PEARSON science

S.B.

2ND EDITION

AUSTRALIAN CURRICULUM

Pearson Australia
(a division of Pearson Australia Group Pty Ltd)
707 Collins Street, Melbourne, Victoria 3008
PO Box 23360, Melbourne, Victoria 8012
www.pearson.com.au

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First published 2016 by Pearson Australia
2021 2020 2019 2018 2017
10 9 8 7 6 5 4 3 2 1

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Publisher: Alicia Brown
Development Editors: Zoe Hamilton, Antonietta Anello
Project Manager: Shelly Wang
Production Manager: Elizabeth Gosman
Editor: Kay Waters, Aptara
Proof Reader: Marcia Bascombe
Designer: Anne Donald
Rights and Permissions Editors: Samantha Russell-Tulip and Amirah Fatin
Desktop Operators: Lauren Statham, Ben Galpin, Aptara
Illustrator: DiacriTech
Printed in China

National Library of Australia Cataloguing-in-Publication entry (paperback)
Creator: Rickard, Greg, author.
Title: Pearson science SB8 / Greg Rickard [and thirteen others]
Edition: 2nd Edition.
ISBN: 9781488656897 (paperback)
Series: Pearson science SB; 8.
Notes: Includes index.
Target Audience: For secondary school age.
Subjects: Science—Study and teaching (Secondary)
Science—Textbooks.
Dewey Number: 500

Pearson Australia Group Pty Ltd ABN 40 004 245 943

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PEARSON Australian Curriculum
Writing and Development Team

Anna Bennett
Differentiation Consultant, Victoria

Ian Bentley
Former Head of Science, VCAA exam and trial exam writer, STEM investigation developer
Victoria

Christina Bliss
Science and senior Biology Teacher, VCE assessor Biology
Author and question writer, Victoria

Donna Chapman
Science Laboratory Technician
Safety consultant, Victoria

Dr Warrick Clarke
Curriculum Writer, Science Communicator and Australian Post-Doctoral Research Fellow at UNSW.
Author, New South Wales

Jacinta Devlin
Science and senior Physics Teacher
Coordinating Author, Victoria

Julia Ferguson
Education Officer,
Earth Science Western Australia
Author and reviewer, Western Australia

Bob Hoogendoorn
Exam-style question writer
VCAA chemistry exam assessor, Victoria

Penny Lee
Science Laboratory Technician
Safety consultant, Victoria

Louise Lennard
Head of Science
Author and STEM investigation developer, Victoria

Greg Linstead
Former Head of Science, Deputy Chief Examiner, STAWA President
Author, Western Australia

Bryony Lowe
Director of Numeracy Improvement. Former Head of Science and Region Teaching & Learning Coach
Author and reviewer, Victoria

David Madden
Science Learning Area Manager at QCAA, Former Head of Science,
Author and reviewer, Queensland

Fran Maher
Bioscience educator, Science teacher, Formerly a bioscience researcher
Author, Victoria

Rochelle Manners
Science and mathematics teacher. Co-ordinating author Teacher Companion, Queensland

Shirley Melissas
Teacher Librarian and Author Development Editor, Victoria

Tamsin Moore
Science and senior Psychology teacher
Author, Western Australia

Natalie Nejad
Head of Science, Science and mathematics teacher
STEM investigation developer
Victoria

Malcolm Parsons
Education consultant, former teacher
Author, Victoria

Greg Rickard
Teacher, Former Head of Science
Coordinating Author, Victoria

Lana Salfinger
Teacher, Head of Science, IB Workshop leader in MYP Sciences
Author, Western Australia

Maggie Spenceley
Former Teacher, Curriculum Writer Queensland Studies Authority
Author, Queensland

Jim Sturgiss
Teacher, Former Coordinating analyst (NSW Department of Education) reporting NAPLAN, Senior test designer for Essential Secondary Science Assessment (ESSA)
Author, Thinking Scientifically questions, New South Wales

Craig Tilley
STAV Trial Exam Coordinator, VCAA Exam Assessor.
Author and exam-style question writer, Victoria

Jo Watkins
Chief Executive Officer,
Earth Science Western Australia
Author and reviewer, Western Australia

Dr Trish Weekes
Science Literacy Consultant,
New South Wales

Rebecca Wood
Science educator and tutor
Author, Victoria

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Key	
	Science inquiry skills
	Biological sciences
	Chemical sciences
	Physical sciences
	Earth and space sciences

How to use this book • STUDENT BOOK

Pearson Science 2nd edition has been updated to fully address all strands of the new **Australian Curriculum: Science** which has been adopted throughout the nation. Since some states have tailored the Australian Curriculum slightly for their own particular students, the coverage of the new **Victorian Curriculum: Science** is also captured in this new edition. We address inclusion by clearly indicating the additional content which enables flexibility to determine the approach, as well as the added bonus of an option to engage with **extension** and **revision** opportunities.

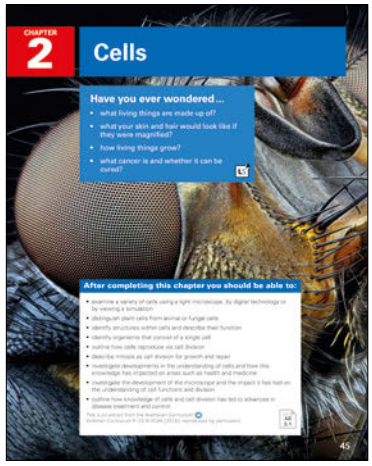
All aspects of the student books have been thoroughly reviewed by our **Literacy Consultant Dr Trish Weekes** and the result is **more accessible** content, **enhanced scaffolding** and **strengthened question and instructions sets**. The design is updated to improve the readability and navigation of the text.

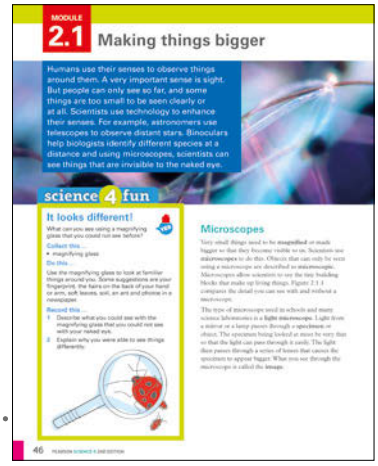
In this edition, we retain a flexible approach to teaching and learning. A careful mix of **inquiry**, **STEM** and a range of **practical investigations**, along with **fully updated** content reflect the dynamic and ever-changing nature of scientific knowledge and developments. Combined with the improved and enhanced sets of questions, this series provides a rich assortment of choice, supporting a **differentiated approach**.

An integrated and research-based approach to science education, which ensures every student has engaging, supportive and challenging opportunities.

Be set

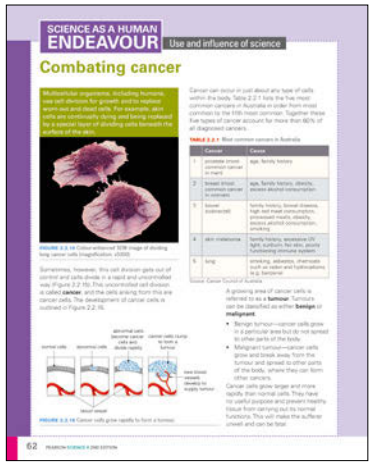
The **Chapter opening page** sets a context for the chapter, engaging students through questions that get them thinking about the content and concepts to come. The chapter learning outcomes are provided in student friendly language and give transparency and direction for the chapter. Each chapter is divided into self-contained modules. The **module opening page** includes an introduction that places the material to come in a meaningful context.

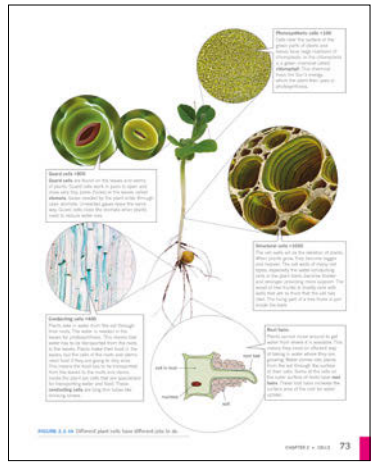




Be interested

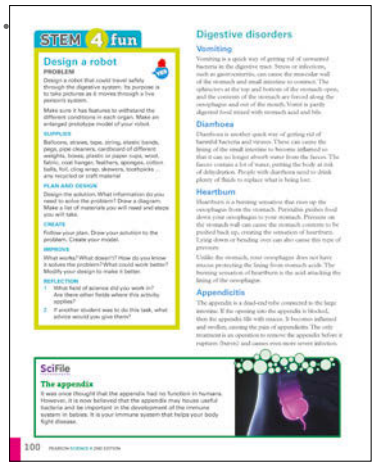
Stunning and relevant **photos and illustrations** are purposefully selected to build understanding of the text. Students know when and how they should engage with artwork as each image is clearly referenced from within the text to develop understanding. Captions for every artwork, along with labels for more difficult images, build further meaning and understanding.





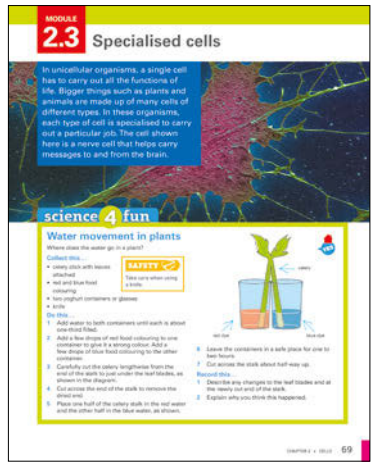
Be inventive

The **STEM4fun** activities are simple STEM-based applications. Students are given an open-ended problem and asked to create, design or improve something. These problems require students to draw on their acquired knowledge and skills, but are more about the process than the actual solution.



Be inquiring

Science4fun are inquiry based activities. They pre-empt the theory and get students to engage with the concepts through a simple activity that sets students up to 'discover' the science before they learn about it. Broadly speaking, they encourage students to think about what happens in the world and how science explains this.



Be inspired

Working with science career profiles cast a spotlight on the diversity of career opportunities available through science with a focus on future science directions, STEM and women in science. Profiles include questions that to relate to the topic.

Be amazed

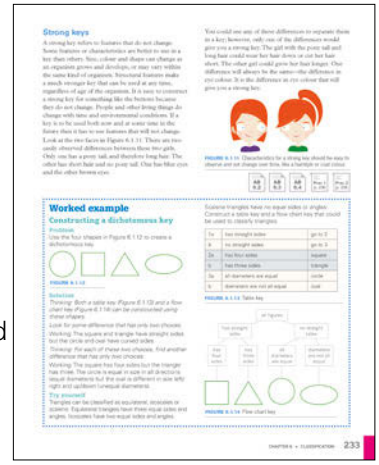
The **Science as a human endeavour** strand is addressed throughout the modules as well as in spreads. Many of the spreads have a special focus on Australian Scientists and highlight exciting developments, innovations and discoveries across all science fields. This feature also includes questions to help students build connections with the content they are learning and the relevance of these contributions.

Be skilled

Skill builders outline a method or technique and are instructive and self-contained. They step students through the skill to support science application.

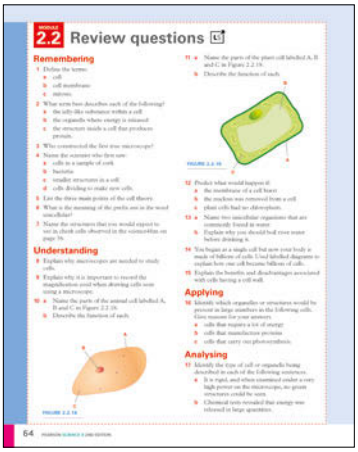
Be guided

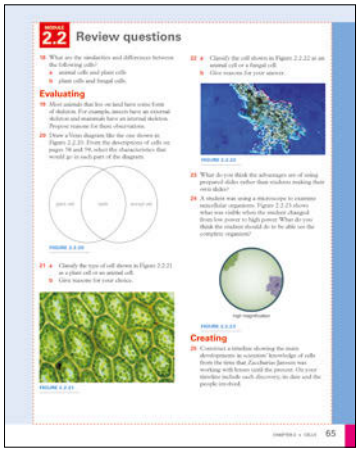
Worked examples scaffold problems and techniques with a new thinking and working approach to guide students through solving problems and applying techniques to master and practice key skills.



Be confident

Each module concludes with a comprehensive **module review** set that checks for understanding of key concepts and ideas developed through a carefully prepared range of Blooms categorised questions. Students enjoy the benefit of checkpoint opportunities to engage with module review questions at key points throughout the module.

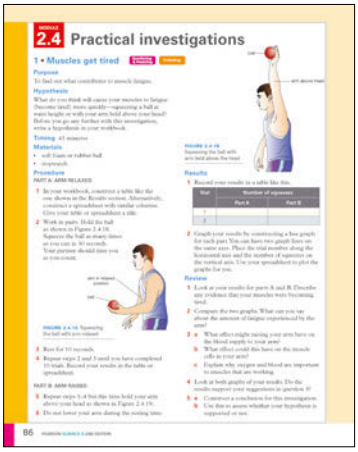




Be investigative

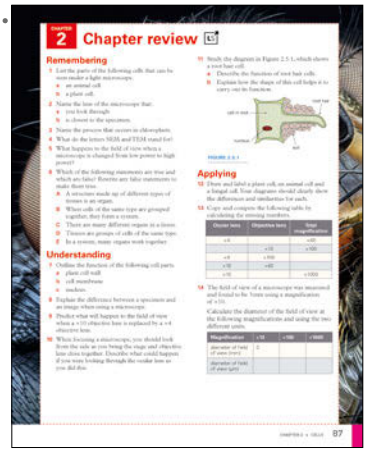
Practical investigations are placed at the end of each module. New Student Designed Investigations and STEM inquiry tasks provide students with opportunities to plan investigations, design and trial their plans to seek answers and solve problems. A timing suggestion assists with planning, whilst safety boxes highlight significant hazards. Full risk assessments, safety notes and technician's checklist and recipes provided via ProductLink and eBooks.

Practical investigation icons appear throughout the modules to indicate suggested times for practical work. An icon will also appear to indicate where a SPARKlab alternative is available.



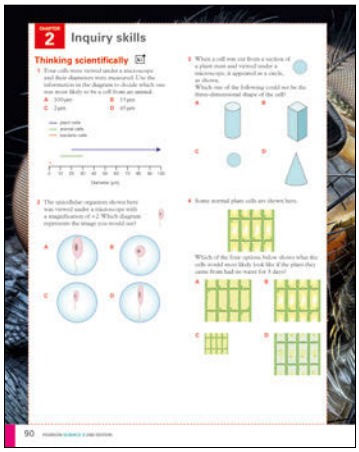
Be extended

Each chapter concludes with an improved and richer assortment of questions organised within the Blooms structure, that bring together the learning of concepts from across a chapter. Apply knowledge and skills to answer questions, engage in fresh new opportunities for **inquiry** and extend into **research** to take your learning to a new level with the enhanced **Chapter review**.



Be a thinker

Following the chapter review are **thinking questions** relevant to the chapter. These test students' science and interpretive skills.



Be supported

Every chapter concludes with an illustrated **glossary** that is an easy reference for additional support in comprehension of key terms. All key terms are bolded throughout the chapter.

Be reinforced

The **Activity Book** provides a set of worksheets for every student book chapter, giving lots of opportunities for practice, application and extension. Reference **Activity Book icons** indicate when the best time is to engage with a particular worksheet.

AB 4.2

Be progressed

LS

Lightbook Starter contains **complementary sets of questions** for the module and chapter review sets from within the **student book**. This serves as alternate or additional assessment opportunities for students who enjoy the benefit of **instant feedback**, **hints** and **auto-correction** when engaging with this cutting-edge digital **formative** and **summative assessment** platform. Questions are all **tracked** against curriculum learning outcomes, making **progress** monitoring simple. A handy icon indicates the best time to engage with Lightbook Starter.

Be prepared

Focussed on supporting the greater **diversity of learners and pathways**, a 'step up' program has been developed to launch students into senior sciences, in addition to the 'core' science program. A series of **step up chapters**, written by experienced senior science teachers, have been developed with the view to providing all students with best chance of success.

The **Year 9 Student Book** features a step up chapter on **Psychology**. The **Year 10 Student Book** includes step up chapters for **Biology**, **Chemistry** and **Physics**. These chapters are referenced from the print text and are provided in full via the **eBook**. The eBook also contains **worksheets** specific to supporting the application and development of skills and knowledge from within the text.

All Year 10 Student book chapters include a new series of **Exam-style questions** to provide students practice and exposure in preparation for examinations.

SERIES COMPONENTS

Pearson Science 2nd edition Teacher Companion

The Teacher Companion makes lesson preparation easy by combining full-colour student book pages with teaching strategies, ideas for class activities and fully worked solutions. All of the Activity Book pages are also included and are complete with model answers.

Be prepared

The **Chapter preview** provides an overview for planning purposes, including things to be aware of and organise ahead of commencing. The **pre-prep** also has an indicator of the time allocation to complete the chapter.

Be an expert

A further improved Teacher Companion places the support of **experts** alongside every Pearson Science 2e teachers, featuring wrap-around teaching and learning strategies and support from:

- **Literacy Consultant: Dr Trish Weekes**
- **Differentiation Consultant: Anna Bennett**
- **School laboratory technicians: Penny Lee and Donna Chapman**

Be confident

All practical activities have been trialled, reviewed, amended and replaced as necessary to ensure teachers and students can undertake practical activities that are tested, work and will yield effective results. Suggested replacement materials and equipment provided to make science more accessible.

Full risk assessments, safety notes and technician's checklist and recipes provided. Pracs and risk assessments have been updated to reflect new regulations around safety and materials in school science classrooms.

Be informed

Full **answers** including suggested findings and possible answers to practical activities, fully worked solutions and support for open-ended research, inquiry and STEM activities.

Pearson Science Lightbook Starter

Lightbook Starter offers a **digital formative and summative assessment tool** with **hints**, **instant feedback** and **auto-correction** of responses. Students and teachers also enjoy the visibility of learning through a **progress tracker** which shows student achievement against curriculum learning outcomes. Lightbook Starter provides questions with the most sophisticated auto-correction of answers.

Be ready

Commence each chapter with questions to establish a baseline for each student around prior knowledge. The **'before you begin'** section includes useful preparatory material with **interactive** resources to **activate prior knowledge** and **reteach key concepts**.

Be in control

Lightbook starter is written to enable teachers and students to use this digital assessment tool as an **alternative** (or additional practice) **to Student Book questions**. The Lightbook Starter structure mirrors the student book question set, thereby providing a complimentary alternative to the student book questions. This supports a fully integrated approach to digital assessment and feedback.

Be assisted

Module review questions (with **hints** and **solutions**), help students **check for understanding** of learning, revise and provide useful **formative assessment** to help teachers identify areas of weakness, great for lesson planning. These serve as a touchpoint throughout the chapter and students benefit from auto-corrected responses which provide **instant feedback** and support.

Be assessed

The **Chapter review** in the student book has a complimentary **assessment** set in Lightbook Starter. Use this as an alternative to a class test at the end of a topic.

Be reflective

An integrated **reflection** set supports students in considering their progress and future areas for focus.

Be tracked

Enjoy seeing progress through the learning outcomes updated instantly in the **progress tracker**.

LightbookStarter LS

Pearson Science eBook

Pearson eBook enables viewing and interaction with the student book online or offline on any device: PC or Mac, Android tablet or iPad and interactive whiteboard. This eBook retains the integrity of the printed page whilst offering easy to access resources, support and linked activities that will engage your students at school and at home.

The eBooks provide a fully integrated, digital learning platform. Enjoy the benefits of having the following digital assets and interactive resources at your fingertips:

* New interactive activities and lessons
* New Untamed Science videos
* Web destinations
* Student investigation templates and teacher support
* New STEP UP Student Book and Activity Book chapters with answers at Years 9 & 10
* Full answers to all Student Book and Activity Book questions
* SPARKlabs
* Risk assessments
* Full teaching programs and curriculum mapping audits
* Chapter tests with answers

Pearson Science ProductLink

Additional student and teacher resources are available free when you purchase **Pearson Science 2nd Edition**. To access, visit **www.pearsonplaces.com.au** and log in. Click on 'Toolkit' then select 'ProductLink' and browse your title.

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Did you know that Pearson also offers teachers a diverse range of training and development product-linked learning programs? We are dedicated to supporting your implementation of Pearson Science, but it doesn't stop here.

Our courses align closely with Pearson Science Second Edition and offer an in-depth learning experience, combining both practical and theoretical elements, enabling you to implement the resource effectively in your classroom.

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Dreamstime: pp. 119l, 124b, 127r; Katrina Brown, p. 287l (ice cubes); Carlos Caetano, p. 287r; Demenevli86, p. 196btl; Design56, p. 292l (crushing); Joseph Gough, p. 292l (shredding); Geoffrey Kuchera, p. 292r (melting); William Manning, p. 243 (cyclists); Roman Milert, p. 292l (mixing); Nikoff, p. 288rb; Otnaydur, p. 264lt; Emin Ozkan, p. 287l (can); Rido, p. 243rb; Huguette Roe, pp. 292l (separation), 292t; Alexey Stiop, p. 44rc; Stratum, p. 292r (solodification); Oliver Suckling, pp. 198lt, 243lb; Stephane Tougard, p. 287lt; Alvaro German Vilela, p. 292r (processing); Visualmatters, p. 2br; Peter Wollinga, p. 289rt; Tetiana Zbrodko, p. 288bl.

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Sinauer Associates Inc.: From Gilbert: Developmental Biology, Sixth Edition, Sinauer Associates, Inc. 2000, p. 189l.

Spencer, Michael: p. 211r.

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CHAPTER 1

Working with scientific data

Have you ever wondered ...

- which internet sites are trustworthy and which are not?
- why scientists sometimes use pie charts but at other times use column or line graphs?
- what the difference is between a mistake and an error?
- how to run a fair test?

LS

After completing this chapter you should be able to:

- identify problems that can be investigated scientifically
- use information from primary and secondary sources to predict results
- plan and conduct fieldwork and experiments
- identify ethical considerations that may apply to an investigation
- assess whether the planned investigations is fair, safe and is able to be performed using available equipment
- identify and explain the differences between controlled, dependent and independent variables
- construct and use tables, graphs, keys and models
- calculate averages and identify outliers in data
- analyse patterns in data using digital technologies as appropriate
- summarise data
- draw conclusions from primary and secondary sources
- evaluate the quality of the data collected and identify improvements.

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AB 1.1

MODULE

1.1 Primary data

Data is all the information and measurements that are collected by scientists from textbooks, encyclopedias, journals and the internet, or from carrying out their own investigations. Scientists collect data and organise it into tables and graphs. They analyse the data, draw conclusions from it and then write it all up so that other scientists can understand it.

science 4 fun

Internet reaction times

How fast can you react?

Do this ...

1. Use the key words *reflex tester* or *reaction time* in your internet search engine to find interactive games that will measure your reaction time.
2. Although most of the games involve detecting a change in colour of the web page, some shoot tranquiliser darts into sheep while in others you play baseball! Try as many as you can to determine your average reaction time.

Record this ...

1. Describe what happened.
2. Explain why you think this happened.

Data

Data is the term given to all the observations and measurements that can be used to describe something. For example, you can be described by your personal data. This includes your height and weight, your hair, skin and eye colour, when and where you were born, the names of your parents and distinguishing features such as a scar or birthmark. Data on the parrot in Figure 1.1.1 would include its colour, sex, body temperature and the type of nest it makes.

FIGURE 1.1.1 Data on this parrot would include its size and mass, the environment it lives in, the number of tail feathers it has, the average number of eggs it lays and the age at which it first flies.

Types of data

Much of the data you find will be measurements that are written as numbers with units attached to them. This type of data is known as **quantitative data**. Other data can only be described in words. This data is **qualitative data**. For example, data about Mt Kosciuszko in New South Wales is shown here and in Figure 1.1.2:

- Quantitative data includes:
  - coordinates (36°27'S, 148°16'E)
  - height (2228 metres above sea level)
  - average temperatures (-6°C in July, 21°C in January).
- Qualitative data includes:
  - Aboriginal name (Tar-Gan-Gil)
  - rock type (granite)
  - the animals that live there (wombats, spotted-tailed quoll, pygmy possum, corroboree frog, flame robin, mountain galaxia and wingless grasshopper)
  - wildflowers found there (alpine stackhousia, hoary sunray and snow beard heath).

FIGURE 1.1.2 Mt Kosciuszko is 2228 metres high and its main rock type is granite.

Data can also be classified according to where you obtain it from.

- **Primary data** is data that you or your **team** personally find out by running your own experiments, surveys and fieldwork. Any measurements that you take are primary data.
- **Secondary data** is data that comes from the work of other people. Secondary data includes the measurements and information that you find on the internet, TV, DVD and video, and in encyclopedias, textbooks, newspapers and magazines. Secondary data can also be obtained by interviewing experts.

AB 1.2 AB 1.3

Collecting your own data

You can generally trust primary data because you collected it yourself from experiments that you ran. If the data is wrong, then it's probably because you made a mistake.

Mistakes are things that can be avoided if you take a little more care. Mistakes happen when you spill material, use the wrong equipment (or the right equipment wrongly), wrongly read an instrument or incorrectly write or copy the measurement down. All these are obvious mistakes because they can be easily avoided.

Errors are not mistakes. Errors are small and unavoidable variations (changes) that occur naturally in measurements. Errors will always happen no matter how careful you are. This means that nothing is exact—even 'accurate' measurements have small variations and errors in them.

Some common forms of errors are:

- **parallax error**—your eye can never be exactly over the marking of a measuring device. Everyone looks at markings at slightly different angles, so everyone will take slightly different readings. Parallax error is caused when you read the instrument at a slight angle. This is shown in Figure 1.1.3.

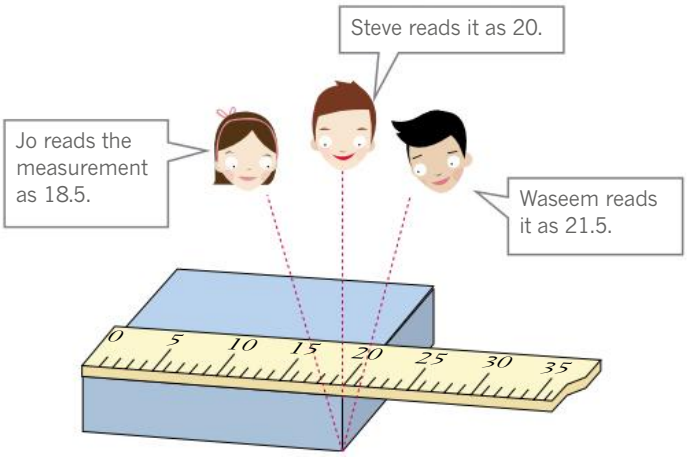

FIGURE 1.1.3 Jo, Steve and Waseem are all looking at the same measurement but at slightly different angles. Only Steve's measurement will be accurate. Jo's and Waseem's measurements will have parallax error.

SciFile

Discovery by mistake

Mistakes and accidents have led to some important scientific discoveries, including an artificial sweetener (saccharine) and the first antibiotic (penicillin).

- **reading errors**—measurements often fall between the markings of a measuring device. You need to estimate your measurement, and different people will make slightly different estimations. An example is shown in Figure 1.1.4.

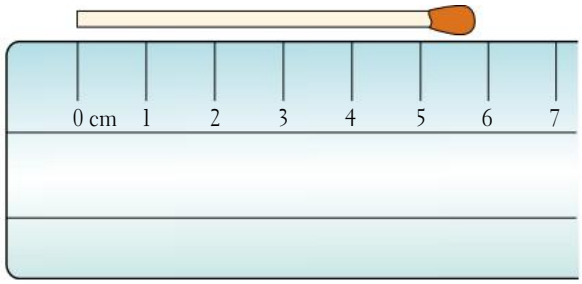

FIGURE 1.1.4 This match is not quite 6 cm long, but is it 5.7, 5.8 or 5.9 cm?

- **instrument errors**—sometimes an instrument may be faulty and will never give the right reading. Some instruments give correct readings only at certain temperatures and will give small errors if used at any other temperature. For example, a metal ruler expands when hot, pushing its markings further apart. As Figure 1.1.5 shows, this makes measurements taken on a hot day slightly smaller than those made on a cold day.

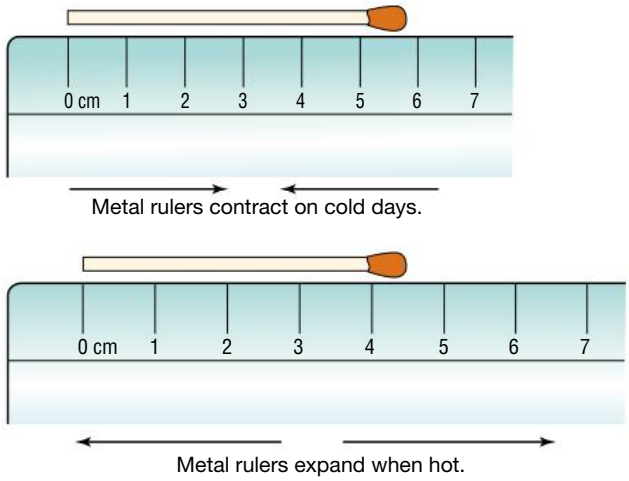

FIGURE 1.1.5 Metal rulers give different measurements at different temperatures. This makes the match appear 'longer' on cold days.

- **human reflex**—a stopwatch typically reads to one-hundredth of a second (0.01 second). The best human reaction time is around 0.11 second and so stopwatches are much more accurate than us. Everyone has different reflex times and so everyone will measure times slightly differently when using a stopwatch.

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p. 9

- **zero errors**—an instrument such as a beam balance or electronic balance should read zero when nothing is placed on it. If it doesn't read zero, then everything you measure will be a little out and all measurements will have a zero error. Balances can usually be adjusted to read zero once more.

SkillBuilder

Tare

When you **tare** an electronic balance, you are resetting it to read zero when something like a beaker is placed on it (Figure 1.1.6). You can then add material without having to worry about the mass of the beaker because it has already been subtracted from the total mass.

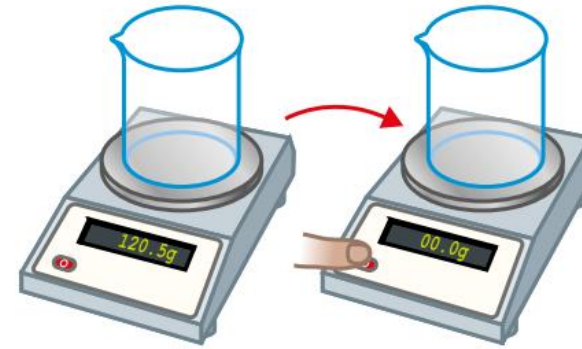


FIGURE 1.1.6 The tare button on an electronic scale resets its zero so that you don't have to worry about the mass of the beaker that is on it.

SciFile

A near disastrous mistake!

In 2009, an Airbus A340/500 jet was taking off from Melbourne with 275 people on board, bound for Dubai. It ran out of runway, scraped its undercarriage, shattered a landing light and only just missed the boundary fence. An investigation concluded that the pilots had mistakenly entered a wrong number into the on-board computer, making the plane 'think' that it was 100 tonnes lighter than it really was!

Improving primary data

Errors always exist and each person in a team will probably take slightly different measurements of exactly the same quantity. Unless someone made a mistake then no one is wrong and everyone's measurement is 'correct'.

One easy way of improving the accuracy of your data is to repeat your measurements. For example, each member in your team could take the same measurement so that they can be compared and obvious mistakes eliminated. Mistakes in data can sometimes be obvious because they are very different from the other measurements. These measurements are known as **outliers** and should be ignored. Even if no mistakes were made, deleting outliers ensures that the remaining measurements are as accurate as possible.

You can then calculate the **average** (or **mean**) of the remaining data. The average will be the most accurate measurement of all because it doesn't include mistakes and has evened out all the small errors everyone made in their measurement.

Prac 2 p. 10

A little give and take

It is useful to write measurements with an estimation of how big the error might be. Scientists allow a little 'give and take' by showing the error as ± (standing for 'plus or minus').

Figure 1.1.7 shows the temperature on a thermometer. The exact temperature falls between the markings and a little guesswork is needed to measure it. It looks as though it should be about 27°C, but it could be a little higher or lower, perhaps by as much as 1°C. The measurement might be written as 27°C 'give or take' 1°C. Scientists write this as 27 ± 1°C.

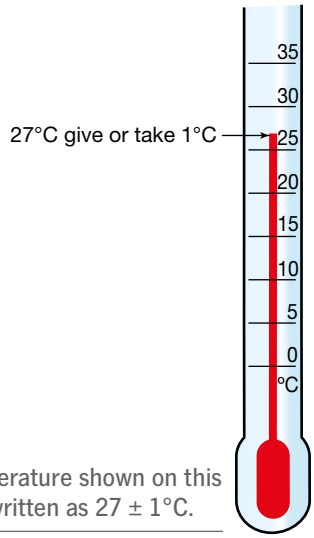


FIGURE 1.1.7 The temperature shown on this thermometer might be written as 27 ± 1°C.

SkillBuilder

Finding averages

1. Delete any outliers as these are the most likely to be inaccurate.
2. Add the rest of the 'good' measurements together.
3. Divide by how many 'good' measurements were taken.

Worked example

Finding averages

Problem

The members of a prac team each measured the length of the mouse's tail. Their measurements are shown below.

Team member	Length (cm)
Karen	8.1
Evan	8.4
Rebecca	7.9
Anna	8.2
Mark	8.5
Andrew	12.9

Solution

Thinking: Delete the highest and lowest measurements (outliers).

Andrew's and Rebecca's results can be ignored.

Add the rest of the 'good' measurements together.

Working: $8.1 + 8.4 + 8.2 + 8.5 = 33.2$

Thinking: Divide by how many 'good' measurements were taken. Four 'good' measurements were taken.

Working: $\text{Average length} = \frac{33.2}{4} = 8.3 \text{ cm}$

Note that no one actually measured 8.3 cm but this is the average and is the most accurate measurement based on the data collected.

Try yourself

Use the above procedure to calculate the average for each of the following sets of data.

1. 9, 10, 6, 13, 12, 10, 11, 15, 12
2. 0.72, 0.57, 1.02, 0.34, 0.74, 0.89

SkillBuilder

± errors in sets of data

You can find the overall ± error for your data by following these steps.

1. Find the average of the data.
2. Find the difference between the highest 'good' value and the average.
3. Find the difference between the lowest 'good' value and the average.
4. The ± error is the biggest of these differences.

Worked example

± errors in sets of data

Problem

In the previous Worked example, six students measured the length of a mouse's tail. Present this measurement as an average ± error.

Solution

Thinking: Find the average of the data.

Working: The average was 8.3 cm.

Thinking: Find the difference between the highest 'good' value and the average.

Working: 8.5 – 8.3 = 0.2

Thinking: Find the difference between the lowest 'good' value and the average.

Working: 8.3 – 8.1 = 0.2

The ± error is the biggest of these differences.

Both differences are the same, so the measurement can be written as 8.3 ± 0.2.

Try yourself

State the answers to the practice questions in the previous Worked example as average ± error.

Working with Science

HUMAN RIGHTS FIELD STATISTICIAN

FIGURE 1.1.8 Supporting Amnesty International's work

Data can be collected and analysed to answer many different questions. Data analysis gives us a way to find patterns, structure and meaning in complex sets of numbers. By applying scientific method along with statistics and mathematics to data, we can gain a better understanding of processes or events and use this understanding to predict outcomes.

Field statisticians in human rights organisations such as Amnesty International (Figure 1.1.8) do this as part of their job. They use statistical methods to answer questions about large-scale conflicts and human rights violations in places such as Lebanon, Sri Lanka, India and Colombia. Field statisticians collect and analyse data to measure rates of mortality (deaths), famine, violence and human rights violations in unsettled environments. Using scientific and mathematical knowledge, statisticians improve the monitoring, reporting and understanding of human rights issues. Their day-to-day jobs involve working in the field, collecting and processing data, developing software tools to analyse data, and applying the data to important questions about human rights issues. The knowledge gained from their work is helping to raise awareness and make positive changes for people living in areas where conflict and rights violations occur.

You might like this job if you enjoy solving problems, working in teams and travelling, while using your knowledge to address social issues. There are many opportunities to apply statistics in a variety of other interesting fields, such as health care and environmental science. A Bachelor of Science with a major in mathematics or statistics will give you the skills you need for these jobs.

Review

1. How do you think statistics can be used to help us to better understand social and environmental issues?
2. List three other fields where you think statistics will play an important role.

MODULE 1.1

Review questions

Remembering

1 Define the terms:
- a primary data
- b tare.

2 What term best describes the following types of data?
- a that includes numbers and units
- b from the internet.

3 Which of the following statements are true and which are false?
- a All measurements are exact.
- b An average is also called the mean.
- c A mistake is the same as an error.
- d A measurement of 56 ± 2°C means that the measurement is somewhere between 54 and 58°C.
- e Human reflexes are always fast and accurate.

4 For Mt Kosciuszko, list three pieces of:
- a quantitative data
- b qualitative data.

FIGURE 1.1.9 The pygmy possum is found through southern Australia, including Mt Kosciuszko.

5 What are the biggest and smallest values these measurements could be?
- a Elvir wrote down the length of an insect as 2.1 ± 0.1 cm.
- b Mang measured the temperature of the lake as 12 ± 3°C.

6 State what these measurements would be with a ± error.
- a The volume of a glass of soft drink was measured by Kim as 185 mL give or take 5 mL.
- b Iona measured the temperature that salt water boiled at as somewhere between 102 and 104°C.

Understanding

7 A scale is reading 0.1 g when there is nothing on it.
- a What errors might this bring to your measurements?
- b Describe two things that you could do to get accurate readings from this scale.

8 Explain why errors cannot be avoided.

9 Scientists generally take multiple measurements for the same quantity. Explain why.

10 Explain how the average of a set of measurements is calculated.

11 Metal rulers are inaccurate in extremely hot and cold temperatures. Explain why.

Applying

12 For each set of data below, eliminate the highest and lowest measurements and then calculate the average of the remaining 'good' measurements.
- a 39 mm, 61 mm, 38 mm, 42 mm, 41 mm, 30 mm, 40 mm
- b 25.3°C, 26.8°C, 38.1°C, 27.4°C, 21.2°C
- c 45 mL, 39 mL, 47 mL, 46 mL, 58 mL, 46 mL.

13 The time a ball took to drop down a 15.0 m cliff was measured by different members of a prac team. Their results are shown below.

Rebecca	1.61 s	Frank	1.74 s
John	3.23 s	Stavros	1.83 s
Christine	1.68 s		

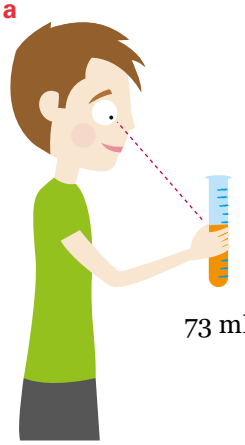
- a Identify who most likely made a mistake.
- b Calculate the average drop time of the ball.
- c Identify the type of error that would have had the biggest effect on the results of this experiment.

MODULE 1.1

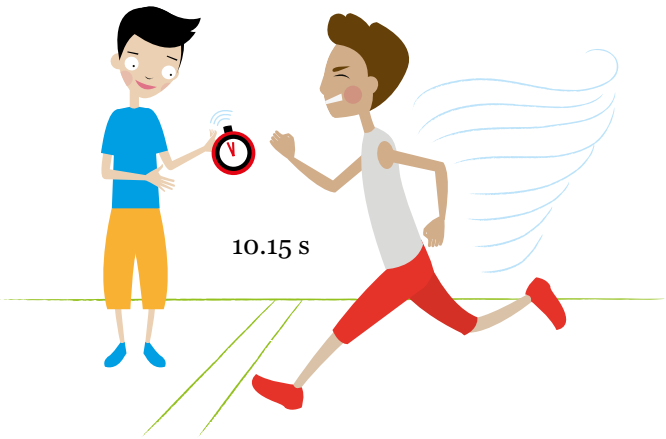
Review questions

14 Identify the types of error shown in Figure 1.1.10.

a



b



c

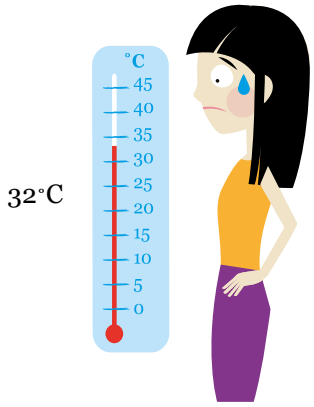


FIGURE 1.1.10

Analysing

15 Contrast:

- **a** errors and mistakes
- **b** reading errors and parallax errors
- **c** instrument errors and zero errors.

16 Classify each of the following as either a mistake or an error.

- **a** Liz poured water from a measuring cylinder but could not get every drop out.
- **b** Sam spilt some of the chemicals he was to use in an experiment.
- **c** Jon didn't bother clearing the dirt off the balance he used.
- **d** Liana found it difficult to decide on measurements that fell between the markings on a tape measure.
- **e** Michael's electronic scale was reading 0.1 g when empty and he didn't 'zero' it.

17 Classify the data on the parrot listed in Figure 1.1.1 on page 2 as quantitative or qualitative.

Evaluating

18 Suppose a watch-glass has a mass of 50 g. Propose a way of measuring 10 g of salt onto a watch-glass:

- **a** without using the tare button
- **b** with the tare button.

19 **a** Identify whether a measurement made with a metal ruler will be too high or too low on a:

- **i** hot day
- **ii** cold day.

b Justify your answers.

MODULE
1.1 Practical investigations

SPARKlab alternative available for this activity

1 • Reaction times

Planning & Conducting | Processing & Analysing

Purpose

To determine your reaction time.

Hypothesis

How long do you think it takes for you to react—a second, half a second or less? Before you go any further with this investigation, write a hypothesis in your workbook.

Timing 45 minutes

Materials

- 30 cm ruler
- access to a calculator
- stopwatch

Procedure

1. Construct a table like the one shown in the Results section in your workbook. Alternatively, construct a spreadsheet that has similar columns to those in the table. Give your table or spreadsheet a title.
2. Work with a partner. Hold the ruler vertically with its zero in line with the top of your partner's hand, as shown in Figure 1.1.11.

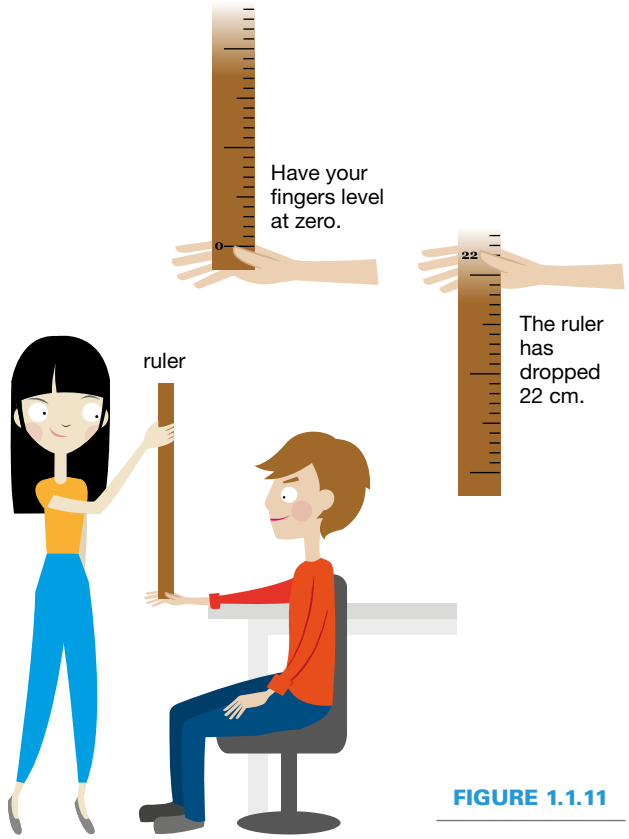


FIGURE 1.1.11

3. Without warning, let go of the ruler. Your partner needs to catch it as quickly as possible with their fingertips.
4. Note the reading of the ruler (in centimetres) at the top of your partner's open hand.
5. Have two trial runs and then record in your table the distance dropped for the next three runs.
6. Repeat the experiment, but this time count down the ruler drop.
7. Try again, but have another student distract your partner (such as by talking to them or tapping their shoulder). Don't count them down.

Results

1. Record all your results in a table or spreadsheet like the one shown below.

Experiment	Distance ruler dropped (cm)			Average ruler drop (cm)	Average reaction time (s)
no distractions, no warnings					
with countdown					
with distractions					

2. Calculate the average distances the ruler dropped in each experiment. Add your own answers to the table.
   Alternatively, program your spreadsheet to calculate the averages for you.
3. Calculate your average reaction time using the mathematical formula:

$$t = \sqrt{\frac{d}{490}}$$

To do this, follow these steps on your calculator:

- [÷] your average ruler drop by 490.
- Push the [=] button.
- Push the [√] (square root) button.

The final answer is the time in seconds that you took to react. Add your times to the table. If you used a spreadsheet, then use the above instructions to program it to calculate the average reaction time for you.

MODULE
1.1 Practical investigations

Review

1. If you have already measured your reaction time using interactive games on the internet, then compare the result you obtained there with the result you obtained in this prac.
2. Of the different methods you tried, assess which is the most reliable way of measuring reaction time.
3. Digital stopwatches normally measure to the nearest 0.01 second. Compare this with your reaction time.
4. Your measurements using a stopwatch should never be thought of as perfect. Explain why.
5. List factors that affected your reaction time. Specify whether they made it better or worse.
6. Measurements taken in an experiment are more accurate when the experiment is repeated a number of times. Explain why.

2 • Repeated measurements

Processing & Analysing | Evaluating

Purpose

To take repeated measurements and calculate their averages.

Timing 45 minutes

Materials

- measuring tape
- thermometer
- stopwatch

Procedure

1. Copy the table below into your workbook. Alternatively, construct a spreadsheet with similar columns to the table. Give your table or spreadsheet a title.
2. Measure each of the following as carefully as you can. Have each member of your prac team do the same.
   - length of the laboratory
   - temperature of tap water
   - number of heartbeats in a minute
   - time it takes for a pen to drop 2 metres to the floor
   - time it takes for a flat piece of A4 paper to flutter from a height of 2 metres to the floor.

Results

1. Use your results table or spreadsheet to record all the measurements made by your prac team.
2. If you have five or more measurements then cross out the outliers (highest and lowest measurement) for each.
3. Calculate the average of the remaining 'good' measurements. (If you have fewer than five measurements use them all.) If you used a spreadsheet, then program it to calculate the average.
4. State each measurement as an average ± error. Include the units you used.

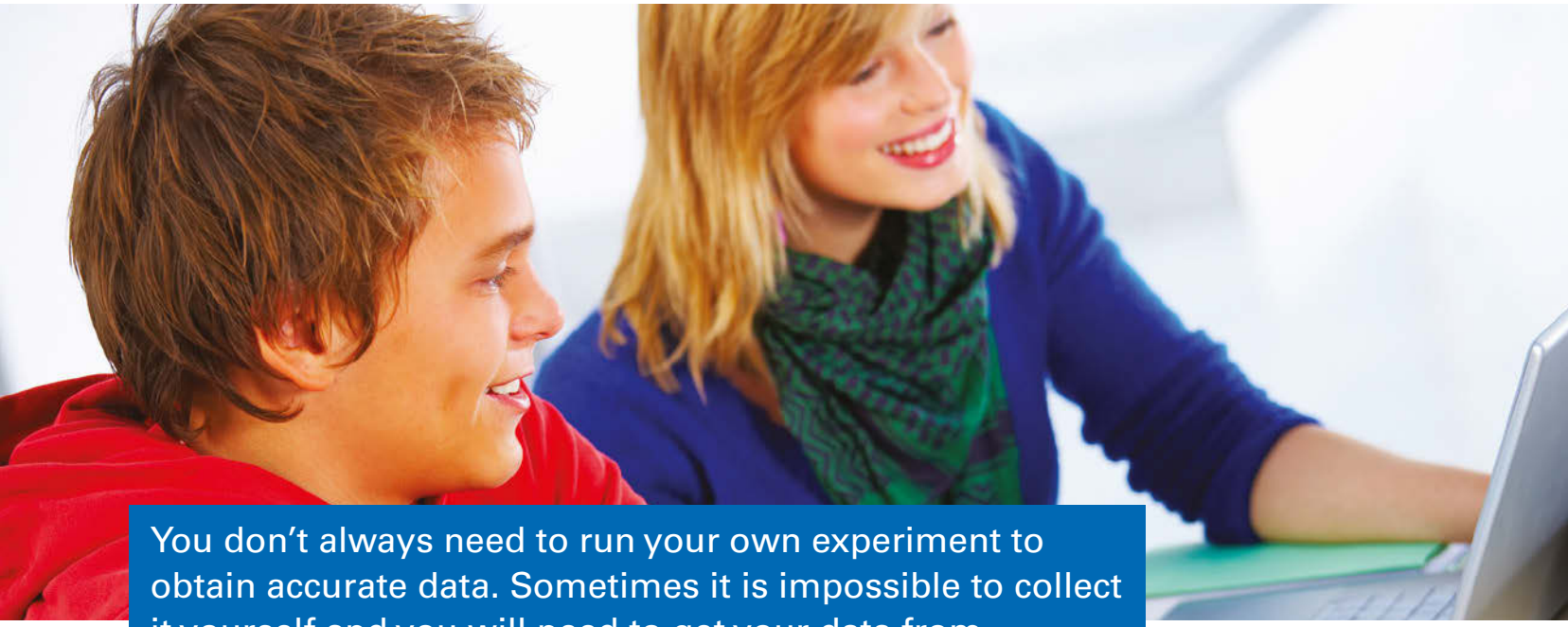
Review

1. Explain why scientists repeat their measurements instead of taking just one.
2. Contrast an error with a mistake.
3. Explain why errors happen in every measurement.
4. List the likely sources of errors in each measurement you took in this investigation.
5. Classify the errors in your list in question 4 as parallax, reading, instrument or human reflex.
6. For each measurement, assess which of these errors was the most important.

	Measurement					Average measurement	Average ± error	Units
	#1	#2	#3	#4	#5			
Length of laboratory								
Temperature of tap water								
Number of heartbeats in a minute								
Time for a pen to drop 2 m to floor								
Time for flat paper to flutter 2 m to floor								

MODULE 1.2

Secondary data



You don't always need to run your own experiment to obtain accurate data. Sometimes it is impossible to collect it yourself and you will need to get your data from somewhere else. It is easy to find secondary data, particularly from the school resource centre or internet. However, you need to be careful because some of the secondary data you find will be out of date or incorrect.

Data that's ready to go

You cannot always run your own experiments or take your own observations and data. This could be for a number of reasons.

- Many experiments require training that is well beyond Year 8 Science. This is why science is offered as a subject throughout secondary school and at university. You learn a bit more each year, allowing you to run more and more of your own investigations and collect more of your own data.
- Many experiments require equipment that is not available at school because of its expense, size and maintenance requirements. For example, your school might have a powerful optical telescope that allows you to see the Moon and planets but it won't have a radio telescope such as that in Figure 1.2.1, which allows you to see into the deeper universe. Likewise, your school will have optical microscopes but not electron microscopes.

FIGURE 1.2.1 Your school is unlikely to have a radio telescope such as this one at Parkes, New South Wales. This means that you must use secondary data about the wider universe.

- Other experiments take far more time than is available in Year 8 Science. For example, a forest takes many years to grow after a bushfire and you would need that long to study it. Genetic diseases pass from generation to generation and so studying their inheritance takes generations to do properly.
- Other observations can only be made in swamps, on top of mountains, in the frozen Antarctic, at the bottom of the ocean or in space. It is unlikely that you will ever go there, especially to run a science experiment.

If you can't run your own experiment, then you need to turn to secondary data. Secondary data is information that has already been found by other scientists. This data can easily be found in textbooks and encyclopedias, scientific magazines and journals, and on the internet. All this information is secondary data. You might be using the data right now but it once belonged to someone else.

FIGURE 1.2.2 Data on climate change is changing so rapidly that it quickly becomes out of date. These two photos were taken from the same location in 2002 and 2003.

Improving secondary data

Secondary data is easy to find but is not always accurate. Simple checks can ensure that the data you find can be trusted.

How old is the data?

Some data never changes. For example, ice melts at 0°C at sea level and will always do so. Hence, it doesn't matter where you get the information from or how old the information is. However, other data quickly becomes out of date and will not accurately describe what is happening right now. For example, climate change is happening much faster than scientists first thought. As Figure 1.2.2 shows, many glaciers are melting quickly and data describing them must be as recent as possible for it to be accurate—data from a year ago can be so inaccurate that any predictions based on it are bound to be wrong.

You can check how old data is by finding the **imprint page** of the book or magazine, such as that shown in Figure 1.2.3.

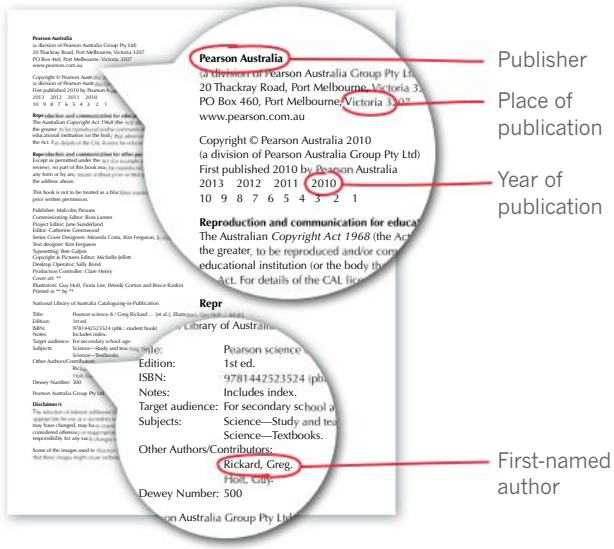


FIGURE 1.2.3 The imprint page shows who published the book or magazine and when it was published.

