart. Some of the remains of the star swirl into the black hole (blue-white cloudy ring on the right). A black hole in the universe.

The Expansion of the Universe: In 1929, astronomer Edwin Hubble made the astonishing discovery that our universe is expanding. Looking at galaxies outside our Milky Way galaxy, he found that all the galaxies he looked at were moving away from the Earth, and that the most distant ones were moving away fastest. This implies that every galaxy is moving away from every other galaxy. In fact, the space between galaxies is itself expanding.

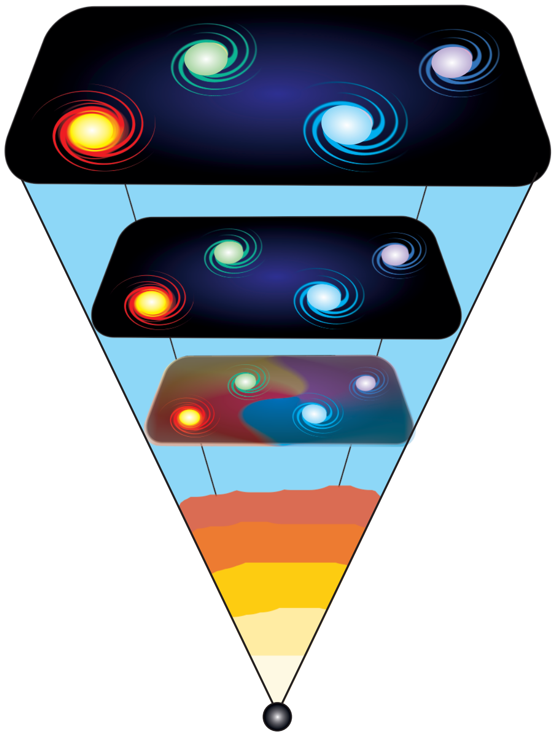
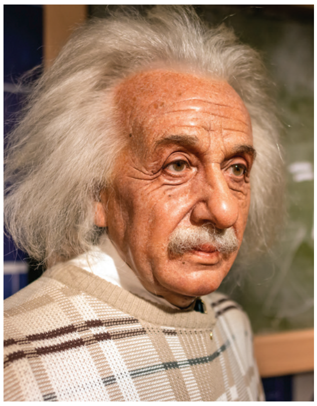


Figure 17.25 As the Universe expands, galaxies move further and further apart.

ACTIVITY Modern-day astronomers and physicists

Instructions

Look at the photographs below and match the face to the description of the person.



Descriptions:

Stephen Hawking, a famous British physicist diagnosed with ALS, a form of Motor Neuron Disease, shortly after his 21st birthday. He is famous for his work on black holes.

Cecilia Payne-Gaposchkin, the astronomer responsible for discovering that stars are made up mostly of hydrogen and helium.

Albert Einstein, a German physicist famous for his work on gravity and the nature of space and time.

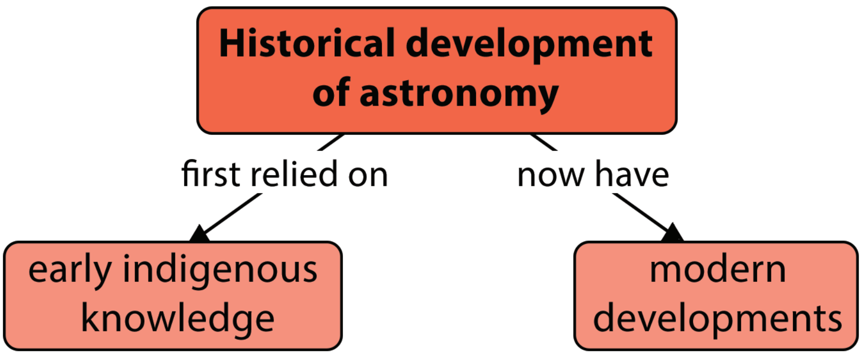
Summary

Key concept

- People have watched the stars for thousands of years. They have created stories about the stars and constellations which have been passed on from generation to generation.
- Early scientists believed that the Earth was at the centre of the solar system.
- Copernicus found that the observations of planetary motion could be more easily explained if the Sun were at the centre of the solar system.
- Galileo was the first astronomer who used a telescope and found that Jupiter had moons orbiting around it.
- Newton discovered gravity and explained that planets and moons are held in orbit by the force of gravity.
- New discoveries are continuously made using modern telescopes.

Concept map

Throughout this year we have been looking at how to produce concept maps after each unit. This is now your chance to make your own concept map. The concepts in this unit about the development of astronomy can easily be divided into two main themes: firstly, about 'early indigenous knowledge', and then about the 'modern developments' that people have made and are still making. The concept map has been started for you. Copy this into your notebook to first practice drawing your concept map. With the help of your teacher, complete your concept map, which will summarise this chapter.