The imprint page can usually be found in the first few pages of any book, magazine or journal. Websites should have the date they were created and last updated at the bottom of their opening pages.

Where did it come from?

Encyclopedias, scientific journals and science textbooks can usually be trusted to provide accurate data. However, the data may be old.

Data can also be trusted if it comes from respected scientific magazines such as *New Scientist*, *COSMOS*, *Scientific American* and *National Geographic*. Many of these magazines will be found in your school's resource centre or your local library.

Gossip and celebrity magazines cannot be relied on to provide accurate data and information.

What is the URL?

The internet will probably be your first choice when looking for data and information. However, some of what you find will be incorrect. Links that don't work are one sign of a suspicious site. More information comes from the last part of its **URL** (Uniform Resource Locator) address (referred to as its **domain**). This tells you who created the website and it gives you some idea whether it can be trusted or not.

Australian sites (.au)

Sites that have URLs ending in .au are based in Australia and need to meet Australian laws. The origin of other sites can also be determined by their domain. A few are shown in Table 1.2.1.

TABLE 1.2.1 Country domains

Country	Domain
USA	None
Australia	.au
United Kingdom	.uk
Canada	.ca
India	.in
United Arab Emirates	.ae

SciFile

TIM and the www

Before 1989, the only people able to use the internet were the US military, organisations such as CSIRO, and various universities around the world. In that year, the English computer scientist Tim Berners-Lee was working at the CERN laboratory in Switzerland. There he wrote software that allowed anyone to access the Net. He called his system TIM! We now know it as the World Wide Web (www).

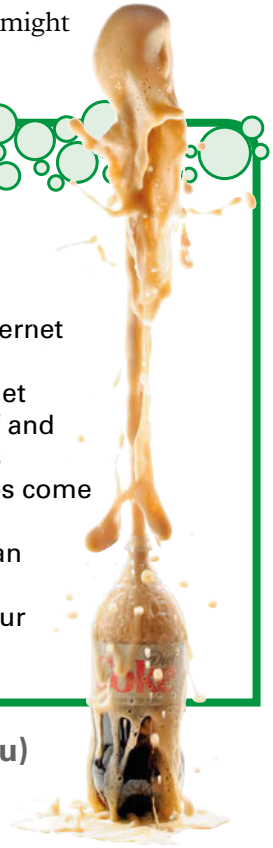
Educational institutions (.edu)

URLs ending in .edu indicate that the website is hosted by an educational institution such as a school, college, university or even kindergarten. Most of the material you find there can be trusted. However, students can sometimes use the school server and .edu domain to construct their own personal webpages. That expert on brain surgery you've found online might be another Year 8 student!

SciFile

Mentos + Diet Coke = nothing!

Plenty of video clips on the internet show the eruption that occurs when Mentos® are added to Diet Coke®. However, try it yourself and nothing much happens. This is because most of the video clips come from the USA where Mentos are different from those you can buy here. This shows that you should always check where your information comes from.



Government (.gov or .gov.au)

Governments have multiple sites ranging from health, finance, immigration and the arts to science. If the URL ends in .gov, then the site belongs to a branch of the government of the USA. If it is an Australian government site, then the URL will end in .gov.au. The data on government sites can be considered to be accurate and up to date.

Commercial businesses (.com)

Businesses want you to buy their products. Their websites will usually be accurate but will be biased towards their products, making them look good. They are unlikely to include links to negative reviews or compare their product with opposition products.

Networks (.net)

These domains include all the other sites that don't fit within one of the other domains. Many of them are personal sites. If so, then their URL is likely to include a ~ (tilde). Many of these websites are biased and some contain incorrect information.

Organisations (.org)

The first site that comes up in most searches is Wikipedia. This is an example of a .org site. Wikipedia is a not-for-profit site that allows anyone to enter information. For this reason, its information may not be totally accurate or up to date. Verify the information for yourself by checking Wikipedia's resource list.

Many .org sites that can be trusted include the Australian Red Cross, the United Nations, zoos such as Taronga Zoo (New South Wales) and Healesville Sanctuary (Victoria), the WWF (World Wide Fund for Nature) and various help groups for diseases such as cancer and multiple sclerosis.

However, some .org sites display a strong bias and only provide information that will support their point of view. Websites regarding vaccination, evolution, stem cell research and abortion are often biased for or against the issue and so they need to be treated with care.

The need to compare

All secondary data should be checked against data found in other sources. If it agrees, then it is probably accurate. If it doesn't match up, then you need to keep looking until you find sets of data that do match.

Data is best collected from a range of resources. In research assignments and investigations, try to gather material from at least one:

- textbook
- encyclopedia (it could be an online or CD version)
- trustworthy internet site.

Resource lists

Ethics is the study of what is right and wrong. Ethics influences how we treat each other and how we want to be treated ourselves. Part of ethics is honesty and respect. We all want to be treated honestly and with respect, and this means we also need to treat others the same way.

As scientists, we must be ethical in whatever we do. It is unethical for a scientist to pretend that data is theirs when it actually came from the work of someone else. We need to be honest and need to respect the scientist or team that originally found the data. For this reason, scientists include a resource list that shows where their information has come from.

A **resource** or **reference list** (sometimes called a **bibliography**) is a list of every textbook, encyclopedia, scientific journal and webpage you collected information from or used to check the accuracy of data you found. Although each type of resource is listed in its own special way, you should try to include the following.

Author(s):

- Write the author's surname first.
- If the author's name is not given, then try and find the editor instead and write 'ed.' after their name.
- Encyclopedias often do not have authors or editors listed. In this case do not include any author.

Title:

- If you are using a magazine or newspaper, then you should also give the title and page numbers of the article you used.
- If you are using a website, then you should give its title and its URL.
- Always underline the title or URL.

Year or date of publication:

- Give the year or date of publication or the date of its most recent update.

Publisher:

- This is the group or the institution that put it all together. The domain in a website's URL will help you here.

Place:

- Include the city or place that the resource has come from (if known).

Some possible entries in a resource list are shown in Figure 1.2.4.

Book: Hopler, Paul and Torok, Simon, Amazing Science, 2005, ABC Books, Sydney.

Encyclopedia: Visual Encyclopedia of Science, 2004, Dorling-Kindersley, London.

Magazine: Catchpole, Heather, 'The atom factory'. COSMOS, 2007, Volume 014, p77.

Newspaper: Medew, Julia, 'Insurance fears deter gene tests', The Age, 7 September 2009, p3.

Website: We Care For Rabbits Society, www.wecare4rabbits.com/rabbits.asp, updated 13 March 2013.

FIGURE 1.2.4 Entries in a resource list

Prac 1 p. 16
Prac 2 p. 17

MODULE 1.2

Review questions

Remembering

1 Define the following terms:
- a domain
- b imprint page
- c ethics.

2 What do the following domains stand for?
- a .gov
- b .gov.au
- c .au
- d .com
- e .edu

3 What internet sites can generally be trusted to give accurate and up-to-date information?

4 Internet sites can give information that is wrong or out of date. What are two examples that show this?

Understanding

5 Explain why:
- a .net sites need to be treated with care
- b .com sites cannot be expected to give a fair assessment of their products.

6 Why is some data known as secondary?

7 Explain why it would be difficult to run your own experiment to:
- a measure the weathering and erosion of rocks
- b detect signals from the outer universe
- c measure the wind speeds on top of Mt Everest
- d determine the mathematical equations that describe the movement of water down a creek.

8 You should use a range of resources to collect secondary data. Explain why.

Applying

9 Would you use primary or secondary data to find information about each of the following?
- a the types of shops that are in your town or suburb
- b how tall your classmates are
- c the population of the major cities of Australia
- d how long an ice-cream takes to melt
- e the length of Australia's coastline.

10 For the following resources, identify:
- i what the resource is (e.g. text, website, magazine)
- ii its author(s)
- iii the title of the resource
- iv the year of publication.

a Devlin, Jacinta, Cochrane, Helen, Coffey, Rhonda, *Heinemann Science Links 1*, 2005, Heinemann, Port Melbourne.

b Govindasmay, Siva, 'Ready for take-off', *Flight International*, 1–7 September 2009, p. 46.

11 Which of the following magazines could be trusted to give accurate scientific data?
- a New Idea
- b COSMOS
- c Top Gear
- d Popular Scientist
- e Dolly
- f Men's Health.

Evaluating

12 Assess whether the following websites are likely to give unbiased information.
- a www.dubbo.org/explore/western-plains-zoo
- b www.antiabortion.org/helpline
- c www.pretendwecare.net
- d www.chrissolarpanels.com.au
- e www.physics.unitas.edu.au
- f www.doctors4stemcellcures.org
- g www.en.wikipedia.org/wiki/frdi
- h www.donkey.org.it/~guido

Creating

13 Gary used the resources shown in Figure 1.2.5 to complete a science assignment. From his rough list, construct a resource list.

The science of the X-Files written by Michael White in 1996. It was Published in London by Random House.

1976, Snakes of Australia, pub Angus and Robertson. SYD. Written Graeme F. Gow.

The article was called Hair today, gone tomorrow and was on page 102 of an old Newton magazine from 2000. It was Vol 2 and it was written by Bob Guntrip.

FIGURE 1.2.5

MODULE 1.2

Practical investigations

1 • Elephant toothpaste

Questioning & Predicting | Planning & Conducting

This experiment is best done outside because it can get very messy.

Purpose

To make elephant toothpaste and then search the internet to find out what happened.

Timing 45 minutes

Materials

- 100 mL 3–6% solution of hydrogen peroxide
- squirt dishwashing detergent
- 3–4 drops food colouring
- 1 large spatula of live powdered yeast
- 40 mL very warm water

SAFETY

Hydrogen peroxide is an irritant if it gets in your eyes. It is also a bleach, so wear gloves and safety glasses and a lab coat at all times.

- empty 500 mL plastic soft-drink or water bottle
- 100 mL measuring cylinder or plastic cup
- stirring rod
- funnel
- beaker
- newspaper or tray to 'catch' the toothpaste
- safety glasses

Procedure

1. Place about 40 mL of very warm water into the beaker and add about 1 large spatula of yeast powder. Mix with the stirring rod and then allow the mixture to sit for about 5 minutes.
2. Insert the funnel into the opening of the plastic bottle and use it to pour 100 mL (about half a cup) of hydrogen peroxide solution, a good squirt of dishwashing liquid and three or four drops of food colouring. Swirl to mix thoroughly.
3. Place the bottle on the tray or newspaper or take it outside. Then add the yeast mixture all at once. Quickly remove the funnel and stand back.
4. Once the reaction has started, feel the sides of the plastic bottle.

Review

1. Describe what you saw.
2. Describe what you felt when you touched the bottle.
3. Search the internet to obtain the following data regarding this prac.
   - State the address of the website you obtained it from.
   - Identify what type of site it was (for example, government, educational or commercial).
   - Assess whether the information you found can be trusted or not.

   Find:
   - a the chemical formulas for hydrogen peroxide and water
   - b the reaction in which hydrogen peroxide breaks down
   - c what a catalyst is and what it does (yeast is a catalyst in this experiment)
   - d what an exothermic reaction is.
4. The 'toothpaste' formed in this prac is just bubbles of oxygen, water and food colouring. Assess whether it is safe to touch.
5. Propose reasons why the 'toothpaste' grew out of the bottle.

MODULE 1.2

Practical investigations

2 • Cartesian diver

Questioning & Predicting | Planning & Conducting

Purpose

To construct a Cartesian diver and use it to demonstrate buoyancy.

Timing

45 minutes

Materials

- 2 L soft-drink bottle
- a 'diver' such as:
  - an eye-dropper or Pasteur pipette
  - plastic straw, paperclip and Blu-Tack®
  - lid of a ballpoint pen and Blu-Tack
- digital camera or mobile phone with video function (optional)

Procedure

1. Completely fill the 2 L bottle with water.
2. Prepare your diver. Your diver needs to be heavy enough so that it just floats upright in water. Three different ways you can do this are:
   - draw water into the eye-dropper
   - attach Blu-Tack to the end of the lid of the ballpoint pen as shown in Figure 1.2.6
   - bend the plastic straw over and hold it in place with the paperclip as shown in Figure 1.2.6. Add Blu-Tack to the paperclip.
3. Slip your diver into the bottle and screw the cap on tightly.
4. Squeeze gently on the sides of the bottle and observe what happens to the diver.
5. Watch what happens when you release the bottle.
6. Perhaps video what you see using a digital video camera or mobile phone.

Review

1. Describe what happened to the diver when you:
   a. squeezed the bottle
   b. released it.
2. What are the advantages of taking a video of this experiment?
3. Search the internet for videos of Cartesian divers. Compare any videos you find with what you saw in your experiment.
4. Search the internet to obtain the following data regarding this practical activity.
   - State the address of the website you obtained it from.
   - Identify what type of site it was (for example, a government, educational or commercial site).
   - Assess whether the information you found can be trusted or not.

   Find:
   a. what buoyancy is
   b. why the diver moved up and down in the bottle
   c. other designs for a Cartesian diver that use a soy sauce 'fish' and a tomato sauce sachet
   d. who the word 'Cartesian' is named after
   e. what Cartesian coordinates are.

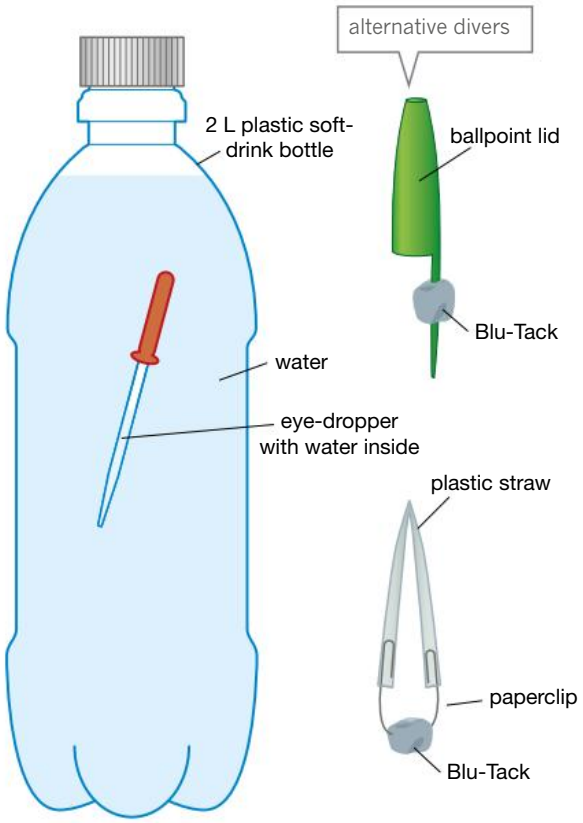
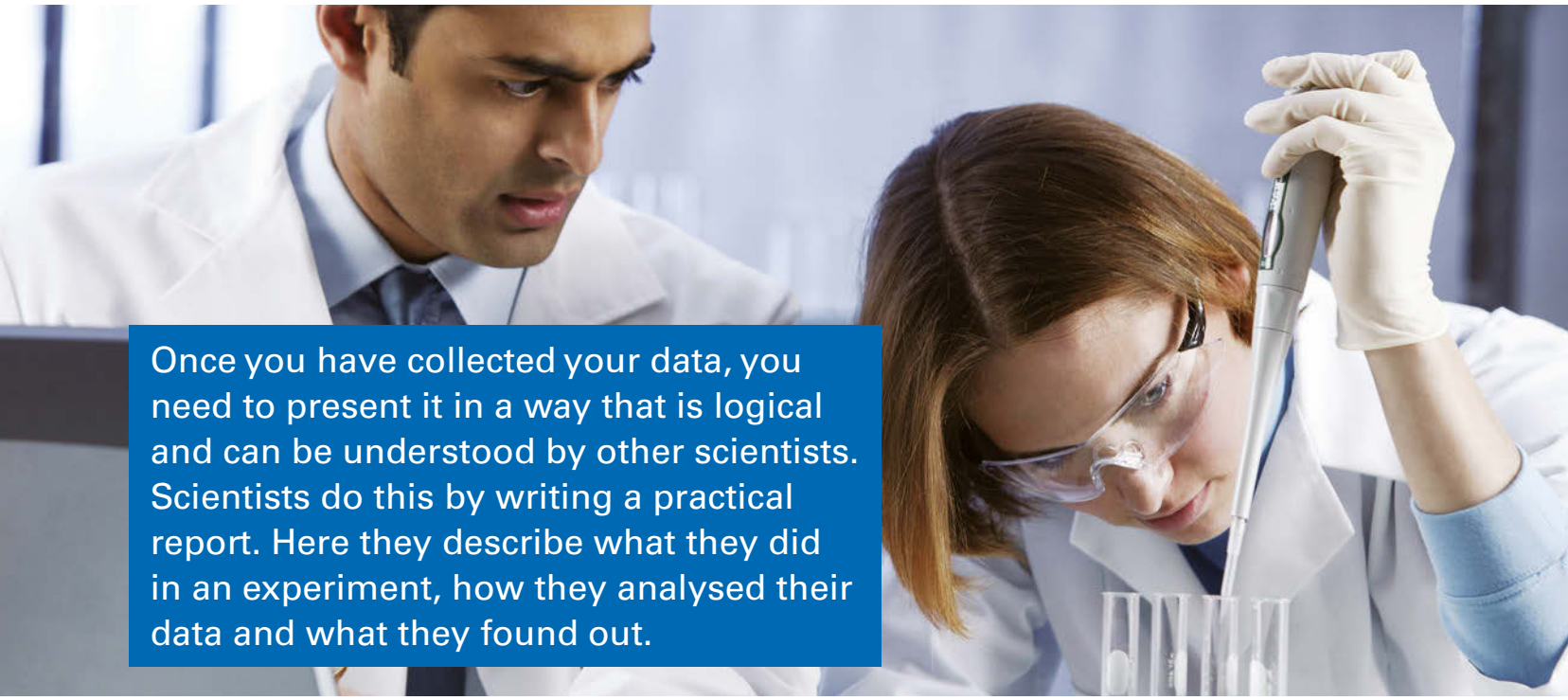


FIGURE 1.2.6

MODULE

1.3 Processing and analysing data



Once you have collected your data, you need to present it in a way that is logical and can be understood by other scientists. Scientists do this by writing a practical report. Here they describe what they did in an experiment, how they analysed their data and what they found out.

Practical reports

Scientists communicate what they found out in an investigation by writing a report (commonly called a prac report).

Prac reports should include the following sections.

Heading

In your heading, include the name and date(s) of the investigation and a list of partners who were in your team.

Purpose

The **purpose** (or aim) is where you describe briefly what you were trying to do.

Hypothesis

You generally have some idea of what will happen in an experiment from your previous experiences, what you have already studied in science and what you have already found from other sources such as the internet. A **hypothesis** is an educated guess about what might happen in an experiment and what might be found out.

Materials

This is a list of everything that you used in the investigation.

It includes all:

- chemicals used—give all chemicals their correct names, chemical formulas (if known), their concentration and the quantity of each (for example, 25 g sodium chloride NaCl or 50 mL 0.5 M hydrochloric acid HCl)
- equipment or apparatus used—give all pieces of equipment their correct names. If the equipment comes in different sizes then specify the size used (for example, 100 mL beaker or 250 mL conical flask) (Figure 1.3.1).

FIGURE 1.3.1 Beakers come in different sizes so you need to say which size you used.

SkillBuilder

Drawing laboratory equipment

Figure 1.3.2 shows some of the equipment commonly found in the laboratory and how the equipment is usually represented in a scientific diagram.

AB 1.4

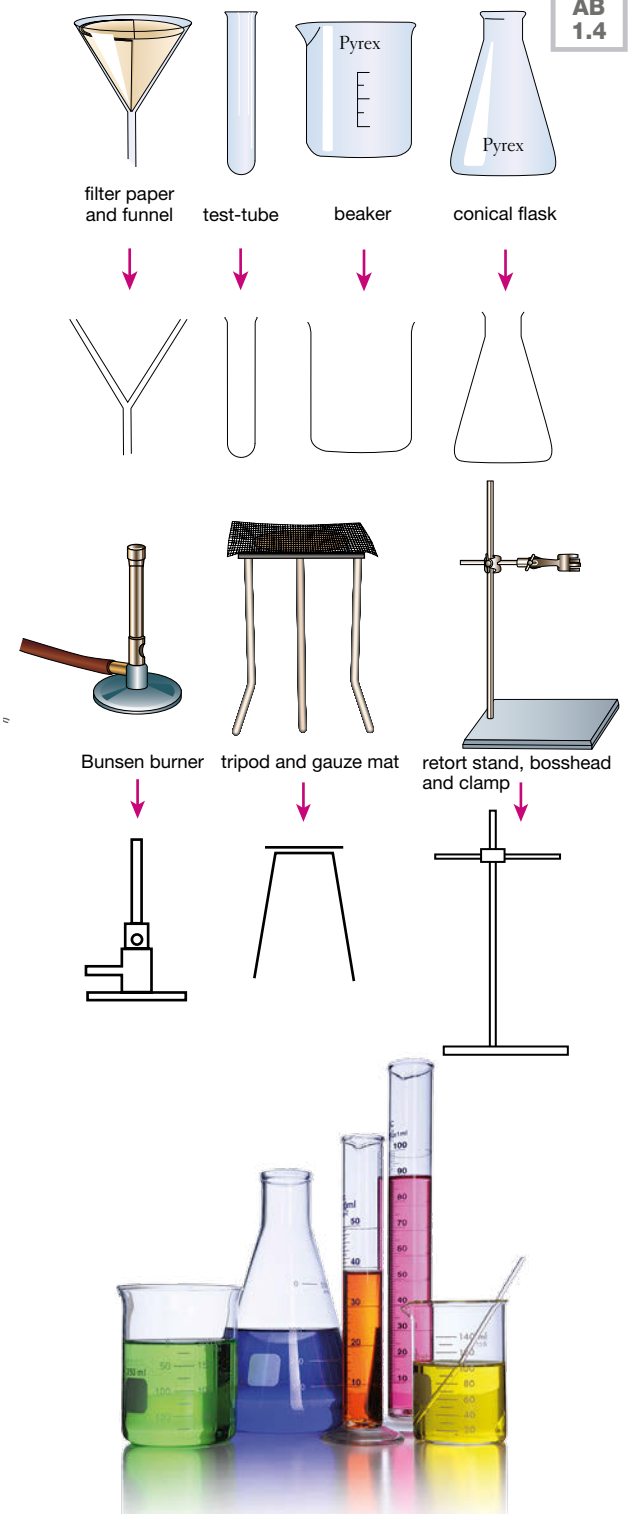


FIGURE 1.3.2 Scientific equipment is normally drawn simply and in two dimensions.

Procedure

The **procedure** (or method) is a description of everything you did in the investigation, perhaps as a list or series of dot points. A labelled diagram is a good way to describe how equipment was set up.

AB 1.5

SkillBuilder

Writing a good procedure

The method you write should not be a story and should not be a recipe. Recipes give a set of instructions for someone else to follow but a practical report is different because it records what you or your team did. Follow these guidelines to write a good method.

1. Write procedures in the past tense. Use words such as *was used* and *were*.

   A measuring cylinder was used to measure out 100 mL of water. ✓

   Use a measuring cylinder to measure out 100 mL of water. ✗

2. Your procedure should state what equipment was used.

   A trundle wheel was used to measure the length of the oval. ✓

   We used a trundle wheel to measure the length of the oval. ✓

   The length of the oval was measured. ✗

   We measured the length of the oval. ✗

3. Include quantities and units with all your measurements.

   The water was heated until it reached 40°C. ✓

   We heated the water until it reached 40°C. ✓

   The water was heated. ✗

   We heated the water. ✗

Results

This section includes a complete list of your observations and your measurements. The best way to display your measurements is in a table.

This is also where you may start analysing your data, such as calculating averages. You might also present your data in different ways such as in spreadsheets, diagrams or by plotting graphs.

Review

This section is sometimes called the *Discussion*. This is where you discuss your experiment, often by answering a set of questions. In the practical review, you:

- describe what happened in your investigation and explain why it happened
- discuss what you think your results show
- include secondary data that relates to your investigation
- describe the problems encountered and what was done to overcome them
- construct a **conclusion**, a brief summary of what you found out in the investigation
- assess your investigation. This includes assessing whether your hypothesis was accurate or not, and suggesting alternative procedures that might improve the investigation and ideas for further experiments.

Resource list

If secondary data was used then a report should end with a bibliography, a list of all resources used in gathering information about the investigation.

TABLE 1.3.1 Common metric unit prefixes

Prefix	Size	Example
G giga	one billion	GL
M mega	one million	ML
k kilo	one thousand	km
c centi	one-hundredth	cm
m milli	one-thousandth	mg
μ micro	one-millionth	μg
n nano	one-billionth	nm

SkillBuilder

Writing a good conclusion

A good conclusion is short (no more than two short sentences) and directly refers to the purpose.

As expected, cooking oil flowed slower than water but faster than honey. ✓

The experiment was fun and we learnt a lot. ✗

Tables of data

Quantitative data (measurements) is best shown in a table or computer spreadsheet. This makes any patterns that may exist more obvious.

Units

The measurements in your results tables and spreadsheets are only meaningful if you specify the units they are measured in. In science, most of your measurements will use metric or SI (Système Internationale) units. Length is measured in metres (m), mass in grams (g), liquid volumes in litres (L) and time in seconds (s). Other units, such as newtons (N) for weight and force, and joules (J) for energy, depend on these units. However, measurements will sometimes be too big or too small to be sensibly measured with these units (Figure 1.3.3). This is when units with prefixes are used. **Prefixes** are letters or words that sometimes appear before unit symbols and unit names. The most common are milli (prefix m), centi (c) and kilo (k). These are shown in Table 1.3.1.

AB 1.6

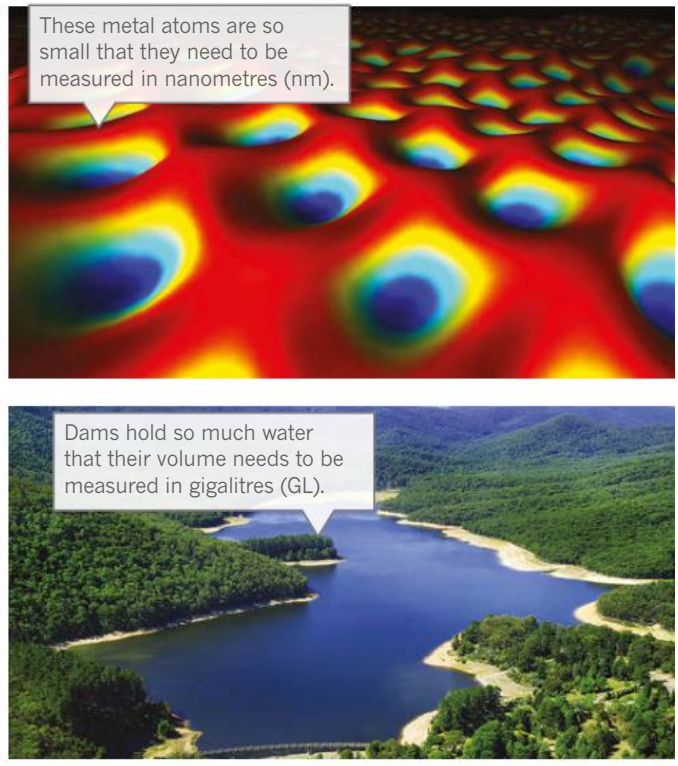


FIGURE 1.3.3 Prefixes allow scientists to measure extremely small and extremely large quantities.

SkillBuilder

Converting units of length

Scientists use many units of length and often have to convert one to the other. In the metric system, these conversions are carried out by multiplying or dividing by a factor of ten such as 10, 100 or 1000. Table 1.3.2 shows you how to make some conversions.

TABLE 1.3.2 Converting units of length

Unit of length	Convert by	To
kilometres (km)	× 1000	metres (m)
metres (m)	× 100	centimetres (cm)
centimetres (cm)	× 10	millimetres (mm)
millimetres (mm)	× 1000	micrometres (μm)
metres (m)	÷ 1000	kilometres (km)
centimetres (cm)	÷ 100	metres (m)
millimetres (mm)	÷ 10	centimetres (cm)
micrometres (μm)	÷ 1000	millimetres (mm)

Worked example

Converting units of length

Problem

1 Convert 3.5 km into metres.

2 Convert 4750 mm into metres.

Solution

Thinking: To convert kilometres to metres, you need to multiply by 1000.

Working: $3.5 \times 1000 = 3500\,\text{m}$

Thinking: To convert millimetres to metres, you need to divide by 1000.

Working: $\frac{4750}{1000} = 4.75\,\text{m}$

Try yourself

1 Convert into metres:

a 2.7 km **b** 1360 mm **c** 250 cm

2 Convert:

a 25 cm into millimetres

b 750 mm into centimetres

c 4500 μm into millimetres

Working with Science

MARKET RESEARCHER

Market researchers, like those shown in Figure 1.3.4, collect and analyse data about consumers' buying habits and their opinions about products. They do this so that they can identify trends and find opportunities in the market. Their data is collected from interviews, surveys, market statistics and customer data such as loyalty cards and memberships. Market researchers use data to help businesses and advertisers find the best strategies to develop and sell their products to consumers. This information plays an important role in helping brands and businesses gain a competitive edge and become successful.

To become a market researcher or market research assistant, you will need to complete a Certificate IV or Diploma of Marketing, or a Bachelor of Business (Marketing). These qualifications will help you gain skills in communication, data collection, analysis and interpretation, and will help you learn how to apply these skills in the market. There are many job opportunities in this field and employment in marketing is expected to grow over the coming ten years.

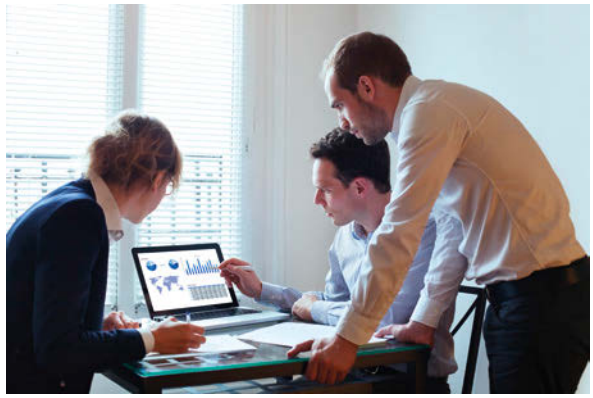


FIGURE 1.3.4 Market researchers collect and analyse data about how and why we purchase products.

Review

1 List three examples of data that you think market researchers would collect.

2 Think of something that you bought recently. If a market researcher interviewed you about this product, what data could they collect about you and your purchase? How do you think this data would be useful to the business that makes the product?

Graphing data

Graphs are better than tables at showing patterns in data. Four types of graphs are shown in Figure 1.3.5.

- Bar graphs and column graphs have a set of continuous numbers along one axis, and discrete (non-continuous) quantities like colours or materials along the other axis.
- Pie charts show the proportions or percentages of different discrete quantities. Pie charts are sometimes called sector graphs.
- Line graphs have sets of continuous numbers along both axes.

Pie charts and bar and column graphs are useful but cannot be used to predict missing measurements or measurements that were never actually taken in the experiment. Only line graphs can do this.

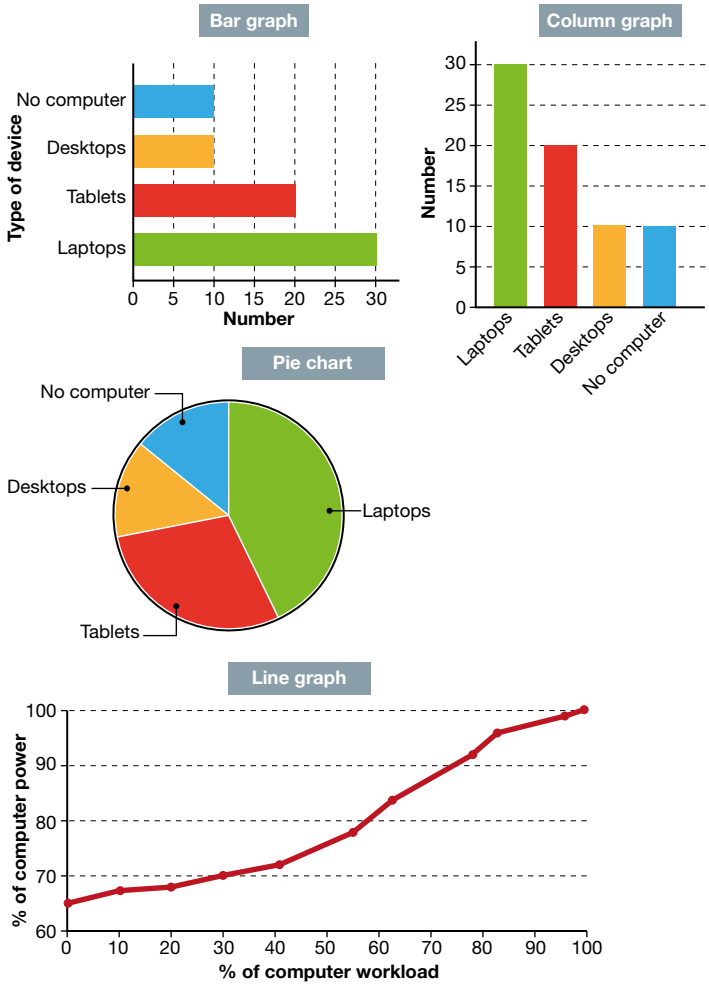


FIGURE 1.3.5 Depending on the data, scientists plot different types of graphs.

Line or curve of best fit

Sometimes your data will produce perfect straight lines or perfect curves. At other times, your data might produce something that looks more like a dot-to-dot picture. This is when you try to construct a **line of best fit** or **curve of best fit**.

All experiments have errors in them. This means that the points on your graph have errors too, and so their positions are not exact. Connecting up the points in a dot-to-dot manner suggests that there is no error. It is more sensible to draw a straight line or smooth curve roughly through the 'centre' of your points. These lines or curves of best fit make patterns in your results easier to see. They also allow you to predict any missing measurements.

Figure 1.3.6 shows a graph that plots how a baby mouse grew during its first week or so of life. The pattern in this data is shown by a line of best fit. This graph shows that at birth (0 days) the mouse was 12 mm long; at 1 day the mouse was 20 mm long; at 2 days the mouse was 25 mm long. The line of best fit passes through most of these measurements.

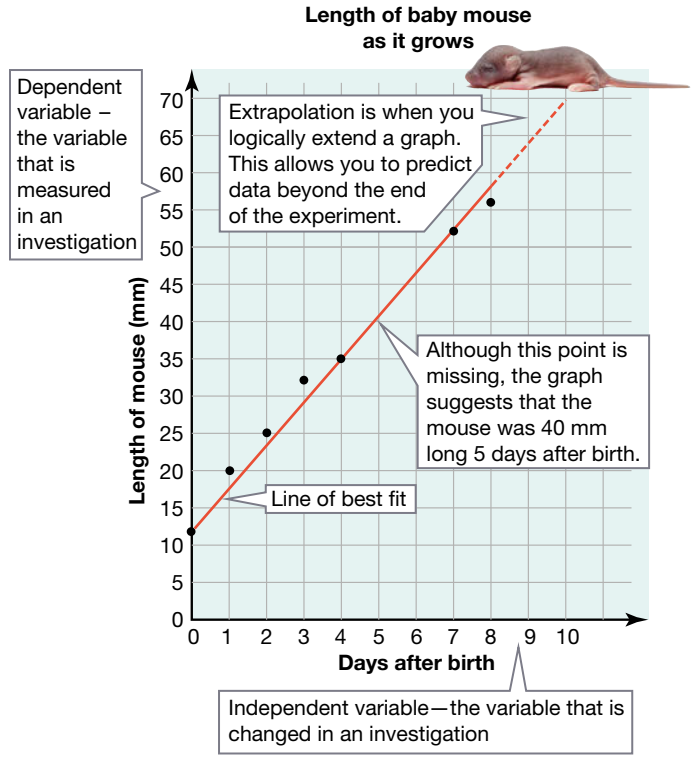


FIGURE 1.3.6 A line graph is the best way of showing the growth of a baby mouse over its first week. A line of best fit is drawn through the 'centre' of the points.

A line of best fit doesn't explain the cooling of water. Figure 1.3.7 shows that the pattern in its data is displayed better by a curve.

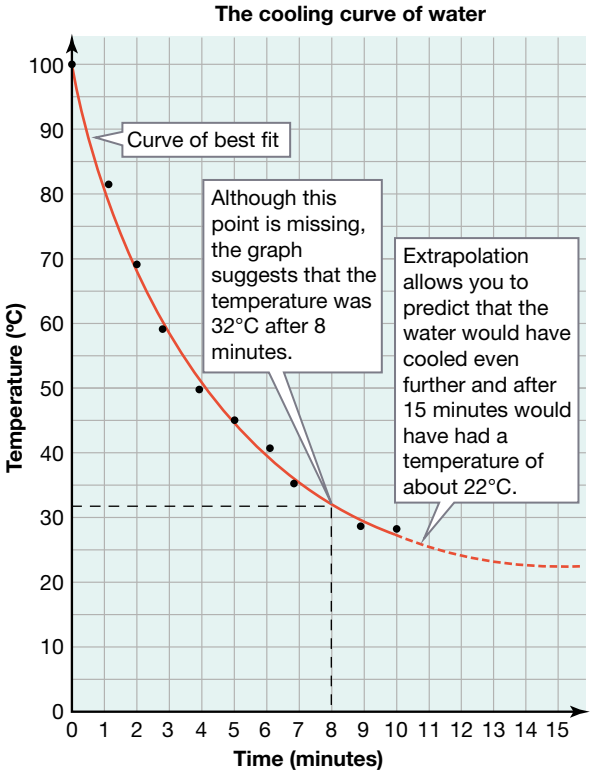


FIGURE 1.3.7 Lines and curves of best fit can be used to predict data that was never actually collected in the experiment.

Line graphs can also be extrapolated. **Extrapolation** is when a line graph is extended beyond its final measured value, allowing you to predict further measurements.

Describing patterns

Graphs that produce straight lines or logical curves indicate that there is a pattern, rule or relationship between the variables that you tested. Some ways of describing these rules are shown in Figure 1.3.8.

Prac1 p. 26 Prac2 p. 27 AB 1.7 STEM p. 28

SkillBuilder

How to avoid making common mistakes in line graphs

Some of the most common mistakes made when plotting line graphs are shown in Figure 1.3.9. It also shows the correct way of plotting them.

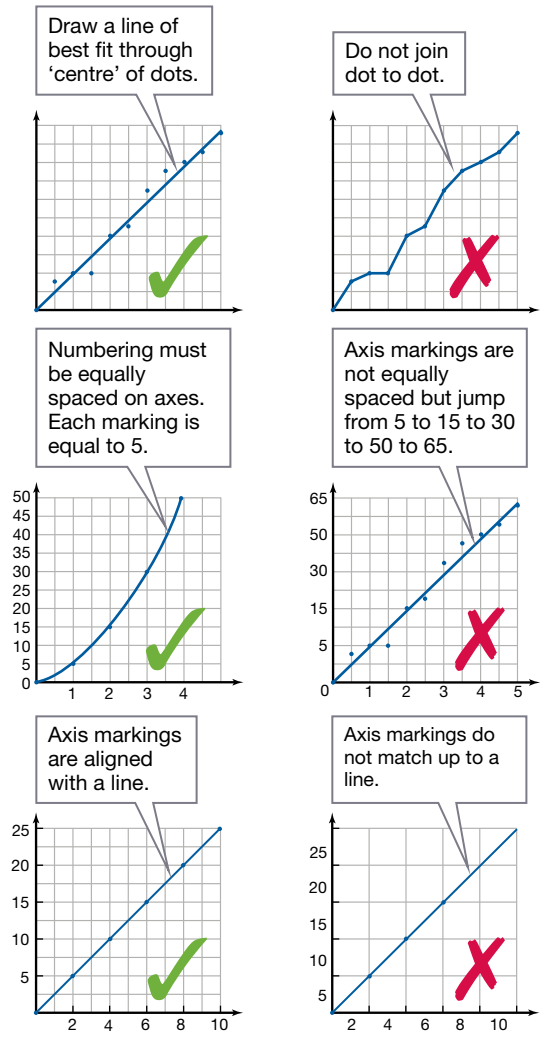


FIGURE 1.3.9

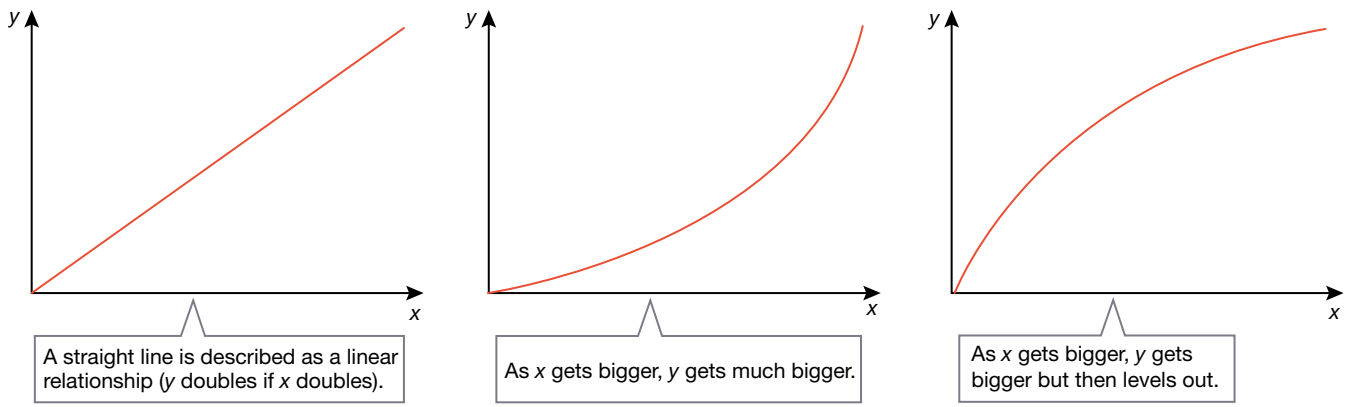


FIGURE 1.3.8 Three ways of describing the shape of a line graph

MODULE
1.3 Review questions LS

Remembering

1 Define the terms:
- a purpose
- b bibliography
- c extrapolation.

2 What term best describes each of the following?
- a an educated guess
- b a summary of what you found
- c letters that appear before unit symbols.

3 What is the standard metric unit for the following? Include their unit symbols in your answer.
- a length
- b mass
- c time
- d liquid volume.

4 List the main advantage that line graphs have over other types of graph.

5 Draw simple diagrams to compare pie charts, bar, column and line graphs.

Understanding

6 Why are lines of best fit drawn through points on a line graph instead of connecting the points up dot to dot?

7 Describe the shape of the line graphs in Figure 1.3.10.

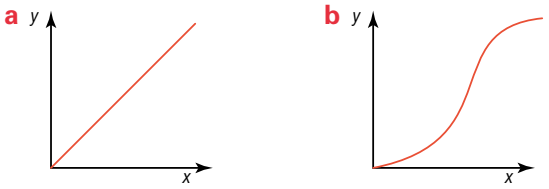


FIGURE 1.3.10

8 Convert the following quantities into the units indicated.
- a 3000 mm in metres
- b 4.5 km in metres
- c 375 mm in centimetres
- d 2850 cm in metres.

Applying

9 Below are four similar sentences that could be used in a procedure. Identify which one is best.
- A Measure the temperature of the water.
- B We measured the temperature of the water.
- C A thermometer was used to measure the temperature of the water.
- D We are going to measure the temperature of the water.

10 A Year 8 prac had the purpose 'To find out if snails remember a path leading to food'. Identify which of the following four possible conclusions is best.
- A I learnt a lot about snails from this prac.
- B Snails cannot remember a path that leads to food.
- C Snails like food.
- D The prac was fun and I would do it again.

11 a Identify the point that is probably a mistake in the graph in Figure 1.3.11.
- b Ignoring this mistake, describe the shape of the graph.

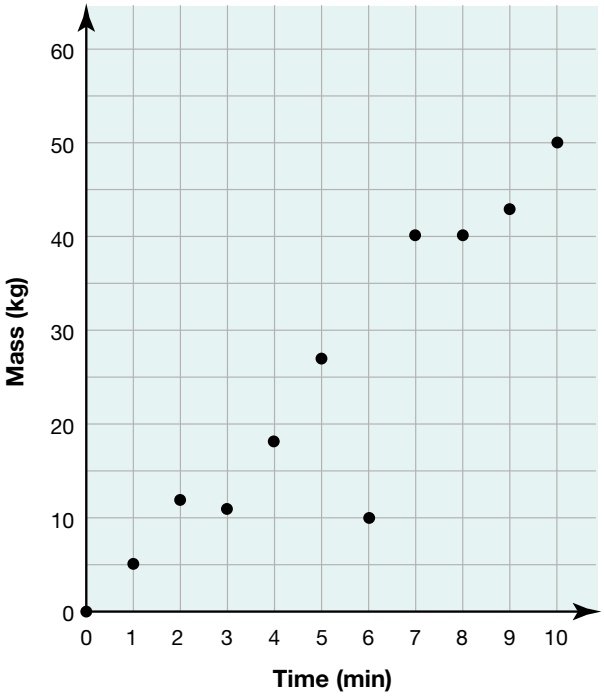


FIGURE 1.3.11

MODULE
1.3 Review questions

Analysing

12 Analyse the graph in Figure 1.3.6 on page 22 and predict:

- **a** how long the mouse is likely to be after 10 days
- **b** when the mouse is likely to be 45 mm long.

13 Analyse the graph in Figure 1.3.7 on page 23 and predict the:

- **a** likely temperature of the water at 4.5 minutes
- **b** time at which the temperature was likely to be 25°C.

14 Nell measured the times it took for a feather and a stone to fall from different heights, so that she could compare them. She came up with the graph shown in Figure 1.3.12.

- **a** Analyse her graph and predict the drop time for the feather and stone from:
  - **i** 1.5 m **ii** 2.5 m **iii** 5.0 m.
- **b** Predict the height the feather and the stone were dropped from if it took this long to fall:
  - **i** 0.5 s **ii** 0.8 s **iii** 1.0 s.

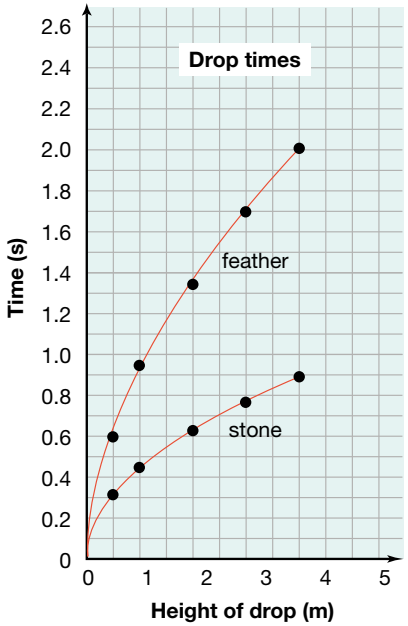


FIGURE 1.3.12

15 Analyse the graph in Figure 1.3.13 and list five things that are wrong about it and the way it is plotted.

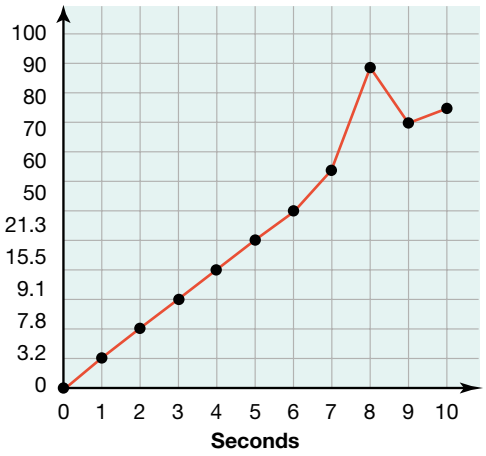


FIGURE 1.3.13

Evaluating

16 The World Health Organization recommends that people eat 10.9 MJ of food each day. On average in Australia we eat 13 500 kJ every day.

- **a** Calculate what these numbers represent in joules.
- **b** Use this information to assess the diet of Australians. Do we eat too little, just enough or too much?

Creating

17 Construct 2D scientific diagrams that show how to set up the equipment required to:

- **a** boil water in a beaker over a Bunsen burner
- **b** filter a mixture of sand and water, with the filtrate passing into a conical flask.

MODULE 1.3

Practical investigations

1 • Candles and rising water

Questioning & Predicting | Processing & Analysing

Purpose

To plot a line graph and use it to make predictions.

Hypothesis

In this experiment, the water level in the glass will rise as the candle burns. What do you think will happen if you double the number of candles—do you think the rise in water will double too? Before you go any further with this investigation, write a hypothesis in your workbook.

Timing 60 minutes

Materials

- 6–8 birthday candles
- matches
- small lump of plasticine or Blu-Tack®
- 2 elastic bands
- shallow pan
- 250 mL beaker or tall, narrow drinking glass
- 30 cm ruler

Procedure

1. Make a small plasticine mound in the centre of the pan and then fill the pan with water.
2. Stick one candle in the plasticine. Place both elastic bands around the glass and then place the glass or beaker upside down over the candle as shown in Figure 1.3.14. If using a beaker, ensure that the water level is well over its pouring lip, to prevent air from getting in.

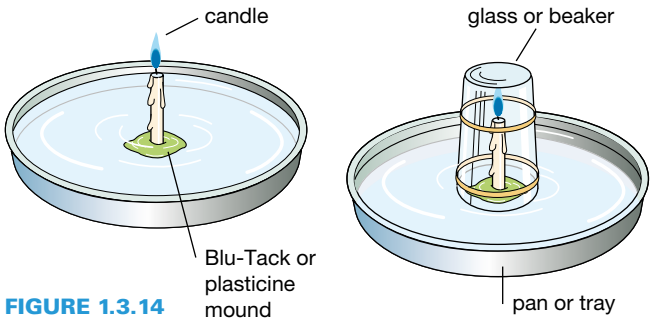


FIGURE 1.3.14

3. Roll the lower elastic band down to mark the water level.
4. Remove the glass, light the candle and quickly replace the glass over the candle.
5. Roll the other elastic band to mark the new water level.
6. Use the ruler to measure the change in water level. Record the change in a table like the one shown in the Results section.
7. Repeat the experiment with three, five and seven candles. Each time, record the change in water level in your results table.

Results

1. In your workbook, construct a table or spreadsheet like the one shown below. Give your table or spreadsheet a title.

Number of candles	Rise in water level (mm)
1	
2	
3	
4	
5	
6	
7	
8	

2. Plot a line graph showing what happened to the height of the water as more candles were added. Alternatively, program your spreadsheet to plot a line graph from your results.
3. Use the graph to predict the water rise for two, four, six and eight candles.
4. Run the practical again for four, six and eight candles to check your predictions.

Review

1. Describe the shape of the graph you plotted.
2. a. Analyse your graph. Does it suggest a relationship between the number of candles and the rise in the water level?
   b. Justify your answer.
3. a. Construct a conclusion for your investigation.
   b. Assess whether your hypothesis was supported or not.
4. Predict what would happen if you kept the number of candles the same but changed the following instead:
   a. the volume or depth of water in the tray
   b. the height or diameter of the glass jar
   c. the amount of plasticine.

MODULE
1.3 Practical investigations

SPARKlab alternative available for this activity

2 • The greenhouse effect

Questioning & Predicting | Processing & Analysing

Purpose

To demonstrate the greenhouse effect.

Hypothesis

Which do you think will heat up faster when placed in sunlight and which do you think will cool the fastest—a thermometer in a sealed plastic bag or one in the open? Before you go any further with this investigation, write a hypothesis in your workbook.

Timing 45 minutes

Materials

- 2 thermometers
- clear plastic bag
- A4 sheet of white cardboard
- sticky tape
- stopwatch, watch or clock

Procedure

1. Cut the A4 sheet of cardboard in two lengthways.
2. Stick one thermometer on each half so that they have a stiff backing.
3. Place one thermometer inside the plastic bag as shown in Figure 1.3.15. Tie it tightly so that no air can escape.
4. Place the plastic bag and the other thermometer side by side in direct sunlight.
5. Record the reading of each thermometer every minute for 15 minutes. Record the temperatures in a table like the one shown in the Results section.
6. After 15 minutes, shift both to the shade to let them cool. Continue reading each thermometer every minute for another 15 minutes.

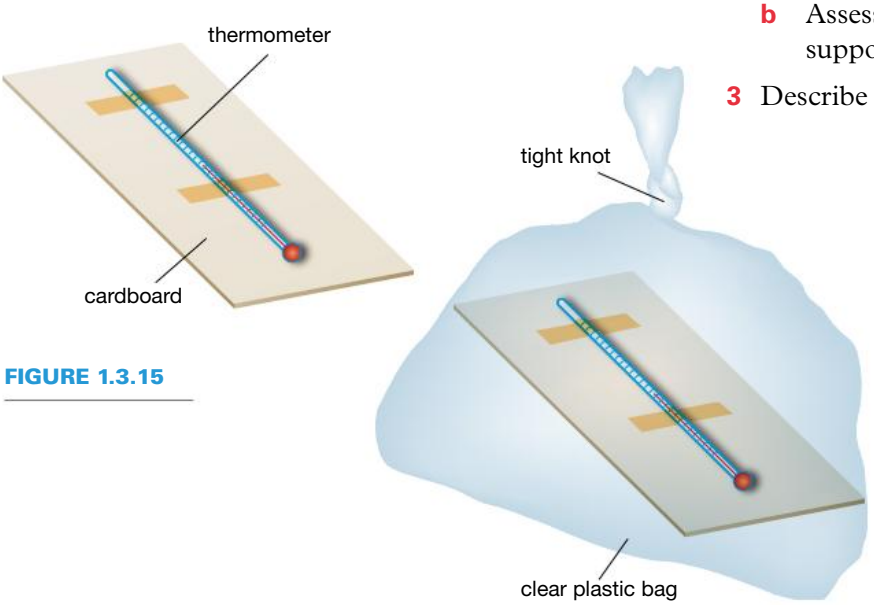


FIGURE 1.3.15

Results

1. In your workbook, construct a table or spreadsheet similar to the one shown below. Give your table or spreadsheet a title.

Time (min)	Temperature in plastic bag (°C)	Temperature in the open (°C)

2. On the same set of axes, plot a line graph for the measurements from each thermometer. If you created a spreadsheet, then use it to generate a line graph for you.

Review

1. Which thermometer showed the faster:
   a. increase in temperature?
   b. drop in temperature?
2. a. Construct a conclusion for your investigation.
   b. Assess whether your hypothesis was supported or not.
3. Describe the shape of each graph.
4. List the errors involved in this experiment.
5. Most scientists think that global warming and climate change are being caused by the enhanced greenhouse effect. How does this experiment relate to global warming?

STEM INQUIRY

Order from disorder

Processing & Analysing | Evaluating

Background

Imagine there is a creek like the one shown in Figure 1.3.16 running through a suburb near your school. The creek starts in the hills surrounding the city and winds its way through native bushland, then farmland, new outer suburbs, an industrial area and finally through inner-city suburban environments. It finally flows into the main river, then runs through the city. An environmental scientist has made measurements from water sampled at various places roughly 8 kilometres apart, starting at the beginning of the creek in the hills.

Timing 90 minutes

Problem

Unfortunately, the scientist has not organised the measurements in a way that is very useful.

The scientist said he measured the water temperature in degrees Celsius as 12, 14, 16, 25, 22, 21; the pH at each location as 7.2, 7, 6.9, 6.5, 6, 5.8; and dissolved oxygen (DO) in mg/L as 11, 10, 8, 6, 0.5, 0.2. The total suspended solids (mg/L) were 2, 10, 100, 600, 500, 300; and the bacteria (*E.coli*) numbers per 100 mL of water were 0, 650, 350, 330, 750, 680.

Your task is to arrange and display the data so the patterns can be more easily seen.

FIGURE 1.3.16 Scientist and students testing river water

Hints

- Scientific data is usually presented in tables and graphs.
- The column heading in a table gives the quantities being measured, including the units.
- When you have tabulated and graphed the data, analyse it to see what patterns have emerged and how this relates to the health of the creek.

MODULE

1.4 Planning investigations

Science would never progress if scientists only ever used secondary data. Progress happens because brand-new, primary data is obtained through experiments and scientific research. This research must be carefully planned or the data obtained will not be reliable.

STEM 4 fun

Pendulum patterns

YES

PROBLEM

Can you make a pendulum that can draw sand patterns?

SUPPLIES

- empty coffee tin, hammer and nail or hole punch, string, broom or mop handle, two chairs, fine sand, large plastic sheet, masking tape, brush and dustpan

PLAN AND DESIGN

A punctured coffee tin full of sand and hung as a pendulum will trace out patterns on the floor as the sand drains from it. What sorts of patterns are produced? Design the solution. What information do you need to solve the problem? Draw a diagram. Make a list of materials you will need and steps you will take.

CREATE

Follow your plan. Draw your solution to the problem.

IMPROVE

What works? What doesn't? How do you know it solves the problem? What could work better? Modify your design to make it better. Test it out.

REFLECTION

1. What area of STEM did you work in today?
2. How did you use mathematics in this task?
3. What did you do today that worked well? What didn't work well?

Questioning, predicting and planning

This year, you and your team will need to design and perform more of your own investigations. Before you start planning any investigation you should:

- **Be clear on the question you need to answer**
  For your investigation, be clear on what you need to do and what you are testing. This means that you need to be clear on what variables you want to test and which you are to control.
- **Get some background knowledge about what you are about to test**
  You may have already done a similar experiment and know something about it already. You might find what you need to know from this book. Otherwise, you might need to search the internet or printed sources to find out something about it. This background information will enable you to predict what might happen. This will then provide you with the basis for a hypothesis.
- **Brainstorm ideas from everyone in your team**
  This way your team will come up with ideas that you may never have thought of by yourself.
- **Know what equipment and materials are available**
  It doesn't make much sense planning an investigation that uses equipment that the school does not own or equipment that is reserved for senior science classes.
- **Find out what is potentially dangerous in your investigation**
  You particularly need to find out whether the chemicals you want to use are dangerous, and how to minimise their risks.
- **Assess whether your planned investigation is ethical**
  You need to make sure it will not hurt animals, the environment or others.
- **Think about the best way to record your observations**
  Consider whether you will use a table or spreadsheet to record your measurements, or whether a series of photos or a video might be better way of recording your observations.
- **Think about the best way to analyse your data**
  Consider whether a graph is needed and, if so, what type of graph (pie, column, line) is best for your investigation.

Safety

Performing experiments can be dangerous and so every laboratory has a set of safety rules that must be followed. One common rule is shown in Figure 1.4.1. Others common to all laboratories are:

- Always follow instructions from your teacher or laboratory technician.
- Move about the lab in a safe way. Do not run, push or shove.
- Always wear safety glasses when using chemicals or a Bunsen burner.
- Unless instructed to do so by your teacher or lab technician, do not eat, taste, drink or sniff anything in the lab.
- Always tell your teacher if you break something or if you are unsure about what to do.
- Turn on the tap before placing anything under it. Otherwise the pressure might break whatever you are holding.
- Always tie back long hair before heating something. Otherwise it's a fire risk!
- When the Bunsen burner is not in use, turn it to a visible yellow safety flame.
- Only use matches to light Bunsen burners. Do not use lighted scraps of paper.
- Always use tongs to pick up objects that have been heated.
- Hotplates, Bunsen burners, tripods and gauze mats remain hot for a long time. Allow them to cool before packing them away.

FIGURE 1.4.1 When heating a test-tube, ensure that it is pointed away from everyone (including you).

Risk assessment

All experiments are risky, or even dangerous, if you do not perform them carefully. For this reason, all experiments require a risk assessment, which tells everyone how risky they are and how those risks can be avoided or minimised. For most experiments, a risk assessment has been done by your teacher or the laboratory technician. For your own investigations, you will need to construct a list of potential risks and ways of minimising them. Without this list, you will not be able to start work.

Some risks will be obvious. For example, you will naturally avoid an experiment that would require someone to climb up a tall tree or one in which someone is hit with stones flung from a slingshot. However, you will not know how dangerous chemicals are. To find out, you need to search the internet for each chemical's Safety Data Sheet (SDS) (Figure 1.4.2).

1. IDENTIFICATION OF THE MATERIAL AND SUPPLIER

Product Name: **HYDROCHLORIC ACID - 20% OR GREATER**

Recommended use of the chemical and restrictions on use: Precursor for generation of chlorine dioxide gas used in water treatment.

Supplier: Ixom Operations Pty Ltd
ABN: 51 600 546 512
Street Address: Level 8, 1 Nicholson Street, Melbourne 3000, Australia

Telephone Number: +61 3 9665 7111
Facsimile: +61 3 9665 7937
Emergency Telephone: **1 800 033 111 (ALL HOURS)**

Please ensure you refer to the limitations of this Safety Data Sheet as set out in the "Other Information" section at the end of this Data Sheet.

2. HAZARDS IDENTIFICATION

Classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for Transport by Road and Rail; DANGEROUS GOODS.

This material is hazardous according to Safe Work Australia; HAZARDOUS SUBSTANCE.

Classification of the substance or mixture:
Corrosive to Metals - Category 1
Skin Corrosion - Sub-category 1B
Eye Damage - Category 1
Specific target organ toxicity (single exposure) - Category 3

SIGNAL WORD: DANGER

Hazard Statement(s):
H290 May be corrosive to metals.
H314 Causes severe skin burns and eye damage.
H335 May cause respiratory irritation.

Precautionary Statement(s):

Prevention:
P234 Keep only in original container.
P260 Do not breathe mist / vapours / spray.
P264 Wash hands thoroughly after handling.
P271 Use only outdoors or in a well-ventilated area.
P280 Wear protective gloves / protective clothing / eye protection / face protection.

FIGURE 1.4.2 Safety Data Sheet

This sheet will tell you everything you need to know about the chemical you are using. It will tell you:

- its physical properties—for example, its melting point, boiling point, colour and density
- its chemical properties—for example, how it reacts with oxygen or whether it is an acid or a base
- what dangers it might present to you—for example, whether it will burn or trigger an asthma attack
- what you can do to minimise those dangers—for example, by wearing rubber gloves or by performing the experiment outside or in a fume hood (Figure 1.4.3)
- appropriate first aid if you accidentally come into direct contact with the chemical.

FIGURE 1.4.3 This police officer is undergoing hazardous materials training and is protecting himself by wearing thick rubber gloves, a protective body suit and a gas mask.

Variables

Variables are factors that might have some influence on an experiment.

As an example, think of a simple experiment in which you are toasting a slice of bread. The time takes will depend on many variables (Figure 1.4.4).

A few variables are:

- the type of bread (Is it light and fluffy or heavy and dense?)
- the thickness of the slice (Is it thick, thin or in between?)
- how dry the bread is (Is it old, dry and stale or new, fresh and moist?)
- the make of toaster (Is it Sunbeam, Breville or another brand?)
- the age of the toaster (Is it new or old?)
- how clean the toaster is. (Is it clean or covered in crumbs?)

FIGURE 1.4.4 Many factors influence the time it takes to toast some bread. These factors are known as variables.

Not all variables are equally important. Some will greatly influence the experiment, while others will have little or no effect. Important variables here are the type of bread, its dryness and thickness, and the type of toaster. The cleanliness and age of the toaster will have some effect but probably not as much as other variables.

Independent variable

Once you have identified all the variables involved in an experiment, you then need to pick one to test. The variable you choose is known as the **independent variable**. It is the only one you are going to change. This is important because if you change more than one variable, it will be hard to work out which variable is having a direct effect on the results. Changing one variable at a time ensures that we know which variable is having an effect on the results.

For the toast experiment, you might choose the thickness of the slice as your independent variable (Figure 1.4.5). You would change the thickness of the slice and test its effect on the cooking time.

FIGURE 1.4.5 The thickness and type of bread will affect how long it takes to toast.

Dependent variable

What you are trying to test and about to measure is known as the **dependent variable**. This is because it depends on the independent variable. Change the size of the independent variable and the size of the dependent variable is likely to change too. The dependent variable in the toast experiment is the time it takes to toast the slice—it depends on the thickness of the slice (the independent variable).

Controlled variables

Any experiment that you run needs to be a **fair test**. This means that only one variable should be changed at any time. All the other variables need to be controlled (or held constant). For this reason, these variables are referred to as **controlled variables**. If they were changed too, then you would never know which variable caused changes in the experiment.

In the toast experiment, the controlled variables would be:

- the type of bread (choose one type of bread and use it throughout the experiment)
- how dry the bread is (all the bread you test would need to be the same dryness and age)
- the make, age and cleanliness of the toaster (stick with one toaster and don't change it).

Scientific research

An experiment only changes one variable at a time. If you want to change another variable, then you need to run another experiment. This means that you could potentially run six or more different experiments to fully investigate the time it takes to toast bread!

A group of related experiments such as this is known as **scientific research**. Each new experiment changes another variable (with all the others kept constant) until you have tested them all.

Scientists do not carry out unrelated experiments but carry out scientific research on the one topic. This gives them a thorough understanding of that topic and allows them to become experts in it.

Teamwork

Scientists generally do not work by themselves but as part of a **team** like the one in Figure 1.4.6. Everyone is good at something and teamwork allows these strengths to be shared. Equally, we all perform less well at some things and teamwork allows others to help out when one of their members is struggling.

FIGURE 1.4.6 You will usually work as part of a team when carrying out scientific prac work.

There are many different ways that teams can be organised. One that works well in the school laboratory is the managerial model in which there are four team members.

- Manager—this team member oversees the whole team and prac. They make sure that everyone knows what to do and that the prac work is completed on time.
- Communicator—this team member communicates with the teacher and laboratory assistant. All communication to and from the team should pass through the communicator. For example, the teacher may gather all the communicators together to go through the safety concerns of the prac or to show them how to use a particular piece of equipment. The communicator then passes on this information to the team.
- Equipment specialist—this team member collects all the required equipment and materials and makes sure the equipment is cleaned and returned to the correct spot at the end of the prac. They report any broken equipment to the communicator, who passes on the information to the teacher.
- Recorder—this team member records all the observations and measurements that are taken throughout the prac. They also ensure that all the other team members have their own copy of results before they leave the laboratory.

Ethical guidelines

Scientists must be ethical in their research and so must you. Any investigation that you carry out needs to:

- be safe—assess all risks before carrying out any prac work and take steps to minimise those risks. Take care with equipment and chemicals and follow all laboratory safety rules
- be careful—avoid silly mistakes and make sure that all data is recorded accurately
- be honest—run fair tests and analyse your data accurately and fairly. If you use data from someone else, then acknowledge them in a resource list
- be respectful—respect the work of others, whether they are part of your prac team, your teacher, the laboratory technician or someone who has provided secondary data
- take care of the environment—chemicals can harm the environment, so dispose of them as instructed by your teacher or laboratory technician. If an experiment requires samples of soil, leaves, plants or animals then take only what you need and no more
- take care of animals—do not carry out unnecessary experiments on animals. If you do need to use animals (even insects and snails), then treat them with care and respect. If possible, return the animals to their habitat when you have completed your work.

Prac1 p. 37 AB 1.8 STEM p. 40

STEM 4 fun

Paper towels versus toilet paper

NO

PROBLEM

Which is more absorbent—paper towel or toilet paper?

SUPPLIES

- paper towel, toilet paper, access to water, eyedroppers, teaspoons, measuring cylinders, cups or beakers

PLAN AND DESIGN

Design a fair test to find the solution. What information do you need to solve the problem? Draw a diagram. Make a list of materials you will need and steps you will take.

CREATE

Follow your plan. Draw your solution to the problem.

IMPROVE

What works? What doesn't? How do you know it solves the problem? What could work better? Modify your design to make it better. Test it out.

REFLECTION

1. What area of STEM did you work in today?
2. How did you use mathematics in this task?
3. If another student was to do this task, what advice would you give?

The pendulum

The pendulum is a simple device but it gave early scientists an accurate way to measure time and length, and it allowed early explorers to accurately determine where they were.

A **pendulum** is a mass (called a **bob**) attached to a rod, chain or rope that swings back and forth repeatedly.

A typical pendulum is shown in Figure 1.4.7. The **period** of a pendulum is the time it takes to complete one entire swing, back and forth, as shown in Figure 1.4.8. Period is measured in seconds (unit symbol s).

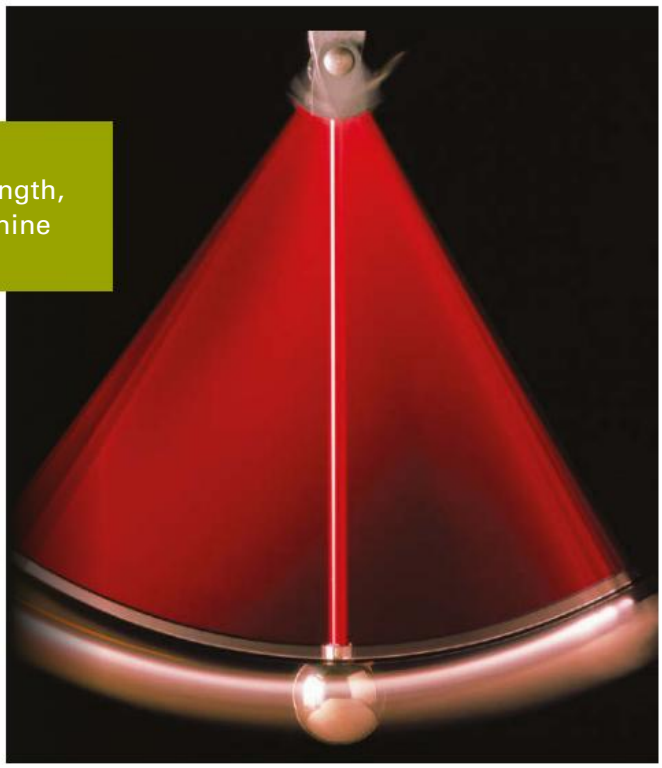


FIGURE 1.4.7 Pendulums are used in metronomes and some clocks.

Pendulum variables

Important variables that affect the period of a pendulum are:

- the length of the string—the longer the string, the slower the bob will swing and the longer the period
- gravity—a pendulum only swings because of gravity, but changing gravity significantly would mean travelling somewhere in space, which is highly unlikely.

The mass of the bob is another variable, but changing it has little or no effect on the swing and period. Likewise, the angle from which the bob is swung has little or no effect until it reaches more than 10°. Above that angle, the pendulum's swing can become messy and irregular.

Prac 2 p. 38
Prac 3 p. 39
AB 1.9

History of the pendulum

In 1602, the Italian scientist Galileo Galilei studied the pendulum and its variables in detail. His findings allowed scientists of the seventeenth century to develop new instruments that changed the way time was measured, how explorers determined their position on Earth and much more.

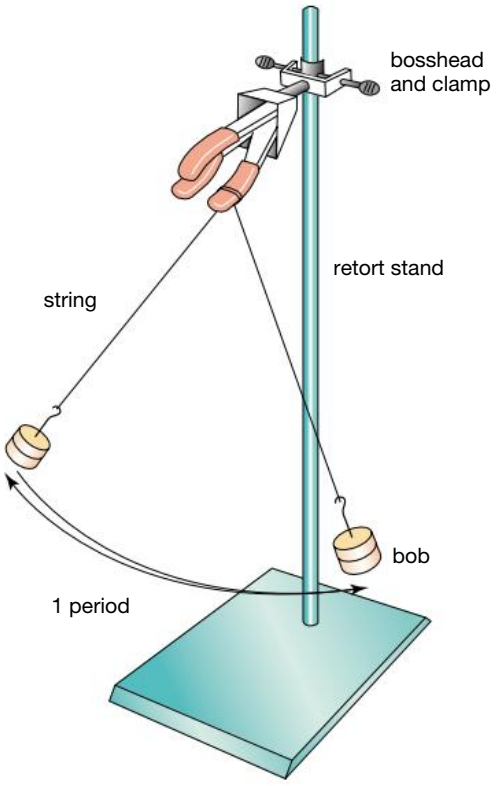


FIGURE 1.4.8 A simple pendulum

SciFile

Foucault's pendulum

Every swing a pendulum makes is in a slightly different direction due to Earth's rotation about its own axis. After 24 hours, the pendulum returns to its original direction. A pendulum that does this is known as a Foucault's pendulum and it is evidence that Earth is spinning.

Timekeeping

Pendulums swing regularly back and forth when allowed to swing from angles of less than 10° from the vertical. This fact allows pendulums to be used in clocks. Before 1656, clocks were often 'out' by as much as 30 minutes. However, in that year, Dutch scientist Christian Huygens built a pendulum-based clock that was accurate to within ten seconds per day.

Pendulums are still used to regulate the timing of grandfather and older-style mantle clocks today. The bob of a grandfather clock is shown in Figure 1.4.9.

FIGURE 1.4.9 Grandfather clocks use a pendulum to keep them accurate.

Metronomes

Musicians use metronomes to keep in time when practising. A typical metronome is shown in Figure 1.4.10. A metronome uses a pendulum to regulate its time. The pendulum can be made to go faster by sliding the mass down the rod, and to go slower by pushing it upwards.

FIGURE 1.4.10 A metronome is an 'upside-down' pendulum. Its period matches the timing of the music being practised.

Standards of length

Scientists, builders and traders all over the world need to know the exact length of one metre. They need a standard length that doesn't change. One early method of setting the standard length of one metre was suggested by French scientist Gabriel Mouton around 1670. His method used a pendulum. Gravity is roughly the same everywhere on Earth, and so the seconds pendulum swings the same way wherever it is located. To achieve a period of one second, a pendulum needs to be one metre long. Hence, anyone with a pendulum has an accurate way of measuring the length of one metre. Although convenient, this method of defining the length of a metre was abandoned in favour of other (non-pendulum) methods.

Navigation

Early explorers were often unsure of where they were on Earth because they had no way of accurately measuring their longitude (how far they were east or west on Earth). The invention of accurate clocks gave them the technology to measure time accurately. They set their clocks when they left port against standard Greenwich Mean Time. At noon, the Sun is directly overhead and the clock should read 12. If it didn't, then it meant that they had travelled east or west. Every hour their clock was 'out' represented another 15° they had travelled from longitude 0°. From this, early explorers were able to calculate their longitude.

Shape of the Earth

Gravity is one of the variables on which the period of a pendulum depends. The swings of a pendulum can therefore be used to measure the value of gravity around the globe. Pendulums swing a little slower at the equator than at the poles. This proves that Earth is not perfectly spherical but has a greater diameter at the equator.

REVIEW

1. Define the term *period*.
2. Outline how the pendulum can be used for:
   - **a** accurate timekeeping
   - **b** measuring the length of one metre
   - **c** navigation
   - **d** determining the shape of Earth.

MODULE 1.4

Review questions

Remembering

1 Define the following terms:
- a variable
- b fair test
- c risk assessment.

2 What term best describes each of the following?
- a variables that you keep constant
- b a group of related experiments
- c the sheet with all the information you need to know about a chemical.

3 List the variables that influence the time it takes to toast a slice of bread.

4 Match the different types of variables in the first column with their correct descriptions in the second column.

independent	fixed
dependent	changes naturally
controlled	changed by you.

5 List six ethical guidelines that you need to follow when carrying out scientific research.

Understanding

6 Why should you (or your teacher) check the SDS of chemicals before an experiment?

7 a How many variables should be changed in a single experiment?
- b Explain why.

8 Predict the pattern that would form in the STEM4fun on page 29.

Applying

9 Imagine aliens land on Earth and begin to carry out experiments on humans.
- a Identify the ethical guideline that you really hope they follow.
- b Explain how this relates to what you do in the school laboratory.

Analysing

10 Contrast:
- a scientific research with an experiment
- b independent and dependent variables.

11 Analyse the following experiments and identify:
- i the dependent variable
- ii two independent variables that are likely to be important.
  - a Prac A: To determine the amount of sugar that can be dissolved in water.
  - b Prac B: To determine the amount of time a pet dog sleeps per day.
  - c Prac C: To determine how long a parachute takes to drop 50 metres.

Evaluating

12 What advantages and disadvantages do you think the managerial model brings to the:
- a team?
- b teacher?

13 Someone in your team just got hurt in a prac. You want to tell the teacher but your team is organised on the managerial model and you're not the communicator. What do you think you should do?

Creating

14 Benji and Bianca carried out an experiment to test how long it took to toast a slice of bread. They repeated the experiment and calculated average times. Their results are shown in the table below.
- a For this experiment, identify the:
  - i independent variable
  - ii dependent variable
  - iii controlled variables.
- b Identify which type of graph below would best represent the above data.
  - A line graph
  - B histogram
  - C bar graph
  - D pie chart/sector graph.
- c Design an experiment that tests which of five different toasters toasts a slice of bread the quickest.

Toaster make	Setting	Bread type	Slice thickness	Fresh or stale	Average time (s)
toastie	high	wholemeal	thick	fresh	40
toastie	high	white	thick	fresh	31
toastie	high	seeded	thick	fresh	45
toastie	high	wholegrain	thick	fresh	44
toastie	high	sourdough	thick	fresh	38

MODULE 1.4

Practical investigations

• STUDENT DESIGN •

1 • Parachute drop time

Questioning & Predicting | Evaluating

Purpose

To determine what influences the drop time of a parachute.

Timing 45 minutes

Materials

- lightweight materials (such as tissue paper, plastic sheet from garbage bags, newspaper)
- fine cotton
- access to a hole punch
- sticky tape
- small masses (plasticine or paperclips are ideal)
- access to an electronic balance
- stopwatch
- metre ruler or tape measure

SAFETY

A risk assessment is required for this investigation.

Procedure

1. Brainstorm all the variables that could affect the drop time of a parachute.
2. Select the two variables that your team thinks will have the most effect.
3. What do you think will happen to the drop time as you change your selected variables—do you think it will increase or decrease? Before you go any further with this investigation, write a hypothesis in your workbook for each of your selected variables.
4. Design several different ways to test each of your selected variables. Select the best procedures and write them in your workbook.
5. Before you start any practical work, assess your procedure. List any risks that your procedure might involve and what you might do to minimise those risks. Show your teacher your procedure and your assessment of its risks. If they approve, then collect all the required materials and start work.

Hints

- Only change the variable you have chosen to test. Keep all the other variables the same.
- When constructing your chutes, reinforce the string holes with patches of sticky tape like the one shown in Figure 1.4.11.

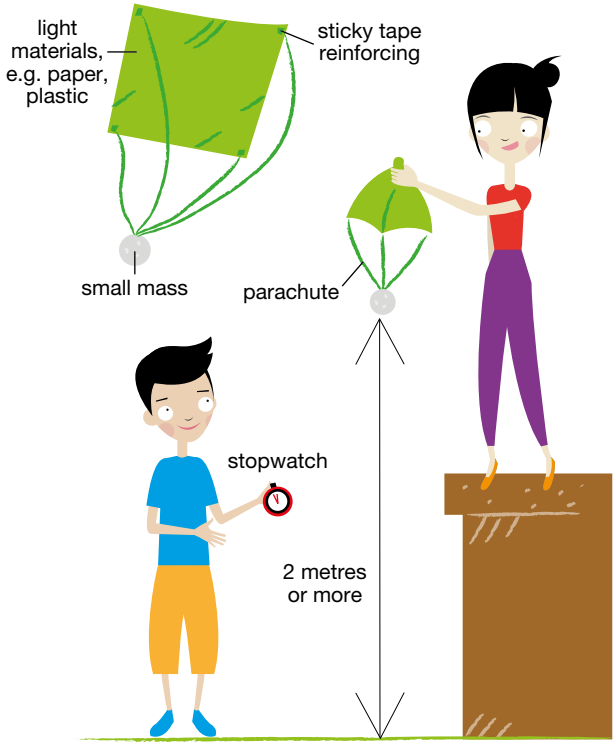


FIGURE 1.4.11

- Drop your chutes from a height of at least 2 metres.
- Make repeated measurements of the time they take to hit the ground, recording the times in a table or spreadsheet.
- Use the STEM and SDI template in your eBook to help you plan an carry out your investigation.

Results

Construct a table and a line graph for each experiment.

Review

1. List the variables that your prac team thought may be important in this experiment.
2. Explain why you chose the variables you tested and not others.
3. Describe the shape of all graphs you plotted.
4. a Construct conclusions for both experiments.
   b Assess whether your hypotheses were supported or not.
5. Evaluate your procedure. Pick two other prac groups and evaluate their procedures too, identifying their strengths and weaknesses.

MODULE
1.4 Practical investigations

SPARKlab alternative available for this activity

• STUDENT DESIGN •

2 • The pendulum and length

Questioning & Predicting | Evaluating

The time it takes for the pendulum to complete one swing (back and forth) is known as its period.

Hypothesis

What do you think will happen to the period of a pendulum when its length is increased—will the period increase, decrease or stay the same? Before you go any further with this investigation, write a hypothesis in your workbook.

Purpose

To test how the length of a pendulum affects its period.

Timing 45 minutes

Materials

- materials to construct a pendulum
- stopwatch or appropriate data-logging equipment
- protractor (optional)

SAFETY

A risk assessment is required for this investigation.

Procedure

1. Design an experiment that tests what happens to the period of a pendulum when its length is changed.
2. Write your procedure in your workbook.
3. Before you start any practical work, assess your procedure. List any risks that your procedure might involve and what you might do to minimise those risks. Show your teacher your procedure and your assessment of its risks. If they approve, then collect all the required materials and start work.

Hints

- The independent variable here is the length of the pendulum, and so you need to keep the mass and the angle the pendulum is swung from the same throughout the prac. Decide what mass and angle you will use, and keep them fixed.
- Decide on the lengths that you will test. At least five different lengths should be tested.
- Don't attempt to measure the time of a single swing. Instead, measure the time for five or ten complete swings.
- You need to repeat measurements for the time taken for ten complete swings. Decide how many times you will repeat each experiment.
- Use the STEM and SDI template in your eBook to help you plan and carry out your investigation.

Results

1. Construct a table or spreadsheet for the measurements you take.
2. Calculate the average time for ten swings and for one swing (the period) or get your spreadsheet to do it for you.
3. Plot a graph of period versus length.
   Extension: One aim of a scientist when analysing results is to try and get a straight line when plotting graphs. If you didn't get a straight line, then try the next few steps.
4. Make another column in your table. Use a calculator to take the square root $\sqrt{}$ of the lengths you used and enter these into the new column.
5. Plot a new graph of period versus square root of length like the one shown in Figure 1.4.12.

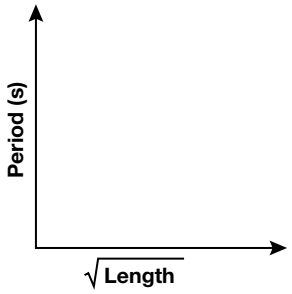


FIGURE 1.4.12

Review

1. Describe the shape of each graph that you plotted.
2. List the controlled variables in this experiment.
3. What were the independent and dependent variables in this experiment?
4. a Construct a conclusion for your investigation.
   b Assess whether your hypothesis was supported or not.

MODULE 1.4

Practical investigations

• STUDENT DESIGN •

3 • The pendulum, mass and starting angle

Questioning & Predicting | Evaluating

Purpose

To test whether mass and starting angles change the period of a pendulum.

Hypothesis

What do you think will happen to the period of a pendulum when its mass is increased or if it is swung from a bigger angle—do you think the period will increase, decrease or stay the same? Before you go any further with this investigation, write a hypothesis in your workbook.

Timing

45 minutes per variable

Materials

- materials to construct a pendulum
- stopwatch
- protractor

SAFETY

A risk assessment is required for this investigation.

Procedure

1. Your task is to design and report on an experiment that tests how starting angle or mass affects the period of a pendulum (Figure 1.4.13).
2. Write your procedure in your workbook.
3. Before you start any practical work, assess your procedure. List any risks that your procedure might involve and what you might do to minimise those risks. Show your teacher your procedure and your assessment of its risks. If they approve, then collect all the required materials and start work.

   Use the STEM and SDI template in your eBook to help you plan and carry out your investigation.

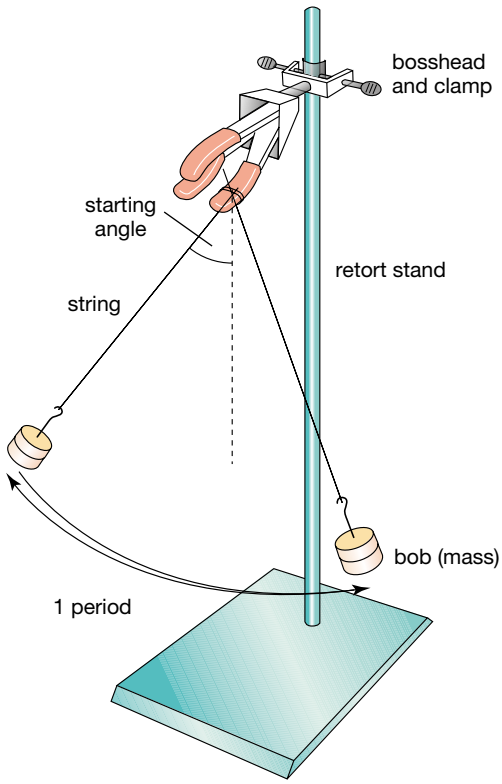


FIGURE 1.4.13

Results

Construct a table or spreadsheet and a line graph to display your results.

Review

1. Explain how you controlled all the variables other than the starting angle in this experiment.
2. a Construct a conclusion for your investigation.
   b Assess whether your hypothesis was supported or not.

MODULE 1.4

Practical investigations

STEM INQUIRY

BMXtreme

Planning & Conducting | Processing & Analysing

FIGURE 1.4.14 BMX rider in full flight!

Background

Sport promoters are developing a new competition for BMX cyclists, like the one shown in Figure 1.4.14. The competition is like ski jumping. The competitors start up a ramp.They gain speed as they travel down the ramp, and leap from the ramp, with the aim of landing upright on two wheels. Unlike ski jumping, where the skier lands on a downhill slope, the ground on which the BMX rider lands is horizontal.

You are hired as a designer, and your job is to find the shape of a ramp that will enable competitors to get maximum horizontal distance from take-off. The difference between competitors will be in the speed that they can gain in travelling down the ramp and in their jumping and landing techniques.

It is too expensive to build a range of different ramps, so initially trial ramps will be modelled in a laboratory using a small ball rolling down and off the end. The challenge is to find the optimum ramp shape so the ball travels the greatest horizontal distance after leaving the ramp. You can use any scientific knowledge that you know about energy, or just use your common sense.

Following your investigation, you are required to write a report for engineers who will be responsible for the final design and construction of the real ramp.

In the report you need to explain the testing procedure, present the data, and accurately communicate your conclusions with justifications.

Task

Your task is to design a ramp for a BMX bike jumping competition (like a ski ramp).

Timing 2–3 hours across several lessons

Procedure

Work in small groups to identify the best shape ramp for use in the BMXtreme jump competition. Your group will propose designs, construct models and systematically test a variety of shapes for the jumping ramp. You will need to decide which shapes of the ramp to test, the measurements you will make and ways to make these measurements accurate and reproducible. During the testing, you will record your measurements (data). You will then analyse the data collected to find out which shape is best. Use the STEM and SDI template available on your eBook to help plan and carry out your investigation.

Materials

You will be provided with some basic materials, including:

cardboard (manila folder), marbles, straws, icy pole sticks, ruler or measuring tape, plasticine, sticky tape or masking tape, a sand or flour tray, and a bulldog clip and chair or table leg.

Your teacher may provide you with other materials.

Planning

1 Identify the purpose.

2 Identify the independent, dependent and controlled variables, and only change one variable at a time.

3 Based on your purpose and the controls and variables, write a hypothesis for this experiment.

4 Summarise your experiment in a scientific report. Include the Purpose, Hypothesis, Materials, Procedure, Risk Assessment, Results (including data presented in table and/or graphs), Discussion and Conclusion.

CHAPTER 1

Chapter review

Remembering

1 Define the terms:
- a purpose
- b hypothesis
- c conclusion
- d bibliography
- e prefix
- f tare.

2 Which of the following statements are true and which are false?
- a A measurement ranging from 10°C to 14°C could be written as 12 ± 2°C.
- b A measurement of 21 ± 1 cm spreads from 21 to 22 cm.
- c Human reactions cannot be faster than 0.5 seconds.
- d A line of best fit connects its points dot to dot.
- e 'The prac was fun' is a good conclusion for an experiment.

3 List three pieces each of qualitative data and three pieces of quantitative data that would help describe where you live.

4 List five types of errors.

5 List four variables that might be expected to influence:
- a a person's fitness
- b the time it takes to fry a sausage
- c the temperature reached inside a parked car.

Understanding

6 Why should you always be ethical in your investigations and research?

Applying

7 Identify the variables that could logically influence:
- a how quickly iron rusts
- b how quickly a banana ripens
- c how often you go to the toilet to urinate
- d how good you are at sport.

Analysing

8 Analyse the graph in Figure 1.5.1 and predict the sound intensity (measured in watts per square metre) at:
- a 2.5 m
- b 3.5 m
- c 150 cm.

9 Extrapolate the graph in Figure 1.5.1, extending it logically backwards to zero. Use your extrapolation to predict what the sound intensity at a distance of 0 metres would be.

10 Analyse the graph in Figure 1.5.1 and predict the distance at which the sound intensity was:
- a 45 W/m^2
- b 15 W/m^2

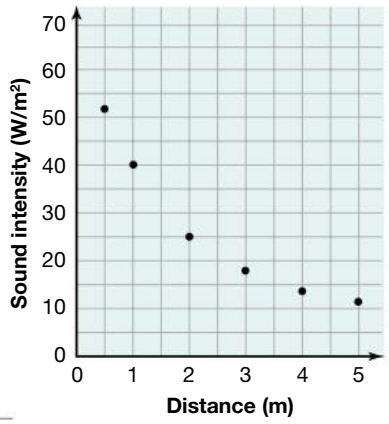


FIGURE 1.5.1

11 Consider the following list of volumes:
87 mL, 82 mL, 90 mL, 86 mL, 97 mL, 93 mL.
- a Which results should be eliminated?
- b Calculate the average.

Evaluating

12 a Determine whether you can or cannot answer the questions on page 1 at the start of this chapter.
- b Assess how well you understand the material presented in this chapter.

Creating

13 Use the following ten key terms to construct a visual summary of the information presented in this chapter.

data	internet	experiment
primary	secondary	variable
independent	dependent	fair test
controlled		

AB 1.11

CHAPTER 1

Inquiry skills

Research

1 Evaluating

Search the internet for games that test how well you:

- **a** take measurements (use measurement games for your search)
- **b** convert units (use skillwise unit conversion for your search).

2 Evaluating

Search the internet for videos showing:

- **a** how pendulum clocks work
- **b** parachute drops and skydiver formations (Figure 1.5.2).

Present your findings as a summary.

FIGURE 1.5.2 Skydivers in formation

3 Communicating | Processing & Analysing

In 1983, Air Canada flight AC143 ran out of fuel and glided to a safe landing at an abandoned air force base at Gimli, Canada. Research this flight to find:

- details of its descent and landing
- images/video of the flight
- how the conversion between litres (a metric unit) and gallons (an older imperial unit) led to the aircraft running out of fuel
- what else went wrong when landing and how this assisted the aircraft
- whether there were any injuries or deaths.

Present your research in digital form. In your presentation, classify the problems the flight crew had with their unit conversions as mistakes or errors. Justify your decision.

4 Communicating | Processing & Analysing

Accidents caused the following discoveries to be made or caused another use for them. Research one of them.

- penicillin (Alexander Fleming)
- Bakelite™ (Leo Hendrik Baekeland)
- Coca-Cola® (John Pemberton)
- heart pacemaker (Wilson Greatbatch)
- microwave oven (Percy L. Spencer)
- radioactivity (Henri Becquerel)
- Teflon® (Roy Plunkett)
- saccharine (Constantin Fahlberg)
- vulcanised rubber (Charles Goodyear).

Whichever one you choose:

- **a** state the year of the discovery
- **b** describe the accident that caused it to be made
- **c** describe the current use of the discovery
- **d** list biographical details about its discoverer.

Present your research as a biography outlining the life of the discoverer and their accidental discovery.

5 Communicating | Processing & Analysing

Advertising often uses data to make claims about particular products. Describe an advertisment that does this and analyse how the data is used to make the product look good.

Present your findings as a:

- print copy or recording of the ad
- summary of the data used
- description of how that data was used to convince people to buy whatever product or service is being advertised.

6 Evaluating | Processing & Analysing

Research the development of different standards for the length of one metre. Find:

- what the *toise* was
- the problems associated with the toise
- how the size of the Earth was used to define the metre
- how modern scientists define the length of one metre.

Present your findings as answers to the above.

CHAPTER 1

Inquiry skills

Thinking scientifically LS

Anila ran an experiment in which she measured the period of a pendulum. The period is the time it takes for a mass on a length of string to swing back and forth once. The data she obtained is shown in the table below.

Mass of bob (g)	Length (cm)	Angle swung from	Time for 10 complete swings (s)	Average period (s)
50	50	10°	142	1.42
50	100	10°	201	2.01
50	150	10°	246	2.46
50	200	10°	283	2.83
50	250	10°	317	3.17

1 Which two variables did Anila control in her experiment?

- **A** mass and length
- **B** length and angle
- **C** mass and angle
- **D** average period and time for ten swings.

2 Which of the following is the most likely aim for her experiment?

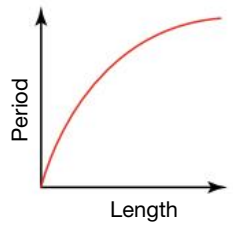
- **A** to test the effect of changing mass on the period of a pendulum
- **B** to test the effect of changing length on the period of a pendulum
- **C** to test the effect of changing angle on the period of a pendulum
- **D** to test the effect of changing times for ten complete swings on the period of a pendulum.

3 Anila did not try to time a single swing but instead timed ten complete swings. Identify the most likely reason explaining why she did this.

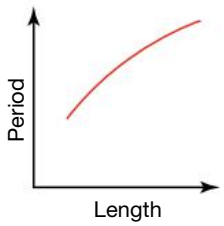
- **A** She can count to ten.
- **B** It reduced the effect of errors in her timing.
- **C** The change in period only becomes noticeable after ten swings.
- **D** It was the only way to test her chosen variable.

4 Identify which of the four sketch graphs A–D best describes her results.

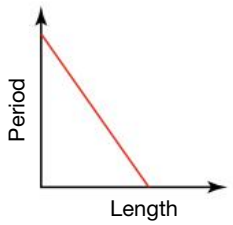
A



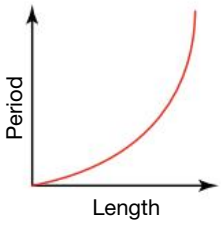
B



C



D



CHAPTER 1

Glossary

average: the mean; add up all the 'good' values and divide by how many there are

bibliography: resource list

bob: the mass on the end of a pendulum

conclusion: a short summary of what you found out in an experiment

controlled variable: the variable that is kept constant throughout an experiment

data: measurements and observations about something

dependent variable: the variable that is being measured in an experiment; it changes as the independent variable changes

domain: the last part of a website's address or URL

errors: small changes to measurements that cannot be avoided, even with care

ethics: the study of what is right and wrong

extrapolation: the logical extension of a line graph

fair test: when only one variable is changed in an experiment

human reflex: your quickest reaction to something; for example, pressing a stopwatch to record a race time

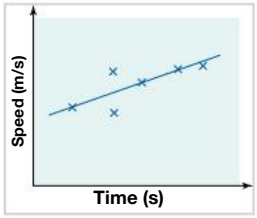
hypothesis: an 'educated guess' about what might happen in an experiment

imprint page: a page that includes all relevant data about a book such as publisher and year of publication

independent variable: the variable changed by you; it will probably cause a change in the dependent variable

instrument error: error due to a faulty instrument or using it at a temperature it is not designed for

line or curve of best fit: a straight line or curve drawn through the 'centre' of points on a graph



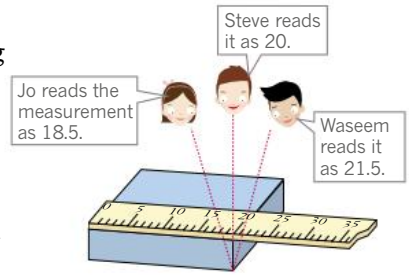
line of best fit

mean: average; add up all the 'good' values and divide by how many there are

mistakes: things that affect your measurements but can be avoided with care; mistakes are not errors

outlier: a value that is much smaller or much larger than the other values in a set of data

parallax error: error caused by not having your eye directly in line with the measurement



parallax error

pendulum: a mass that swings back and forth

period: time taken for a pendulum to complete one swing, back and forth

prefixes: letters in front of standard unit symbols, e.g. m for milli, c for centi, k for kilo

primary data: data you collect yourself from an experiment

primary data

procedure: a description of what you did in an experiment

purpose: aim; what you are trying to do in an experiment

qualitative data: observations that are descriptive only (no numbers)

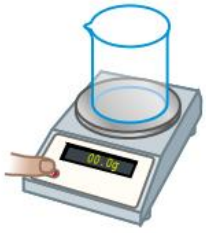
quantitative data: measurements that use numbers (and usually units)

reading error: an error caused by having to guess, when a measurement falls between an instrument's markings

resource list: a list of all resources used in gathering data for an experiment or report; also called a reference list or a bibliography

scientific research: a series of experiments on one topic

secondary data: data you have not found through an experiment; sources can be textbooks, encyclopedias, internet etc.


tare

tare: changing the zero on an electronic balance

team: your prac partners and you

URL: website address

variables: factors that may influence an experiment

zero error: error caused by an instrument giving a small reading when it should read zero

AB 1.10

CHAPTER 2

Cells

Have you ever wondered ...

- what living things are made up of?
- what your skin and hair would look like if they were magnified?
- how living things grow?
- what cancer is and whether it can be cured?

LS

After completing this chapter you should be able to:

- examine a variety of cells using a light microscope, by digital technology or by viewing a simulation
- distinguish plant cells from animal or fungal cells
- identify structures within cells and describe their function
- identify organisms that consist of a single cell
- outline how cells reproduce via cell division
- describe mitosis as cell division for growth and repair
- investigate developments in the understanding of cells and how this knowledge has impacted on areas such as health and medicine
- investigate the development of the microscope and the impact it has had on the understanding of cell functions and division
- outline how knowledge of cells and cell division has led to advances in disease treatment and control.

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AB 2.1

MODULE

2.1 Making things bigger

Humans use their senses to observe things around them. A very important sense is sight. But people can only see so far, and some things are too small to be seen clearly or at all. Scientists use technology to enhance their senses. For example, astronomers use telescopes to observe distant stars. Binoculars help biologists identify different species at a distance and using microscopes, scientists can see things that are invisible to the naked eye.

science 4 fun

It looks different!

What can you see using a magnifying glass that you could not see before?

Collect this ...

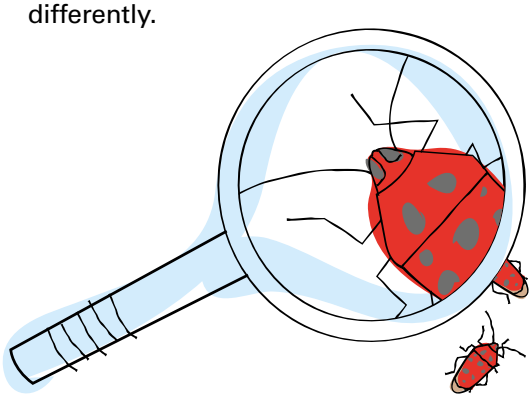
- magnifying glass

Do this ...

Use the magnifying glass to look at familiar things around you. Some suggestions are your fingerprint, the hairs on the back of your hand or arm, soft leaves, soil, an ant and photos in a newspaper.

Record this ...

1. Describe what you could see with the magnifying glass that you could not see with your naked eye.
2. Explain why you were able to see things differently.



Microscopes

Very small things need to be **magnified** or made bigger so that they become visible to us. Scientists use **microscopes** to do this. Objects that can only be seen using a microscope are described as **microscopic**. Microscopes allow scientists to see the tiny building blocks that make up living things. Figure 2.1.1 compares the detail you can see with and without a microscope.

The type of microscope used in schools and many science laboratories is a **light microscope**. Light from a mirror or a lamp passes through a **specimen** or object. The specimen being looked at must be very thin so that the light can pass through it easily. The light then passes through a series of lenses that causes the specimen to appear bigger. What you see through the microscope is called the **image**.

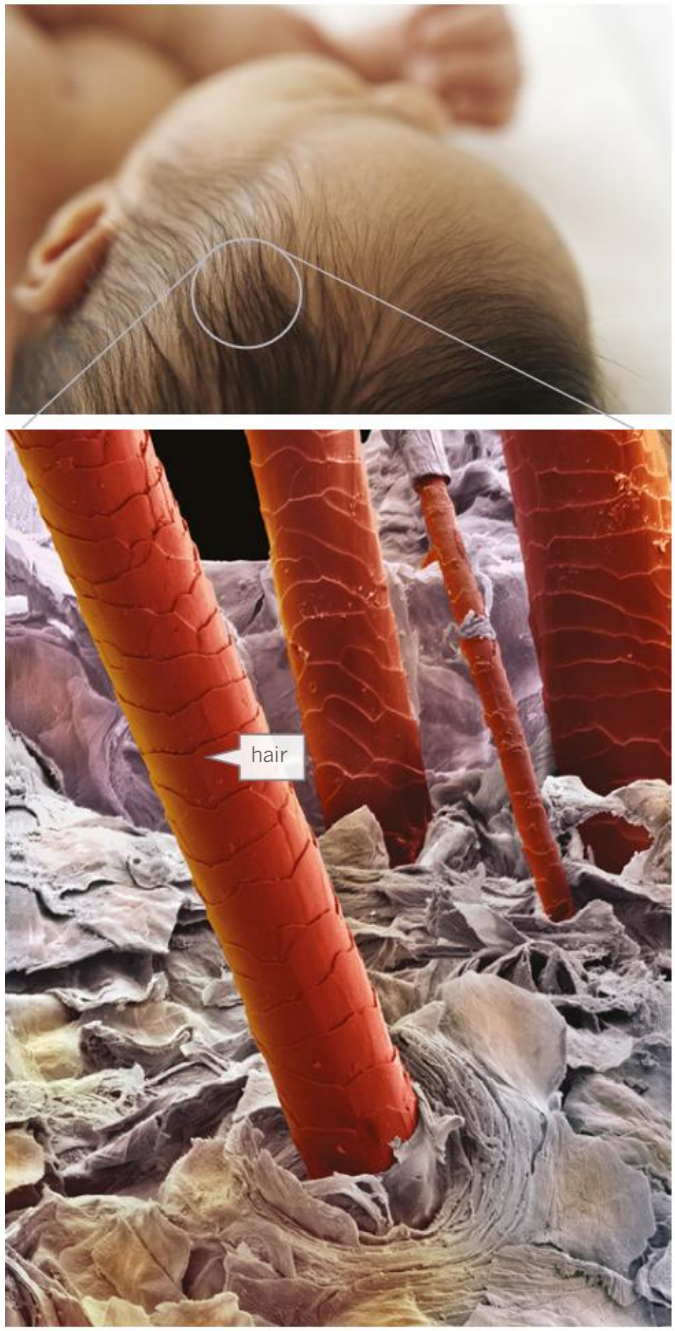


FIGURE 2.1.1 Microscopes allow scientists to look more closely at the world around them, such as the skin and hairs on this baby's scalp.

You will probably use a microscope like the one shown in Figure 2.1.2. This light microscope is a **monocular microscope**. It is called a monocular microscope because it has only one eyepiece or ocular lens. Some light microscopes have two eyepieces or **ocular lenses**. They are **binocular microscopes**.

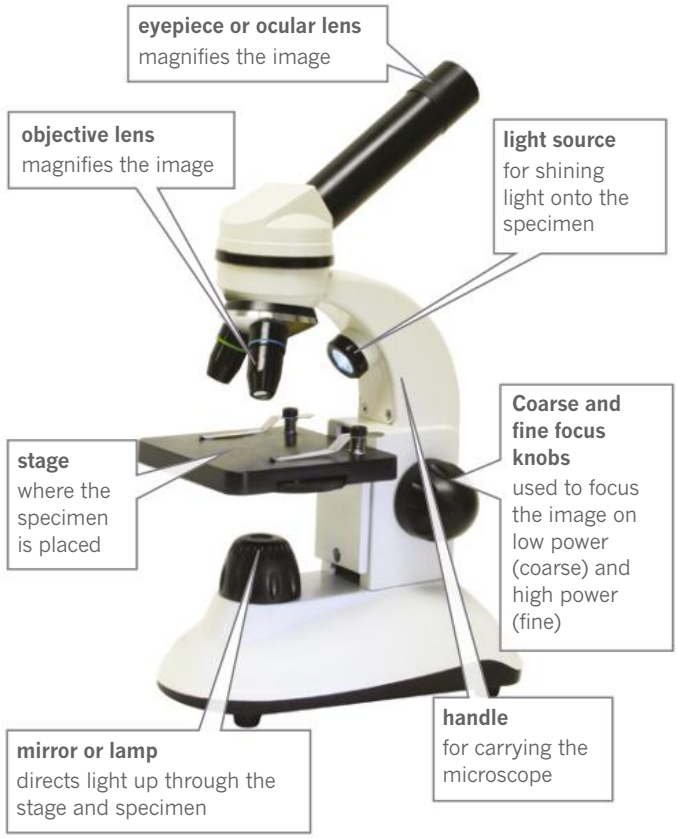


FIGURE 2.1.2 The parts of a microscope and their function

Stereo microscopes

When you hear music in stereo or see an image in stereo, it means that the information is coming from two different directions. Using a **stereo microscope** is like having two monocular microscopes joined together, with each one focusing on the same point but from different angles. The image you see is in three dimensions.

Light shining onto the specimen is reflected back up through the lenses to create the image. Light does not pass through the specimen, and so the specimen does not have to be thinly sliced or prepared in any other way. This means that anything can be placed under a stereo microscope.

The distance between the **objective lens** and the specimen is much greater than in a monocular or binocular microscope. This means that you can work on the specimen as you are viewing it. Because it shows things in three dimensions, a stereo microscope is often used to examine and **dissect** small plants and animals, or parts of plants and animals. This is why the stereo microscope is also called the dissecting microscope. The scientist in Figure 2.1.3 on page 48 is dissecting a plant.

FIGURE 2.1.3 Stereo microscopes give a realistic 3D view of the specimen. The distance between the specimen and the objective lens allows scientists to work on the specimen.

TABLE 2.1.1 Comparison of types of light microscope

Monocular or binocular microscope	Stereo microscope
Provides a two-dimensional image of the specimen	Provides a three-dimensional image of the specimen
Maximum magnification ×1000 (1000 times)	Maximum magnification ×100 (100 times)
When you move the object, the image appears to move in the opposite direction.	When you move the object, the image appears to move in the same direction.
Light passes through the specimen	Light reflects off the specimen
Specimen is placed on a slide. Specimens may be complete objects such as microscopic organisms or fibres. However, specimens are frequently a very thin slice.	Specimen can be anything—no preparation is required.
When the specimen is sliced, it provides a view of the inner structure of the specimen.	Provides a view of the surface of the specimen
Shows colour of the original specimen. Stains or dyes can be used to increase the contrast between parts.	Shows colour of the original specimen

When you move a specimen under a stereo microscope, the image moves the same way. That is, you move the specimen to the right and the image also moves to the right. The opposite occurs in monocular and binocular microscopes. That is, when you move the object to the right, the image appears to move to the left.

Table 2.1.1 compares monocular and binocular microscopes with stereo microscopes.