Revision

1. What motions could the ancient Greek model of the solar system not explain? [2]
2. How did Copernicus's model of the solar system differ from the ancient Greek model of the solar system, and how was it similar? [2]
3. Explain in your own words why Mars sometimes appears to move backwards relative to the motion of the background stars. [3]
4. List two different discoveries that Galileo made using his telescope. [2]
5. Do planets travel around the Sun in circles or ellipses? [1]
6. How does the speed of a planet vary as it travels around the Sun? [2]
7. What practical uses for the stars were used by early cultures? [2]
8. How did early San people explain the Milky Way? [2]
9. Do the phases of the Moon have an effect on human behaviour? [1]

Total [17 marks]

Glossary 4

acceleration due to gravity the acceleration given to an object by the attractive gravitational force of the Earth or other celestial body
axis a real or imaginary straight line about which something turns; the imaginary axis of the Earth passes through the North and South Pole

cellulose a carbohydrate which plants use to form leaves and stems
coal brown or black rock that can be ignited and burned, and which consists of carbonised plant matter
constellation a group of stars that when viewed from Earth form a pattern in the sky
crude oil a dark oil found in rock formations deep underground, used as fuel

day the length of time it takes for a planet to spin once on its axis
decompose to break down or decay
direct the shortest way

eclipse the blocking of light coming from a celestial object, for example, a solar eclipse or a lunar eclipse
ecosystem a community of living organisms and their interaction with the environment
equator an imaginary horizontal line around the middle of the Earth, at an equal distance from the North Pole and the South Pole
equinox occurs twice a year (around 22 March and 22 September) when the Sun's rays fall directly on the Earth's equator

fossil fuels a natural fuel such as coal, oil or natural gas, formed in the geological past from the remains of living organisms

glucose a carbohydrate produce by most plants, which is energy rich
gravitational force the force that attracts an object with mass towards another object with mass
gravity the force that attracts a body towards the centre of the Earth or towards any other celestial body having mass

hemisphere one half of a sphere or globe; the Earth is divided at the equator into the Northern and Southern hemispheres
indirect not direct, by a longer way

intensity the concentration or amount of something
intertidal zone an area that is above water at low tide and under water at high tide (it lies between low- and high-tide levels)

lunar calendar a calendar based on lunar cycles (phases of the Moon)
lunar related to the Moon, for example, lunar surface (Moon's surface), lunar day (the Moon's day)

mass the quantity of matter an object contains
moon a body that orbits around a planet, or a small body such as an asteroid (not a star)

natural gas a flammable gas, consisting largely of methane, occurring naturally underground and used as fuel
neap tides tides with the minimum difference between low and high tides which occur when the Moon and Sun are at right angles to each other
non-renewable something of which there is a limited supply, or which can only be used once

oblique at an angle other than 90 degrees, slanting inward
observatory a room or building housing a telescope or other scientific equipment for observations and research, especially of objects in space.
orbit the path followed by a planet , moon, or other object in space as it travels around another object; the path of the Earth around the Sun is an orbit

photosynthesis the process whereby green plants use sunlight (energy), water and carbon dioxide to produce glucose, which is food for the plant; oxygen is released during this process

prograde direct or forward motion (proceeding from west to east across the sky)

renewable something of which there is an unlimited supply found in nature, or which can be reused

retrograde reversed motion (proceeding from east to west across the sky)

revolution the orbit of Earth (or other object or planet) around the Sun

rotation the spinning of the Earth (or other object or planet) on its axis

season each of the four divisions of the year (spring, summer, autumn and winter) which have different weather patterns and daylight hours

solar calendar a calendar whose dates indicate the position of the Earth in its orbit around the Sun

solar energy energy from the Sun's light and heat

solstice occurs twice in a year (around 21 June and 21 December), when the Sun's rays strike the Tropic of Capricorn (southern summer solstice) or the Tropic of Cancer (northern summer solstice) directly

sphere any round object that has a surface that is the same distance from its centre at all points, for example, a ball or globe

spring tides extreme tides with the maximum difference between low and high tides which occur when the Earth, Moon and Sun are in alignment

star lore mythical stories about the stars, planets and constellations

starch a carbohydrate consisting of a large number of glucose units

telescope an instrument designed to make distant objects appear nearer and magnified

tidal bulge a swell in the sea level in line with the Moon on either side of the Earth (along the Earth-Moon line)

tides the regular rise and fall of the oceans (and some rivers and lakes) twice a day, caused by the gravitational attraction of the Moon and, to a lesser extent, the Sun

tilt to slant or tip

vegetation the general word used for plants growing in an area or region

weight the force exerted on a mass due to gravity