AB 2.2

Magnification

The **magnification** of the microscope tells you how much bigger the image is than the real object. If the microscope has a magnification of ×10, then the image is ten times bigger than the actual object. The symbol × stands for *magnified by*.

How much you can see of the specimen when you look down a microscope is called the **field of view**. If we magnify one small part of an object, we can see less of the whole. So as magnification increases, the field of view becomes smaller.

The maximum magnification achieved by light microscopes is about ×1000. At this magnification, some of the largest bacteria are just visible.

The magnification of stereo microscopes is lower than in monocular or binocular microscopes, with ×100 the usual maximum magnification.

AB 2.4

Very small measurements

Units like metres (m) or centimetres (cm) are normally used to describe your height, and centimetres or millimetres (mm) are used to describe the diameter of a coin or the length of a pin. However, it is difficult to measure the diameter of the full stop at the end of a sentence because a full stop is less than one millimetre in diameter. You either have to estimate the size of the full stop as a fraction of a millimetre, or use a smaller unit. Many of the objects observed using a microscope are much smaller than a full stop and so they must be measured in units smaller than a millimetre.

A **micrometre** (μm) is one-thousandth of a millimetre, or one-millionth of a metre. It is the unit most often used by scientists to measure microscopic objects.

SkillBuilder

Calculating magnification

The microscope in Figure 2.1.2 on page 47 has two lenses—the eyepiece or ocular lens, and the objective lens. Both lenses magnify the specimen. To calculate the total magnification, you multiply the magnification of the ocular lens by the magnification of the objective lens.

Total magnification = ocular lens magnification × objective lens magnification

Worked example

Calculating magnification

Table 2.1.2 shows examples of how magnification is calculated.

TABLE 2.1.2 Calculation of common magnifications

Ocular lens magnification	Objective lens magnification	Total magnification
×10	×4	× 10 × 4 = ×40
×10	×10	× 10 × 10 = ×100
×10	×40	× 10 × 40 = ×400

Problem

If a microscope has an ocular lens magnification of ×5 and an objective lens magnification of ×10, what is the total magnification?

Solution

Thinking: Identify the ocular lens magnification.

Working: Ocular lens magnification = ×5

Thinking: Identify the objective lens magnification.

Working: Objective lens magnification = ×10

Thinking: Total magnification = ocular lens magnification × objective lens magnification

Working: Total magnification = ×5 × 10 = ×50

Try yourself

1 Calculate the magnification for each of the following combinations of lenses.

Ocular lens magnification	Objective lens magnification	Total magnification
×2	×5	
×10	×5	
×2	×10	

Electron microscopes

Electron microscopes are much more powerful than light microscopes. You can see this in Figure 2.1.4. Electron microscopes use beams of tiny particles called electrons instead of light, and are able to magnify up to a million times. There are two types of electron microscopes: transmission electron microscopes (TEM) and scanning electron microscopes (SEM). Table 2.1.3 compares a TEM with a SEM.

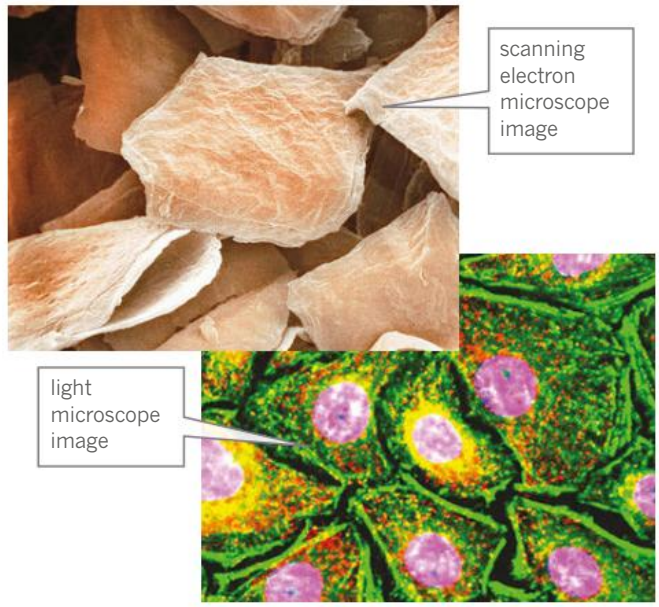


FIGURE 2.1.4 These two images show the same skin cells under a scanning electron microscope and a light microscope.

TABLE 2.1.3 Comparison of TEM and SEM

TEM	SEM
specimen is a very thin slice	specimen can be anything; no need to slice
electrons pass through specimen	electrons reflect off surface of specimen
provides a view of the inner structure of the specimen such as a cell	gives greatly magnified views of objects (e.g. insects, leaf surface, bacteria)
image is black and white but can be coloured to increase contrast	image is black and white but can be given false colour using computers

Prac 1 p. 54 Prac 2 p. 55 AB 2.5 AB 2.6

SciFile

Microscopic cracks—major disaster

In 1988 Aloha Airlines Flight 243 was flying at 10 000 metres when a large part of its roof blew off. Remarkably, only one person died and the pilot was able to land the plane safely. Using an SEM, investigators were able to determine the cause. Microscopic stress fractures in the metal fuselage had eventually joined to form cracks, which allowed some of the roof to break away. SEMs are now used in the aircraft industry to better understand and prevent serious accidents.

Working with Science

PHOTOMICROGRAPHER

Microscopic photography, or photomicrography, reveals a world that is invisible to the naked eye. Photomicrographers take photos through a microscope to capture a magnified image of an object or organism (Figure 2.1.5). Photomicrography has many important uses in a wide variety of areas, including medicine, geology, gemology, forensics, and scientific research in cell biology and microbiology.

FIGURE 2.1.5 This microscope is connected to a camera and a computer to capture digital images of magnified cells.

As well as its practical applications, photomicrography offers a unique way to engage people with the scientific world. It brings art and science together by using visually interesting images to communicate scientific information. Even things we encounter every day look completely different through a microscope. For example, Figure 2.1.6 shows how skin looks under a microscope. In this way, art can help us understand the complexities of organisms and objects that we might otherwise never see or know of.

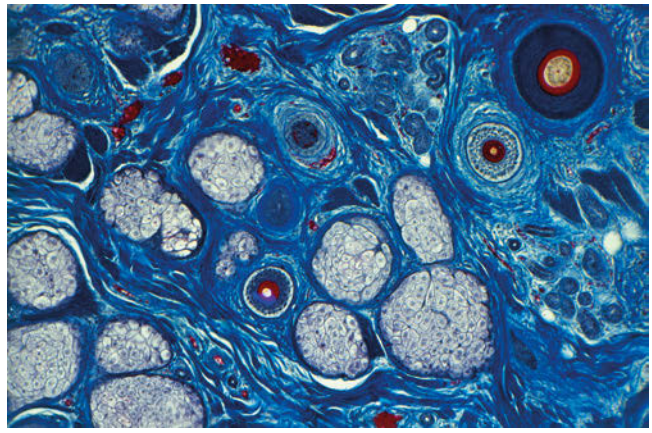


FIGURE 2.1.6 Human skin under a microscope, showing sweat glands and hair shafts. Cells have been stained with a blue dye to make their structures more visible. This image was taken by award-winning photomicrographer, Spike Walker.

Photomicrographers come from many different backgrounds and apply their work in many different fields. They will often have a background in science, enjoy working with microscopes and have a good eye for detail. People who don't have science qualifications can also work as photomicrographers with an artistic focus or as a hobby. There are short courses that can teach you the basics of photomicrography. With improving technology in microscopes and photography, this is a rapidly developing field with many exciting and important applications.

Review

1. What are some important applications of photomicrography that you can think of?
2. What images would you like to capture under a microscope?

Fighting infections in a flash

A handheld torch that kills bacteria could revolutionise wound treatment and possibly save lives in remote areas where antibiotics and clean water are not available.

FIGURE 2.1.7 Natural disasters like this 2015 earthquake in Nepal injure many people and expose them to bacterial infections that can quickly kill.

The Plasma Flashlight® is a bacteria-killing torch that was developed by a team of Australian and Chinese scientists. It only needs a 12-volt battery to run, and is small and inexpensive. These features make the torch ideal for use by ambulance workers, in treatment after surgery, in military operations and in emergency situations such as natural disasters (Figure 2.1.7).

On Earth, there are usually just three states of matter—solid, liquid and gas. However, there is a fourth state of matter—plasma. Plasma is common in stars but rare on Earth, usually only found when lightning strikes or electrical sparks jump from one thing to another. The Plasma Flashlight works by producing plasma which is delivered to the wound site via the handheld device (Figure 2.1.8). The researchers are still investigating how exactly the Plasma Flashlight works. They think that reactions between the plasma from the flashlight, the air surrounding it and ultraviolet light create an environment similar to our own immune system, killing the disease-causing organisms.

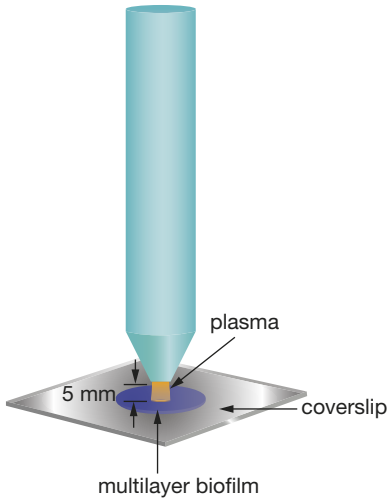


FIGURE 2.1.8 The Plasma Flashlight can kill bacteria on and under the skin in just tens of seconds. This makes it an important innovation for emergency and hospital medical care.

In the laboratory, the Plasma Flashlight was able to kill a thick layer of bacteria in just five minutes. In real-life situations, where bacterial cells are less dense, it is likely that the Plasma Flashlight will kill the bacteria in just seconds. Usually, high temperatures are needed to kill such thick layers of bacteria, but these high temperatures would burn our skin. The Plasma Flashlight works at room temperature so it can be safely used to kill bacteria both on and under the surface layers of the skin. The Plasma Flashlight can also kill bacteria in water, and so it has important potential for sterilising water in areas where safe drinking water is hard to access.

REVIEW

1. How does our understanding of cells help us to find ways to fight infection and disease?
2. An international team worked together to develop the Plasma Flashlight. Why do you think it is important for scientists from different countries and different areas of science to work together?
3. List any other ways that the Plasma Flashlight technology might be used to solve problems.

MODULE 2.1

Review questions

Remembering

1 Define the terms:
- a microscope
- b image
- c specimen.

2 What term best describes each of the following?
- a a light microscope that has two ocular lenses
- b a microscope that use a beam of electrons rather than light
- c the unit of measurement equal to one-thousandth of a millimetre.

3 Name the lenses found in a light microscope.

4 What happens to the field of view as the magnification used in a light microscope increases?

5 Name two different types of:
- a light microscope
- b electron microscope.

Understanding

6 Scientists use technology to extend their sense of sight.
- a What are three ways that technology can extend the sense of sight?
- b For each of the above, explain why this is needed.

7 Explain why people examining a crime scene might use a magnifying glass as they search for clues.

8 Describe what happens to the image seen in a monocular microscope when the slide is moved:
- a to the left
- b to the right
- c downwards.

9 Why does a specimen prepared for viewing under a light microscope have to be very thin?

10 Explain why there is more detail in an image produced using a TEM than in the image from a light microscope.

Applying

11 a How is the total magnification of a microscope calculated?

b Copy the table below into your workbook. Then calculate the total magnification for each set of lenses.

Ocular lens	Objective lens	Total magnification
×4	×10	
×10	×100	
×4	×40	

12 A specimen was placed under a monocular microscope and magnification was set to ×40. The image obtained is shown in Figure 2.1.9.
- a What is the name given to how much of an object or specimen you can see when you look down the microscope?
- b If the magnification is increased to ×80, what will happen to the size of the image?
- c Draw a picture of the image at ×80.

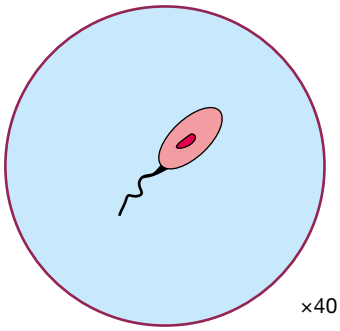


FIGURE 2.1.9

MODULE 2.1

Review questions

Analysing

13 Use the information in Figure 2.1.10 to compare the size of a human cheek cell, a fat cell, a red blood cell and a white blood cell.

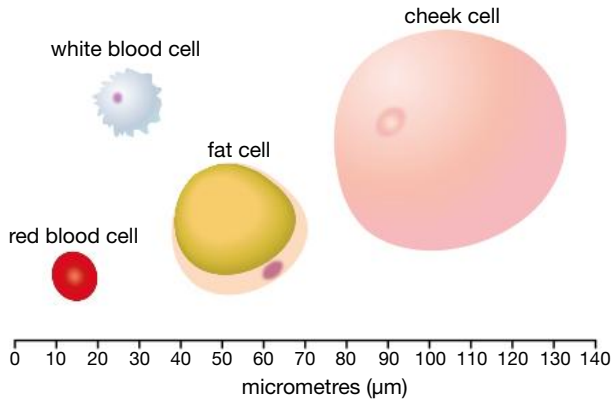


FIGURE 2.1.10

14 Both the SEM and the TEM use beams of electrons to form an image of a specimen, but the beams move differently in each. Compare the way electrons move to produce the images in each type of electron microscope.

15 Compare the way that specimens are prepared for a stereo microscope and a monocular microscope.

16 Compare the image seen using a stereo microscope with the image created with an SEM.

17 Figure 2.1.11 shows a mosquito viewed with a magnifying glass. Figure 2.1.12 shows the same type of mosquito viewed at a higher magnification with a scanning electron microscope. Compare both images and list the extra information that greater magnification brings.

FIGURE 2.1.11 A mosquito seen through a magnifying glass

FIGURE 2.1.12 A mosquito seen with a scanning electron microscope

Evaluating

18 a What type of microscope was most likely used to produce the image shown in Figure 2.1.13?

b Justify your choice.

FIGURE 2.1.13

Creating

19 Construct a table that lists the parts of the microscope and summarises the functions of each part.

MODULE 2.1

Practical investigations

SkillBuilder

Preparing a wet mount

1 Place a drop of water onto the specimen on the microscope slide. If a stain is being used, then it can be added to the drop of water at this stage.

2 Use a toothpick or your finger to gently lower a thin glass coverslip onto it. This is shown in Figure 2.1.14.

3 Soak up any excess water or stain with a piece of filter paper or tissue.

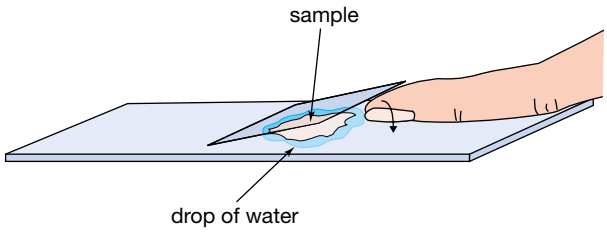


FIGURE 2.1.14

1 • Getting to know the microscope

Processing & Analysing

Before starting this experiment, make sure that you have read and understood the SkillBuilders 'Preparing a wet mount' and 'Using a microscope'.

Purpose

To make a wet mount and view it using a monocular or binocular microscope.

Timing 30 minutes

Materials

- a section of newspaper containing small print
- monocular microscope
- microscope lamp (if needed)
- eye-dropper
- glass microscope slide
- cover slip
- toothpick (optional)

SAFETY

Cover slips and microscope slides break easily. Treat them with care.

Procedure

1 Cut out a small section (1 cm × 1 cm) of newspaper with small print. Make sure that there is a letter 'e' in the section.

2 Use the newspaper to prepare a wet mount slide.

3 Set the microscope to the lowest magnification and focus the image of the newsprint. Try to get the letter 'e' into the field of view.

4 Slowly move the slide containing the newsprint to the left, and record which way the image appears to move.

5 Record how the image moves when the slide is moved to the right and away from and towards you.

6 Increase the magnification and then observe the newsprint again.

Results

For two different magnifications:

1 Sketch what you see in a field of view.

2 Record the magnification used.

3 Count how many letters fit in the field of view.

Review

1 When you viewed the letter 'e' under the microscope, was the image the same way up as on the newsprint, or upside down?

2 Copy and complete the following sentences in your notebook.
When I moved the slide to the right, the letters appeared to move to the ____.
Moving the slide towards me seemed to make the letters move ____ from me.
When I moved the slide away from me, the letters moved ____ me.
Every time I moved the slide, the letters seemed to go in the ____ direction.

3 How many letters fitted into the field of view at each magnification?

4 Describe what happens to the field of view when the magnification is increased.

MODULE 2.1

Practical investigations

SkillBuilder

Using a microscope

1 Place the slide on the stage and hold it in place using the clips (Figure 2.1.15).
2 Adjust the mirror or diaphragm so that the maximum amount of light is passing through the slide.
3 Select the objective lens with the lowest magnification.
4 Looking at the microscope from its side, adjust the coarse focusing knob to bring the stage and objective lens as close as possible to each other without touching.
5 Looking through the eyepiece, turn the coarse focusing knob so that the stage and objective lens move further apart.
6 Keep doing this until the specimen is in focus.
7 Adjust the fine focusing knob to sharpen the focus on the specimen.
8 If you miss the point of focus, go back to step 4 and start again.

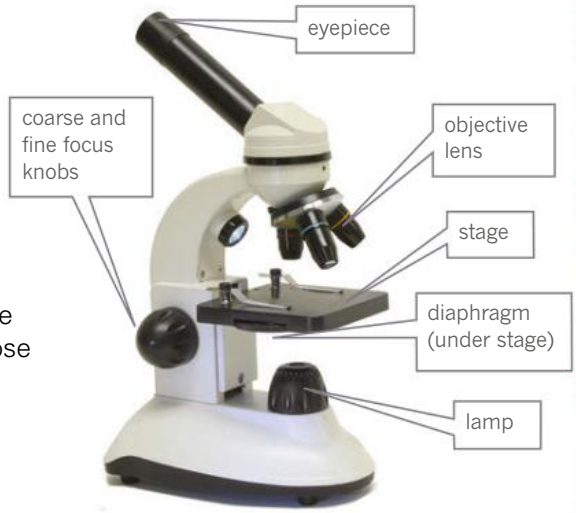


FIGURE 2.1.15

2 • Using the microscope

Planning & Conducting | Communicating

SPARKlab alternative available for this activity

Before starting this activity, make sure that you have read and understood the SkillBuilders 'Preparing a wet mount' and 'Using a microscope'.

Purpose

To observe common objects at various magnifications.

Timing 30 minutes

Materials

- small samples suitable for viewing under a microscope, such as a sugar crystal (both plain and caster), salt, copper sulfate, hair, clothing fibres, leaf, insect, writing sample (in ballpoint pen ink), mini grid (optional). Note: These do not need to be viewed as wet mounts.
- monocular or binocular microscope
- microscope lamp
- glass microscope slides
- cover slips
- eye-dropper
- toothpick (optional)

SAFETY
Cover slips and microscope slides break easily. Treat them with care.

Procedure

1 Observe a small specimen of each item under the microscope.
2 If you do not see an image, try shining the microscope lamp onto the surface of the object. You may notice that this works very well with solid objects.

Results

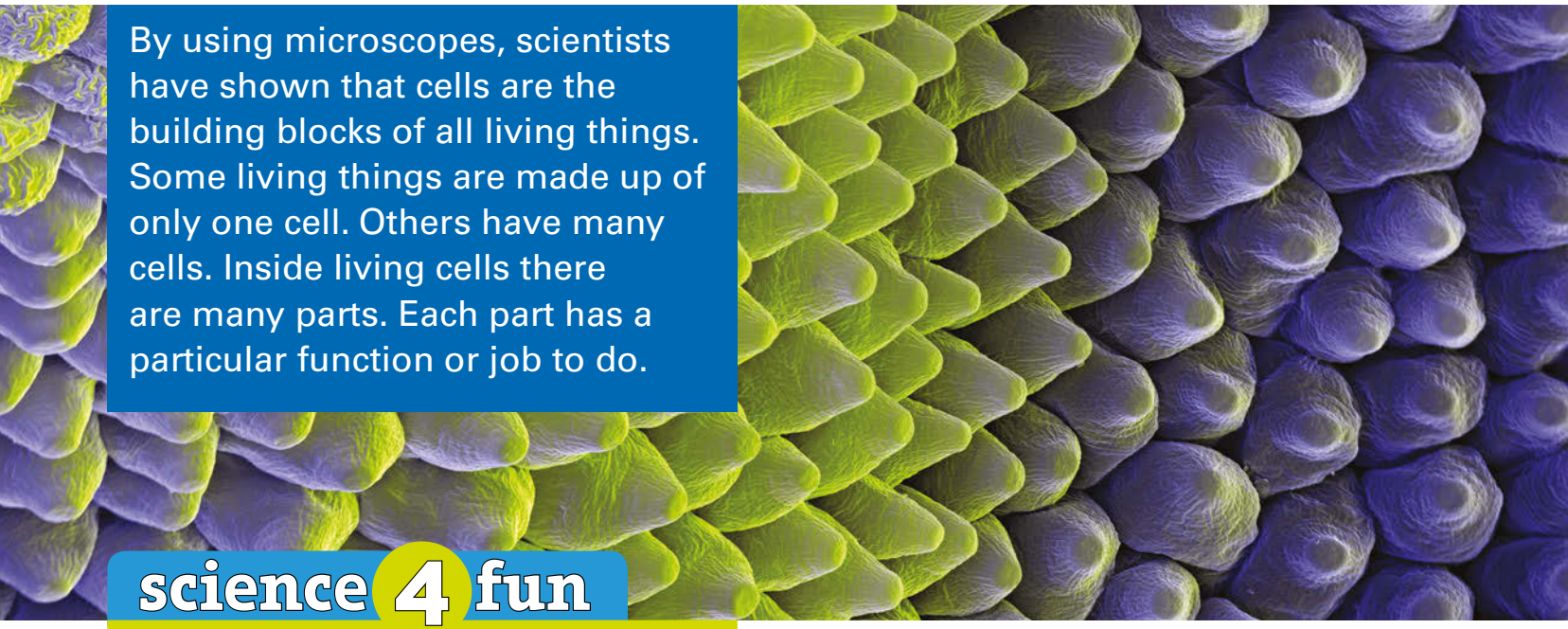
Sketch what you see in each case and record the magnification used to obtain the clearest image.

Review

1 Describe how each specimen appeared. In your description, note observations that were not possible without the microscope.
2 a Which specimen or specimens did you find most interesting?
b Explain why you found it interesting.

MODULE

2.2 Building blocks of life



By using microscopes, scientists have shown that cells are the building blocks of all living things. Some living things are made up of only one cell. Others have many cells. Inside living cells there are many parts. Each part has a particular function or job to do.

science 4 fun

Human cells

NO

What do your cells look like?

Collect this ...

a monocular microscope and lamp (if needed), prepared slide of cheek cells, or access to YouTube

Do this ...

1. Place the prepared slide of cheek cells on the microscope stage. These cells have probably been prepared using a stain that makes them easier to see.
2. Observe the cells first under low power and then under high power.

Or

Search YouTube for 'human cheek cells' and view the clip.

Record this ...

1. Describe what you saw.
2. Explain the function of each feature you observed in the cell.

The first microscope

Zacharias Janssen (1585–1632) was a Dutch spectacle (reading glasses) maker who lived during the 16th century. Around 1590 he was experimenting with lenses and placed two lenses inside a tube. When he looked through the tube, objects appeared much larger than when he had used a single lens. Janssen had created the first true microscope, and a new world of previously unknown microscopic life was about to be discovered.

SciFile

Spectacle maker, inventor and counterfeiter

Janssen lived next door to the mint, where his brother-in-law worked making legal coins. In the years 1613–1619, Janssen was charged several times for counterfeiting or making fake coins. The penalty for counterfeiting was severe but Janssen avoided jail on each occasion and eventually died around 1632. At the time of his death he was bankrupt.

Hooke's little boxes

In 1665, English scientist Robert Hooke (1635–1703) was using a microscope like the one shown in Figure 2.2.1 to investigate cork.

FIGURE 2.2.1 Robert Hooke's microscope

He saw that the thin slices of cork resembled honeycomb and contained little boxes or cells. You can see them in his drawing in Figure 2.2.2. Hooke had discovered the building blocks of life—**cells**.

FIGURE 2.2.2 Hooke's original 1665 drawing of cork cells. Hooke was actually looking at the remains of dead plant cells with only the cell walls remaining.

Leeuwenhoek's animalcules

Antonie van Leeuwenhoek (1632–1723) was an expert microscope builder. He built microscopes that were able to magnify up to ×250. A few years after Hooke's discovery, he used one of his own microscopes to look at pond water. In it he saw tiny organisms moving about. He called these organisms *animalcules* (Latin for *little animals*). What he was seeing were tiny, single-celled living things, which we now call microorganisms. This made Leeuwenhoek the first person to observe and describe microscopic living things. He was also the first person to observe and describe human red blood cells and bacteria.

Cell theory

Many years later, in 1833, the Scottish botanist Robert Brown (1773–1858) discovered that plant cells were not just empty boxes. They had even smaller structures inside them. The first structure to be identified was the nucleus (Figure 2.2.3). It took another 70 years to identify other structures within cells, such as chloroplasts.

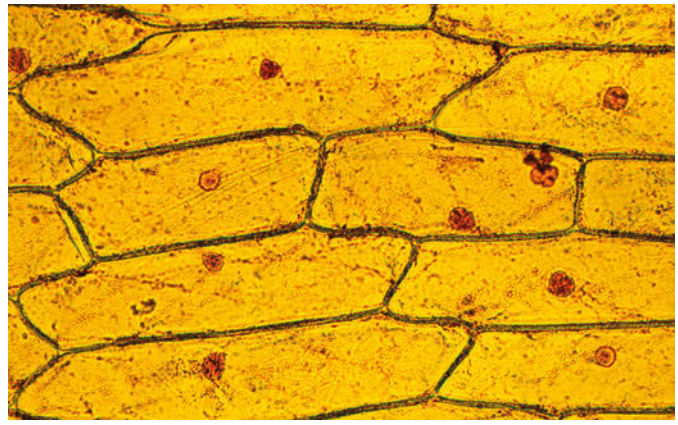


FIGURE 2.2.3 Plant cells from a leek (a vegetable) stained with iodine and magnified hundreds of times. The nucleus and cell wall can be seen clearly.

In 1838, the German scientist Matthias Schleiden (1804–1881) analysed the known information about plant cells. He proposed that cells are the basic building blocks of all plants, and that new plants start off as a single cell. As plants grow, new cells are produced.

A year later, a friend of Schleiden's, Theodor Schwann, (1810–1882) proposed that animals are also made of cells. This meant that cells are the basic unit of life for both plants and animals. Identifying this link between plants and animals is regarded by scientists as one of the most important discoveries in the development of biology.

In 1842 the Swiss scientist Karl Nägeli (1817–1891) observed cells dividing to make new cells. This was the first time that scientists realised that new cells came from existing cells. In 1855 the German scientist Rudolf Virchow (1821–1902) linked the observations of Nägeli and Brown. He proposed that all cells develop from existing cells and don't just appear from nowhere.

The work of these people led to the development of **cell theory**, which explains the relationship between cells and living things.

- All living things are made up of one or more cells.
- Cells are the basic building blocks of all living things.
- New cells are produced from existing cells. This is what is happening in Figure 2.2.4.

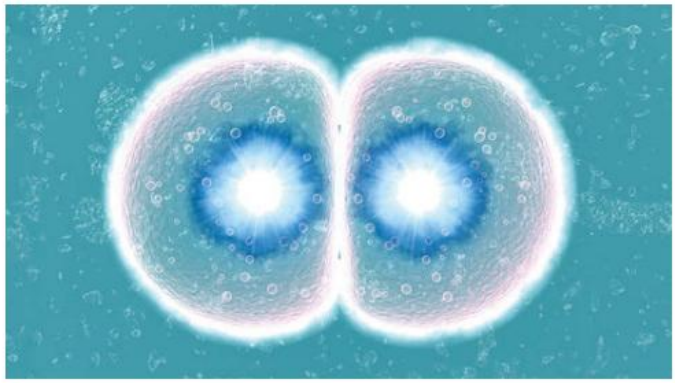


FIGURE 2.2.4 One cell dividing to produce two cells

Animal cells

If an animal cell was made big enough to hold in your hands, then it would probably feel like a clear balloon filled with water or thin jelly. You would also be able to see that there are other structures inside the cell. These would range in size from tiny to quite big. These structures are known as **organelles** (little organs). Each organelle has a special job or function. Organelles are usually only visible using a microscope. Figure 2.2.5 shows the structure of a typical animal cell as seen using a light microscope.

Some organelles are too small to be seen with a light microscope and are only visible using an electron microscope (Figure 2.2.6). Examples are:

- **mitochondria**—the powerhouses of the cell that release energy from food
- **lysosomes**—the garbage disposal units that get rid of wastes from the cell
- **endoplasmic reticulum**—forms pathways that allow materials to move quickly and easily through the cell.

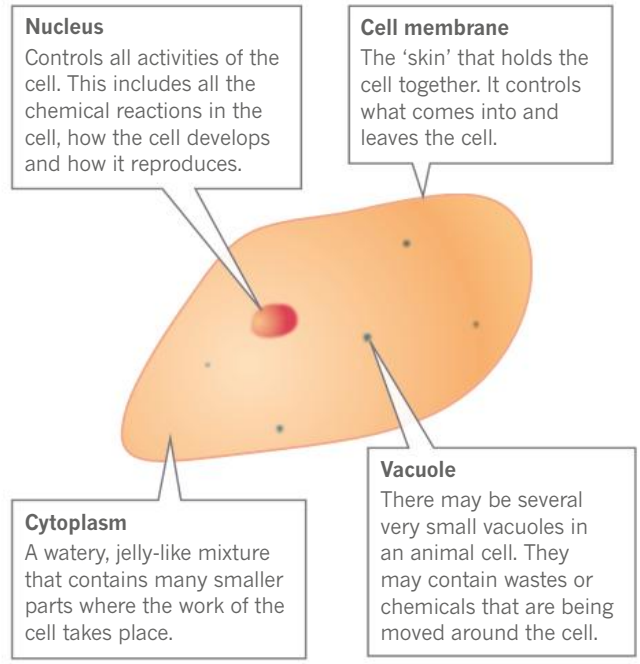


FIGURE 2.2.5 This is of a typical animal cell magnified × 400. The cell also contains smaller parts known as organelles that cannot be seen in this view through a light microscope.

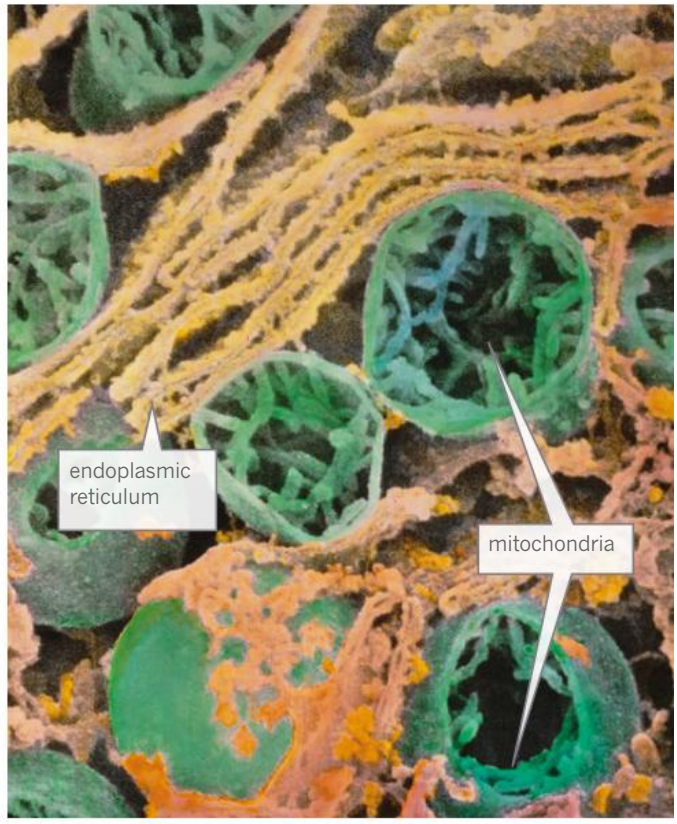


FIGURE 2.2.6 Some organelles within a cell are so small that they can only be seen clearly with an electron microscope at magnifications of more than ×100 000.

Organelles are enclosed in a membrane. Other structures within the cell are ribosomes. **Ribosomes** are microscopic 'factories' that produce proteins used by the animal for growth and repair. Ribosomes are not considered to be true organelles, because they are not always enclosed in a membrane.

Plant cells

Plants are similar to animal cells but have a few additional structures. Figure 2.2.7 shows the structure of a typical plant cell. Like animal cells, plants cells have a cell membrane, cytoplasm and a nucleus. The vacuole in a plant cell is much larger than in animal cells. Plant cells also have a **cell wall** outside the cell membrane. The cell wall helps support the plant and gives it shape. Many plant cells contain additional organelles called chloroplasts. **Chloroplasts** contain a green substance called chlorophyll and are found in the green parts of plants. Plants cannot go hunting for their food. Instead, they make it themselves using energy from the Sun to chemically combine water and carbon dioxide from the air to make a sugar called glucose. This process is called **photosynthesis**. It takes place in chloroplasts.

AB 2.3 Prac 1 p. 66 Prac 2 p. 67

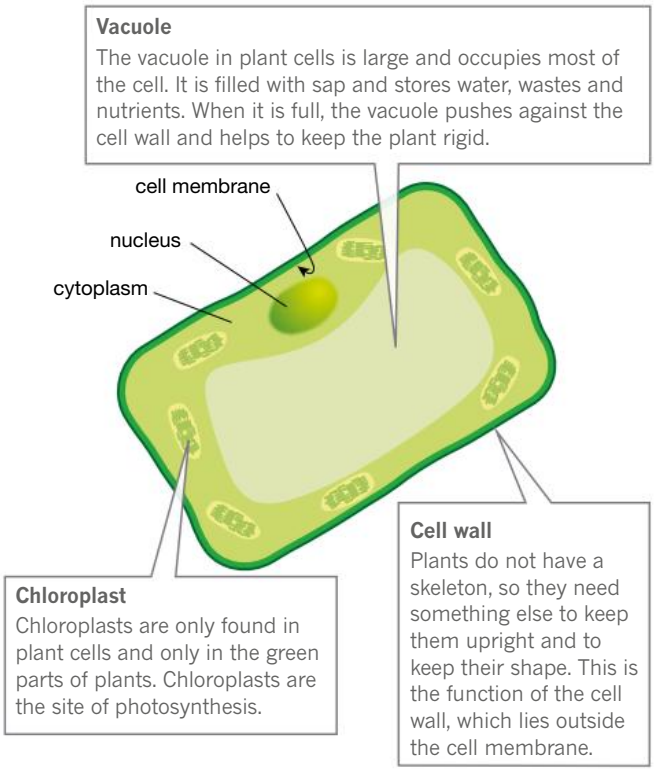


FIGURE 2.2.7 A typical plant cell has all the organelles that an animal cell has. It also has chloroplasts and a cell wall.

SciFile

Fibre

Plant cell walls are made of a complex substance called cellulose. Humans cannot digest cellulose. When we chew plant foods, the cells are broken open, releasing the nutrients inside. The undigested cellulose makes up the fibre in our diet and leaves the body as waste.

Fungal cells

Fungi (plural of fungus) are organisms that can be made of just a single cell or many cells. Yeast is an example of a single-celled fungus, while the toadstool in Figure 2.2.8 is an example of a fungus with many cells.

FIGURE 2.2.8 This toadstool is a fungus made up of many cells.

Cells of fungi have the same structures as animals cells plus a cell wall like plant cells. Figures 2.2.9 and 2.2.10 on page 60 show these structures. However, plant and fungal cell walls are made of different chemicals. Fungal cells do not have chloroplasts; therefore they cannot make their own food. Fungi produce and release chemicals that digest the material they are growing on. They then absorb the digested materials into their cells.

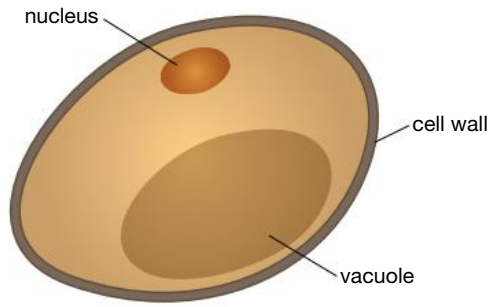
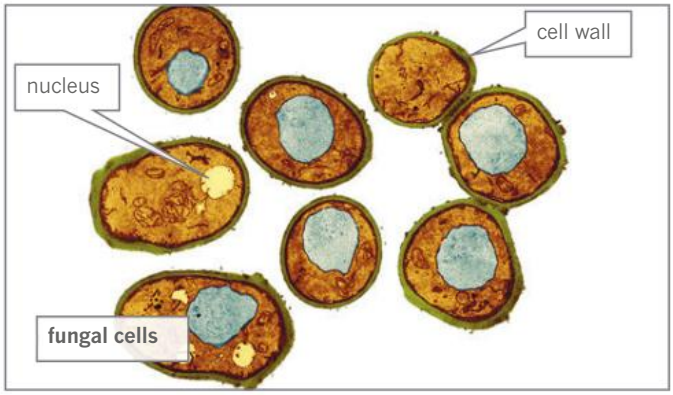
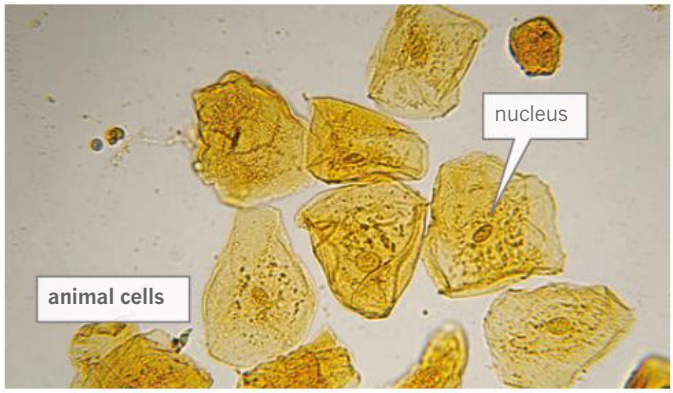


FIGURE 2.2.9 A typical fungal cell has the same organelles as an animal cell but with a cell wall.





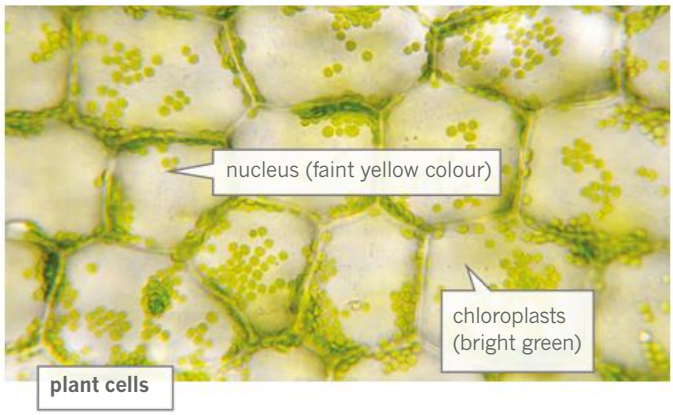


FIGURE 2.2.10 Fungal cells share similarities and differences with animal cells and plant cells.

Unicellular organisms

Living things that are made up of only one cell are known as **unicellular organisms**. The prefix *uni* means *one* and *organism* means a *living thing*. Therefore a unicellular organism is a living thing that is made up of a single cell. **Bacteria** are from the Monera kingdom. They are small and simple cells that do not have any organelles or a true nucleus. Some bacteria cause disease and infection, like the infected wound in Figure 2.2.11. Others live on and in your body and help you to stay healthy. Bacteria are also used in the production of cheese and yoghurt.

FIGURE 2.2.11 A wound becomes infected when bacteria enter the wound. White blood cells try to fight the harmful bacteria, forming a yellow pus.

Many different types of unicellular organisms live in watery environments. A drop of pond water seen through a microscope can reveal a variety of living things you will not have seen before, like the diatoms and rotifers shown in Figure 2.2.12.

FIGURE 2.2.12 Microscopic organisms such as diatoms and rotifers are found in pond water.

Unicellular organisms belong to a group called the **protists**. Most protists are harmless, but some can make you very sick. For example, giardia is an infection caused by the protist *Giardia lamblia*. This unicellular organism is found in the faeces of humans and other animals. A person becomes infected when they swallow the parasite from their unwashed hands or drink infected water. The water that comes through the taps has been treated to kill any harmful organisms such as *Giardia*. If you are in the bush and using untreated water, then for your health's sake it is best to boil the water before you drink it.

Prac 3 p. 68

Dividing cells

Unicellular organisms reproduce by dividing to produce two new identical cells. Figure 2.2.13 shows a single-celled protist called Euglena dividing to form two new organisms. Each is identical to the parent cell.

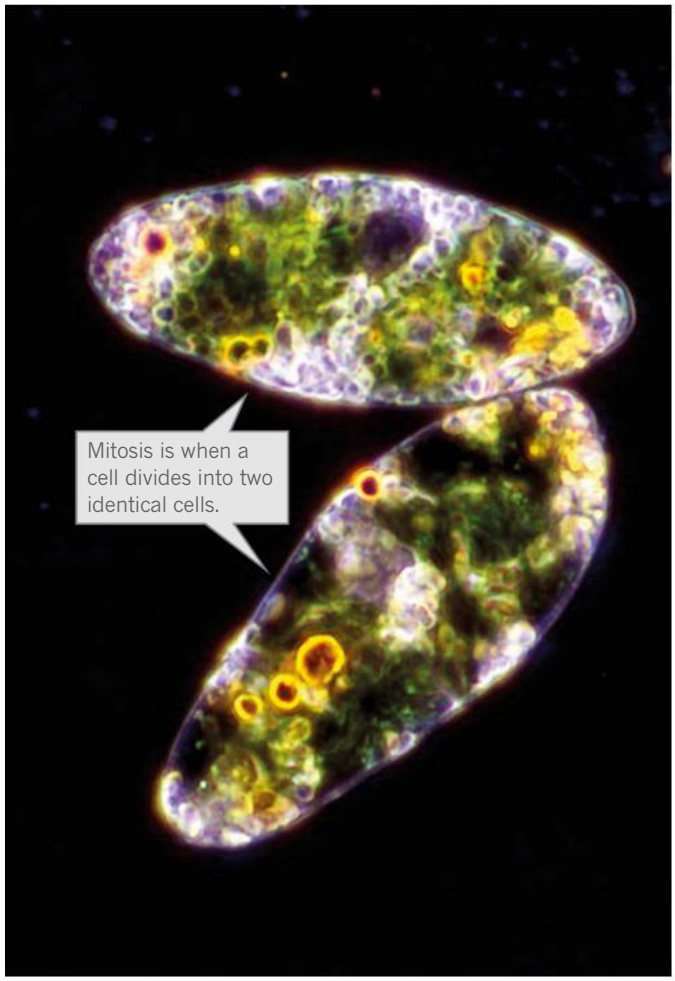


FIGURE 2.2.13 *Euglena* is a single-celled protist that reproduces via mitosis. Here one cell is about to become two new cells.

Mitosis is when a cell divides into two identical cells. At the beginning of mitosis, there is one cell. First the nucleus divides into two. Then the cytoplasm divides. At the end of the process, there are two identical cells.

Single-celled organisms use mitosis for reproduction. Multicellular organisms use mitosis for growth and repair. All multicellular organisms, such as animals and plants, begin life as a single cell. This cell undergoes mitosis but the cells remain attached to each other and the organism grows. Figure 2.2.14 shows mitosis in plant cells. These plant cells are root cells that are dividing into two, allowing the root to grow.

Mitosis is also important for repair. Cells in multicellular organisms often wear out or are damaged and need to be replaced. For example, each time you cut yourself or scrape the skin off your knee, the damage is repaired by mitosis producing new cells.

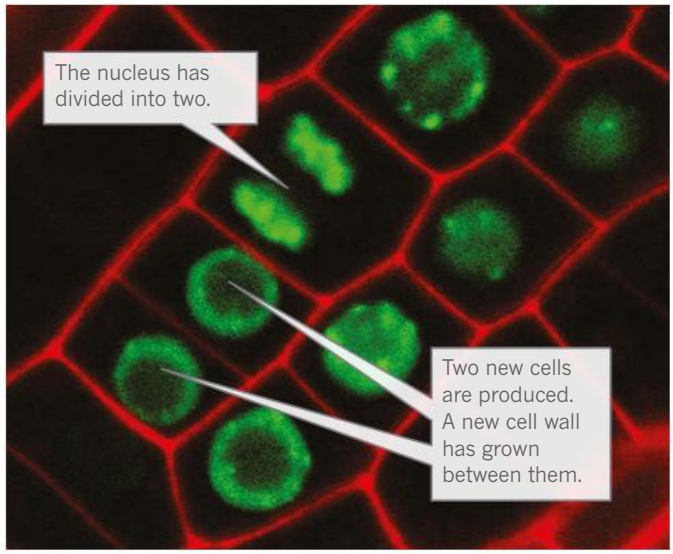


FIGURE 2.2.14 These cells from a plant root are dividing by mitosis.

SciFile

How many and what do they do?

There are about 50 trillion cells in your body. They come in different shapes and sizes, each with their own special job to do. For example, cells in the heart cause it to beat. Some blood cells fight infection, while others carry oxygen around your body.

Combating cancer

Multicellular organisms, including humans, use cell division for growth and to replace worn-out and dead cells. For example, skin cells are continually dying and being replaced by a special layer of dividing cells beneath the surface of the skin.

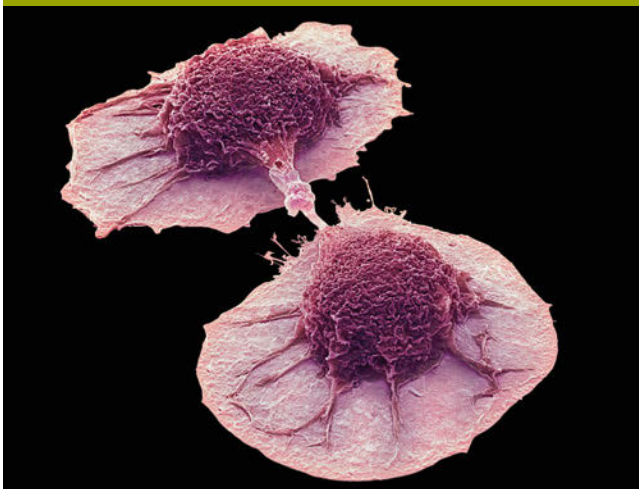


FIGURE 2.2.15 Colour-enhanced SEM image of dividing lung cancer cells (magnification: x5000)

Sometimes, however, this cell division gets out of control and cells divide in a rapid and uncontrolled way (Figure 2.2.15). This uncontrolled cell division is called **cancer**, and the cells arising from this are cancer cells. The development of cancer cells is outlined in Figure 2.2.16.

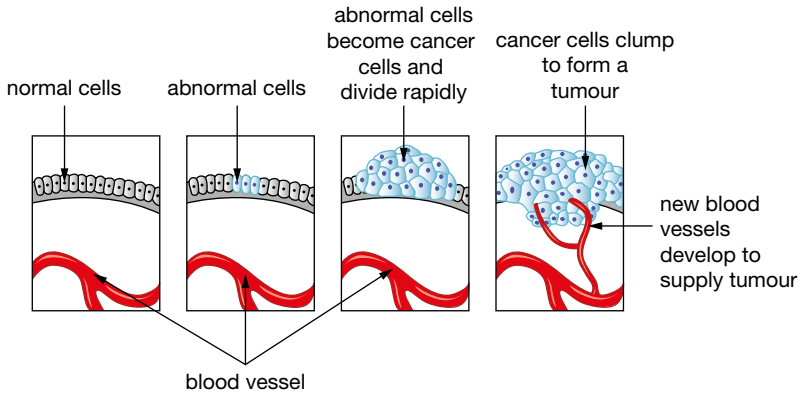


FIGURE 2.2.16 Cancer cells grow rapidly to form a tumour.

Cancer can occur in just about any type of cells within the body. Table 2.2.1 lists the five most common cancers in Australia in order from most common to the fifth most common. Together these five types of cancer account for more than 60% of all diagnosed cancers.

TABLE 2.2.1 Most common cancers in Australia

	Cancer	Cause
1	prostate (most common cancer in men)	age, family history
2	breast (most common cancer in women)	age, family history, obesity, excess alcohol consumption
3	bowel (colorectal)	family history, bowel disease, high red meat consumption, processed meats, obesity, excess alcohol consumption, smoking
4	skin melanoma	family history, excessive UV light, sunburn, fair skin, poorly functioning immune system
5	lung	smoking, asbestos, chemicals such as radon and hydrocarbons (e.g. benzene)

Source: Cancer Council of Australia

A growing area of cancer cells is referred to as a **tumour**. Tumours can be classified as either **benign** or **malignant**.

- Benign tumour—cancer cells grow in a particular area but do not spread to other parts of the body.
- Malignant tumour—cancer cells grow and break away from the tumour and spread to other parts of the body, where they can form other cancers.

Cancer cells grow larger and more rapidly than normal cells. They have no useful purpose and prevent healthy tissue from carrying out its normal functions. This will make the sufferer unwell and can be fatal.

Causes of cancer

The nucleus of cells contains DNA that controls all cell activities, including cell division. Cells can become cancer cells if the DNA is damaged in any way. There are many things that can damage a person's DNA. These include excessive sunlight and toxic chemicals, such as those found in pollution and cigarette smoke. Cancer can also be an inherited disease. The probable causes of the five most common cancers in Australia are included in Table 2.2.1.

Cancer is the leading cause of death in Australia. In 2013 there were 44 108 deaths from cancer (source: Cancer Australia).

Prevention and treatment of cancer

Prevention

To prevent cancer, risk factors that are known to cause cancer are reduced. For example, smoking and consuming excessive amounts of alcohol and red meat increase the risk of developing bowel cancer. Also eating healthy foods, such as fruit and vegetables, exercising regularly and maintaining a healthy weight can reduce the risk of developing many cancers.

Screening for cancers can detect cancers at a very early stage before any symptoms arise. This makes treatment much more effective.

Treatment

Once a tumour is detected, it can be treated. There is a range of treatments that can be used. Often a combination of treatments are used to ensure that all cancer cells are removed or destroyed. With early detection and modern treatments most cancers will be able to be treated successfully (Figure 2.2.17).

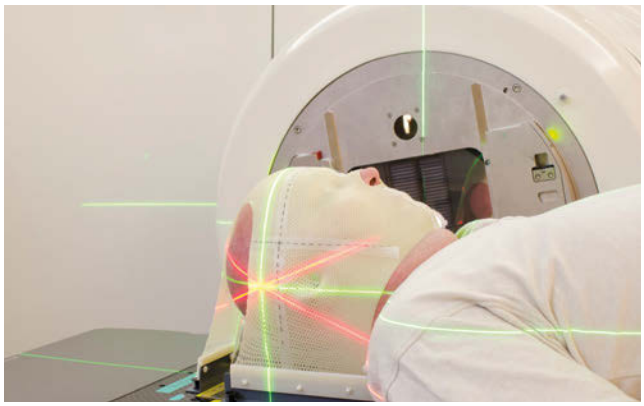


FIGURE 2.2.17 Patient undergoing radiotherapy for brain cancer. Coloured laser beams are used to target the radiation.

Table 2.2.2 summarises the main techniques used to treat cancer.

TABLE 2.2.2 Techniques used to treat cancer

Technique	Description
surgery	The tumour is surgically removed. Surgery is often supported by radiotherapy and chemotherapy to make sure that any cancer cells remaining in the body are removed.
chemotherapy	Powerful drugs are used to kill cancer cells. Traditional drugs attack cells that divide rapidly. As well as cancer cells this affects normal cells that divide rapidly, such as digestive tract and hair cells. Newer drugs target cancer cells specifically, by attacking their DNA or cell membranes or by helping the immune system fight cancer cells.
radiotherapy	High energy radiation can be directed from outside the body or internally from a radioactive source placed directly into a tumour. The radiation destroys the DNA inside the cancer cells.
hormone therapy	Can only be used for cancers that use hormones to grow such as prostate and breast cancer. Drugs that block the release of hormones are used to slow down or stop the growth of tumours.

REVIEW

1 **a** What is cancer?
   b List the five most common cancers that occur in Australia.
   c What are the causes of cancer?
2 Explain the difference between a benign tumour and a malignant tumour.
3 As our knowledge of cells increases, so does our ability to treat and cure diseases such as cancer. Justify this statement, with reference to the structure and function of cells.
4 Chemotherapy uses powerful drugs to kill cancer cells but can have serious side effects.
   a Explain why the traditional treatment for cancer causes hair loss and problems with the digestive tract.
   b Discuss the newer drugs used and why it is hoped that these will have fewer side effects.

MODULE 2.2

Review questions LS

Remembering

1 Define the terms:
- a cell
- b cell membrane
- c mitosis.

2 What term best describes each of the following?
- a the jelly-like substance within a cell
- b the organelle where energy is released
- c the structure inside a cell that produces protein.

3 Who constructed the first true microscope?

4 Name the scientist who first saw:
- a cells in a sample of cork
- b bacteria
- c smaller structures in a cell
- d cells dividing to make new cells.

5 List the three main points of the cell theory.

6 What is the meaning of the prefix *uni* in the word unicellular?

7 Name the structures that you would expect to see in cheek cells observed in the science4fun on page 56.

Understanding

8 Explain why microscopes are needed to study cells.

9 Explain why it is important to record the magnification used when drawing cells seen using a microscope.

10 a Name the parts of the animal cell labelled A, B and C in Figure 2.2.18.
- b Describe the function of each.

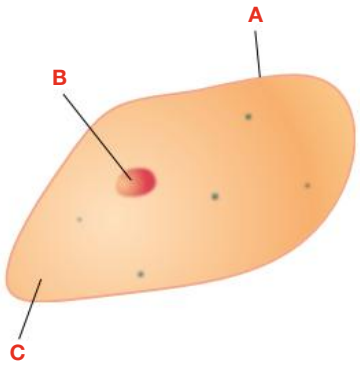


FIGURE 2.2.18

11 a Name the parts of the plant cell labelled A, B and C in Figure 2.2.19.
- b Describe the function of each.

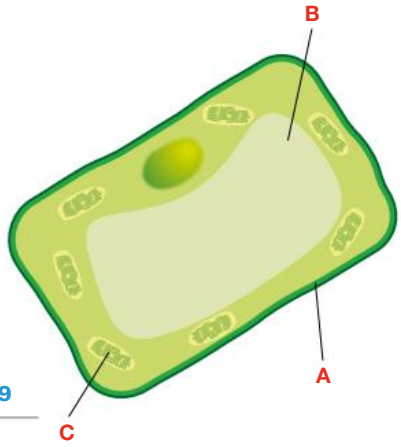


FIGURE 2.2.19

12 Predict what would happen if:
- a the membrane of a cell burst
- b the nucleus was removed from a cell
- c plant cells had no chloroplasts.

13 a Name two unicellular organisms that are commonly found in water.
- b Explain why you should boil river water before drinking it.

14 You began as a single cell but now your body is made of billions of cells. Used labelled diagrams to explain how one cell became billions of cells.

15 Explain the benefits and disadvantages associated with cells having a cell wall.

Applying

16 Identify which organelles or structures would be present in large numbers in the following cells. Give reasons for your answers.
- a cells that require a lot of energy
- b cells that manufacture proteins
- c cells that carry out photosynthesis.

Analysing

17 Identify the type of cell or organelle being described in each of the following sentences.
- a It is rigid, and when examined under a very high power on the microscope, no green structures could be seen.
- b Chemical tests revealed that energy was released in large quantities.

MODULE 2.2

Review questions

18 What are the similarities and differences between the following cells?
- **a** animal cells and plant cells
- **b** plant cells and fungal cells.

Evaluating

19 Most animals that live on land have some form of skeleton. For example, insects have an external skeleton and mammals have an internal skeleton. Propose reasons for these observations.

20 Draw a Venn diagram like the one shown in Figure 2.2.20. From the descriptions of cells on pages 58 and 59, select the characteristics that would go in each part of the diagram.

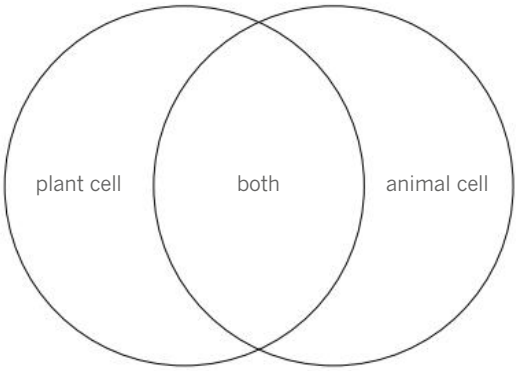


FIGURE 2.2.20

21 **a** Classify the type of cell shown in Figure 2.2.21 as a plant cell or an animal cell.
- **b** Give reasons for your choice.

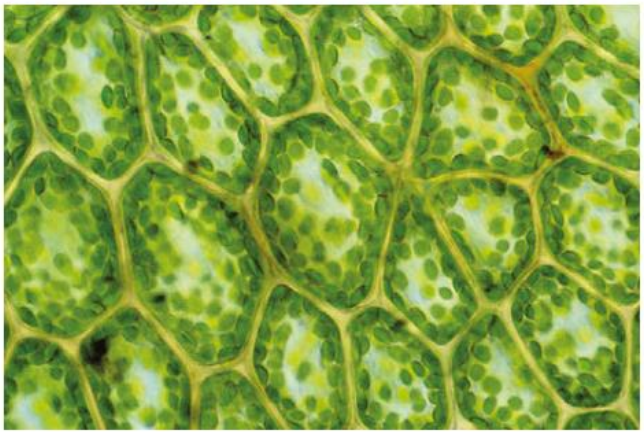


FIGURE 2.2.21

22 **a** Classify the cell shown in Figure 2.2.22 as an animal cell or a fungal cell.
- **b** Give reasons for your answer.

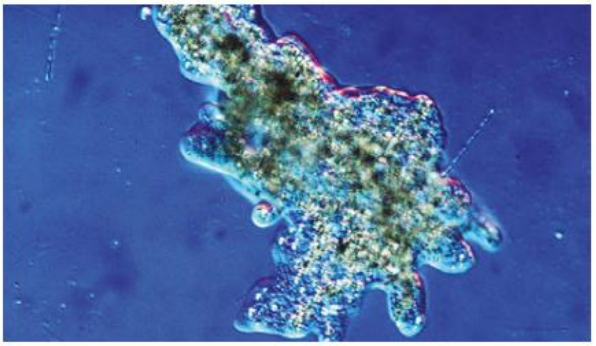


FIGURE 2.2.22

23 What do you think the advantages are of using prepared slides rather than students making their own slides?

24 A student was using a microscope to examine unicellular organisms. Figure 2.2.23 shows what was visible when the student changed from low power to high power. What do you think the student should do to be able see the complete organism?

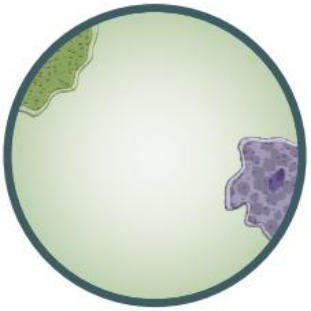


FIGURE 2.2.23

Creating

25 Construct a timeline showing the main developments in scientists' knowledge of cells from the time that Zaccharias Janssen was working with lenses until the present. On your timeline include each discovery, its date and the people involved.

MODULE 2.2

Practical investigations

1 • Observing cells

Processing & Analysing | Communicating

Before starting this activity make sure you have read and understood the SkillBuilders 'Drawing from the microscope' and 'Increasing magnification' to make your results consistent with the pracs in module 2.1.

Purpose

To observe and draw cells.

Timing 45 minutes

Materials

- slices of onion and rhubarb leaf stalk
- a few drops iodine
- a few drops water
- microscope and lamp
- filter paper
- microscope slide and cover slip
- eye-dropper and tweezers

SAFETY

Iodine stains. Wear a lab coat to avoid contact with skin and clothes.

Procedure

1. Carefully peel a thin (one cell thick) layer of onion skin.
2. Use tweezers to place a small sample of the onion skin onto a glass microscope slide. Make sure the skin is not folded.
3. Place a drop of water and a drop of iodine on the sample and carefully place a cover slip on top of the onion skin and water. The iodine stains the cells and makes them easier to see.
4. Use the microscope to observe the cells at two different magnifications.
5. Carefully peel a thin layer of skin from the outside of the rhubarb leaf stalk. Repeat the procedure, but do not use the iodine stain.

Results

Draw a few cells at the higher magnification. On your diagram record the type of cell you have drawn and the magnification used.

Review

1. Refer back to the diagram of the typical plant cell shown in Figure 2.2.7 on page 59. Of the parts labelled on that diagram, list the parts you were able to see clearly in the onion skin cell and in the rhubarb skin cell.
2. a List the parts you could not see.
   b Explain why you were not able to see them.
3. Compare the onion cells and rhubarb cells.
4. Propose a reason why onion cells were stained with iodine but rhubarb cells were not.

SkillBuilder

Drawing from the microscope

Follow these steps to draw what you see through the microscope.

1. Use a sharp lead pencil.
2. Draw only the lines that you see. Don't use shading or colouring.
3. Each diagram should take up one-quarter to one-third of an A4 page.
4. Record the magnification used to draw this specimen next to its diagram.
5. State the name of the specimen and the date of the observation.
6. Include a written description below the diagram.
7. When the image has many cells of the same type, you only need to draw a few cells to represent the specimen.

SkillBuilder

Increasing magnification

When you want to change the magnification of a microscope from a lower magnification to a higher magnification, follow these steps.

1. Make sure that the specimen, or the part of the specimen that you want to look at, is in the centre of the field of view.
2. Focus the specimen on low power.
3. Without moving anything else, carefully turn the objective lenses around so that one with a higher magnification is above the slide.
4. Look through the eyepiece. If the specimen is not in focus, use the fine focus only to sharpen the image.

MODULE 2.2

Practical investigations

2 • Membrane at work

Questioning & Predicting | Evaluating

A hen's egg is really just a very large cell with a shell around it. When you break an egg, you can sometimes see a very thin skin just under the shell. That skin is the membrane of the egg.

Purpose

To observe a membrane at work.

Hypothesis

What do you think will happen to an egg that has no shell when left in salt water and to an egg with no shell that is left in distilled water—will they stay hard, go soft or do something else? Before you go any further with this investigation, write a hypothesis in your workbook.

Timing

45 minutes plus 10 minutes (on 3 days)

Materials

- 2 eggs
- 500 mL white vinegar
- 1 tablespoon salt
- 500 mL distilled water

- electronic balance or beam balance
- 200 mL measuring cylinder
- container large enough to hold two eggs immersed in vinegar
- 2 wide-mouthed glass jars with lids

Procedure

PART A

1. In your workbook, construct tables like those in the Results section. Give your tables titles.
2. Place the two eggs in a container of vinegar so that both eggs are completely covered.
3. Leave the eggs undisturbed for 2 days. By this time the vinegar should have dissolved the eggshell. The membrane inside the shell becomes the outer layer of the egg.

PART B

4. Make a concentrated salt solution by adding a tablespoon of salt to 250 mL of distilled water.
5. Label the two glass jars 'salt water' and 'distilled water'.
6. Measure out 200 mL distilled water and pour it into the container labelled 'distilled water'.
7. Measure out 200 mL of the salt water and add it to the container labelled 'salt water'.
8. Carefully remove the eggs from the vinegar and rinse them. Pat them dry with paper towel.
9. Use a balance to determine the mass of each egg and record the mass in a table like the one shown in the Results section.
10. Place one egg in each container of water and put on the lid or cover with plastic wrap.
11. Each day, for the next 3 days, measure and record the mass of the egg.
12. Predict what you think will happen to the eggs. Record your prediction.
13. On day 3 measure and record the volume of the water remaining in each of the containers.

Results

1. Observe and record any changes to the eggs.

Treatment	Mass of egg (g)				
	Day 0	Day 1	Day 2	Day 3	Change
distilled water					
salt water					

2. Record any change in volume of the water.

Treatment	Volume of water (mL)		
	Day 0	Day 3	Change
distilled water	200		
salt water	200		

Review

1. Describe any changes that took place in the two eggs. Propose reasons for this change.
2. Describe any change in the volume of the water in the two containers. Propose reasons for this change.
3. Explain what you think was happening to the eggs, and the role the membrane played.
4. Compare the actual results with your hypothesis. Did your results support your hypothesis? Explain.

MODULE 2.2

Practical investigations

SPARKlab alternative available for this activity

3 • Microscopic life in pond water

Processing & Analysing | Communicating

Purpose

To observe microscopic organisms in pond water.

Timing 45 minutes

Materials

- pond water
- light microscope
- microscope slides
- cover slip
- eye-dropper
- cotton wool
- paper towel or tissue
- toothpick (optional)

SAFETY

Do not drink pond water. Wash your hands thoroughly after the activity.

Procedure

1. Place two drops of pond water on a slide.
2. Tease out a few fibres of cotton wool and place them on the slide.
3. Carefully lower the cover slip onto the slide and dry off any excess water.
4. Examine the slide using the low power of the microscope.
5. Now try high power. Remember that you are not only magnifying the size of the organisms but they also appear to be moving faster.

Results

1. Record the number of different types of organisms.
2. Draw the organisms you see and label any parts you can identify.
3. Use Figure 2.2.24 to identify the organisms you saw.

Review

1. a List the different types of organisms you saw.
   b For each organism:
   i state whether it was unicellular or not
   ii describe its characteristics.
2. Describe any difficulties you had observing the organisms. How did you overcome these difficulties?
3. Why do you think the cotton wool fibres were added to the slide? Did the fibres achieve this?
4. Describe the most interesting organism you observed.

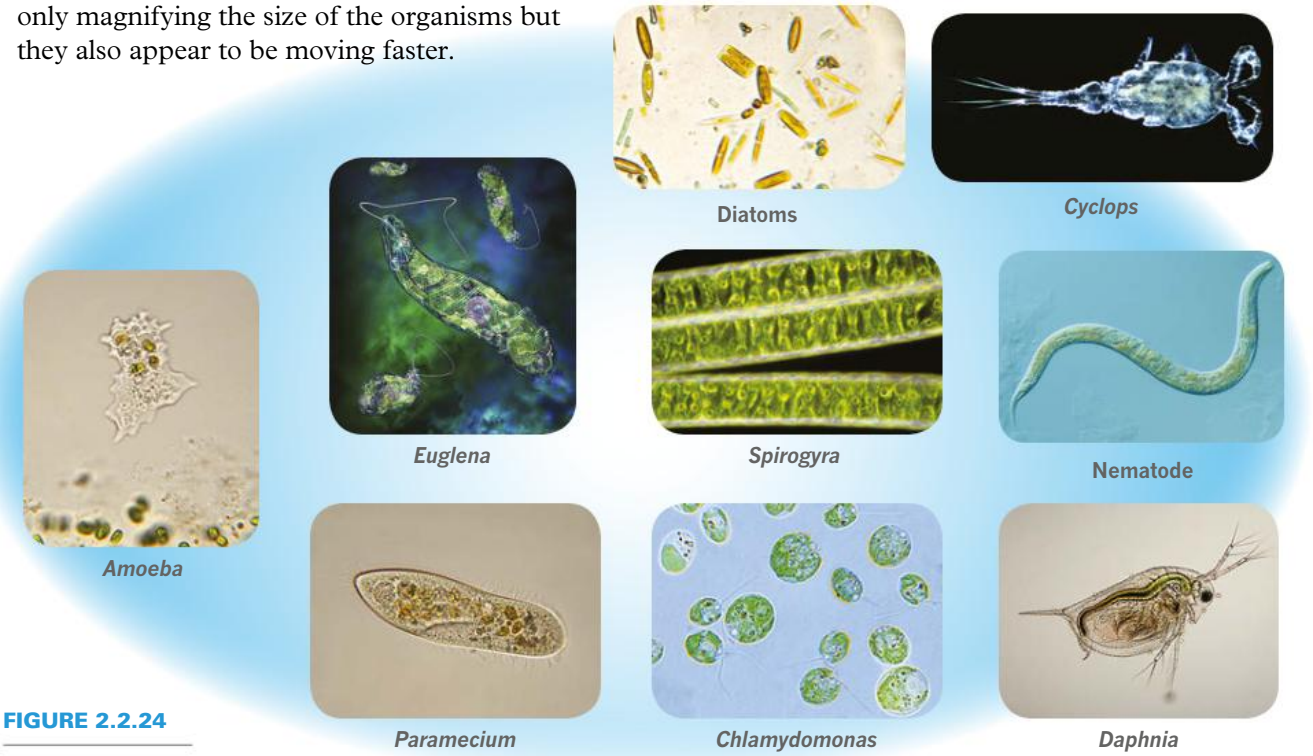


FIGURE 2.2.24

MODULE
2.3 Specialised cells

In unicellular organisms, a single cell has to carry out all the functions of life. Bigger things such as plants and animals are made up of many cells of different types. In these organisms, each type of cell is specialised to carry out a particular job. The cell shown here is a nerve cell that helps carry messages to and from the brain.

science 4 fun

Water movement in plants

Where does the water go in a plant?

Collect this ...

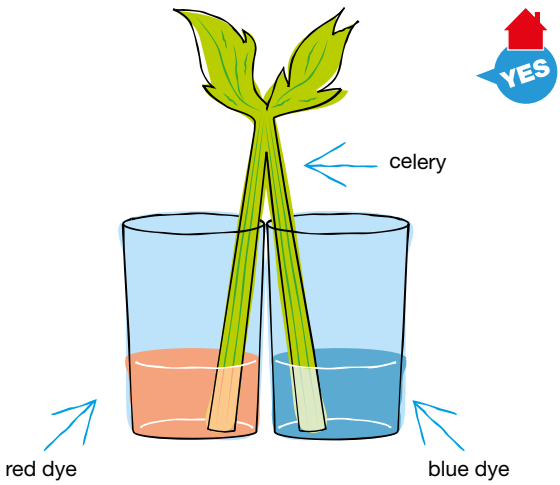
- celery stick with leaves attached
- red and blue food colouring
- two yoghurt containers or glasses
- knife

SAFETY

Take care when using a knife.

Do this ...

1. Add water to both containers until each is about one-third filled.
2. Add a few drops of red food colouring to one container to give it a strong colour. Add a few drops of blue food colouring to the other container.
3. Carefully cut the celery lengthwise from the end of the stalk to just under the leaf blades, as shown in the diagram.
4. Cut across the end of the stalk to remove the dried end.
5. Place one half of the celery stalk in the red water and the other half in the blue water, as shown.



6. Leave the containers in a safe place for one to two hours.
7. Cut across the stalk about half-way up.

Record this ...

1. Describe any changes to the leaf blades and at the newly cut end of the stalk.
2. Explain why you think this happened.

Multicellular organisms

The tree and the koala in Figure 2.3.1 are made of millions and millions of cells. These organisms are known as **multicellular organisms**—*multi* means many. Humans, birds, fish and insects are also multicellular organisms.

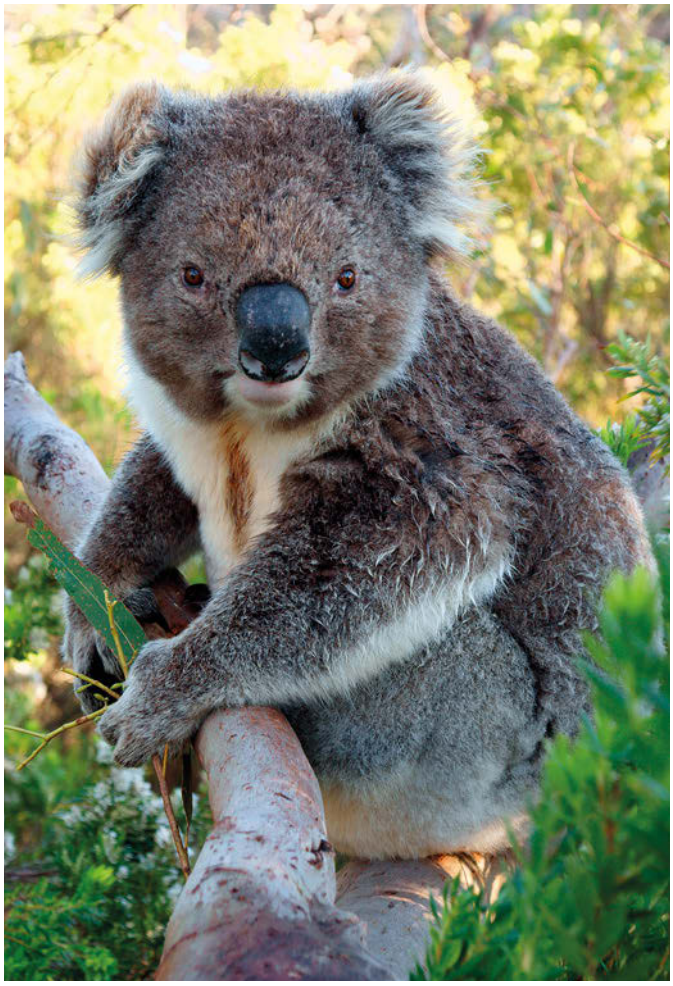


FIGURE 2.3.1 This koala and the tree in which it is sitting are both multicellular organisms.

In multicellular organisms, all the cells work together but they do not all do the same thing. Cells are **specialised**. This means that they have a special job to do in the body, and they have a structure that makes them better able to do their job.

Specialised animal cells

Animals are complex multicellular organisms with a large number of different cell types. The human body contains about 50 trillion cells and more than 200 different types of cells. A few of these 200 types are described below.

Muscle cells

The three types of muscles in your body are voluntary muscles (also called skeletal muscles), involuntary muscles (also called smooth muscles) and cardiac muscles.

Skeletal muscles are attached to the bones of your skeleton. These muscles are used for support and movement. You can choose to make these muscles move and so they are referred to as voluntary muscles. For example, biceps and triceps are skeletal muscles that you use to control your arm. You can see a magnified view of skeletal muscle in Figure 2.3.2.

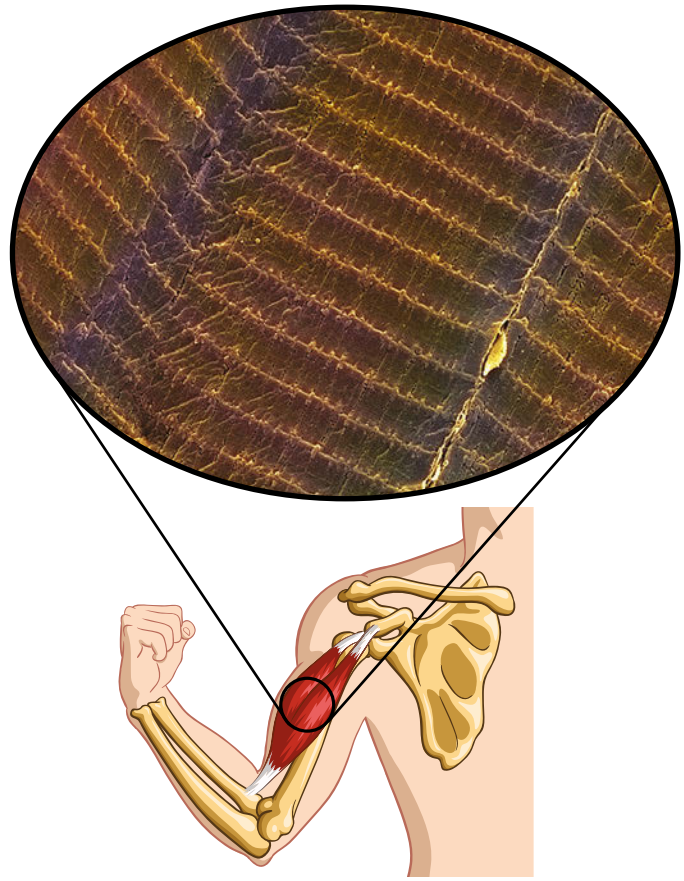


FIGURE 2.3.2 Skeletal muscles attached to bones have a striped appearance. These voluntary muscles are also known as striped muscles or striated muscles.

You have other muscles in your body that work without you having to think about it. These are the muscles involved in breathing and those that keep food moving through your gut. These muscles are known as involuntary muscles. Your diaphragm controls your breathing and is an involuntary muscle, as are the muscles in the wall of your digestive tract or gut. An image of involuntary muscle is shown in Figure 2.3.3.

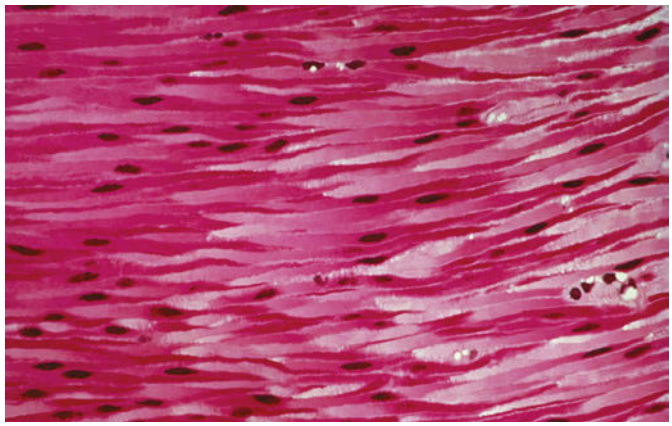


FIGURE 2.3.3 Most involuntary muscles do not have a striped appearance. They are also known as smooth muscles.

All voluntary and involuntary muscles contain a large number of mitochondria. This is because these muscles require a lot of energy to keep working and it is the mitochondria that provide the energy.

Cardiac muscle is the muscle that makes up the heart. Cardiac muscle is involuntary muscle but it has a striped appearance like voluntary muscles (Figure 2.3.4). Unlike other muscles that are striped, cardiac muscle does not get tired. It has very large numbers of mitochondria to provide a continuous supply of energy. These characteristics allow the heart to beat continuously.

FIGURE 2.3.4 Cardiac muscle is an involuntary muscle that has characteristics of both striated muscle and smooth muscle.

SciFile

Facial expressions

Not all skeletal muscles are attached to bones. Some in your face are attached directly to your skin. Even the slightest contraction (shortening) of one of these muscles can give rise to a change in your expression (Figure 2.3.5).

FIGURE 2.3.5 Your facial muscles change your expression and the message this sends to other people.

Nerve cells

Nerve cells make up your brain. They also carry information from your brain to other parts of your body such as your muscles, and from your muscles back to your brain. As Figure 2.3.6 shows, some nerve cells have very long fibres extending from the cell. These fibres are called **axons**—they allow the cell to carry messages over long distances. The longest axon of a human nerve cell reaches from the base of the spine to the toes, and can be more than a metre long.

FIGURE 2.3.6 Nerve cells are found in your brain. The axons make connections with other brain cells.

Blood cells

Figure 2.3.7 shows some blood cells and one white blood cell. **Red blood cells** carry oxygen from your lungs around your body to the cells, where it is used to release the energy you need. They also carry some of the waste carbon dioxide from the cells back to your lungs so that you can get rid of it from your body. The **white blood cells** have a very different job. They are part of the immune system and help the body to fight infection.

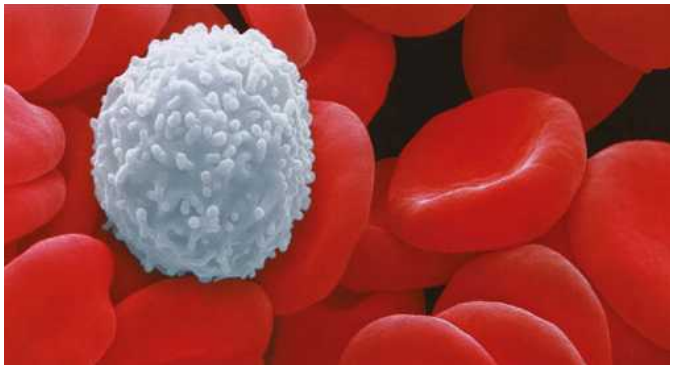


FIGURE 2.3.7 There are many more red cells in your blood than white cells.

Fat cells

You have two different types of fat cells in your body. Brown fat cells are used to produce heat for the body, especially when it gets cold and you are shivering. The white fat cells in Figure 2.3.8 are used as a store of energy. They also form an insulating layer under the skin that helps to keep your body at a constant temperature.

FIGURE 2.3.8 White fat cells under the skin insulate you from the cold and keep you warm. These cells have been stained purple.

SciFile

New blood

Red blood cells are the only cells in the human body that do not have a nucleus. This means they can't reproduce and need to be continually replaced. Your body makes billions of new red blood cells every day.

SciFile

What do babies and bears have in common?

Newborn babies and hibernating animals have large amounts of brown fat (Figure 2.3.9). Brown fat cells contain many mitochondria, which give brown fat its dark colour. Newborn babies cannot shiver and rely on brown fat to produce heat when cold. Hibernating animals, such as bears, also rely on brown fat to keep them warm when hibernating in cold conditions.

FIGURE 2.3.9 Colour-enhanced SEM of a brown fat cell. Brown fat cells have a rich blood supply because they require large amounts of oxygen. Their dark colour is due to large numbers of energy producing mitochondria.

Specialised plant cells

Like animals, plants are multicellular organisms. Plants have specialised cells of different shapes and sizes, but they do not have as many different types of cells as animals.

Each type of cell is specialised to carry out a different function within the plant. Figure 2.3.10 shows some plant cells that have different functions.

AB 2.7 AB 2.8 Prac 1 p. 76 Prac 2 p. 76

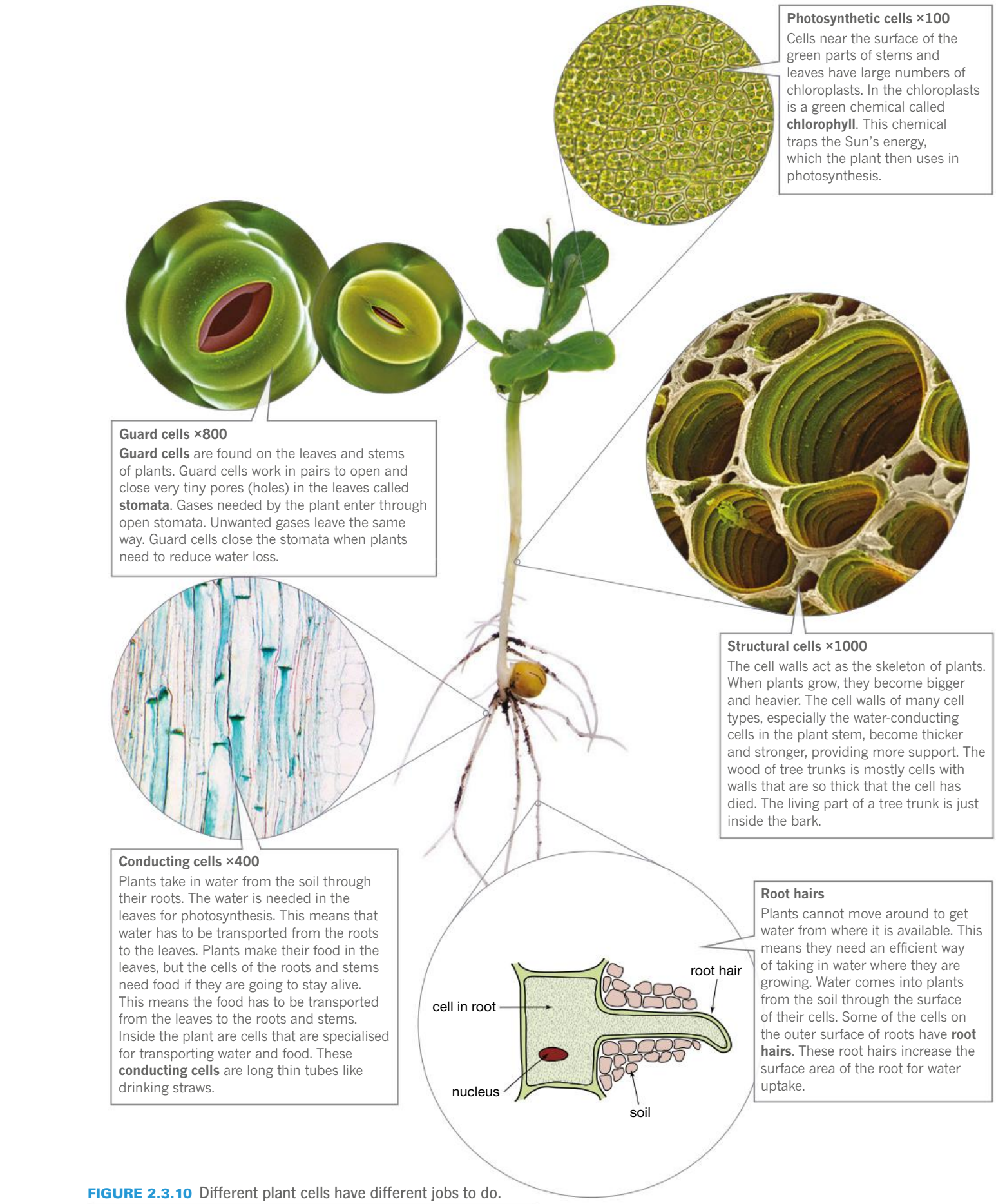


FIGURE 2.3.10 Different plant cells have different jobs to do.

MODULE 2.3

Review questions

Remembering

1 Define the terms:
- a axon
- b chlorophyll
- c multicellular organism.

2 What term best describes each of the following?
- a cells that have a structure that suits them to a particular job
- b cells that carry oxygen from the lungs to the rest of the body
- c pores in a leaf surrounded by two guard cells.

3 Name three specialised cell types found in:
- a plants
- b animals.

4 Which has more different types of cells: plants or animals?

5 Name the type of cells described.
- a leaf cells where the plant's food is made
- b animal cells that send electrical messages around the body
- c animal cells that help fight infection
- d cells that control the gases entering and leaving a leaf.

6 Match the different types of animal cells with their specialised tasks.

fat cells	cells that contract, causing bones to move
cardiac muscles	carry oxygen from the lungs to the cells
red blood cells	where the body stores energy
skeletal muscle	muscle that does not get tired and keeps the heart pumping

Understanding

7 a Define the term *specialised cell*.
- b What are two examples of specialised cells, and what organism they are found in?

8 Once water has entered the root of a plant, explain how it is able to get to the leaves where it is needed.

9 Look at the experimental set-up in the science4fun on page 69. Suggest what will happen in each side of the celery stick. Why do you think so?

10 Draw a table with three columns.
- a In the left-hand column, list four specialised plant cells.
- b In the middle column, describe what the cells do.
- c In the right-hand column, describe how the cell is specialised to do this job.

Applying

11 There are about 5 million red blood cells in every millilitre of blood. Calculate the number of red blood cells in an:
- a average blood donation of about 450 mL
- b adult human (about 6 litres of blood).

12 Figure 2.3.11 below shows the surface of a leaf as seen under a light microscope and magnified ×400. At least two different types of specialised cells can be observed.
- a Identify and describe one type of specialised cell.
- b Why is this cell referred to as specialised?

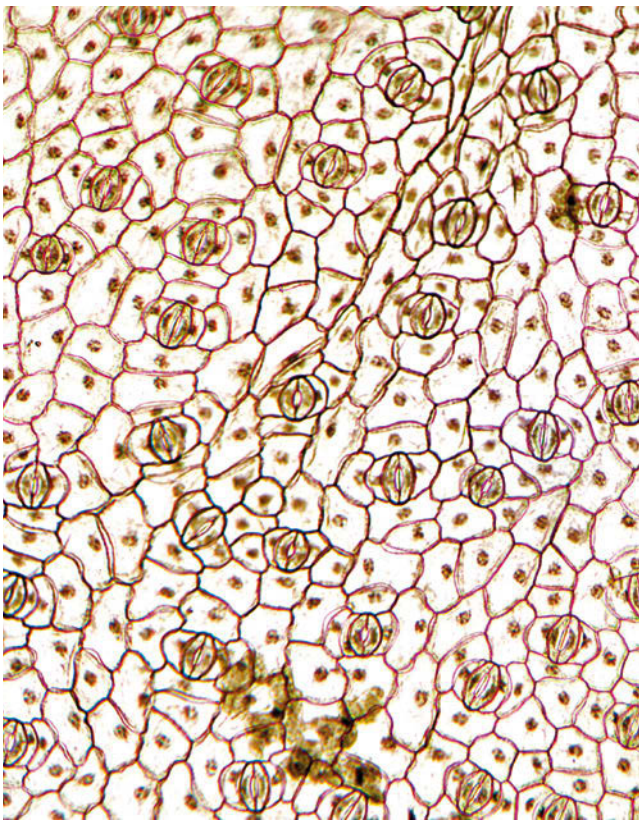


FIGURE 2.3.11

MODULE 2.3

Review questions

Analysing

13 There are three different types of muscle in the human body.

- **a** Name the three types.
- **b** Describe each type of muscle and state its function.
- **c** Classify the following muscles as voluntary or involuntary.
  - **i** muscles of upper leg
  - **ii** tongue
  - **iii** muscles in the oesophagus (the tube carrying food from the mouth to the stomach)
  - **iv** muscles that make up the heart.

Evaluating

14 What if the cells in your body were all the same? Discuss how this would change the way your body works.

15 There are many mitochondria in the muscle cells of animals.

- **a** Which type of plant cells could also have very high numbers of these organelles?
- **b** Justify your answer.

16 Look at Figure 2.3.12.

- **a** Compare the size of plant cells and animal cells.
- **b** Propose reasons for the following.
  - **i** Plant cells were the first cells to be seen.
  - **ii** Bacteria were not discovered until long after plant cells.
- **c** Bacteria do not form true multicellular organisms. Suggest how this may have contributed to bacteria not being discovered until long after animals and plants.

Creating

17

- **a** Why is water important to a plant?
- **b** Draw a diagram of a plant similar to the one in Figure 2.3.10 on page 73. Use arrows to show how water moves in and through your plant. Label your diagram to show:
  - **i** where water enters and leaves the plant
  - **ii** which specialised cells it travels through, and how the structure of these cells assists this
  - **iii** what the water is used for.

18 You have been shown a type of cell you have never seen before. It is a small cell but the membrane on the outside has many extensions, giving it a very large surface area.

- **a** Create a diagram of what this cell would look like.
- **b** Predict the sort of job this cell would do and whether the cell is from a plant or an animal.

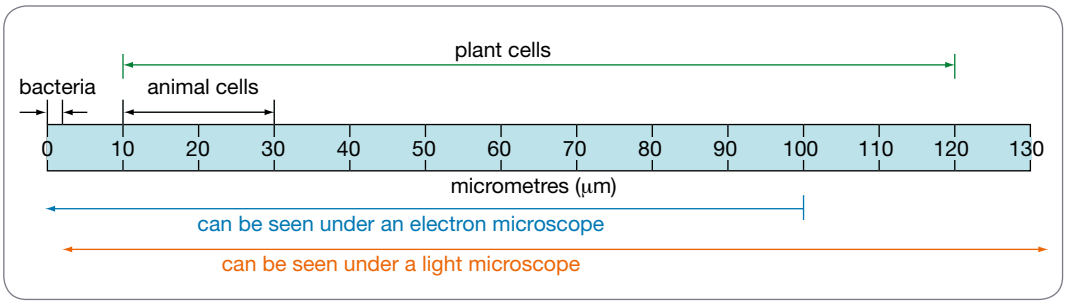


FIGURE 2.3.12

MODULE 2.3

Practical investigations

1 • Modelling water transport cells

Processing & Analysing | Communicating

Purpose

To model the effect of very thin tubes on the movement of water in plants.

Timing 30 minutes

Materials

- food colouring
- 125 mL water
- 500 mL beaker
- 1 × 30 cm length of capillary tubing
- 2 × 20 cm lengths of glass tubing with different diameter bores, both larger than the capillary tubing

SAFETY

A risk assessment is required for this investigation.

Be careful if you are using hot water or sharp instruments.

Procedure

1. Place the water into the beaker and add enough food colouring to give the water a distinct colour.
2. Hold the three pieces of glass tubing upright in the water as shown in Figure 2.3.13. Make sure the tubing is touching the bottom of the beaker.

FIGURE 2.3.13

Results

1. Observe the height to which the water has risen in the different tubes.
2. Construct a diagram showing the apparatus and the results.

Review

1. Describe how the diameter of each tube affects the level of water.
2. Specialised water-conducting cells in plants join together to make up long thin tubes that travel from the roots to the leaves. The diameter of these tubes is many times smaller than the capillary tubes used in this experiment. Explain what effect this would have on water level in the tubes within the plant, and suggest how this could help move water through the plant.

• STUDENT DESIGN •

2 • My cell

Planning & Conducting | Communicating

Purpose

To construct a model of a cell.

Timing 45 minutes

Materials

You can decide. Suggestions include:

- plastic food wrap or freezer bags
- cotton wool, wool, thread
- gelatine and hot water
- container for mixing gelatine
- container for heating water
- buttons, marbles, lollies such as jelly beans
- stiff cardboard

Procedure

1. Decide whether you are going to make a plant cell or an animal cell, a typical cell or a specialised cell.
2. Make a list of the parts of the cell and their characteristics.
3. Decide what you could use to represent the cell parts. Make a list of your choices, giving a reason for each choice.
4. Construct your cell.
5. Explain to other members of the class how you have constructed your cell and why you chose the material you did.

Use the STEM and SDI template in your eBook to help you plan and carry out your investigation.

Review

1. List the positive comments others in the class make about your cell.
2. List the suggestions of areas you could improve on.
3. Describe what you would change if you were to make another cell.

MODULE

2.4 Cell to organism

Multicellular organisms are complex organisms that perform a variety of functions. For example, a frog breathes, reproduces, digest foods and gets rid of wastes. A plant absorbs and transports water and makes glucose via photosynthesis. To perform these functions, the cells of multicellular organisms are organised into tissues, which in turn are organised into organs and then into systems.

science 4 fun

Soft bones

Bones are complex structures consisting of living cells and deposits of calcium. Vinegar is a weak acid that dissolves calcium.

Collect this ...

- 2 uncooked chicken bones
- vinegar
- jar

Do this ...

1. Fill a jar with vinegar and place one chicken bone in the jar overnight.
2. Leave the other chicken bone untreated.
3. Predict what you think will happen to the bone in the vinegar.
4. Compare the two bones the next day.
5. Carefully rinse the vinegar down the sink, wrap the chicken bone and put it in the rubbish.

Record this ...

1. Describe what happened. Was your prediction correct?
2. Explain why you think this happened.

Animal tissues and organs

The boy and the dog in Figure 2.4.1 are multicellular organisms. Like all multicellular organisms, they are made up of many millions of different types of specialised cells. These cells need to work together if the organism is to survive. For example, an individual muscle cell can contract but cannot move a large organism. To do this, it needs to work with other muscle cells. The muscle cells also need something to pull on to bring about movement, so they need to work with other types of cells.

FIGURE 2.4.1 Both the boy and the dog are complex organisms. Their cells are organised into tissues, tissues into organs, and then organs into systems.

Specialised cells are not just scattered around the body. They are organised together with other cells of the same type, and often with other types of cells. There are several levels of organisation. These levels are shown in Figure 2.4.2.

- **Tissues**: Tissues are similar specialised cells working together to complete a specific task.
- **Organs**: Tissues are organised into organs. An organ is a structure that contains at least two different types of tissue working together to complete a task.
- **Organ systems**: Organs are arranged into organ systems. Organ systems have two or more different organs that work together.

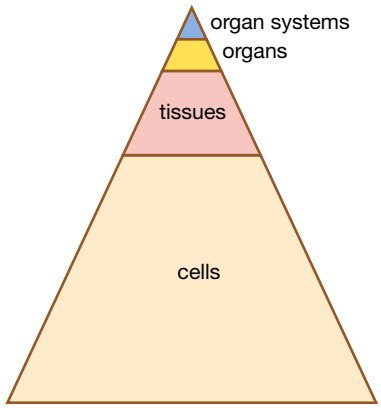


FIGURE 2.4.2 In a complex organism, there are many more cells than there are tissues, many more tissues than organs, and many more organs than systems.

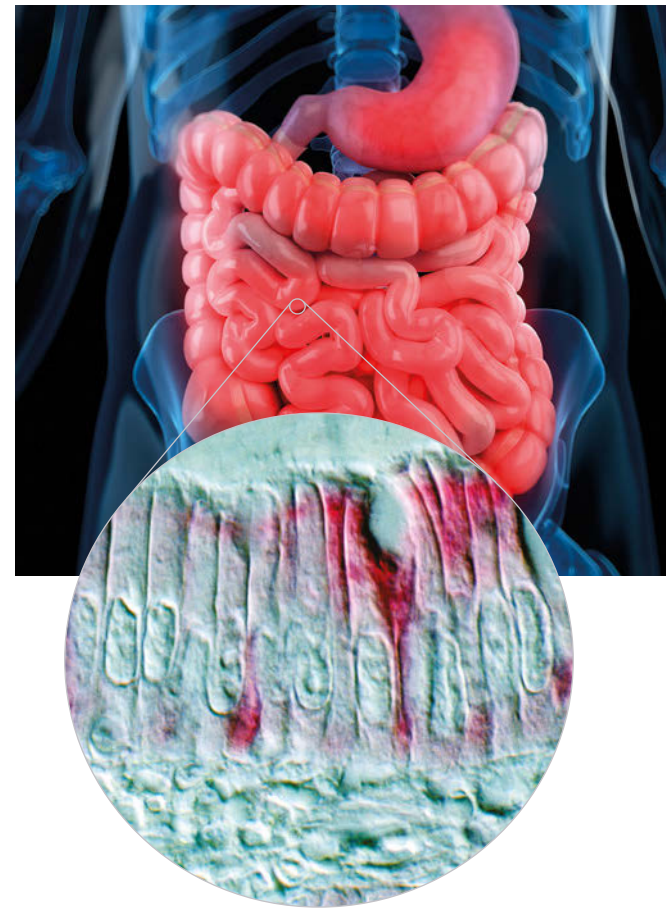


FIGURE 2.4.3 Column-shaped cells make up the epithelial tissue lining your small intestine.

Tissues

In the human body there are four types of tissues:

- epithelial tissue
- connective tissue
- muscle tissue
- nerve tissue.

Epithelial tissue is made up of cells that form surfaces over other organs. Your skin is the best known organ that has an outer layer of epithelial tissue called the **epidermis**. Epithelial tissue also lines the inside of your mouth and the rest of the digestive system. Figure 2.4.3 shows the cells making up the epithelial tissue that lines the small intestine. The respiratory system and the reproductive system also have a layer of epithelial tissue lining their surfaces.

Connective tissue supports and holds together other tissues in the body. Examples of connective tissue are fat, bone, cartilage, ligament and tendon. A tendon is shown in Figure 2.4.4. Some types of connective tissue are strong and fibrous, which means that it is made of strands or fibres, like threads.

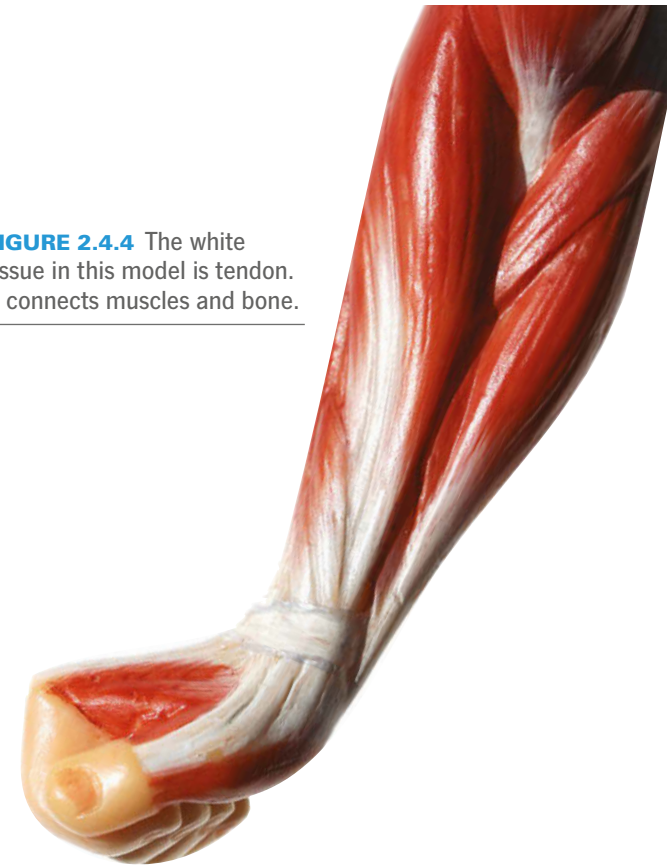


FIGURE 2.4.4 The white tissue in this model is tendon. It connects muscles and bone.

Ligaments hold bones together at the joints. If you sprain your ankle or wrist badly, then it is likely that you have torn some of the fibres of the ligaments holding the bones together. Tendons join muscles to bones.

Muscle tissue is a specialised tissue that can contract, becoming shorter and fatter. For example, the muscle on the front of your upper arm (the biceps) bulges when you pull up your forearm. You can see this in Figure 2.4.5. Each individual cell of the muscle has contracted.

Prac 1
p. 86

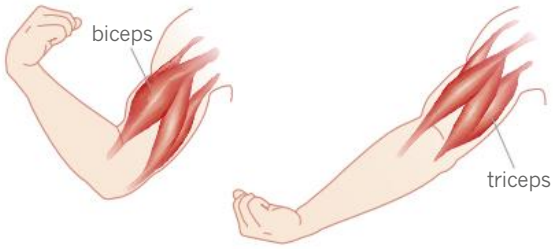


FIGURE 2.4.5 Biceps are the muscles that contract to pull your arm up. Muscles cannot expand, so another set of muscles need to contract to pull the arm back down. These are your triceps.

Nerve tissue such as that in Figure 2.4.6 can send electrical signals around the body. These electrical signals are managed by nerve tissue in the brain and passed down the a large bundle of nerve tissue called the spinal cord to the body. One nerve cell would not be able to pass information around your body effectively. Thousands of nerve cells are grouped together to form your nerves.

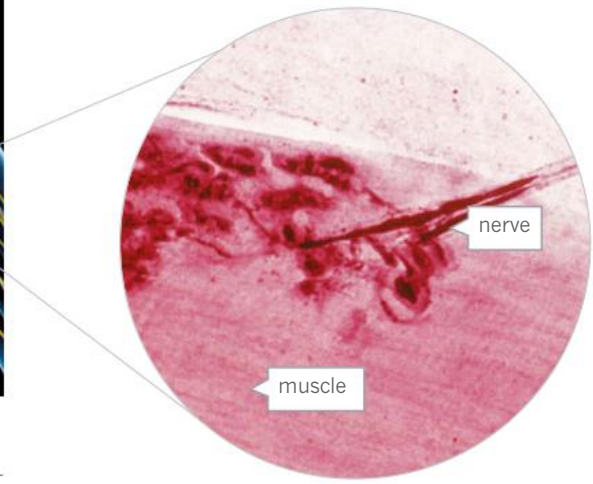


FIGURE 2.4.6 These nerve endings are attached to the muscle. The message passing along the nerve causes the muscle to react.

Organs

Tissues are grouped together into organs. All the different tissues contribute to the job that the organ has to do. There are many different organs in your body, such as the liver, kidneys and heart. Even your skin is an organ—the largest organ of your body. As you can see in Figure 2.4.7, the skin is made up of many different tissues.

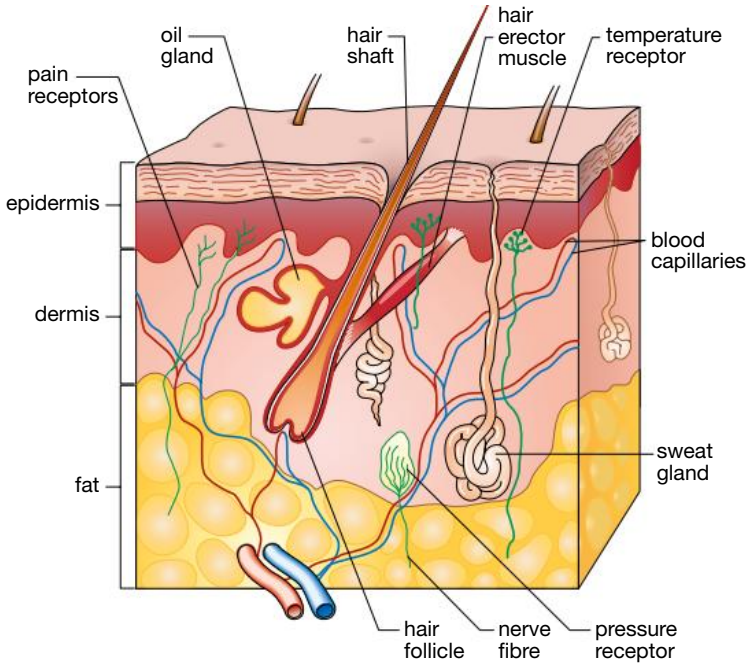


FIGURE 2.4.7 The skin is a complex organ. It consists of many tissues including fat, dermis, epidermis, blood and blood vessels.

In the heart shown in Figure 2.4.8, the tissues work together to pump blood around the body. The blood carries nutrients and oxygen to the cells, and carries wastes away from the cells.

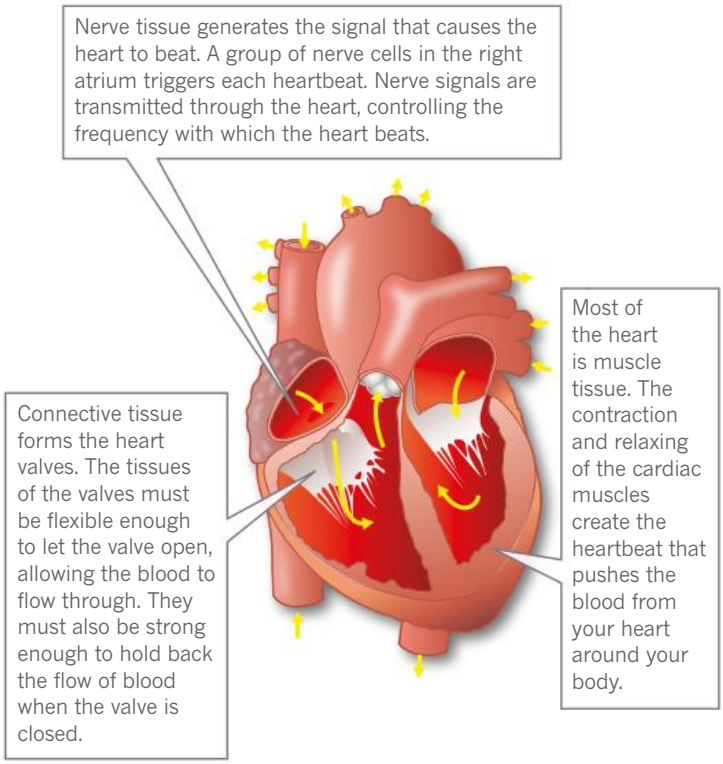


FIGURE 2.4.8 The heart is an organ made of different tissues.

Organ systems

The organs of your body do not work independently. Organs are organised so that they can work together to complete a task. These organs form an organ system. For example, a series of organs work together to change the food you eat into a form that your body can use. This system digests the food. For this reason the system is called the digestive system. It is shown in Figure 2.4.9.

There are other systems in your body, such as the:

- respiratory system, which gets oxygen from the air into your body and gets rid of waste carbon dioxide
- skeletal system, which is your skeleton and muscles
- excretory system, which gets rid of wastes from the body
- nervous system, which sends messages from your sense organs to the brain and from the brain to other parts of the body, including the muscles
- reproductive system, which creates and transports the specialised cells necessary for reproduction. In females it provides structures and nutrients for the development and birth of a baby.

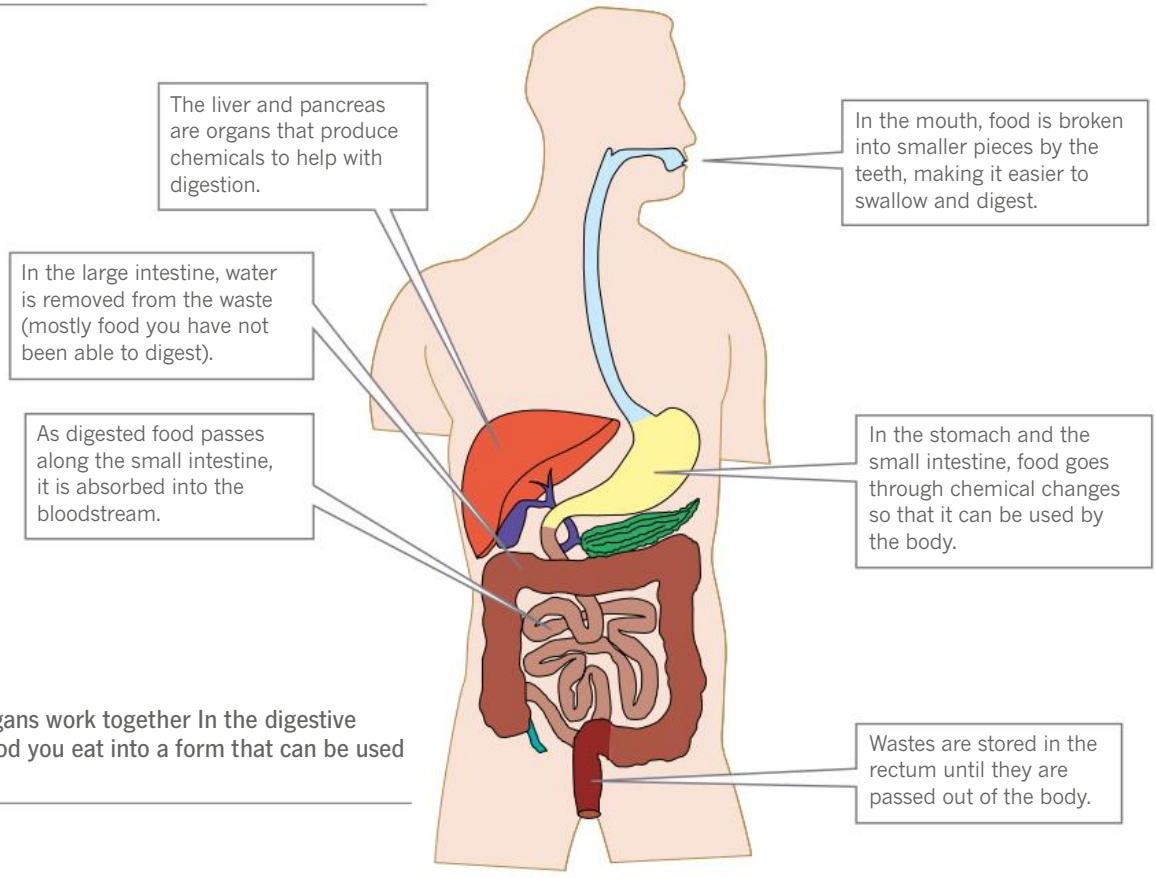


FIGURE 2.4.9 Many organs work together In the digestive system to change the food you eat into a form that can be used by your cells.

Plant tissues and organs

Plants have fewer organs and organ systems than animals. Plants are mainly organised at the tissue level and only have a small number of organs. These tissues and organs enable the plant to carry out essential functions such as photosynthesis, transport and reproduction.

Vascular tissue

Materials are transported around plants via **vascular tissue**. Vascular tissue is composed of two types of cells:

- **Xylem** carries water from the roots. Xylem cells are long thin tubes with strong walls that help support the plant. You can see them clearly in Figure 2.4.10.
- **Phloem** carries glucose from the leaves to all other plant parts (Figure 2.4.11).

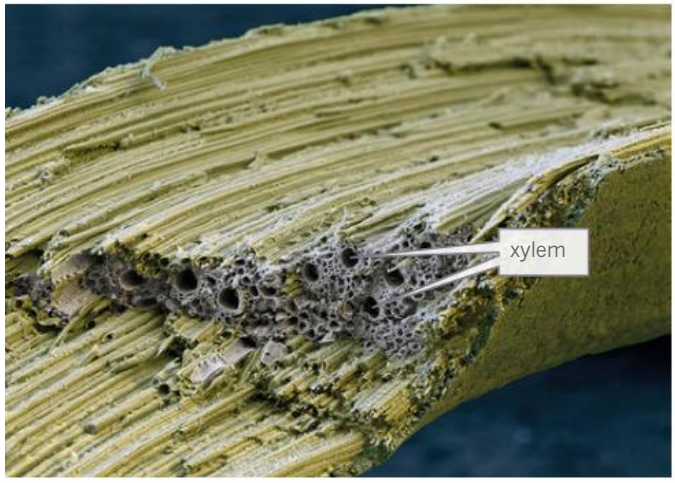


FIGURE 2.4.10 A piece of bamboo showing the long bundles of xylem cells that carry water throughout the plant x200

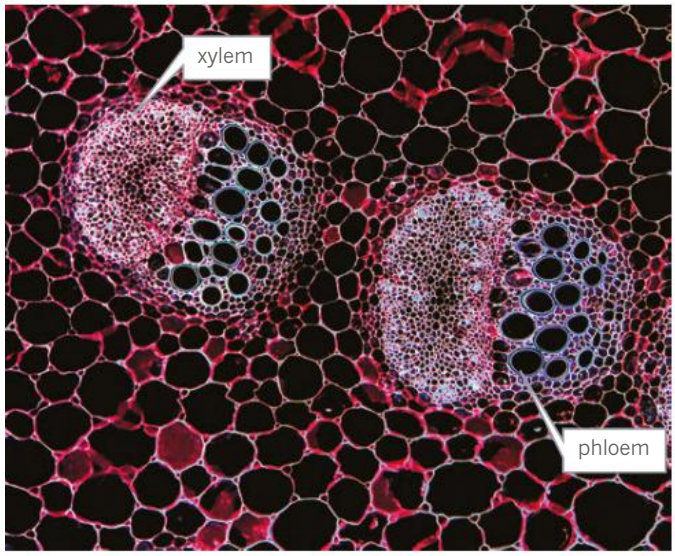


FIGURE 2.4.11 Cross section through a parsnip stem, x100. Hollow phloem cells have been stained blue. The xylem is also present and is the smaller tubes.

Phloem and xylem together form a network of vascular tissue throughout the plant. The vascular tissue in a leaf can be seen in Figure 2.4.12.

FIGURE 2.4.12 The network of vascular tissue can been seen in this leaf. This transport system extends throughout the stem and roots as well.

Plant organs

The main organs of a plant are its roots, stems and leaves. These organs work together to bring together the raw materials required for photosynthesis. **Photosynthesis** is the process by which plants make glucose. Plants use the energy from glucose for their life processes; without it they could not survive. For photosynthesis to take place, water from the soil and carbon dioxide from the air are needed. Chlorophyll is a chemical that converts the Sun's energy into chemical energy the plant can use. Oxygen is produced as a waste product.

The process of photosynthesis is summarised in Figure 2.4.13.

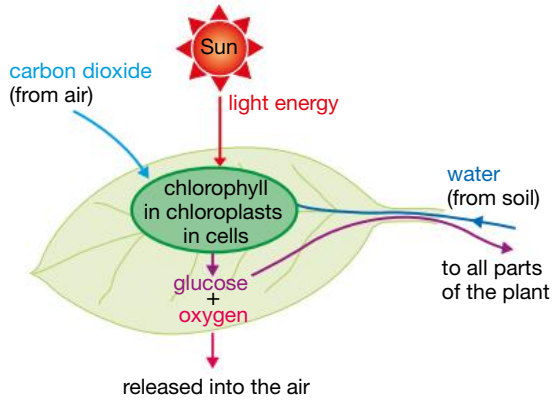


FIGURE 2.4.13 Photosynthesis takes place in the chloroplasts of leaf cells. Chloroplasts contain the green chemical chlorophyll.

The root is the plant organ that takes water into the plant from the soil. Water moves through cells to the vascular tissue. It moves up the xylem to the stem.

The stem is the organ that holds the leaves of the plant up to the light. Stems also carry water from the root to the leaves and transport glucose to all parts of the plant.

Figure 2.4.14 shows these structures in the root and stem.

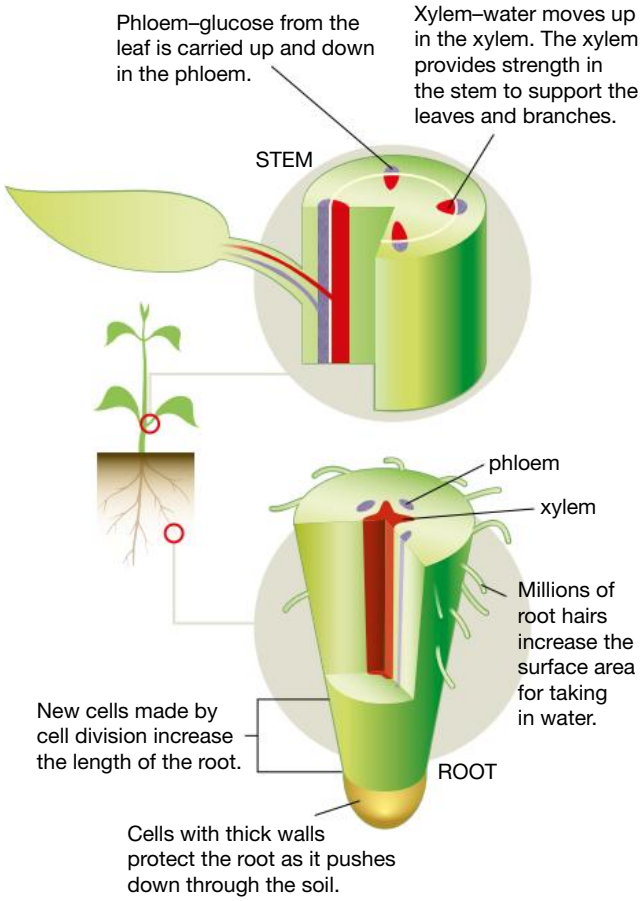


FIGURE 2.4.14 The roots and stem are plant organs that help get the water necessary for photosynthesis up to the leaves.

The leaves are the organs in plants that carry out photosynthesis.

You can see the different parts of a leaf in Figure 2.4.15.

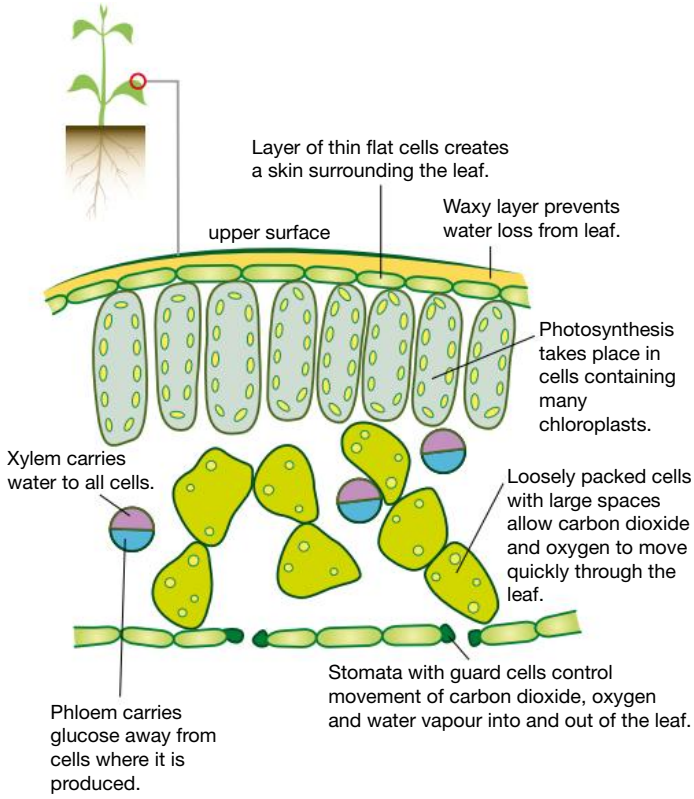


FIGURE 2.4.15 Leaves are important plant organs. The glucose that plants need for energy is manufactured in leaves.

AB 2.9

Growing cells

In the past 100 years, scientists have learnt how to grow cells separately from the organism they came from. This process is called **cell culture** (Figure 2.4.16). The cells for cell culture can come from a living organism or an existing cell culture.

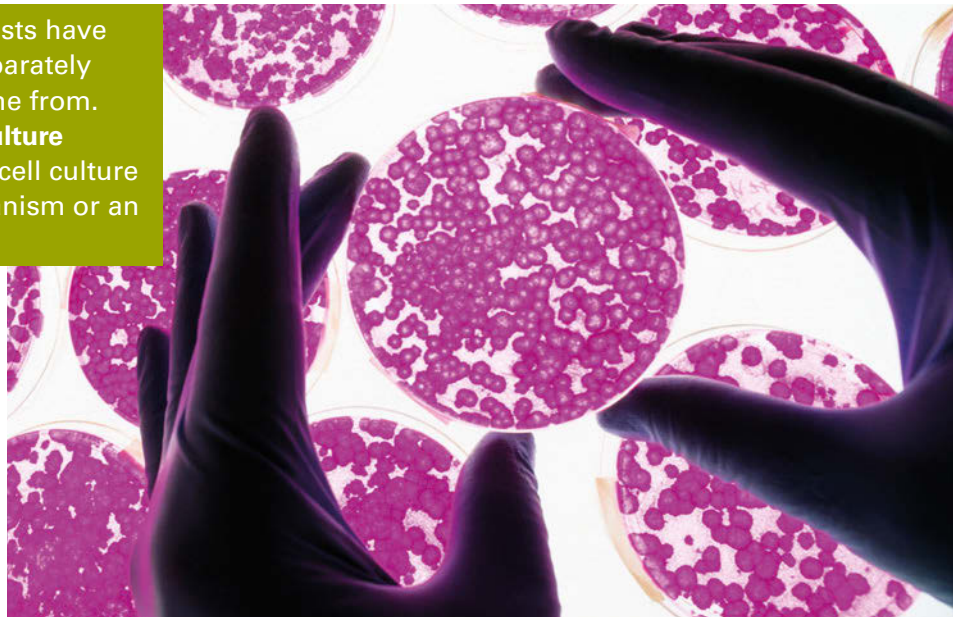


FIGURE 2.4.16 Cell culture can be used to grow cells outside a living organism.

The cells are kept at the correct temperature and in a solution that provides them with all the minerals and nutrients they require to keep them alive. The cells divide, producing masses of identical cells.

Cell cultures enable scientists to study cells without having to worry about other cells from an organism, or disease-causing organisms and chemicals. The cells can be studied to simply learn more about cells, or can be used to test drugs or toxic chemicals, including those thought to cause cancer.

Cell culture can also be used to produce vaccines that protect us from diseases such as measles, rubella, mumps, chickenpox and polio. These cells are also used to produce agents that can help fight cancer.

Tissue engineering

Tissue engineering is the process of growing tissues, and even whole organs, to replace those that are diseased or defective.

The cells used to grow new tissue can come from three sources:

- cells from the organ or tissue to be replaced
- cell culture
- stem cells.

Stem cells are cells that have not become specialised. They are found in areas of the body where cells are continually being made, such as in bone marrow and parts of the skin. Stem cells are able to become different types of cells under the right conditions.

Whatever method is used, it is most likely to succeed if the cells come from the patient who will receive the new tissue.

The major steps in tissue engineering are:

1. Source the cells to be grown into tissue.
2. Grow these cells in cell culture.
3. Create a scaffold for the tissue to grow and develop on. This could be a tube to grow a blood vessel or a flat matrix to grow skin cells.
4. Add the cells grown in cell culture to the scaffold, and add growth chemicals and physical stimuli such as pressure and temperature.
5. Transplant the new tissue onto or into the patient.

Figure 2.4.17 on page 84 summarises the process of tissue engineering.

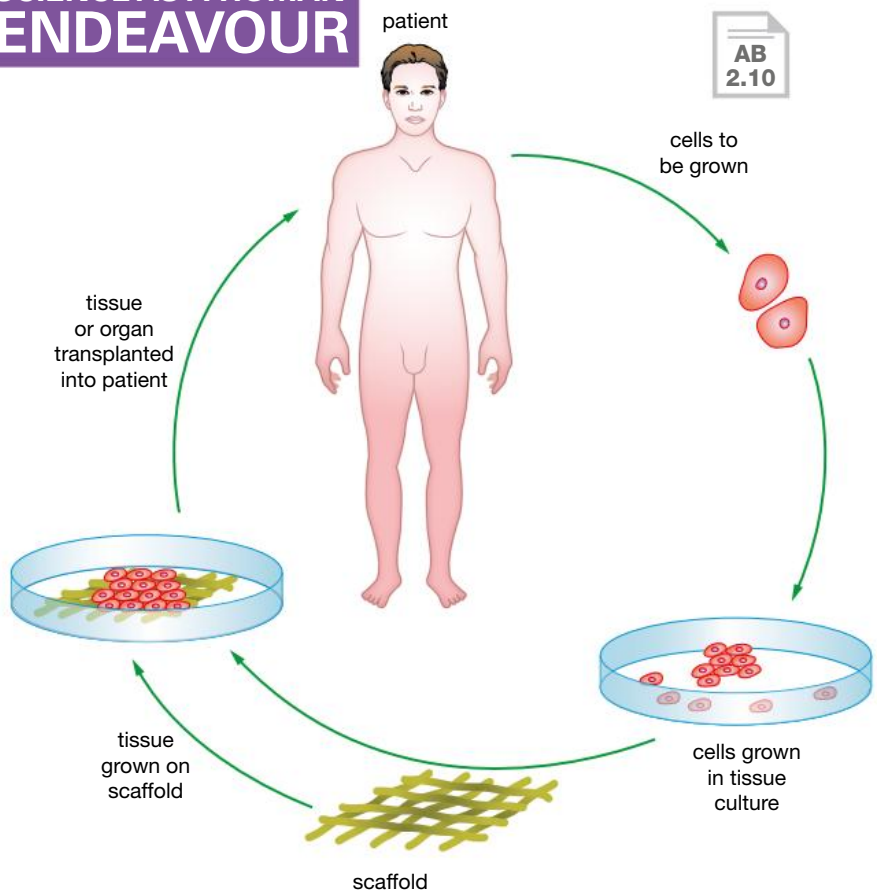


FIGURE 2.4.17 The main steps in tissue engineering

Many types of tissues have been successfully engineered, including skin, blood vessels, bladder and muscle. Skin tissue can be used to treat wounds, including burns. Skin cells from the patient are cultured for two weeks, then added to a scaffold and exposed to air. This produces sheets of skin, like that shown in Figure 2.4.18, made of cells that are identical to the patient's cells.

FIGURE 2.4.18 A strip of skin is held above the culture medium.

The skin is then grafted onto the wound. Within a few days, doctors will know if the graft is going to work. A successful skin graft will look just like the patient's old skin within 10 weeks. In the past, healthy skin had to be taken in large amounts from another area of the patient's body. This left the patient with a large scar.

Growing organs

Scientists hope that in the future, complete organs can be grown for transplant. There are children in the USA who have new bladders that were grown from their own cells using tissue engineering. These children were born with defective bladders. Doctors took cells from the lining of the bladder and muscle cells from the outside. These cells were grown in culture solution.

When there were enough cells, they were placed on a bladder-shaped scaffold made from a biodegradable material. The lining cells went on the inside of the shell and the muscle cells on the outside. The new bladder continued to grow in culture for another seven weeks. After that it was transplanted into the body of the patients, where the new bladders continued to grow and remain healthy.

REVIEW

1 Explain what the following terms mean.
   - **a** cell culture
   - **b** stem cells

2 Tissue culture is the process of growing new tissues or organs outside the body of a living thing.
   - **a** Where do the cells used to grow new tissue come from?
   - **b** Outline the main steps in creating new tissue via tissue culture.
   - **c** Suggest reasons why it is preferred that the cells used for tissue engineering come from the person who will receive the new tissue.

3 **a** Describe one situation where skin tissue grown via tissue engineering would be used.
   - **b** Before tissue engineering, what would have been done?

MODULE 2.4

Review questions

Remembering

1 Define the terms:
- a epithelial tissue
- b epidermis
- c tissue.

2 What term best describes each of the following?
- a a structure containing at least two different types of tissue
- b two or more organs working together.

3 List these words in order from simplest structure to most complex.
tissue system cell organ.

4 List two types of tissues found in the human body.

5 Name four different organs in the body.

6 List three systems in the human body.

7 Name the plant organ:
- a in which most photosynthesis takes place
- b through which water enters the plant.

Understanding

8 Explain why skin is an organ rather than a tissue.

9 How do root hairs make roots more efficient?

10 Explain, with an example, why specialised cells need to work with other specialised cells of the same type.

Applying

11 Draw labelled diagrams to demonstrate the difference between cells, tissues and organs. Add notes and comments to assist where necessary.

12 Draw and label a diagram of a plant that shows the path water travels from the soil to the cells in the leaves, where photosynthesis takes place.

Analysing

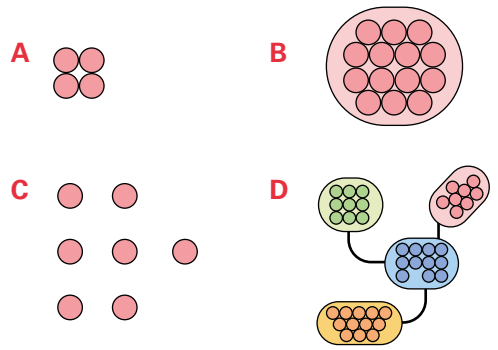
13 Contrast:
- a a cell and a tissue
- b an organ and a system.

14 What are the similarities and differences between cardiac muscle and skeletal muscle?

Evaluating

15 How do you think the amount of photosynthesis taking place in a leaf would change if:
- a the stomata were closed?
- b the number of chloroplasts was reduced by half?

16 In diagrams A–D, each small circle represents a cell. Select the diagram that best represents:
- a individual cells
- b a body system
- c an organ.



17 Photosynthesis is the process by which plants make their own food in the form of glucose. Photosynthesis is often described as the most important process on Earth.
- a Describe photosynthesis in words or diagrams.
- b Propose reasons to support the view that photosynthesis is the most important process on Earth.

18 In the science4fun on page 77, vinegar (an acid) slowly removed calcium from chicken bones.
- a Propose what might happen to your bones if they lost calcium.
- b Predict how the functioning of your skeleton might change if you do not have enough calcium in your diet.

Creating

19 Construct a diagram showing the organisation of muscles, tendons and bones in the arm, and how they work together to bend and straighten your arm.

MODULE 2.4

Practical investigations

1 • Muscles get tired

Questioning & Predicting | Evaluating

Purpose

To find out what contributes to muscle fatigue.

Hypothesis

What do you think will cause your muscles to fatigue (become tired) more quickly—squeezing a ball at waist height or with your arm held above your head? Before you go any further with this investigation, write a hypothesis in your workbook.

Timing 45 minutes

Materials

- soft foam or rubber ball
- stopwatch

Procedure

PART A: ARM RELAXED

1 In your workbook, construct a table like the one shown in the Results section. Alternatively, construct a spreadsheet with similar columns. Give your table or spreadsheet a title.

2 Work in pairs. Hold the ball as shown in Figure 2.4.18. Squeeze the ball as many times as you can in 30 seconds. Your partner should time you as you count.

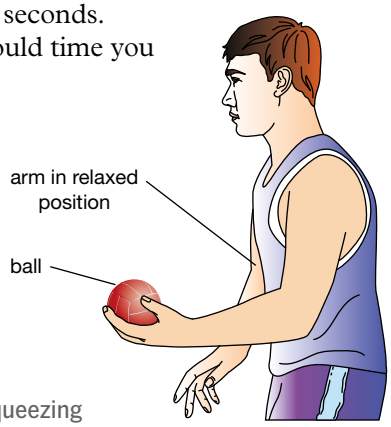


FIGURE 2.4.18 Squeezing the ball with arm relaxed

3 Rest for 10 seconds.

4 Repeat steps 2 and 3 until you have completed 10 trials. Record your results in the table or spreadsheet.

PART B: ARM RAISED

5 Repeat steps 1–4 but this time hold your arm above your head as shown in Figure 2.4.19.

6 Do not lower your arm during the resting time.

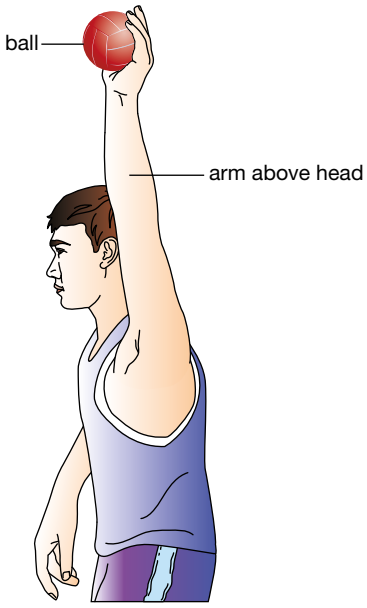


FIGURE 2.4.19 Squeezing the ball with arm held above the head

Results

1 Record your results in a table like this.

Trial	Number of squeezes	
	Part A	Part B
1		
2		

2 Graph your results by constructing a line graph for each part. You can have two graph lines on the same axes. Place the trial number along the horizontal axis and the number of squeezes on the vertical axis. Use your spreadsheet to plot the graphs for you.

Review

1 Look at your results for parts A and B. Describe any evidence that your muscles were becoming tired.

2 Compare the two graphs. What can you say about the amount of fatigue experienced by the arm?

3 a What effect might raising your arm have on the blood supply to your arm?
b What effect could this have on the muscle cells in your arm?
c Explain why oxygen and blood are important to muscles that are working.

4 Look at both graphs of your results. Do the results support your suggestions in question 3?

5 a Construct a conclusion for this investigation.
b Use this to assess whether your hypothesis is supported or not.

CHAPTER 2

Chapter review

Remembering

1 List the parts of the following cells that can be seen under a light microscope.
   a an animal cell
   b a plant cell.

2 Name the lens of the microscope that:
   a you look through
   b is closest to the specimen.

3 Name the process that occurs in chloroplasts.

4 What do the letters SEM and TEM stand for?

5 What happens to the field of view when a microscope is changed from low power to high power?

6 Which of the following statements are true and which are false? Rewrite any false statements to make them true.
   A A structure made up of different types of tissues is an organ.
   B When cells of the same type are grouped together, they form a system.
   C There are many different organs in a tissue.
   D Tissues are groups of cells of the same type.
   E In a system, many organs work together.

Understanding

7 Outline the function of the following cell parts.
   a plant cell wall
   b cell membrane
   c nucleus.

8 Explain the difference between a specimen and an image when using a microscope.

9 Predict what will happen to the field of view when a ×10 objective lens is replaced by a ×4 objective lens.

10 When focusing a microscope, you should look from the side as you bring the stage and objective lens close together. Describe what could happen if you were looking through the ocular lens as you did this.

11 Study the diagram in Figure 2.5.1, which shows a root hair cell.
   a Describe the function of root hair cells.
   b Explain how the shape of this cell helps it to carry out its function.

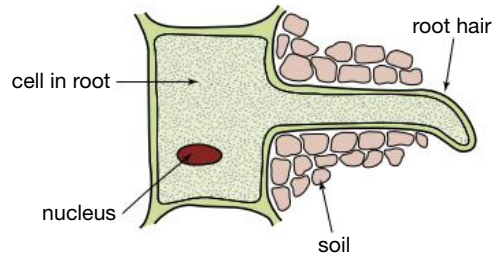


FIGURE 2.5.1

Applying

12 Draw and label a plant cell, an animal cell and a fungal cell. Your diagrams should clearly show the differences and similarities for each.

13 Copy and compete the following table by calculating the missing numbers.

Ocular lens	Objective lens	Total magnification
×4		×40
	×10	×100
×4	×100	
×10	×40	
×10		×1000

14 The field of view of a microscope was measured and found to be 3 mm using a magnification of ×10.

Calculate the diameter of the field of view at the following magnifications and using the two different units.

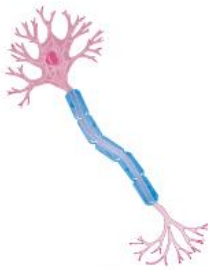
Magnification	×10	×100	×1000
diameter of field of view (mm)	3		
diameter of field of view (µm)			

CHAPTER 2

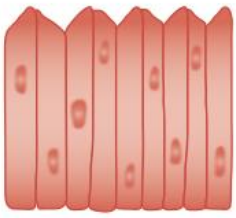
Chapter review

15 Identify the types of cells represented in these diagrams.

a



c



b

d

Analysing

16 Classify each of the following cell types as plant or animal cells.

- **a** guard cells
- **b** nerve cells
- **c** muscle cells
- **d** photosynthetic cells
- **e** root hair cells.

17 Compare the cells that Hooke studied in 1665 with the cells that Leeuwenhoek observed in 1674.

18 **a** Compare the magnification of the microscope Leeuwenhoek used with the magnification of modern electron microscopes.

b Discuss any advantages that Leeuwenhoek's microscopes had over electron microscopes.

19 Classify each of the organisms in Figure 2.5.2 as unicellular or multicellular.

a

b

c

FIGURE 2.5.2

Evaluating

20 Look back at Figure 2.3.4 on page 71, showing cardiac muscle. The fibres of cardiac muscle are arranged in a network. What do you think the benefit is of having the fibres interlocking in this way?

21 Many plants have leaves that are thin and flat. How do you think changing the shape of a leaf to a cube would affect the functioning of the leaf as an organ of photosynthesis?

22 **a** Assess whether you can or cannot answer the questions on page 45 at the start of this chapter.

b Use this assessment to evaluate how well you understand the material presented in this chapter.

Creating

23 Use the rules for drawing cells to construct a diagram showing the cells in Figure 2.2.21 on page 65.

24 Use the following ten key terms to construct a visual summary of the information presented in this chapter.

cell	plant
animal	unicellular organism
multicellular organism	tissue
organ	organ system
specialised cell	microscopic

AB 2.12

CHAPTER 2

Inquiry skills

Research

1 Questioning & Predicting | Communicating

Research different types of microscopes to find:

- images of each type of microscope
- what each type of microscope is used for
- the maximum magnification for each type of microscope
- the advantages and disadvantages of each type of microscope.

Present your research as a poster.

2 Processing & Analysing | Evaluating

Robert Hooke is best known for being the first person to observe and name cells. What isn't as well known is that he studied many other areas of science, including chemistry, physics and astronomy, and made many important discoveries. Some people argue that Hooke was one of the greatest scientists of the seventeenth century and should be more famous than he is.

Research Robert Hooke. Find:

- when and where Hooke was born
- what areas of science Hooke studied
- what discoveries Hooke made
- Hooke's relationship with other scientists.

Present your research as a booklet on Hooke's life and work, in which you address the above dot points.

In the last section of your booklet, write one to two paragraphs in which you use the information gathered in your research to answer the question: Should Robert Hooke be more famous than he is?

3 Processing & Analysing | Communicating

Jellyfish (Figure 2.5.3) have very specialised stinging cells. Investigate how these cells help the jellyfish to survive. Include:

- which jellyfish have stinging cells
- why jellyfish have stinging cells
- how stinging cells are structured and how they function
- what causes the sting and how this affects other organisms.

Present your research as a poster.

FIGURE 2.5.3

4 Processing & Analysing | Communicating

The invention of the light microscope led to the discovery of singled-celled organisms. The combination of improvements in light microscopes and the invention of electron microscopes have greatly improved our understanding of these microorganisms. It is now understood that some microorganisms cause disease. Techniques have now been developed to kill these organisms or minimise their spread.

Research:

- how the microscope led to the discovery of microorganisms
- key discoveries related to microorganisms and disease
- the role played by electron microscopes
- how these discoveries helped minimise the spread of the diseases that unicellular organisms caused
- the main people involved in these discoveries.

Present your findings as a timeline.

5 Processing & Analysing | Evaluating

Research stem cells and the advantages and disadvantages that their use in the future may bring. Your research should:

- include images of stem cells
- compare embryonic stem cells with adult stem cells
- list the advantages and disadvantages of using embryonic and adult stem cells
- find reasons why some people support the use of embryonic stem cells while others argue against their use
- discuss the statement: *Supporting scientific research in new areas such as stem cells is important.*

Present your research in a digital form.

CHAPTER 2

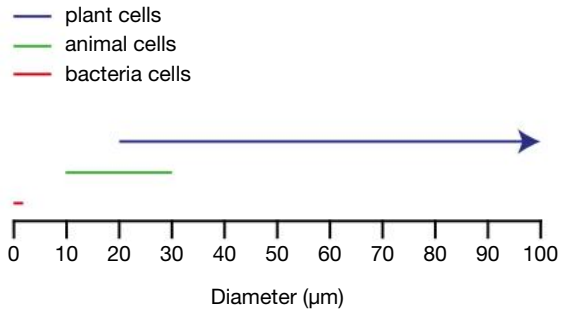
Inquiry skills

Thinking scientifically

1 Four cells were viewed under a microscope and their diameters were measured. Use the information in the diagram to decide which one was most likely to be a cell from an animal.

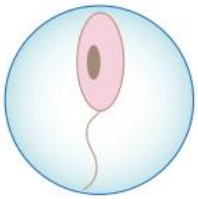
A 100 µm **B** 15 µm

C 2 µm **D** 45 µm

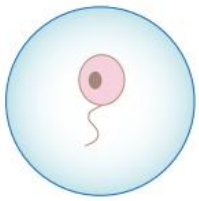


2 The unicellular organism shown here was viewed under a microscope with a magnification of ×2. Which diagram represents the image you would see?

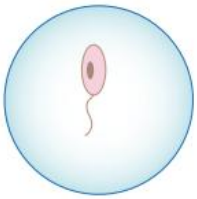
A



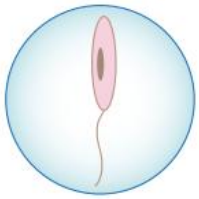
B



C



D

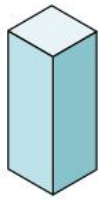


3 When a cell was cut from a section of a plant stem and viewed under a microscope, it appeared as a circle, as shown.

Which one of the following could *not* be the three-dimensional shape of the cell?

A

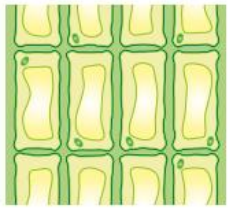
B



C

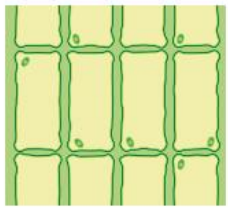
D

4 Some normal plant cells are shown here.

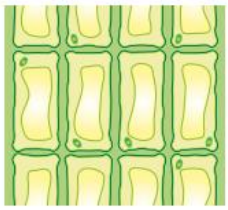


Which of the four options below shows what the cells would most likely look like if the plant they came from had no water for 3 days?

A

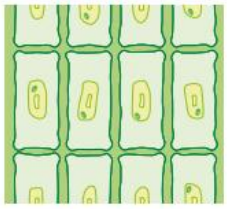


B



C

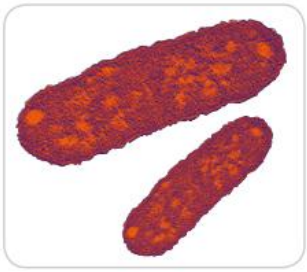
D



CHAPTER 2

Glossary

axon: long fibres that extend from nerve cells and carry messages over long distances



bacteria

bacteria: very simple unicellular organisms that lack a nucleus and other organelles

benign: describes a tumour that is not able to spread to other parts of the body

binocular microscope

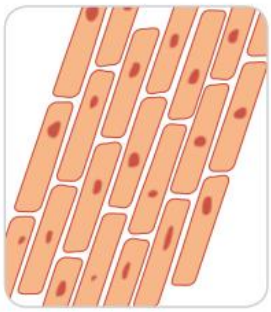
binocular microscope: a light microscope that has two ocular lenses

cancer: uncontrolled growth of cells

cell culture: growing cells separately from organisms in the laboratory

cell membrane: the 'skin' that holds the cell together; it controls what comes into and leaves the cell

cells: the building blocks of all living things



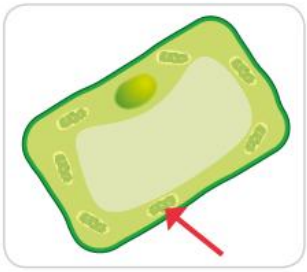
cells

cell theory: the idea that all living things are made up of one or more cells that come from existing cells

cell wall: a rigid layer on the outside of a plant cell; provides the skeleton of a plant

chemotherapy: the use of drugs to destroy cancer cells

chlorophyll: the green chemical in chloroplasts that traps the Sun's energy for photosynthesis



chloroplast

chloroplast: an organelle within the cell where photosynthesis takes place

connective tissue: a type of tissue that adds support and structure to the body, e.g. fat, bone, cartilage, tendon and ligament

cytoplasm: a watery, jelly-like mixture that contains many smaller parts, where the work of the cell takes place

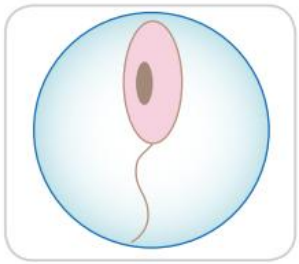
dissect: to cut apart a dead plant or animal to study it

electron microscope: a type of microscope that uses beams of electrons to magnify up to a million times. There are two types of electron microscopes: transmission electron microscopes (TEM) and scanning electron microscopes (SEM)

endoplasmic reticulum: pathways along which materials move through a cell

epidermis: epithelial tissue forming the outermost layer of the skin

epithelial tissue: tissue that covers other tissues and organs



field of view

field of view: the amount of the specimen seen through a microscope

guard cells: cells that work in pairs to open and close the stomata

image: what is seen using the microscope

light microscope: a microscope that uses light to reveal the image

lysosomes: organelles that get rid of wastes from cells

magnification: the amount by which the image is magnified (made bigger) compared to the real object (specimen)

magnified: made bigger

malignant: describes a tumour whose cells can break away and spread to other parts of the body

micrometre: one-thousandth of a millimetre, or one-millionth of a metre

microscope: an instrument used to make very small things look bigger

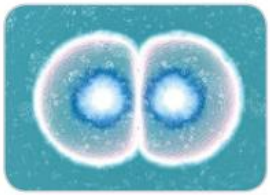
microscopic: describes objects that can only be seen using a microscope

mitochondria: the powerhouses of the cell, where the energy is released from food

CHAPTER 2

Glossary

mitosis: cell division that produces two identical cells



mitosis

monocular microscope: a light microscope that has only one ocular lens

multicellular organisms: living things made of many cells

muscle tissue: specialised tissue that can contract

nerve cells: cells that carry information in the body

nerve tissue: many nerve cells grouped together

nucleus: the control centre of a cell

monocular microscope

objective lens: the lens of the microscope closest to the stage

ocular lens: the lens of the microscope closest to your eye, also known as the eyepiece

organ: a structure that contains at least two different types of tissues that work together to complete a task

muscle tissue

organ system: two or more different organs that work together

organelles: the smaller parts of a cell. Found in the cytoplasm and have a variety of important functions

phloem: cells in a plant that carry glucose from the leaves to all other parts of the plant

photosynthesis: the process used by plants to make food from water and carbon dioxide using energy from the Sun

protists: a group of unicellular organisms often found in ponds and soil

radiotherapy: the use of radiation such as X-rays and gamma rays to destroy cancer cells

red blood cells: cells that carry oxygen from the lungs around the body

red blood cell

ribosomes: structures that produce proteins

root hairs: extensions on the outer surface of some root cells

specialised cells: cells that have a special job to do in the body and have a structure that makes them better able to do their job

specimen: the object being looked at through a microscope

stem cells: cells that can become different types of cells under specific conditions

stereo microscope: a binocular microscope that creates a three-dimensional image

stomata: very tiny pores in leaves

stomata

tissue: groups of similar cells that all perform the same function in the body

tissue engineering: the growing of tissues or organs outside a living thing

tumour: a group of cancer cells; can be benign or malignant

unicellular organisms: living things made up of only one cell

unicellular organism

vacuole: a small structure in animal cells that may contain wastes or chemicals, or a large sap-filled structure in plant cells that stores water, wastes and nutrients

vascular tissue: made up of cells that create hollow tubes for the transport of nutrients and other substances in fluid

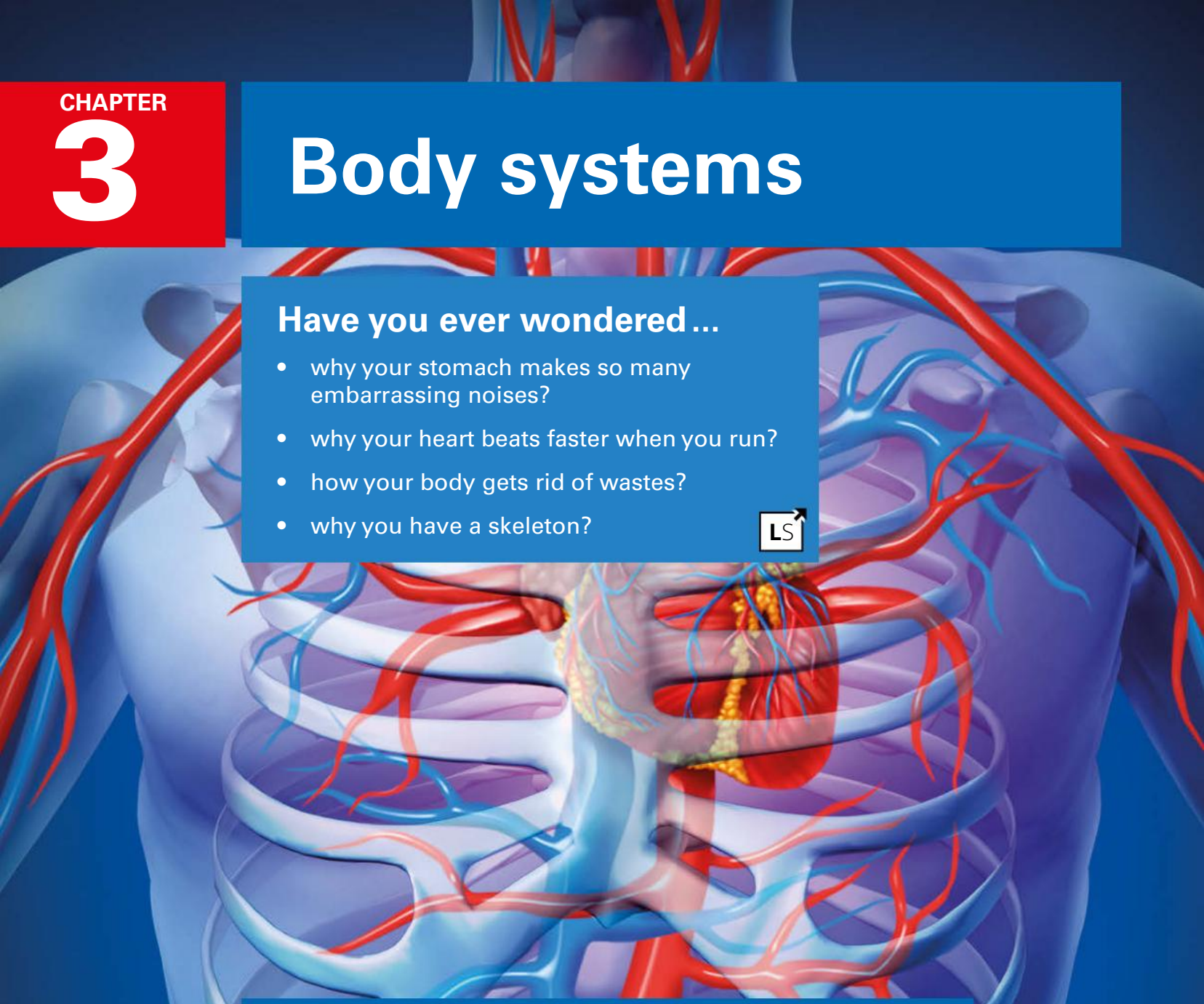
white blood cells: part of the immune system; help the body to fight infection

xylem: cells in a plant that carry water from the roots to the rest of the plant

AB 2.11

CHAPTER
3

Body systems



Have you ever wondered ...

- why your stomach makes so many embarrassing noises?
- why your heart beats faster when you run?
- how your body gets rid of wastes?
- why you have a skeleton?

LS

After completing this chapter you should be able to:

- describe the overall function of a body system in supporting life
- identify organs in body systems
- describe the structure and function of each organ in a body system
- investigate how better understanding of cells, tissues and organs has changed medicine
- discuss ethical issues that arise from organ transplantation
- compare the digestive systems in herbivores and carnivores
- compare the respiratory systems in fish and mammals
- outline how advances in technology have allowed organs to be repaired and replaced.

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AB 3.1

MODULE

3.1 Digestion

Food is something you probably think about often during the day. Food provides your body with all its building materials and the energy you need for all your activities. However, your body cannot unlock the energy in food until after your digestive system has been to work on it.

science 4 fun

Where's the sugar?

Is there sugar in bread?

Collect this ...

- 3 cm x 3 cm piece of bread or water cracker biscuit (not a sweet biscuit)

Do this ...

1. Chew the bread or biscuit so that it is broken up and well moistened with saliva.
2. Keep it in your mouth for about a minute—don't swallow it.

Record this ...

1. Describe any change you observed in the taste.
2. Explain why you think this happened.

The need for body systems

Humans are multicellular organisms. This means that our bodies are made up of millions of tiny building blocks called **cells**. These are so small that you cannot see them without the help of a microscope.

Your cells are where most of your body's work is carried out. To do this, cells need raw materials. Your body is organised in a way that makes sure the cells are supplied with what they need.

Cells come in many types, such as skin cells, brain cells and muscle cells. Cells of the same type that carry out the same job in the body are then grouped together to form **tissues**. For example, skin cells group together to form skin tissue, brain cells form brain tissue and muscle cells form muscle tissue. At the next level of organisation, tissues are grouped to form organs, such as the stomach or brain.

An **organ** is a structure that contains at least two different types of tissue that work together to complete a task. Figure 3.1.1 shows how cells form tissues that together form an organ, in this case the heart.

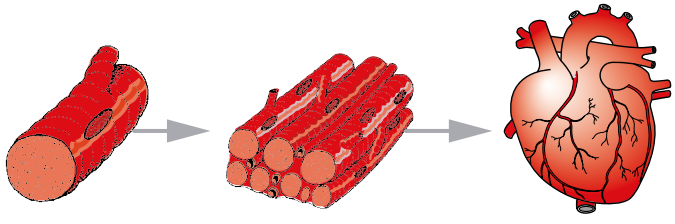


FIGURE 3.1.1 Cells form tissue. Tissues form organs.

Different organs are then arranged into systems. In a system, organs work together to perform a particular job. Different body systems have different jobs:

- The digestive system makes food available in a form the body can use.
- The respiratory system takes in oxygen.
- The circulatory system carries the food and oxygen to the cells where it is needed.
- The excretory system gets rid of wastes.
- The skeletal/muscular system supports the body and enables it to move.

The digestive system

The food you eat is not in a form that can be used by your cells. The bread, meat, cheese, tomato and lettuce in the roll in Figure 3.1.2 are made of complex chemicals. These need to be digested (broken down) into simple, soluble chemicals that can be used by your cells. These chemicals are known as nutrients and your body needs them for energy, growth and repair. **Digestion** is the process of breaking down food into a useable form and making its nutrients available.

FIGURE 3.1.2 The roll has to be digested before you can use the nutrients it contains.

Digestion takes place in your **digestive system** which consists of a digestive tract and other organs.

The human digestive system is shown in Figure 3.1.3.

The digestive tract is the pathway that the food takes through a series of organs. The digestive tract starts at the mouth and finishes at the anus. Organs off to the side of the digestive tract produce chemicals to assist with digestion.

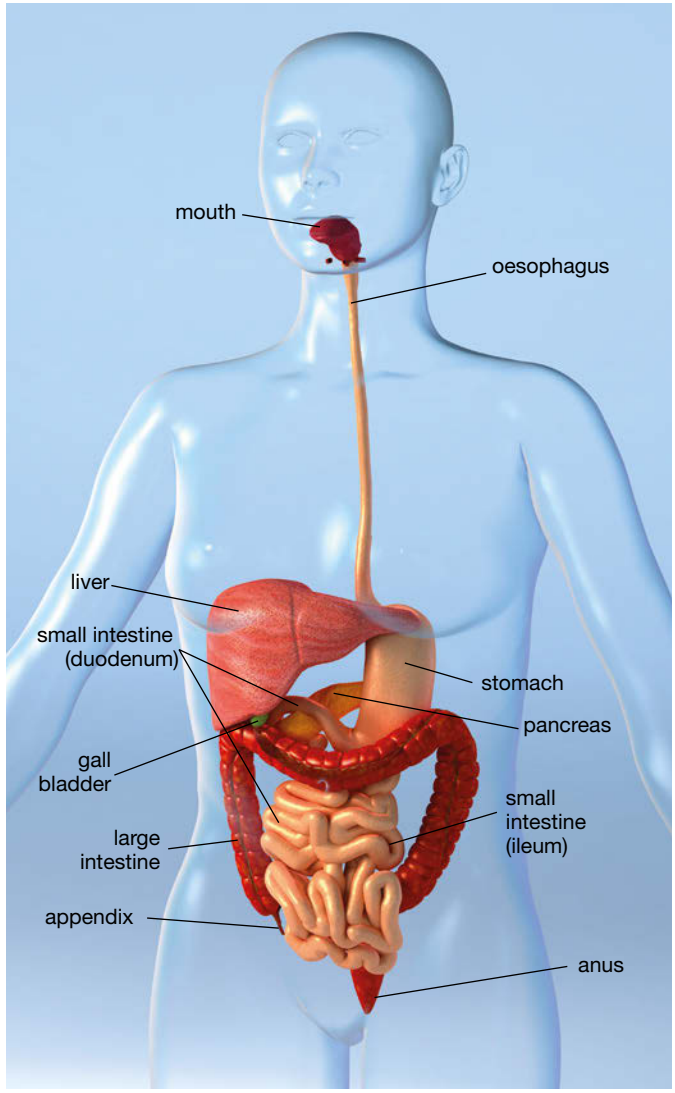


FIGURE 3.1.3 The human digestive system

Types of digestion

There are two different types of digestion:

- mechanical digestion
- chemical digestion.

Mechanical digestion is when the food is sliced, torn and crushed by your teeth, breaking it down into smaller pieces. Mechanical digestion is a physical change because no new substances are made.

In chemical digestion the large, complex substances in the food are broken down into simpler chemicals by saliva in your mouth and gastric juice in your stomach. This produces new, smaller chemicals that the body can absorb.

Chemical digestion is a chemical change because new substances are produced. You can compare the two forms of digestion in Figure 3.1.4.

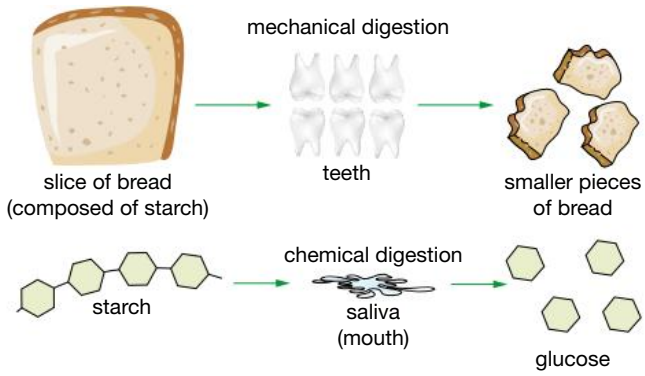


FIGURE 3.1.4 Mechanical digestion breaks food into smaller bits of the same substance. Chemical digestion breaks down complex substances into different, simpler ones.

The mouth

Biting and chewing is a form of mechanical digestion, so the process of digestion starts with your teeth.

As Figure 3.1.5 shows, you have four types of teeth: incisors, canines, premolars and molars.

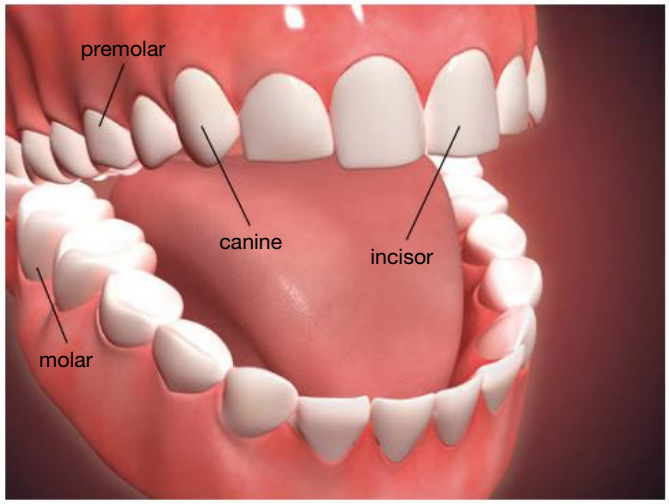


FIGURE 3.1.5 The different types of teeth in your mouth each have a specific job to do.

The incisors are the four pairs of teeth at the front. Their job is to bite off pieces small enough to chew. Your tongue then pushes the food back to the premolars and molars. These teeth grind the food into smaller and smaller pieces as you chew.

In humans, the canine teeth have no significant function.

Chemical digestion also takes place in your mouth. As you chew, food gets mixed with saliva. **Saliva** is a watery liquid produced by your salivary glands. It contains a chemical that starts to change any starch in the food into glucose. Starch is a complex sugar that cannot be absorbed directly, whereas glucose is easily absorbed. Saliva also moistens the food, making it slippery, slimy and easy to swallow. The tongue rolls the food into a ball (called a **bolus**), which is pushed down into the next part of the system, the oesophagus.

AB 3.3

The oesophagus

Your **oesophagus** (foodpipe) is a long muscular tube that starts at your mouth and ends at your stomach. The muscles of the oesophagus push the ball of food down the tube by contracting behind the ball. The muscles then relax. This process is called **peristalsis**, which can be seen in Figure 3.1.6.

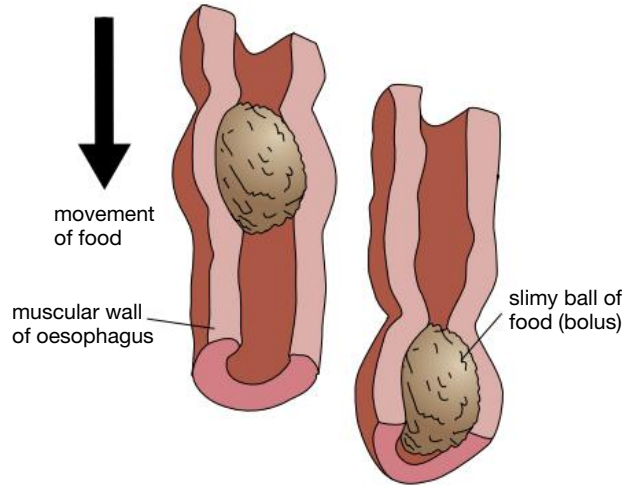


FIGURE 3.1.6 Peristalsis is the rhythmic contracting and relaxing of the muscles of the oesophagus that keeps food moving through the oesophagus and other parts of the digestive system.

SciFile

Tongue tied

Your tongue is a muscle that is unique. All your other muscles (such as your biceps and pectorals) attach to bone at both ends, whereas your tongue only attaches at one end.

A flap of skin called the **epiglottis** closes the end of the windpipe as you swallow. This makes sure that the food goes into your stomach and not into your lungs via the windpipe. If food does get into the windpipe, you start to choke. You then cough to force the food back up into your mouth so that it can be swallowed correctly.

Along your digestive tract are rings of muscle called **sphincters**. The first sphincter separates the oesophagus from the stomach and it opens to let food pass through. The sphincter then closes to stop food or stomach juices from flowing back up. A second sphincter separates the stomach from the small intestine. You can see it in Figure 3.1.7.

The stomach

The stomach is shaped like a bag. It is the big red shape in the middle of Figure 3.1.7. Food is stored in the stomach for one to six hours and it really begins to change while there. The muscular walls of the stomach contract and relax, churning up the food. This further digests the food mechanically as well as mixing it with gastric juice.

Gastric juice is produced by special cells in the stomach wall. Gastric juice contains:

- hydrochloric acid—a strong acid that kills many of the bacteria (germs) that may have been swallowed with the food
- mucus—a layer on the lining of the stomach that prevents the stomach digesting itself
- digestive juices—juices containing chemicals that start the digestion of protein, the main nutrient found in meat. All that churning in the stomach is what causes the gurgling noises that you sometimes hear. Another sphincter separates the stomach from the small intestine. You can see it in Figure 3.1.7.

The small intestine

The **small intestine** is the longest part of your digestive tract—up to 6 metres long. The 'small' intestine gets its name because of its diameter, which is only 3 cm.

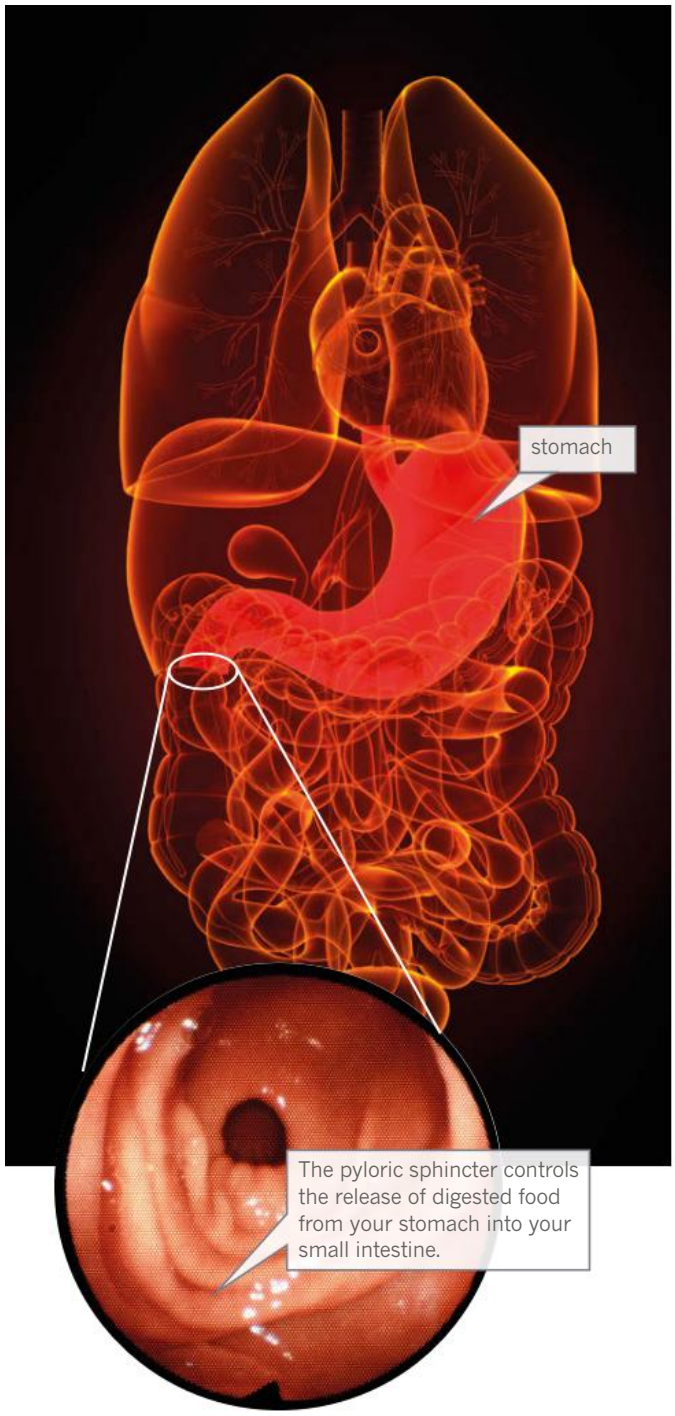


FIGURE 3.1.7 In the stomach, food is digested both mechanically and chemically. The food is turned into a thick, acidic soup.

The duodenum

The **duodenum** is the first part of the small intestine. Two tubes entering the duodenum carry chemicals important for digestion from the pancreas and liver. Figure 3.1.8 shows how they connect to the duodenum.

The walls of the duodenum are muscular and they continue to squeeze and churn the food. Squeezing and churning breaks the food down further and makes sure that it is thoroughly mixed with the digestive chemicals. These change the remaining food into forms that can be used by the body.

The pancreas and liver

The **pancreas** is not part of the digestive tract but is an organ connected to it. The pancreas produces pancreatic juice, which contains chemicals that help digest fats, protein and carbohydrates (starches and sugars).

The **liver** is the body's largest internal organ and you cannot survive without it. It performs over 500 different chemical processes. One of these is removing toxins from the blood. Blood carries nutrients from the digestive system to the liver, before going anywhere else. While the blood passes through the liver, the liver removes toxins, such as alcohol, and acts as a short-term store for glucose.

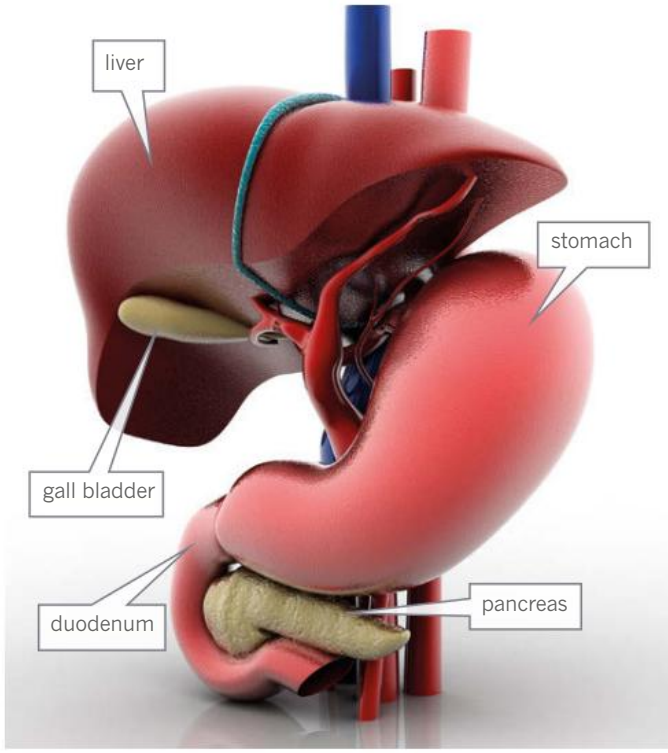


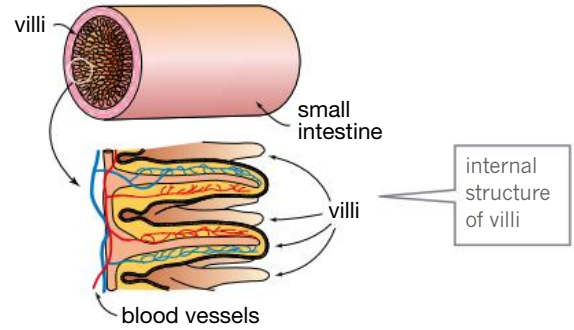
FIGURE 3.1.8 The liver, pancreas and gall bladder are connected to the digestive tract but are not part of it.

Producing bile is another chemical process performed by the liver. **Bile** is a greenish liquid responsible for mechanical digestion of fats. Bile acts in a similar way to dishwashing detergent. Detergent breaks up fats and oils on dirty plates into tiny droplets that can be easily washed away. In a similar way, bile breaks down large pieces of fat in food into tiny pieces that can be digested more easily.

Prac 1 p. 103

The ileum

The lower part of the small intestine is known as the **ileum**. This is where digested food is absorbed by (taken into) the body. By the time food has reached the ileum, it has been broken down into tiny, simple particles that can be absorbed by the blood. This happens through microscopic 'fingers' that line the inside of the ileum. These 'fingers' are called **villi**. You can see them in Figure 3.1.9.



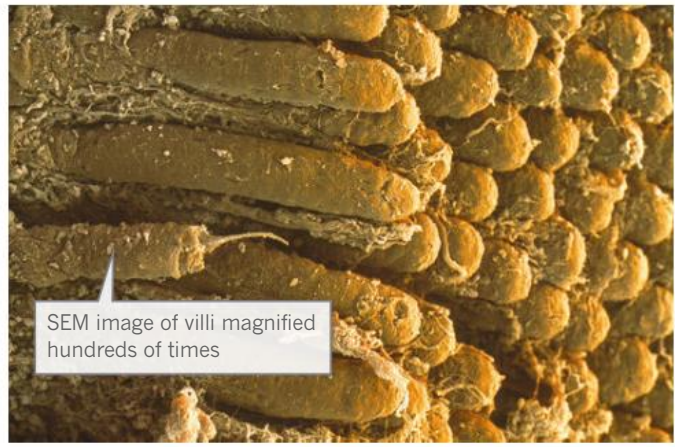


FIGURE 3.1.9 Villi greatly increase the surface area through which nutrients can be absorbed from the small intestine.

Villi greatly increase the surface area of the intestine wall and so they greatly increase the amount of nutrients being absorbed. Within each villus are tiny blood vessels called capillaries. The walls of villi and the walls of capillaries are only one cell thick, and so nutrients only need to travel a microscopic distance to move into the blood—this distance is about one-hundredth of the diameter of a full stop!

Within the villi are tiny blood vessels called capillaries. The walls of the villi and the walls of the capillaries are only one cell thick. This means that the nutrients only travel a very tiny distance as they move from the digestive system into the blood system—this distance is about one-hundredth of the diameter of a full stop!

The nutrients that pass from the small intestine are:

- fatty acids and glycerol (from the digestion of fats)
- amino acids (from the digestion of proteins)
- glucose (from the digestion of carbohydrates.

Your body uses glucose as its main source of energy. Figure 3.1.10 summarises the major changes that occur in the digestive system.

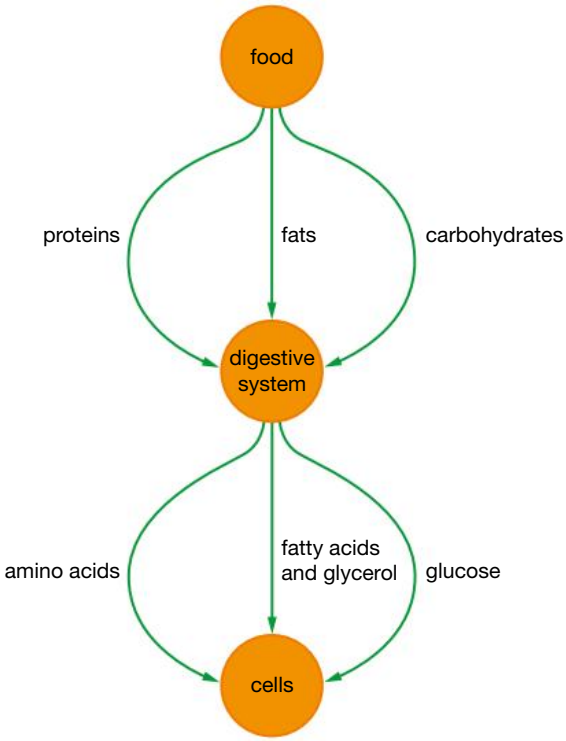


FIGURE 3.1.10 The digestive system breaks down complex substances like carbohydrates into simpler substances like glucose.

Prac 2 p. 104
AB 3.4

The large intestine

The final section of your digestive tract is the **large intestine** (Figure 3.1.11). It is 1.5 metres long and 6 to 7 cm in diameter, making it shorter but wider than the small intestine. In the large intestine, water is reabsorbed into the body from what is left of the food, along with any remaining nutrients. The waste forms lumps of faeces known as stools.

These are later expelled from the body through the **anus**. The anus is a sphincter muscle at the end of the digestive tract. As Figure 3.1.12 shows, about one-third of the solid material in faeces is bacteria from the intestine. Most of these helped your body digest the food but they are passed out and contribute to the smell of the faeces.

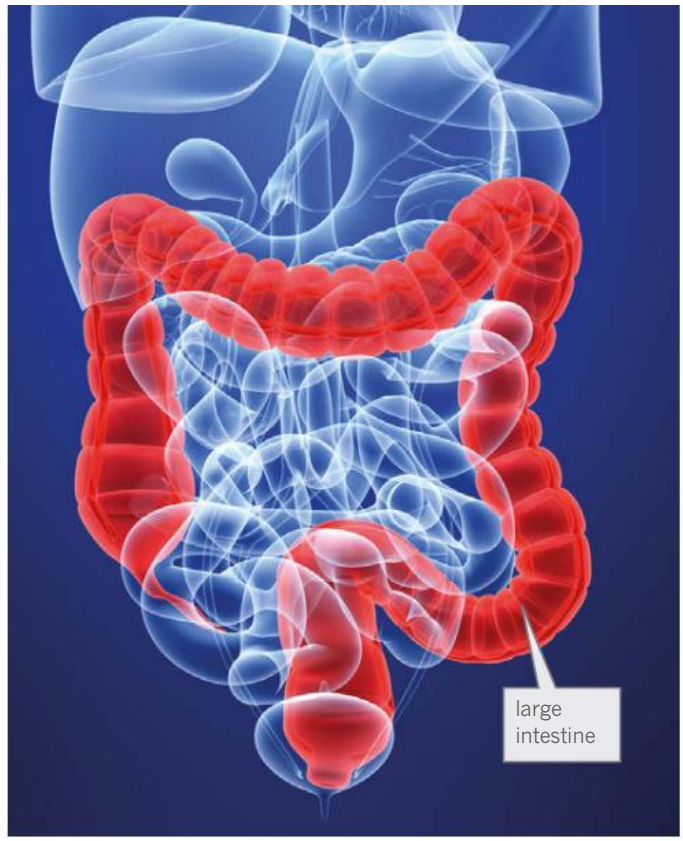


FIGURE 3.1.11 The large intestine is the part of the digestive system where wastes from the food you eat are processed into faeces.

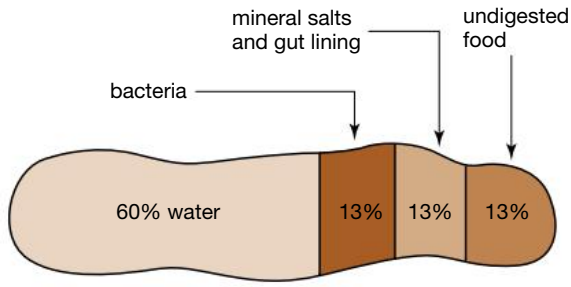


FIGURE 3.1.12 A large percentage of faeces is water. If there is too little water in your faeces you will become constipated. If there is too much water you will experience diarrhoea.

AB 3.2

STEM 4 fun

Design a robot

PROBLEM

Design a robot that could travel safely through the digestive system. Its purpose is to take pictures as it moves through a live person's system.

Make sure it has features to withstand the different conditions in each organ. Make an enlarged prototype model of your robot.

SUPPLIES

Balloons, straws, tape, string, elastic bands, pegs, pipe cleaners, cardboard of different weights, boxes, plastic or paper cups, wool, fabric, coat hanger, feathers, sponges, cotton balls, foil, cling wrap, skewers, toothpicks ... any recycled or craft material

PLAN AND DESIGN

Design the solution. What information do you need to solve the problem? Draw a diagram. Make a list of materials you will need and steps you will take.

CREATE

Follow your plan. Draw your solution to the problem. Create your model.

IMPROVE

What works? What doesn't? How do you know it solves the problem? What could work better? Modify your design to make it better.

REFLECTION

1. What field of science did you work in? Are there other fields where this activity applies?
2. If another student was to do this task, what advice would you give them?

Digestive disorders

Vomiting

Vomiting is a quick way of getting rid of unwanted bacteria in the digestive tract. Stress or infections, such as gastroenteritis, can cause the muscular wall of the stomach and small intestine to contract. The sphincters at the top and bottom of the stomach open, and the contents of the stomach are forced along the oesophagus and out of the mouth. Vomit is partly digested food mixed with stomach acid and bile.

Diarrhoea

Diarrhoea is another quick way of getting rid of harmful bacteria and viruses. These can cause the lining of the small intestine to become inflamed so that it can no longer absorb water from the faeces. The faeces contain a lot of water, putting the body at risk of dehydration. People with diarrhoea need to drink plenty of fluids to replace what is being lost.

Heartburn

Heartburn is a burning sensation that rises up the oesophagus from the stomach. Peristalsis pushes food down your oesophagus to your stomach. Pressure on the stomach wall can cause the stomach contents to be pushed back up, creating the sensation of heartburn. Lying down or bending over can also cause this type of pressure.

Unlike the stomach, your oesophagus does not have mucus protecting the lining from stomach acids. The burning sensation of heartburn is the acid attacking the lining of the oesophagus.

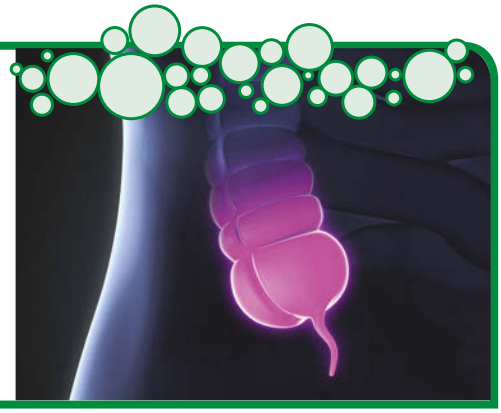
Appendicitis

The appendix is a dead-end tube connected to the large intestine. If the opening into the appendix is blocked, then the appendix fills with mucus. It becomes inflamed and swollen, causing the pain of appendicitis. The only treatment is an operation to remove the appendix before it ruptures (bursts) and causes even more severe infection.

SciFile

The appendix

It was once thought that the appendix had no function in humans. However, it is now believed that the appendix may house useful bacteria and be important in the development of the immune system in babies. It is your immune system that helps your body fight disease.



MODULE 3.1

Review questions LS

Remembering

1 Define the terms:
- a digestion
- b digestive tract
- c bolus
- d stools.

2 What term best describes each of the following?
- a the rhythmic squeezing of food down a pipe
- b a ring-like muscle
- c the largest internal human organ
- d the 'fingers' lining the small intestine.

3 List the organs of the digestive tract in order from the beginning to the end.

4 What are the roles of the following chemicals in digestion?
- a bile
- b hydrochloric acid
- c saliva
- d pancreatic juice.

5 What organs are part of the digestive system but not part of the digestive tract?

6 Name three disorders of the digestive system.

Understanding

7 Describe how peristalsis keeps food moving through the digestive tract.

8 How does the structure of the these organs make them well suited for the job they do?
- a stomach
- b small intestine.

9 Figure 3.1.13 shows the shape of your incisors (a) and molars (b). Explain why these shapes are ideal for the jobs each type of tooth does.

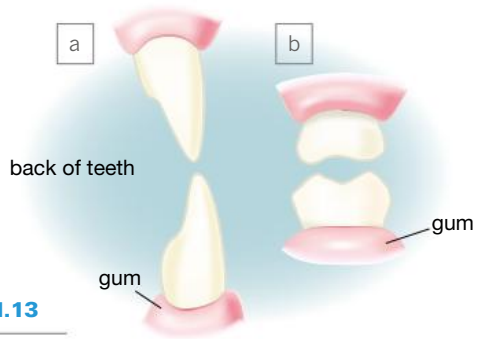


FIGURE 3.1.13

10 Describe what might happen if:
- a the lining of the small intestine becomes inflamed
- b too many bacteria enter the digestive tract
- c the appendix gets blocked.

11 Why is it important that you keep your teeth strong and healthy?

Applying

12 Identify the part of the digestive system that:
- a churns the food
- b absorbs most of the nutrients from food
- c re-absorbs water from the food
- d stops food going down 'the wrong way'
- e is the final sphincter in the digestive tract
- f makes bile.

Analysing

13 Compare:
- a mechanical digestion and chemical digestion
- b the duodenum and ileum
- c the sizes of the small and large intestines
- d the actions of detergent and bile on oil.

14 Classify the following as mechanical or chemical digestion.
- a Digestive juice caused a mass of oil to break up into tiny droplets.
- b At the end of an experiment, Amed tested the food for the starch and didn't find any but he did find glucose, which was not there at the start of the experiment.
- c Julie nibbled at a biscuit.

Evaluating

15 A dry biscuit or a piece of bread doesn't taste sweet when you start chewing, but after a while it does. Propose reasons why.

16 Look at the STEM4fun activity on page 100. What features would the robot need to survive passing through the stomach?

MODULE 3.1

Review questions

17 **a** Predict what would happen to the amount of nutrients being absorbed if:

- **i** the length of the small intestine was reduced
- **ii** the walls of the villi thickened
- **iii** the production of saliva and gastric juices reduced
- **iv** the stomach did not have sphincters at its top and bottom.

b Justify your answers above.

18 **a** Why is heartburn painful?

b Your stomach doesn't normally cause pain like this. Why not?

c A stomach ulcer is a small hole in the mucous lining of the stomach, which causes a lot of pain. Propose a reason why.

19 Snakes are carnivores (meat eaters) that do not chew their prey but swallow them whole. A diagram of the digestive system of a snake is shown in Figure 3.1.14.

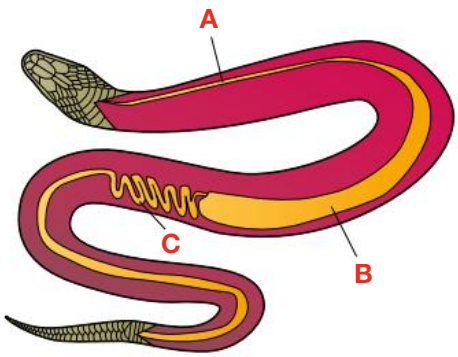


FIGURE 3.1.14

a Identify the parts labelled A, B and C. Use the human digestive system as a model.

b Propose a reason why snakes:

- **i** have sharp teeth but no molars
- **ii** have fangs that bend backwards when not in use
- **iii** have hollow fangs if they are venomous.

c What do you think is the main purpose of saliva in a snake?

d Why would gastric juice in snakes need to be particularly effective in breaking down protein? Justify your answer.

e Snakes are ectothermic (commonly called cold-blooded). What effect do you think this has on their digestion? Justify your answer.

20 Cows and sheep are herbivores (plant eaters) and so eat lots of tough fibre and very little fat. The digestive system of a cow is shown in Figure 3.1.15. To follow the path food takes, first follow the green arrows, then the pink arrows then the blue arrows then the black arrows.

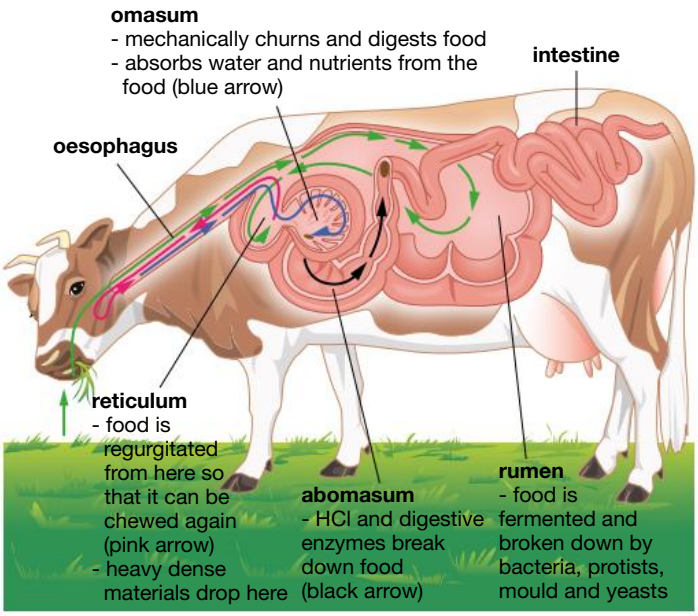


FIGURE 3.1.15

a Compare the digestive tract of a cow with that of a human.

b How many 'compartments' does a cow's stomach have?

c Which of these compartments acts most like a human's stomach?

d Fermentation in the rumen produces lots of carbon dioxide, which must be expelled. What do you think might happen to the carbon dioxide?

e 'Hardware disease' is when rocks, nails and pieces of wire are found doing damage to the digestive tract of a cow. Which part of the digestive tract do you think this will affect? Justify your answer.

Creating

21 Imagine that you have been miniaturised and placed in a capsule that has been swallowed. You are in the human stomach. Write a short story that describes the conditions around you.

MODULE 3.1

Practical investigations

1 • Breaking down fats and oils

Planning & Conducting | Processing & Analysing

Purpose

To model the effect of bile.

Timing 45 minutes

Materials

- 10 mL vegetable oil
- 1 cm^3 block of animal fat
- 20 mL detergent
- 600 mL warm water at about 38°C

SAFETY

Wash your hands thoroughly after the activity.

- 4 × 250 mL beakers
- 10 mL measuring cylinder
- 200 mL measuring cylinder
- 4 stirrers
- 4 labels

Procedure

1. In your workbook, draw up a table like the one in the Results section. Give your table a title.
2. Label the beakers 'fat', 'fat and detergent', 'oil' and 'oil and detergent'.
3. Cut the block of animal fat in half and add one piece to each of the beakers labelled 'fat' and 'fat and detergent'.
4. Using the 10 mL measuring cylinder, add 5 mL of oil to each of the beakers labelled 'oil' and 'oil and detergent'.
5. Wash the measuring cylinder carefully or use a clean cylinder to add 10 mL of detergent to each of the beakers labelled 'fat and detergent' and 'oil and detergent'.
6. Using the 200 mL measuring cylinder, add 150 mL of warm water to all four beakers.
7. Using a clean stirrer for each beaker, stir the contents gently to mix them together.
8. Stop stirring and after 3 minutes observe any changes in the beakers.

Results

Record all observations in your table.

Beaker contents	Observations after 3 minutes
oil	
oil and detergent	
fat	
fat and detergent	

Review

1. Propose a reason why the temperature of the water used was about 38°C.
2. Compare the changes in the two beakers containing:
   a. vegetable oil
   b. fat.
3. Compare the changes to the fat and oil in the beakers that also contained detergent.
4. Based on the observations you made, what do you think happened to the fat and oil?

MODULE 3.1

Practical investigations

2 • A model intestine

Evaluating | Questioning & Predicting

Tes-Tape tests for the presence of glucose in a solution.

Purpose

To investigate how the small intestine works.

Hypothesis

Which chemical do you think will move through the walls of the dialysis tubing into the surrounding water. Do you think it will be starch or glucose? Before you go any further with this investigation, write a hypothesis in your workbook.

Timing 60 minutes

Materials

- starch solution
- glucose solution
- 2–5 mL iodine solution
- water

SAFETY

Iodine stains. Wear a lab coat to avoid contact with skin and clothes.

- 2 × 500 mL beakers
- 2 × 20 cm lengths of dialysis tubing
- 2 × 10 cm lengths of thin string
- 2 × retort stands and clamps
- small funnel
- Tes-Tape

Procedure

1. Two-thirds fill both beakers with water.
2. Label one beaker 'starch'. Add 2–5 mL of iodine solution to this beaker.
3. Label the other beaker 'glucose'. Use Tes-Tape to prove that there is no glucose present in the water.
4. To prepare the dialysis tubing:
   - Soften the tubing by placing it under a tap and running water over it.
   - Tie a knot at the end of each tube.
   - Rub the other end of the tube to open it up.
5. Insert the small funnel into the end of one dialysis tube and use it to fill the tube with starch solution. Tie the open end firmly with string.
6. Carefully rinse the outside of the dialysis tubing to ensure that there is no starch solution on the outside. Place this tube into the beaker labelled 'starch'.

Use the string to hang the tube from the clamp on the retort stand (Figure 3.1.16). Make sure the tube cannot touch the sides of the beaker.

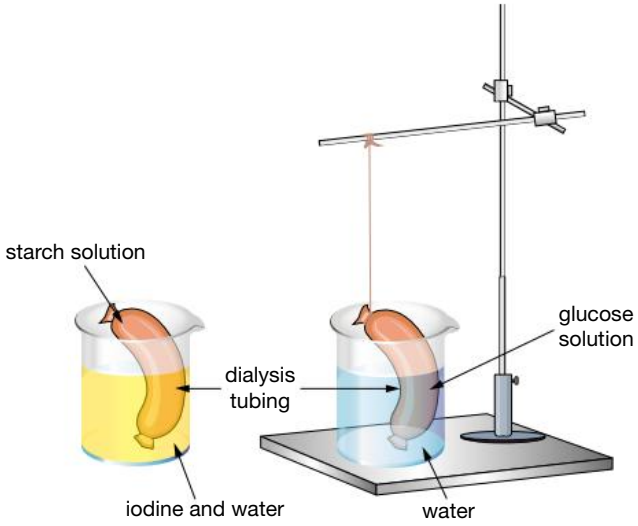


FIGURE 3.1.16

7. Fill the other tube with glucose solution and tie the open end firmly with string. Carefully rinse the outside of the dialysis tubing to ensure that there is no glucose solution on the outside. Place this tube into the beaker labelled 'glucose' As before, hang the tube from the retort stand clamp.

Results

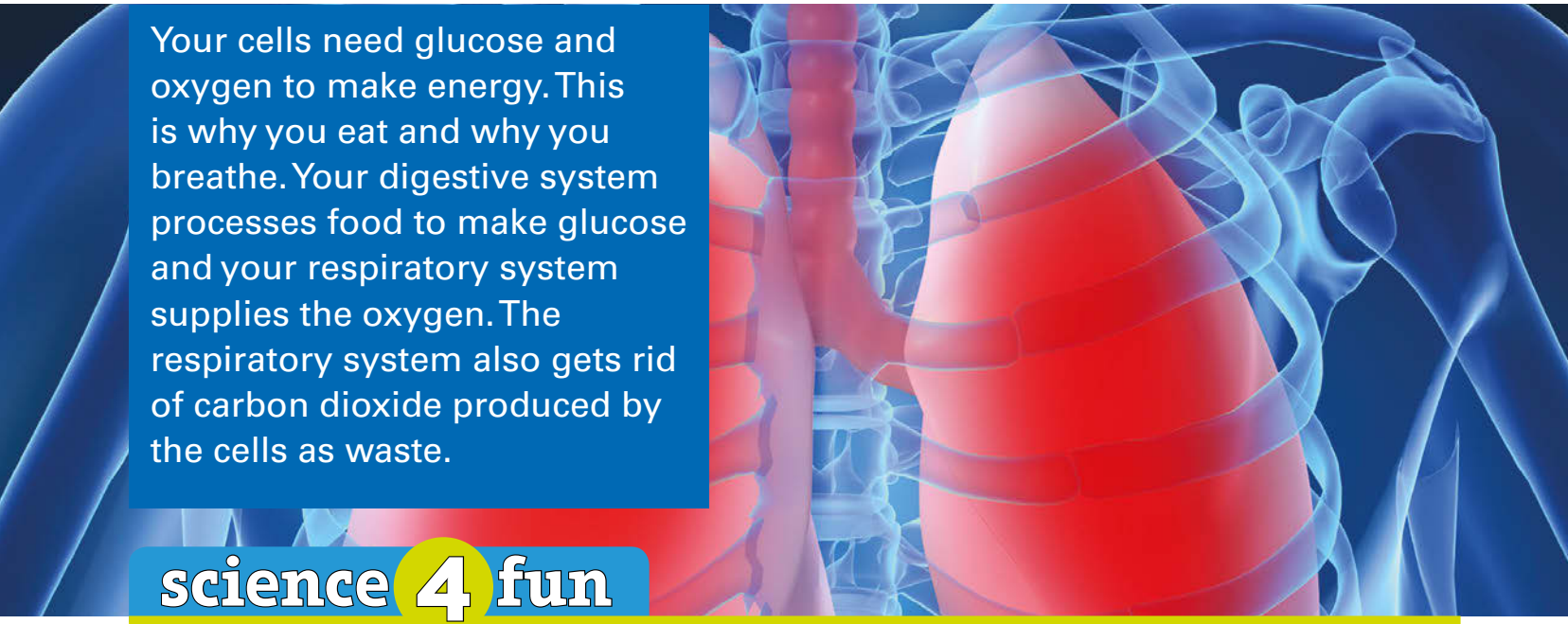
1. After 15 minutes record any changes.
2. Test the water in the 'glucose' beaker with Tes-Tape. Record the result.

Review

1. What indicates that:
   a. starch is present in a solution
   b. glucose is present in a solution?
2. Describe the changes that happened in the:
   a. 'starch' beaker b. 'glucose' beaker.
3. Explain any changes you saw in both beakers.
4. Starch cannot be digested by the body, but glucose can be. Explain why.
5. Compare what happened in this experiment with what happens in the small intestine.
6. a. Construct a conclusion for your investigation.
   b. Assess whether your hypothesis was supported or not.

MODULE

3.2 Breathing and respiration



Your cells need glucose and oxygen to make energy. This is why you eat and why you breathe. Your digestive system processes food to make glucose and your respiratory system supplies the oxygen. The respiratory system also gets rid of carbon dioxide produced by the cells as waste.

science 4 fun

How big?

The lungs have a large surface area, but what does that mean?

Collect this ...

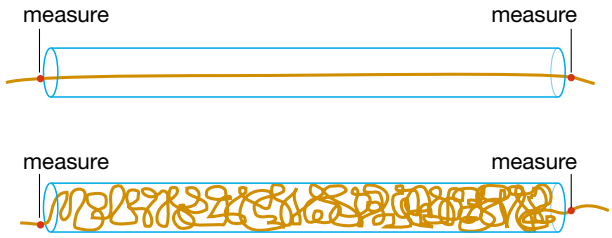
- 20 cm length of plastic tubing (such as garden hose) at least 1 cm in diameter
- ball of string
- measuring tape

Do this ...

1. Thread the string through the plastic tubing without twisting or folding it.
2. Measure the length of the string.
3. Twist and fold the string to find out how much string can be fitted inside the tubing.
4. When you cannot get any more string in, mark the end or cut off the string.
5. Unravel the string from the tubing and measure the length of the string you were able to fit inside.

Record this ...

1. Describe the difference between the two lengths of string.
2. Explain why the twisted piece of string has the larger surface area.



What cells need

Cells need energy to function and they get their energy from respiration. **Respiration** refers to a series of chemical changes that take place in cells to release energy. Respiration requires glucose and oxygen, and the two chemicals react together in the cells to produce energy. This chemical reaction can be represented by the word equation:

oxygen + glucose → carbon dioxide + water + energy

For humans and many other animals, oxygen comes from breathing in air. Glucose is a simple sugar that comes from the digestion of food in the digestive system. Respiration produces energy for the cells but it also produces carbon dioxide and water vapour as waste. Both need to be breathed out. The system that takes air into your body and ultimately makes the oxygen available to the cells is known as the **respiratory system**.

SkillBuilder

Word equations

A word equation is one way of recording what happens when chemicals react together. On one side are the chemicals that react together. These are known as the reactants.

On the other side are the chemicals that are produced. These are known as the products.

Between the reactants and products is an arrow pointing to the products of the reaction. For example in the equation:

reactants → products

A + B → C + D

A and B are the reactants and C and D are the products.

Worked example

Word equations

Problem

Identify the reactants and products in the word equation for respiration:

oxygen + glucose → carbon dioxide + water + energy

Solution

Thinking: Reactants are substances on the left side of the arrow. Products are on the right.

Working: Reactants = oxygen, glucose.
Products = carbon dioxide, water.
(Energy is not a product, because it is not a chemical.)

Try yourself

Identify the reactants and products in the following word equations.

a iron + oxygen → iron oxide

b lead nitrate + sodium chloride → lead chloride + sodium nitrate

The respiratory system

Your respiratory system takes in air and extracts oxygen from it. It allows oxygen to pass into your bloodstream, to be distributed to the cells for respiration. Figure 3.2.1 shows the structure of your respiratory system.

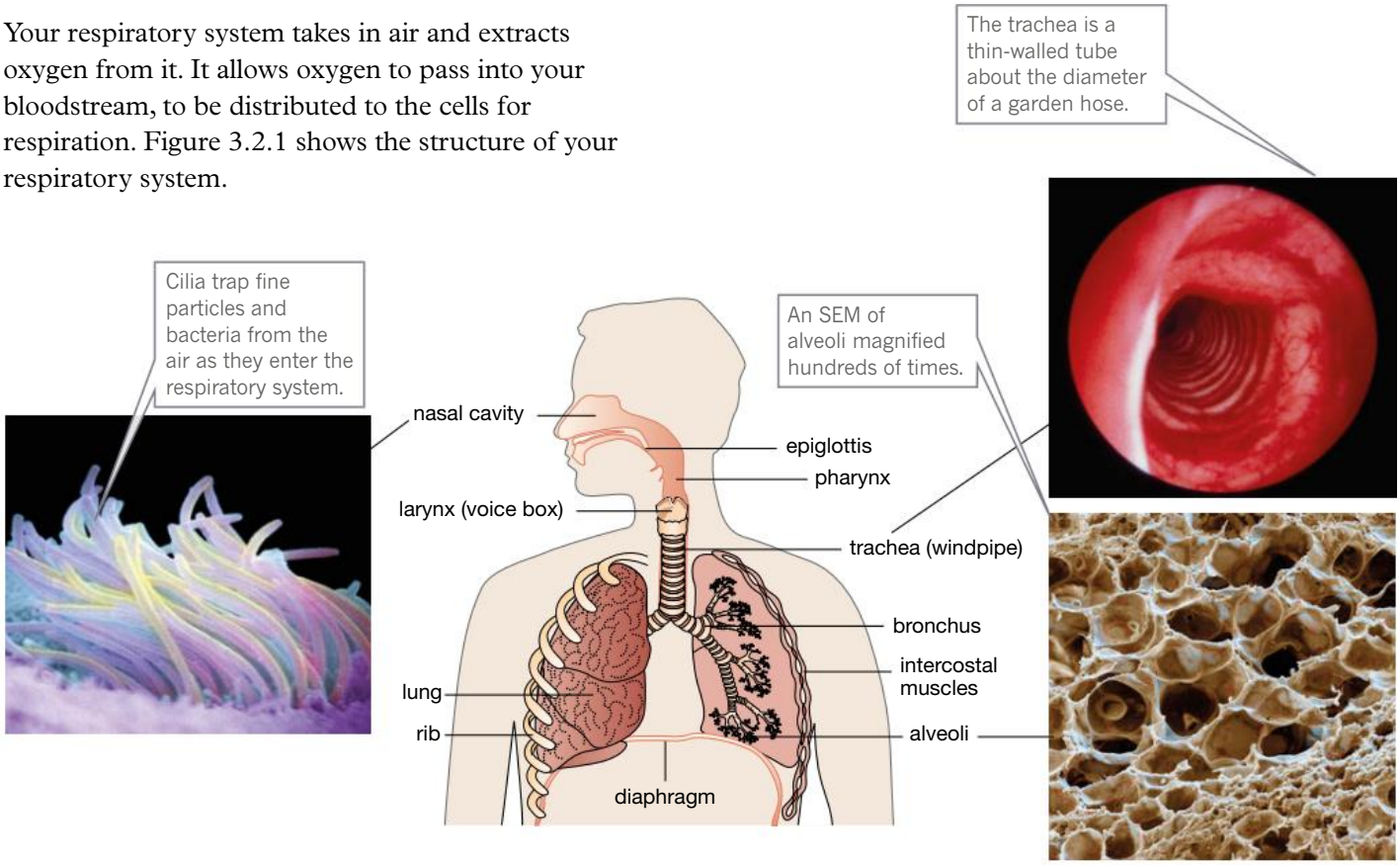


FIGURE 3.2.1 Structure of the human respiratory system

The nasal cavity

When you inhale (breathe in), some air may come in through your mouth but most of it comes in through your nose. Within the nasal cavity, the air is warmed, moistened and cleaned. Large dust particles are filtered out by hairs inside your nostrils. Finer particles and some bacteria are trapped by a combination of sticky mucus and tiny hairs called **cilia**. This is what is happening in Figure 3.2.2. The mucus is produced by glands in the skin lining the inside of your nose, and millions of cilia line it. These cilia wave back and forth 14 to 16 times per second and push the mucus to the back of your nose and into the **pharynx**. The pharynx connects the mouth and nose to the oesophagus where the mucus is then swallowed.

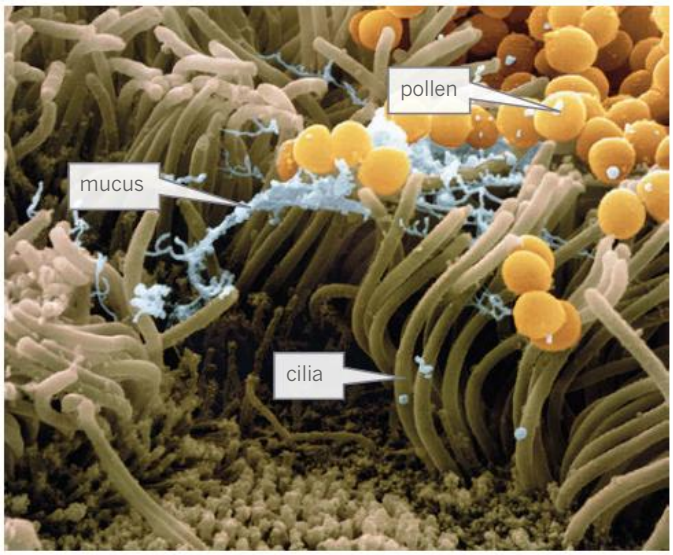


FIGURE 3.2.2 This SEM image shows cilia magnified thousands of times. Cilia are fine hairs that line your nostrils. Together with mucus they trap pollen, dust and some bacteria.

SciFile

Breathing big numbers

Every day, you breathe in and out about 20 000 times and process between 7200 and 8640 L of air. You also swallow about 600 mL of mucus without even being aware of it!

From trachea to alveoli

The warm, moist air then passes down the **trachea** (windpipe). The trachea is a tube about as thick as a garden hose. Its thin walls are reinforced with rings of a firm elastic material called cartilage. These rings stop your trachea from collapsing as you breathe in. You can feel as ridges on the front of your throat.

The trachea divides into two **bronchi**. Each bronchus then divides and divides into ever smaller tubes called **bronchioles**, eventually ending in a cluster of sacs called **alveoli** in the lungs. This series of divisions from trachea to alveoli is shown in Figure 3.2.3.

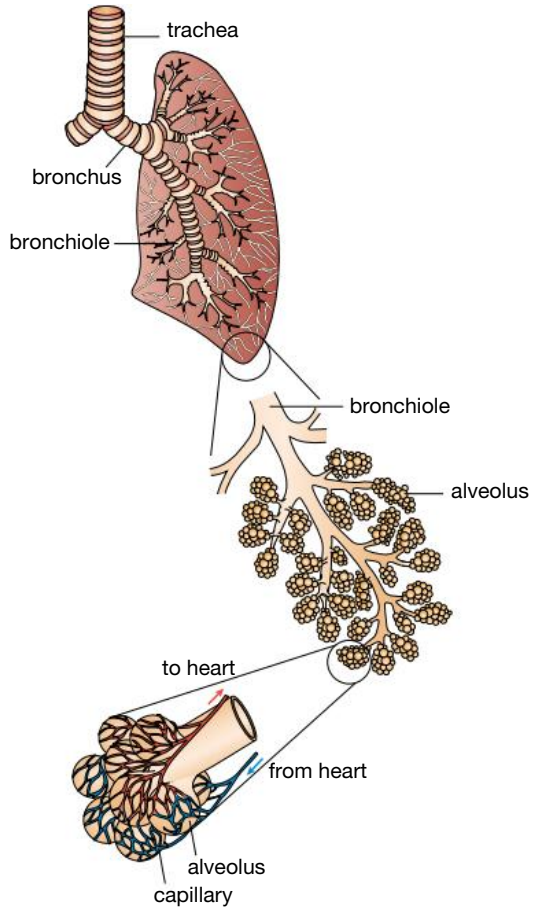


FIGURE 3.2.3 The air follows a path that starts with the trachea and finishes in a microscopic sac called an alveolus.

Alveoli are microscopic in size and about 600 million of them make up your lungs. The alveoli provide a very large surface area, allowing gas to be easily exchanged between the lungs and the bloodstream.

Gas exchange

The walls of the alveoli are only one cell thick and they are surrounded by tiny blood vessels called capillaries. Oxygen dissolves in the moist surface of the alveoli and moves by a process called diffusion into the blood. Figure 3.2.4 on page 108 shows how this happens.

When oxygen enters the blood, it enters the red blood cells, and the flow of blood carries the oxygen to cells where it is needed. The blood flowing from the lungs is therefore rich in oxygen and is bright red.

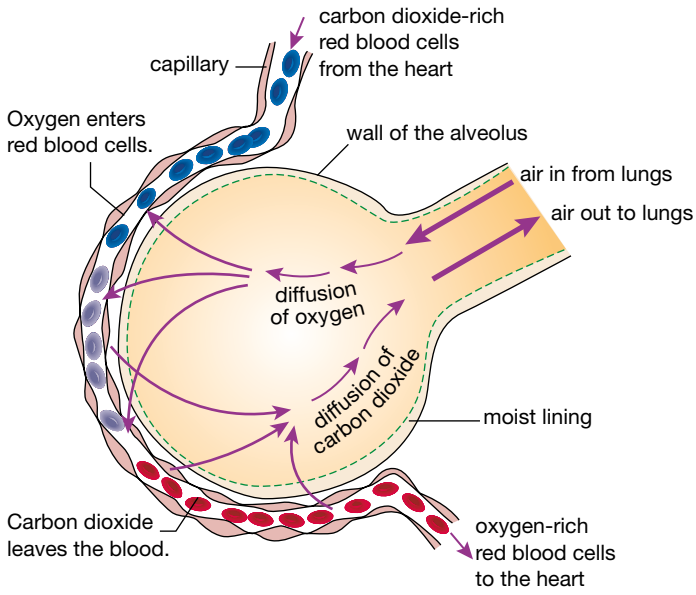


FIGURE 3.2.4 An alveolus. The walls of alveoli and capillaries are only one cell thick. This allows gases to be exchanged easily between air and blood.

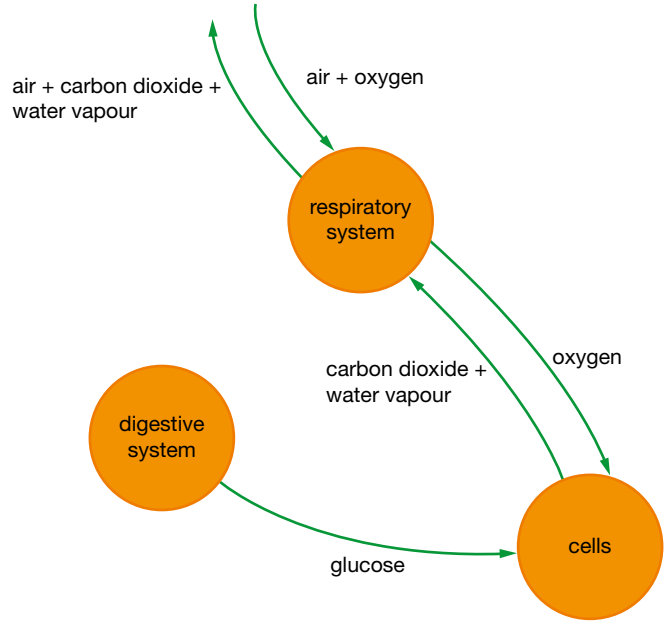


FIGURE 3.2.6 Summary of what happens in the respiratory system

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p. 112

The cells use the oxygen to release energy from glucose. As they do this, carbon dioxide is produced. Carbon dioxide is a waste product that would harm your body if you did not get rid of it. Carbon dioxide moves from your cells into your blood and from your blood into your alveoli, where it mixes with the remaining air. It then leaves your body when you next exhale (breathe out).

Figure 3.2.5 compares the composition of the air you inhale with the air you exhale. The role of the respiratory system is summarised in Figure 3.2.6.

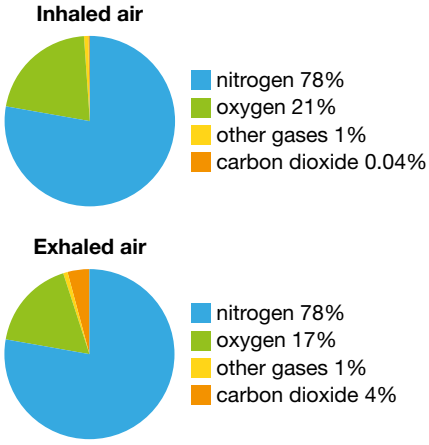

FIGURE 3.2.5 The composition of air when breathed in and breathed out

Breathing

The air in the alveoli is constantly replaced when you breathe. Breathing is involuntary—although you can force yourself to stop breathing for a while, breathing is something you do without thinking, all day, every day.

As you breathe in, the muscles between your ribs contract. This pulls the rib cage up and out. At the same time the **diaphragm** contracts and flattens. The diaphragm is a sheet of muscle that separates the chest from the abdomen. Its action in breathing can be seen in Figure 3.2.7.

SciFile

Breathing space

In each of an adult's lungs, there are about 300 million alveoli. If they could be spread out, then they would cover an area about the same size as a tennis court (about 160 m^2). This is about 80 times the area of your skin.

AB
3.5

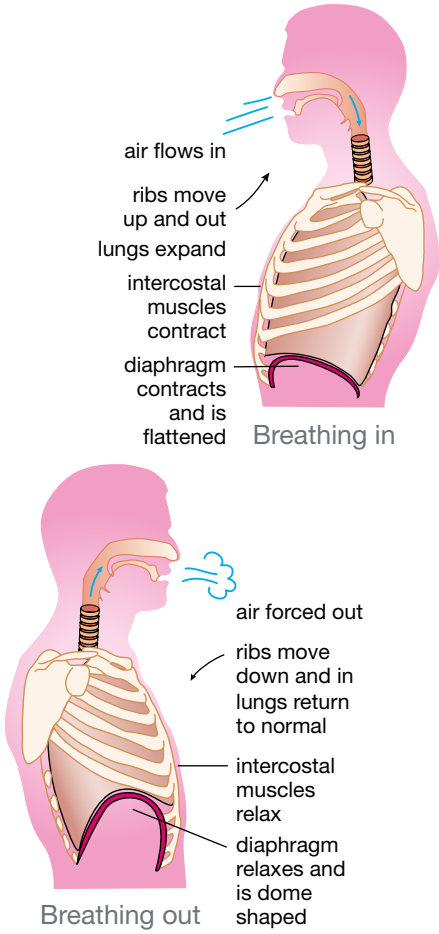

FIGURE 3.2.7 When you breathe in, your diaphragm flattens and your lungs expand. When you breathe out, the opposite happens.

These changes increase the space inside your chest. Your lungs expand, which causes the air pressure in them to decrease. Air is sucked in through the nose (and mouth) to fill up the extra space. This makes the air pressure inside your lungs equal to the air pressure outside your body.

When you exhale, the opposite happens. All the muscles relax. The ribs therefore move down and in, and the diaphragm arches upwards. The volume inside the chest returns to its normal size and the air pressure increases. This forces air out of the lungs, to exit through the nose and mouth.

SciFile

Couch potato!

You use about 250 kilojoules every hour you sleep, but use as little as 200 joules every hour you watch TV. This means you use more energy per hour while sleeping than while watching TV!

Exercise and energy

When you exercise, your cells need to release more energy than usual. The more energy you need to release, the faster your respiration needs to be, and so more oxygen and glucose are required. Your body responds to this increased energy need by:

- breathing faster and deeper—this increases the flow of air into your lungs and the amount of oxygen entering your blood. It also increases the flow of air out of your lungs and so quickly removes the extra carbon dioxide being produced (Figure 3.2.8).
- your heart beating faster—this increases the speed at which oxygen and glucose get to the cells that need them to make energy. It also speeds up the flow of carbon dioxide back to the lungs.

FIGURE 3.2.8 You breathe harder when you exercise because your cells need more oxygen to release the extra energy required. This athlete is having his oxygen and carbon dioxide measured while exercising.

Your body gets energy from oxygen and food. Breathing automatically controls the amount of oxygen entering the blood. It is sometimes more difficult to control the energy you receive from food because your body relies on you to control the amount and type of food you eat. Ideally, the nutrients from food will balance the energy that the body requires. Many Australians consume too much food or too much of the wrong types of food. This means more nutrients are absorbed than required. If your cells do not use those extra nutrients, then any excess is converted into fat and stored under your skin and around your internal organs. This fat can convert back into glucose for the cells but only if food intake is less than the cells need. This is why you are likely to lose weight when you exercise regularly or if you control your diet—you need more energy than you are taking in.

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Prac 3 p. 114

MODULE
3.2 Review questions LS

Remembering

1 Define the terms:
- a respiration
- b exhale.

2 What term best describes each of the following?
- a breathing in
- b the sheet of muscle that controls breathing.

3
- a What is the word equation that describes respiration?
- b Name the reactants and products for this reaction.

4 List in order the parts of the respiratory system that air passes through as it is breathed out.

5 Name each of the parts labelled A–E in Figure 3.2.9.

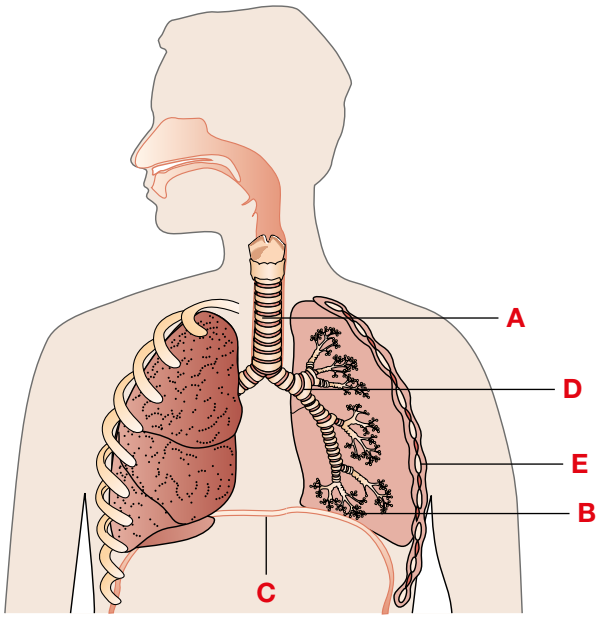


FIGURE 3.2.9

6 What is the function of each of the following?
- a the respiratory system
- b cilia
- c alveoli.

Understanding

7 Explain how the science4fun on page 105 relates to the working of the lungs.

8 Explain why lungs work far better with alveoli than they would without them.

9
- a Describe what happens to your breathing rate as you walk along, and then start to run, run faster, and then stop running.
- b Explain why this happens.

10 Predict the type of cells that will need to release more energy when you are running.

Applying

11 The following letters form a word equation.

$$R + S \longrightarrow T + U + V$$

- a Identify the products in this equation.
- b Identify the reactants in this equation.

Analysing

12 Figure 3.2.10 shows a model that is often used to demonstrate how the lungs work.
- a Analyse how this model works and identify what represents:
  - i the lungs
  - ii the diaphragm.
- b Use this model to explain how your diaphragm allows you to breathe.

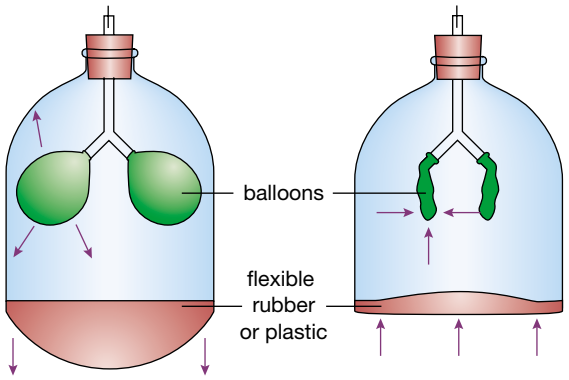


FIGURE 3.2.10

13 Compare:
- a bronchi and bronchioles
- b breathing and respiration.

MODULE
3.2 Review questions

Evaluating

14 **a** Limewater is a clear liquid that turns milky when carbon dioxide is bubbled through it. You can see this happening in Figure 3.2.11. Deduce what would happen to limewater if:

- **i** air that you were about to breathe in was bubbled through it
- **ii** you blew air into it through a straw.

b Justify your answers to part a.

FIGURE 3.2.11 Limewater turns milky in the presence of carbon dioxide.

15 Propose the advantage for your body of having many blood capillaries surrounding the alveoli.

16 Bronchitis is an illness in which large amounts of mucus coat the inside of particular air passages.

- **a** What is the most likely place for this mucus to occur?
- **b** Predict the symptoms of bronchitis.
- **c** Justify your predictions.

17 Smoking can damage and inflame the alveoli, leading to an incurable condition called emphysema.

- **a** Predict the symptoms of emphysema.
- **b** Justify your predictions.

18 Humans die within a few minutes if they cannot breathe, but can live for a few days without water and for a longer time without food. Propose a reason why.

19 Living underwater, fish cannot breathe in air. Instead they need to filter oxygen from the water in which they swim. They do this by allowing water to pass through their mouths and then over gills on each side of their head. Gills are feathery structures with a very large surface area. Capillaries lie close to the surface of the gills, allowing oxygen dissolved in the water to move across into the blood. Waste carbon dioxide moves from the blood back into the water to be flushed away as the fish swims. This exchange is shown in Figure 3.2.12.

- **a** What parts of the human respiratory system are most like the gills of a fish? Justify your answer.
- **b** Fish have a swim bladder that acts like an air pocket, allowing the fish to move to different depths of water. The bladder fills by absorbing oxygen from the blood, and empties by returning oxygen to the blood. When a fish swims to the surface of a pond, does it need to increase or reduce its density? Justify your answer.
- **c** Will it need to fill or empty its swim bladder? Justify your answer.
- **d** A person will usually float in water if they hold their breath, and sink if they exhale completely. Compare our lungs with a swim bladder.

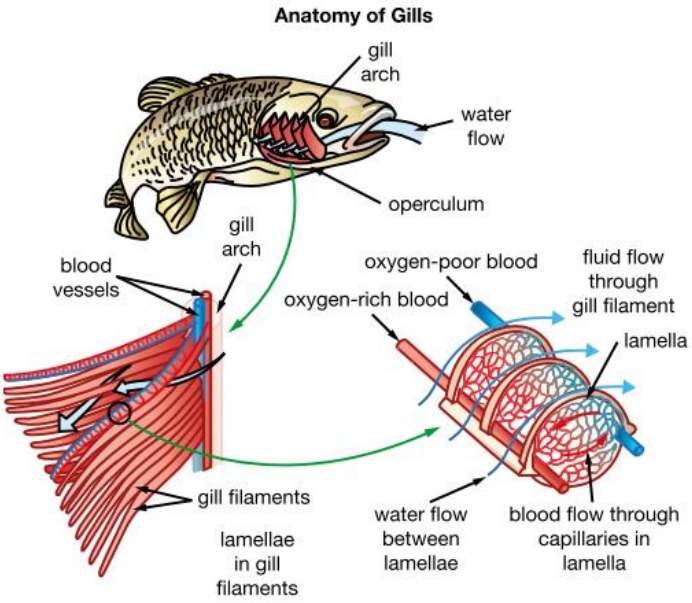


FIGURE 3.2.12

MODULE 3.2

Practical investigations

SPARKlab alternative available for this activity

1 • Changing air

Questioning & Predicting | Evaluating

Bromothymol blue is an indicator that changes from blue to yellow-green when carbon dioxide is present.

Purpose

To compare inhaled and exhaled air.

Hypothesis

The two flasks in Figure 3.2.13 contain water and bromothymol blue, which turns yellow-green if carbon dioxide is present. What do you think will occur in both flasks when you breathe in and out using the apparatus—do you think they will stay as they are, or will they change colour? Before you go any further with this investigation, write a hypothesis in your workbook.

Timing 30 minutes

Materials

- few drops bromothymol blue
- disposable straw
- flasks or large test-tubes and glassware as shown in Figure 3.2.13
- rubber tubing
- digital camera or mobile phone with video function (optional)

SAFETY

Ask your teacher or lab technician to check your set-up before you start.

Do not swallow any of the liquid.

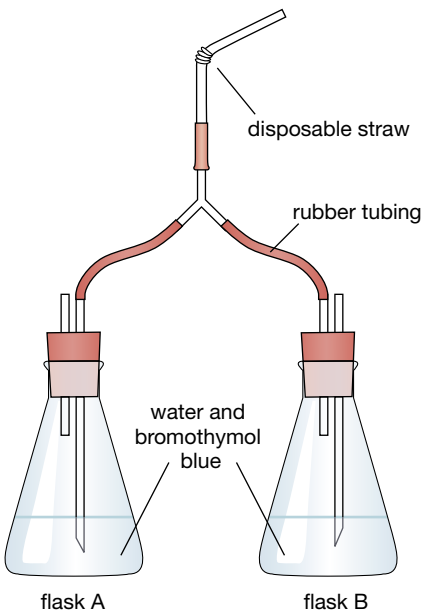


FIGURE 3.2.13

Procedure

1. Set up the equipment exactly as shown in Figure 3.2.13. Only one tube in each flask should extend below the level of the liquid. All the joins should be airtight.
2. Add a few drops of bromothymol blue to the water in each flask.
3. Ask your teacher to check your set-up before proceeding.
4. Place your lips over the disposable straw and breathe gently in and out continuously for a few minutes. You could use your mobile phone or digital camera to video what happens.

Results

1. Construct a diagram of the apparatus. Add arrows that show the passage of air as you breathed in and out.
2. On this diagram, record any changes to the colour of the liquid in the flasks.

Review

1. Which flask showed a colour change? Was it the flask through which air was inhaled or exhaled?
2. Explain the cause of any colour change in the flasks.
3. Explain how the results of this activity relate to the changes that take place in the respiratory system.
4. a Construct a conclusion for your investigation.
   b Assess whether your hypothesis was supported or not.

MODULE 3.2

Practical investigations

SPARKlab alternative available for this activity

2 • Energy production

Questioning & Predicting | Evaluating

Heat is a form of energy and is produced as a by-product of respiration.

Purpose

To record evidence that energy is released in respiration.

Hypothesis

In which thermos flask in Figure 3.2.14 do you think most heat will be produced—the one with living seeds or the one with killed seeds? Before you go any further with this investigation, write a hypothesis in your workbook.

Timing 30 minutes + 24 hours

Materials

- 40 germinating pea or bean seeds
- boiling water
- mild disinfectant
- 2 wide-mouthed thermos flasks
- 2 thermometers
- cotton wool
- 2 × 250 mL beakers

SAFETY

Take care with boiling water. Pour it carefully so that it doesn't splash.

Procedure

1. Label the two flasks 'live seeds' and 'killed seeds'.
2. Divide the germinating seeds into two equal groups.
3. Lightly dampen one group of seeds with water. These seeds are alive, so put this group of seeds into the flask labelled 'live seeds'.
4. To kill the other seeds:
   - Place them into a beaker and add boiling water. After 1–2 minutes, they should be dead.
   - Allow the seeds and beaker to cool, then pour off the water.
   - Replace that water with cold tap water and allow to return to room temperature.
   - Soak the killed seeds in disinfectant, then place them in the flask labelled 'killed seeds'.
5. Set the two flasks up as shown in Figure 3.2.14.

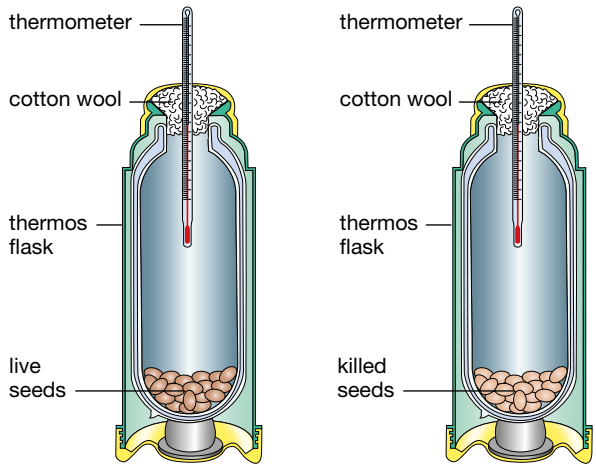


FIGURE 3.2.14

6. Record the temperature in both flasks at the start of the experiment, and then another three or four times in the next 24 hours.

Results

1. Record the temperatures in a table or spreadsheet like the one below. Give your table or spreadsheet a title.
2. On the one set of axes, plot a line graph of your results for both flasks. Alternatively, use your spreadsheet to produce a line graph for you.

Time (h)	Temperature (°C)	
	Live seeds	Killed seeds

Review

1. Why is a change in temperature in the flasks evidence of energy release?
2. Compare and explain any change in temperature in the two flasks.
3. Explain why the flask with the killed seeds was included in the experiment.
4. Explain how the results of this experiment relate to respiration in human cells and the uses made of energy in the body.
5. a Construct a conclusion for your investigation.
   b Assess whether your hypothesis was supported or not.

MODULE
3.2 Practical investigations

• STUDENT DESIGN •

3 • Breathing rate

Questioning & Predicting | Evaluating

Purpose

To test the effect of exercise on breathing rate.

Hypothesis

What do you think will happen to your breathing rate as you exercise—will it stay the same, increase or level out? Before you go any further with this investigation, write a hypothesis in your workbook.

Timing 45 minutes

Materials

- as selected by students

SAFETY

A risk assessment is required for this investigation.

Do not test students with asthma, as the exercise might trigger an attack.

Procedure

1. Design an experiment that tests the effect of exercise on breathing rate.
2. Brainstorm in your group and come up with several different ways to investigate the problem. Select the best procedure and write it in your workbook. Draw a diagram of the equipment you will need, and construct a table in which you intend to record your results. Give your table a title.
3. Before you start any practical work, assess your procedure. List any risks that your procedure might involve and what you might do to minimise those risks. Show your teacher your procedure and your assessment of its risks. If your teacher approves, then collect all the required materials and start work.

Hints

- Choose an exercise that can easily be done for 5 minutes.
- Use the STEM and SDI template in your eBook to help you plan and carry out your investigation.

Results

Record your results in your table.

Review

1. a Construct a conclusion for your investigation.
   b Assess whether your hypothesis was supported or not.
2. Use a word equation to help explain why you need more oxygen as you exercise.
3. Evaluate your procedure. Pick two other prac groups and evaluate their procedures too, identifying their strengths and weaknesses.

MODULE

3.3 Circulation

The circulatory system is the transport system that makes sure everything gets to where it needs to go in your body.

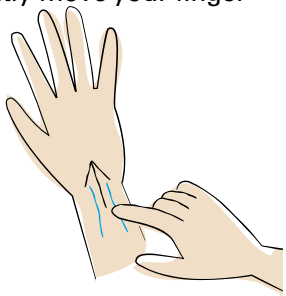
science 4 fun

No blood

Can you make the blood stop flowing in your veins?

Do this ...

1. Hold your hand out and turn it over so that the inside of the wrist is facing you.
2. You should be able to see veins as blue lines coming from the base of your palm and your thumb into your arm.
3. Place the index finger of your other hand on the vein coming from the middle of your palm. Firmly but gently move your finger along the vein back towards the hand. The blood should empty from the vein.



Record this ...

1. Describe what happened.
2. Explain why you think this happened.

The circulatory system

The digestive system provides the body with nutrients and the respiratory system supplies it with oxygen. These substances then need get to the cells. This is one of the jobs of the **circulatory system**. The circulatory system is your body's transport system. It:

- carries nutrients and oxygen to the cells so that respiration can happen
- removes carbon dioxide from the cells, taking it to the lungs where it is exhaled
- transports other waste products to where they can be disposed of
- distributes heat around the body. Heat is a by-product of respiration.

Your circulatory system consists of your heart, blood vessels and blood. The heart is the engine room of the circulatory system. It pumps continuously to keep the blood moving through the blood vessels. The blood vessels are the motorways, main roads and side streets along which the blood flows. Some of these are shown in Figure 3.3.1 on page 116.

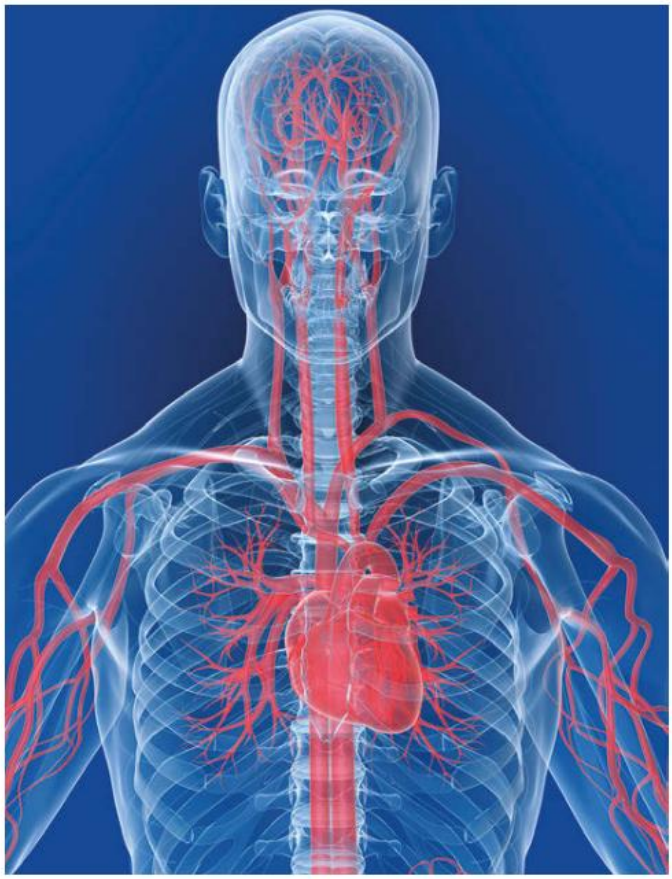


FIGURE 3.3.1 The blood vessels of your body are like motorways. Instead of cars and trucks transporting goods, it is blood and blood cells that carry materials to their destination.

Blood vessels

There are three types of blood vessels in your body:

- arteries
- capillaries
- veins.

Arteries

Arteries carry blood away from the heart. When the heart beats, it pumps blood through the arteries under pressure. To be able to withstand the pressure, the walls of the arteries (Figure 3.3.2) need to be tough and elastic, bouncing back into shape after each beat.

If an artery is cut, then the high pressure within it causes blood to spurt out very quickly. Within a very short time, most of the blood would be lost from the body. All major arteries are protected deep in the body. In a few places, the regular expansion and contraction of the arteries in response to the heartbeat can be felt. This is your **pulse**. You can feel it most easily in your neck and wrist.

SciFile

Where does it fit?

There are about 97 000 km of blood vessels in the body of a child and 161 000 km in the body of an adult. End to end they would go round the Earth about four times!

FIGURE 3.3.2 Blood pressure in arteries is much higher than in veins. For this reason, arteries have much thicker walls than veins. This can be seen clearly in this cross-section as viewed through a microscope.

Capillaries

As they extend through the body, arteries branch into smaller and smaller blood vessels. Eventually they are so small and so fine that they reach nearly every cell of the body. These finest of blood vessels are called **capillaries**. Capillary walls are only one cell thick. This allows dissolved materials to pass through them. Materials needed by the cell pass out of the capillary and into the cell, and waste materials from the cell pass into the capillary. The blood then carries the wastes back towards the heart.

The capillaries join back together to form larger and larger blood vessels called veins. Figure 3.3.3 shows how this happens.

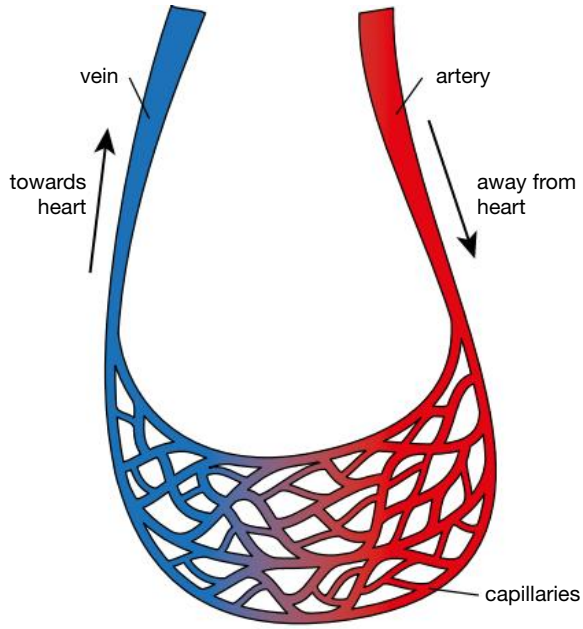


FIGURE 3.3.3 The capillaries are a network that joins the arteries and veins.

Veins

Veins carry blood back to the heart. The pressure of the heartbeat is lost as the blood flows through the very narrow capillaries, so veins do not need thick muscular walls like arteries do.

Blood is pushed back up to the heart by the contraction of the muscles pressing against the veins. This is shown in Figure 3.3.4. To make sure that the blood flows in one direction only, there are valves along the length of veins.

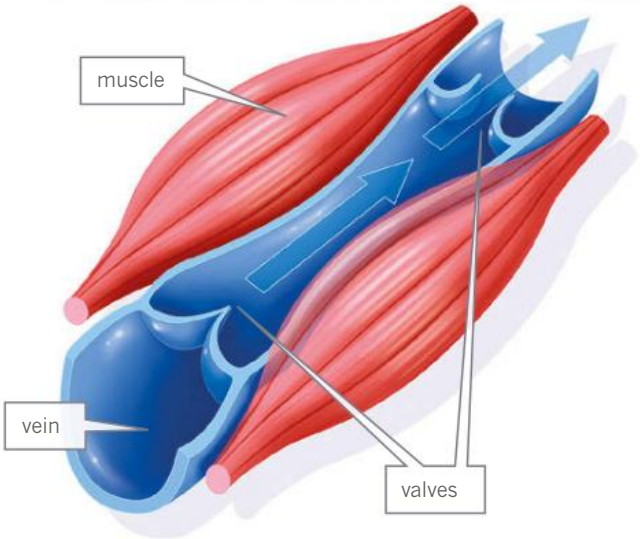


FIGURE 3.3.4 Veins have muscles next to them to ensure that blood is pushed towards the heart. Valves ensure that the blood cannot flow in the opposite direction.

The valves open when the blood is flowing towards the heart and close if the blood flows away from it. When you sit still for very long periods of time, the flow of blood in the veins slows and blood can 'pool' in the veins. The blood may thicken and form a dangerous blood clot called a **thrombus**. For example, you cannot move much when travelling overseas by plane and sometimes passengers develop a thrombus in a deep vein in a leg. This condition is called deep vein thrombosis (DVT) and is dangerous because the clot can dislodge and be carried away in the blood. It can then get stuck in the main artery to the lungs, reducing or blocking their blood supply. This can cause death.

Bruises

When you bump yourself hard, some of the tiny capillaries near the skin burst and the blood leaks out into the surrounding tissue. Immediately after the injury, a red mark appears where blood has leaked into the tissue. Gradually the bruise turns purple and then fades to yellow as the blood is broken down and cleared away by the body.

The heart

Your heart is about the size of your fist and is situated in the middle of your chest, behind the breastbone. The location of the heart is shown in Figure 3.3.5. The heart is made of a special type of muscle called **cardiac muscle**.

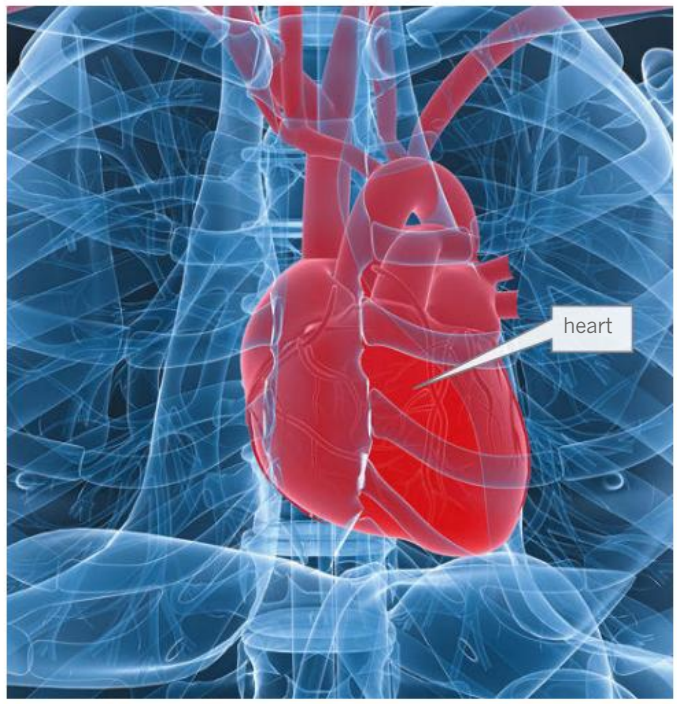


FIGURE 3.3.5 Your heart lies within your chest, protected by your breastbone, ribs and spine.

Cardiac muscle does not get tired like the muscles of your legs and arms do. Cardiac muscle works continuously in response to signals from an area of the heart called the pacemaker. The circulatory system is referred to as a double system because there are two separate circuits through which blood flows (Figure 3.3.6).

- In one circuit, blood flows from the heart to the body (head, trunk, legs and arms) and back to the heart. This circuit carries nutrients and oxygen to the cells and carbon dioxide and waste away from the cells.
- In the second circuit, blood flows from the heart to the lungs and back again. The blood that arrives at the lungs is known as **deoxygenated blood** (commonly shown in blue in diagrams). This is blood that has very little oxygen in it but lots of waste carbon dioxide from the cells. Inside the lungs, this carbon dioxide is expelled and replaced by oxygen. This oxygen-rich blood is referred to as **oxygenated blood** (commonly shown in red).

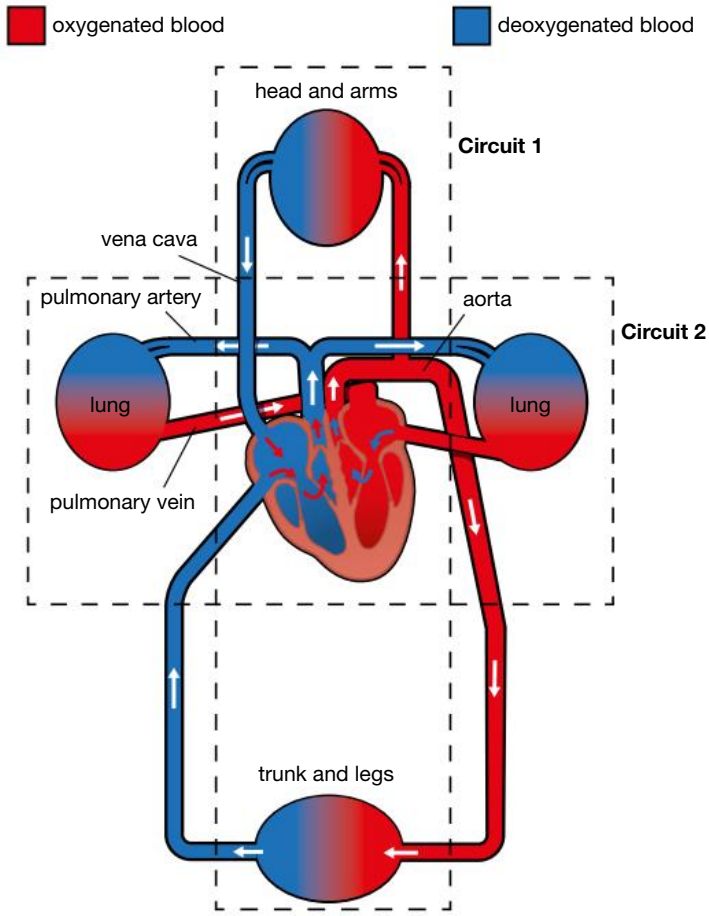


FIGURE 3.3.6 The circulatory system has two circuits. Both start with the heart. One circuit services the body, the other services the lungs.

For the circulatory system to work, oxygenated and deoxygenated blood must be kept separate where the two circuits meet in the heart. The heart is divided in two by a thick wall called the septum. One half of the heart collects oxygenated blood from the lungs and pumps it round the body. The other half collects deoxygenated blood from the body and pumps it to the lungs. Each half is split into two chambers, giving the heart four chambers in total. In each side, blood enters the atrium and exits the ventricle.

Figure 3.3.7 shows how this happens.

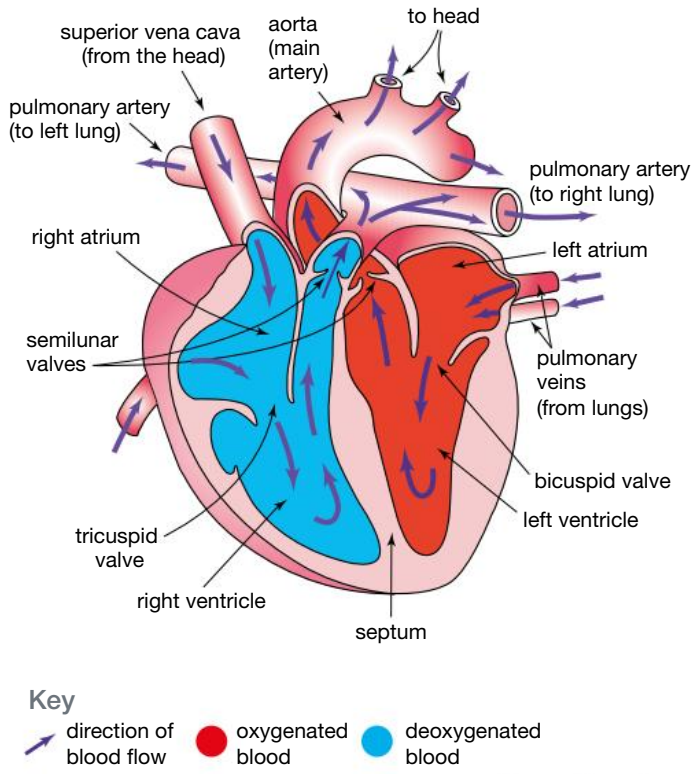


FIGURE 3.3.7 This diagram of the heart shows the heart as it would appear to someone looking at the front of the heart owner's body.

Prac 1 p. 123
AB 3.6

Heartbeat

There are three main phases of a heartbeat.

1 The two atria contract, pushing blood down into the ventricles.
2 The ventricles contract, forcing blood out of the heart to the body and lungs.
3 The heart muscle relaxes and the atria fill with blood.

When the atria or ventricles are contracting, valves open or close to make sure that the blood flows in the correct direction. An electrocardiogram (ECG) of a heartbeat is shown in Figure 3.3.8.

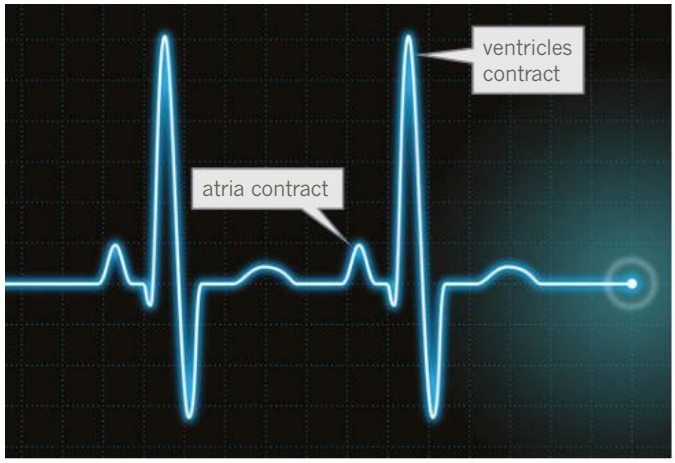


FIGURE 3.3.8 An ECG is an electronic recording of a heartbeat. Peaks show which parts of the heart are contracting. The heart is resting between the peaks.

Prac 2 p. 125

Heart disease

Coronary arteries supply the muscles of the heart with blood. The inner wall of healthy arteries is normally smooth and the blood flows easily. However, blood flow can be reduced by a build-up of **plaque** on the inner walls, which narrows the arteries. This can be seen in Figure 3.3.9. Blood carries oxygen, so reduced blood flow means the oxygen supply to the heart muscles is reduced too. A lack of oxygen to the heart muscle causes a condition called **angina**. A person suffering an angina attack experiences severe chest pain. If the arteries become completely blocked, then the part of the heart that the arteries normally supply with oxygen dies. The result is a heart attack.

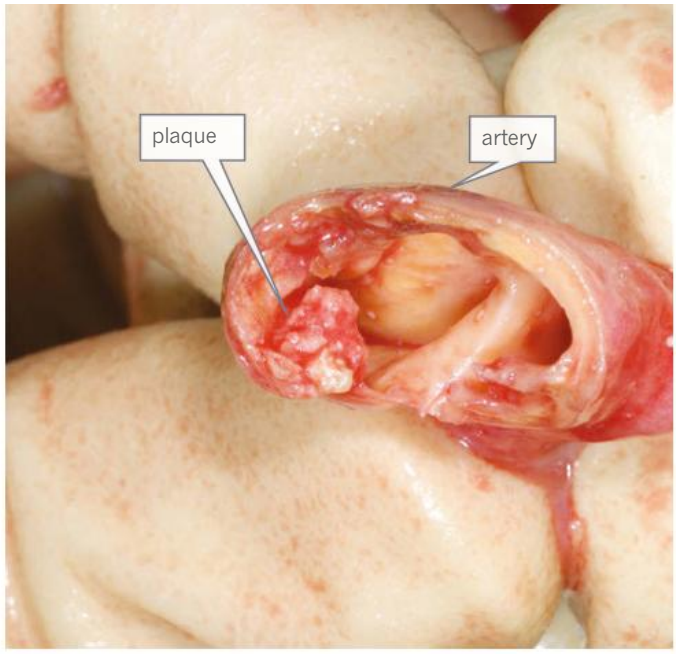


FIGURE 3.3.9 A surgeon's gloved hands hold an artery partly blocked by plaque.

Plaque is made up of various substances that occur naturally in the blood. These substances include **cholesterol**, calcium and fibrin (a material involved in blood clotting). Some scientists believe that damage to the artery wall leads to inflammation. Cholesterol is a fatty substance that moves to the inflamed area to protect it. Research into the causes of the inflammation is continuing.

Other scientists believe that too much animal fat in the diet leads to a build-up of cholesterol in the blood, and that this excess cholesterol is the reason that plaque builds up.

STEM 4 fun

Heart tour

PROBLEM

Can you create a walk-through guided tour of the heart?

SUPPLIES

Chalk or masking tape, flat surface inside or outside

PLAN AND DESIGN

Design the solution. What information do you need to solve the problem? Draw a diagram. Make a list of materials you will need and steps you will take.

CREATE

Follow your plan. Draw your solution to the problem.

IMPROVE

What works? What doesn't? How do you know it solves the problem? What could work better? Modify your design to make it better. Test it out.

QUESTIONS

1. What field of science did you work in? Are there other fields where this activity applies?
2. In what career do these activities connect?
3. What did you do today that worked well? What didn't work well?

Blood

Blood is the only organ of the body that exists as a liquid. The average-sized adult has about 5 litres of blood. In blood, there are red blood cells, white blood cells, platelets and plasma (Figure 3.3.10).

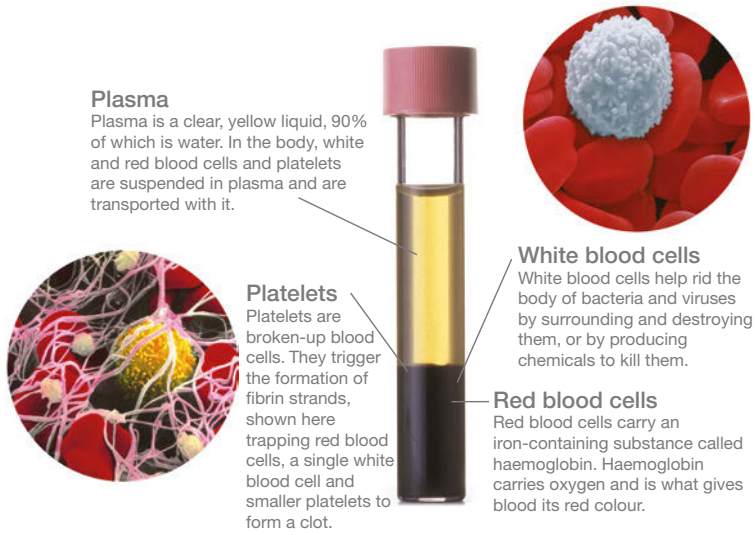


FIGURE 3.3.10 Blood readily settles into its different parts: 55% plasma, 45% red cells, with small amounts of white blood cells and platelets.

Red blood cells

Red blood cells are made in the bone marrow of long bones such as the femur (the thigh bone) and ribs. They contain the chemical **haemoglobin**, which gives red blood cells their colour (Figure 3.3.10). Haemoglobin contains iron, and its job is to carry oxygen around the body. When it is carrying oxygen, haemoglobin is bright red.

White blood cells

White blood cells are bigger than red cells. White blood cells are part of the immune system that helps fight disease.

Platelets

Platelets are broken-up bits of cells produced in the bone marrow. They help blood to clot. If you do not have enough platelets, then you could bleed excessively. However, too many platelets can cause blood to clot in the blood vessels. A blood clot can cause:

- angina or a heart attack if it occurs in the heart
- a stroke if it occurs in the brain.

Plasma

Plasma is a clear yellowish liquid that is 90% water. The other 10% is dissolved materials such as nutrients and wastes. Red blood cells, white blood cells and platelets are suspended in plasma.

Working with Science

PARAMEDIC

Paramedics are specialist healthcare professionals who deliver emergency care and transport patients to hospital (Figure 3.3.11). They respond to emergency calls, provide initial health assessments, make treatment decisions, deliver medical care and manage patients' wellbeing until they are transported to a medical facility for further treatment.

A paramedic's job is rewarding but also challenging. They must be able to remain calm and make important decisions under pressure.

Job prospects for paramedics are increasing. You can start your career by completing a Certificate IV in Health Care to begin working as a medic who can provide basic health care. A Diploma of Paramedical Science (Ambulance) is required for roles in pre-hospital emergency care. With these skills, you could work for private hospitals, the Australian Defence Force and some State ambulance authorities. To work for organisations such as Ambulance Victoria, you will need to complete a recognised degree, such as a Bachelor of Health Science (Paramedicine).

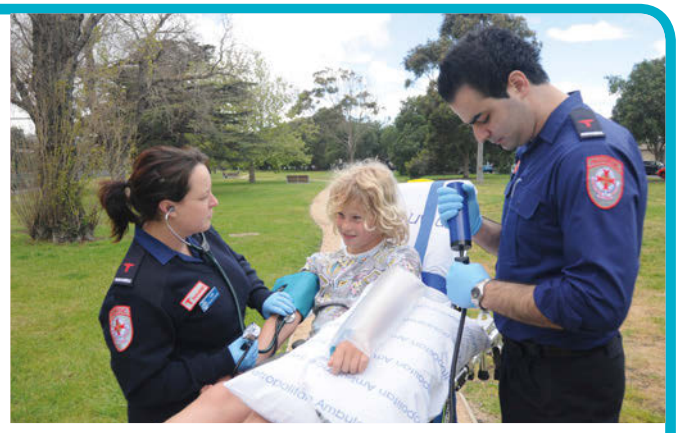


FIGURE 3.3.11 Paramedics delivering medical care to a child with an injured arm

Questions

1. What are some of the skills that you think a paramedic would need to do their job well?
2. Where have you seen paramedics working in your community?

SCIENCE AS A HUMAN
ENDEAVOUR

Use and influence of science

Dark chocolate boosts heart health

Most of the chocolate sold and eaten in Australia is milk chocolate. Although tasty, milk chocolate contains far more sugar and milk fats than your body needs. For this reason, milk chocolate cannot be considered a healthy food choice. However, scientists are uncovering the many benefits of eating dark chocolate, and are now recommending that we eat a small amount regularly to improve heart health and athletic performance.

FIGURE 3.3.12 Dark chocolate has been shown to have many benefits for heart health and athletic performance. Milk chocolate is not a healthy food choice.

The key ingredient that gives athletes a boost is thought to be the compound nitric oxide. Beetroot juice has also been linked to improved athletic performance due to its rich supply of nitrates, which the body converts to nitric oxide. This compound is known to open blood vessels and reduce oxygen consumption, allowing athletes to endure physical activity for longer.

Dark chocolate like that shown in Figure 3.3.12 is well known for improving cardiovascular health and increases the levels of nitric oxide in the body. Beetroot is known to do the same. Scientists at Kingston University in London thought that dark chocolate might have similar benefits as beetroot juice in improving athletic performance. For this reason the scientists decided to investigate the effects of this sweet treat on people's fitness and stamina.

The scientists measured the fitness of nine cyclists and then split them into two groups. Over 14 days one group ate 40 grams of dark chocolate every day while the other group ate 40 grams of white chocolate. The cyclists' oxygen consumption and heart rates were then measured while they were doing moderate exercise (Figure 3.3.13). After a seven-day break, the cyclist groups swapped chocolate types for another 14 days and were tested again as they exercised.

The study found that after eating dark chocolate, the cyclists used less oxygen and were able to ride further during the exercise tests than the cyclists who ate white chocolate.

REVIEW

1. Why do you think the scientists measured the fitness of the cyclists before they ate any chocolate?
2. If you were an exercise scientist, what dietary advice would you give to athletes based on the findings of this study?
3. How do you think this study could be improved, and what further questions could the scientists research in the future?

FIGURE 3.3.13 Tests on cyclists showed that they used less oxygen after eating dark chocolate.

MODULE 3.3

Review questions

Remembering

1 Define the terms:
- a angina
- b plaque
- c haemoglobin.

2 What term best describes each of the following?
- a the wall between two halves of the heart
- b the heart chamber that acts as an 'entry' for blood
- c the main component of blood.

3 List the three main functions of the circulatory system.

4 What are the parts of the heart labelled in Figure 3.3.14?

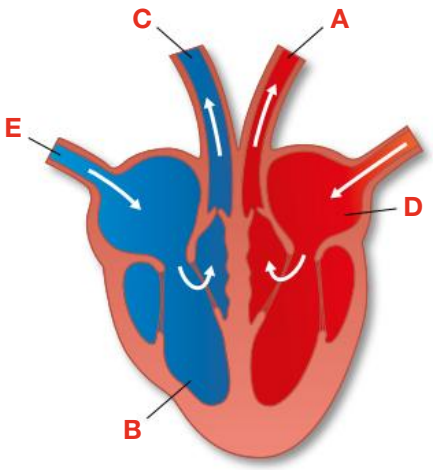


FIGURE 3.3.14

Understanding

5 Outline what happens to cause:
- a a pulse
- b a bruise
- c DVT.

6 Explain how the circulatory system acts as the body's transport system.

7 Explain what makes capillaries suited to their function.

8 Explain why the left side of the heart is shown on the right in Figure 3.3.7 on page 118.

9 Look at the STEM4fun activity on page 119. What is the role of valves in the heart?

Applying

10 Identify the following parts of the circulatory system.
- a carries blood away from the heart
- b muscle that does not get tired
- c blood vessels with the thickest walls.

Analysing

11 a Calculate the pulse rate (in beats per minute) for the students listed in the table below.

Student	Beats counted	Time (s)
Jo	15	10
Karl	22	15
Jack	12	5

- b Analyse the data and identify which student was most likely to be the one who had just finished playing soccer.
- c Identify which results would provide the most accurate measure of pulse rate.

12 Compare:
- a oxygenated blood and deoxygenated blood
- b a heart attack and a stroke
- c arteries and veins
- d red and white blood cells.

Evaluating

13 You can block the flow of blood through a vein in your wrist by putting pressure on it for a short time, like in the science4fun on page 115. Propose a reason why this doesn't cause any damage to your hand if done for a short time.

14 You can often see blood vessels in your wrists and on the insides of your elbows.
- a What do you think these are: arteries, veins or capillaries?
- b Justify your answer.

MODULE 3.3

Practical investigations

1 • Heart dissection

Planning & Conducting | Processing & Analysing

Purpose

To investigate the structure of the heart.

Timing

45 minutes + clean-up

Materials

- sheep or bullock heart
- scalpel
- tweezers
- blunt probe
- disposable gloves
- dissection board

SAFETY

Take care with sharp instruments.

Wear disposable gloves when handling the heart.

Wash your hands thoroughly after you have completed the dissection.

Procedure

1 Place the heart on the dissecting board as shown in Figure 3.3.15.

2 Identify as many of the external features as you can: right and left atria, right and left ventricles, aorta, vena cava, pulmonary arteries and veins.

3 Lightly compress the heart with the palm of your hand, as if you were trying to squash it.

4 Use the blunt probe to investigate which chamber of the heart the blood vessels enter or leave. Use the scalpel to make cut 1 as shown in Figure 3.3.14. Cut with the blade pointing upwards and away from you.

5 Observe the thickness of the wall of the right ventricle.

6 Open out the ventricle.

7 Observe the tendons (thread-like structures) and the valves (flaps of tissue) to which they are attached.

8 Work out how the valves work to control blood flow.

9 Observe the flaps of skin at the base of the pulmonary artery. These are the semilunar valves.

10 Make cut 2 to open up the left ventricle. Continue the cut up into the aorta.

11 Observe the thickness of the wall of the left ventricle.

12 Find the position of the semilunar valves at the end of the aorta.

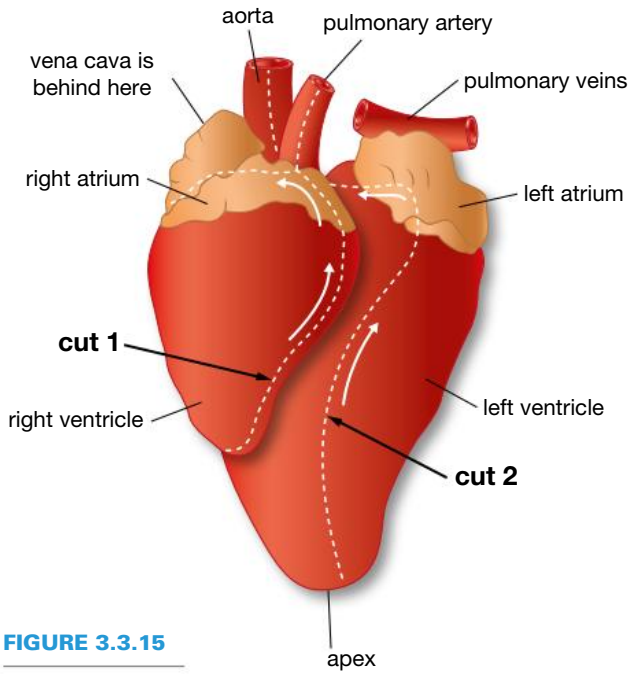


FIGURE 3.3.15

13 Just above the semilunar valves you should be able to find two small openings from the aorta. These are the branches of the coronary arteries. Use the probe to find out where they go.

Review

1 a How hard was the heart to compress?
b What does this say about the tissues making up the heart?

2 Compare the thickness and texture of the aorta and vena cava.

3 Draw simple diagrams to explain how the valves between the atria and ventricles control the direction of blood flow.

4 a Use diagrams to explain how semilunar valves work.
b Propose a reason why these valves are known as semilunar.

5 a Compare the thickness of the walls of the right and left ventricles.
b Propose a reason for the difference.

6 a Where did the coronary arteries go?
b What do you think is their purpose?

7 Construct a diagram of the heart and use arrows to show the path of blood flow through the heart.

SkillBuilder

Measuring your pulse

Your pulse is a measure of your heart rate—the number of times your heart beats per minute. Two of the easiest places to feel your pulse are at the wrist and at the neck, as shown in Figure 3.3.16. The pulse on your wrist is known as the radial pulse. The pulse in your neck is the carotid pulse.

FIGURE 3.3.16 Your pulse can be felt on your neck or your wrist.

To take your pulse you need a stopwatch, a digital watch or a watch, with a second hand.

To measure the radial pulse:

1. Turn your hand so that the palm is facing upwards.
2. Place your index and middle fingers of your opposite hand on your wrist, approximately 2.5 cm below the base of your thumb.
3. Gently but firmly press your fingers in the area between the tendons of the wrist and the outside bone. You should feel a throbbing, which is your pulse.
4. Count the number of beats for 15 seconds, then multiply this number by 4. This will give you your heart rate for one minute.

For example, if you count 18 beats in the span of 15 seconds, then multiply $18 \times 4 = 72$. This means your pulse rate is 72 and your heart rate is 72 beats per minute.

To measure the carotid pulse:

1. Place your fingertips gently on one side of your neck, below your jawbone and halfway between the large neck muscle behind your ear and your windpipe.
2. Count the number of beats and calculate the pulse rate in the same way.

When taking a resting pulse rate—your pulse rate when you have been sitting still for some time—the longer you count the pulse, the more accurate the measurement will be. In that situation, count the pulse for 20 or even 30 seconds. If you count the pulse for 20 seconds, then you would multiply the number of beats by 3 to get beats per minute. Counting for 30 seconds means you multiply by 2.

Ten seconds is long enough if you are taking your pulse directly after exercise, when it could be changing rapidly. In this instance, you would multiply the number of beats by 6 to get the heart rate.

AB 3.7

MODULE 3.3

Practical investigations

SPARKlab alternative available for this activity

2 • Heart rate and exercise

Questioning & Predicting | Evaluating

Purpose

To investigate the effect of exercise on heart rate.

Hypothesis

What do you think happens to your heart rate as you exercise? Before you go any further with this investigation, write a hypothesis in your workbook.

Timing 30 minutes

Materials

- stopwatch or timer
- graph paper
- ruler and pencil

SAFETY

Do not run or jog if you have been ill recently or if you have asthma or a heart condition.

Procedure

1. Copy the tables in the Results section into your workbook. Alternatively, construct a spreadsheet with similar features to both tables. Give your tables or spreadsheet a title.
2. When you are sitting quietly, find your resting pulse rate (the number of beats per minute). Do this by finding your pulse on your wrist or at the side of your neck and counting the number of pulses for 15 seconds. Multiply this number by 4. For more advice on taking your pulse, see the SkillBuilder on page 124.
3. Repeat this step twice more and calculate an average by adding up the results and dividing by 3.
4. Run or jog on the spot for 3 minutes.
5. When you stop, immediately take your pulse rate again.
6. Sit down and take your pulse rate every minute until it does not get any lower.

Results

1. Record all your results in tables or spreadsheet(s) like the ones shown.

Resting pulse rate

Trial	1	2	3	Average
Resting pulse rate				

Pulse rate following activity

Time after end of jog (min)	Pulse rate (per minute)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

2. Construct a line graph from the results in the second table. If you have used a spreadsheet, then use it to construct the line graph.

Review

1. a What happened to your pulse rate when you started exercising?
   b Propose reasons for this change.
2. a What happened to your pulse rate after you stopped exercising?
   b Propose reasons for this change.
3. a Compare your results with those from other members of the class.
   b Account for differences in the results.
4. a Construct a conclusion for your investigation.
   b Assess whether your hypothesis was supported or not.
5. Predict from these results what changes would be expected if you:
   a ran a lot faster for 3 minutes
   b ran faster and for a longer period of time
   c walked slowly round the room.

MODULE

3.4 Waste disposal

While your body is working to provide you with all your needs, it is also producing wastes. Wastes are harmful to the body if they are allowed to build up, so we need a system to get rid of them.

science 4 fun

It smells!

Does what you eat affect the smell of your urine?

Collect this …

- tin of asparagus or freshly cooked asparagus

Do this …

1. Eat the asparagus.
2. Next time you urinate, pay attention to the smell.

Record this …

1. Describe what happened.
2. Explain why you think this happened.

Defecation and excretion

Your digestive system absorbs any nutrients that the body will use. Anything that can't be used is passed from the anus as faeces. This process is called **defecation**.

Excretion is also a process of getting rid of wastes. However, these wastes are ones that your body has produced itself. The lungs, liver, skin and kidneys are involved in excretion and so they all belong to the **excretory system**.

Lungs

The lungs are part of two body systems—the excretory system and the respiratory system. Respiration produces carbon dioxide and water as waste products. These are carried back to the lungs and breathed out.

Liver

Your liver carries out many processes. Some are involved in excretion. The liver breaks down amino acids, removes poisonous substances and breaks down old red blood cells.

Amino acids are the end products of protein digestion. They are used by your body to make proteins and for growth and repair. Amino acids cannot be stored. If you have more than needed, then they are broken down and excreted. The liver breaks amino acids down into a substance called **urea**.

Poisonous substances may enter the body from the digestive tract. These are carried to the liver, where they are broken down into harmless substances. The harmless substances are then returned to the blood and from there they pass to the kidneys.

The liver breaks down old red blood cells. Any unwanted haemoglobin is added to bile and passes with the bile into the intestines.

Skin

Your skin helps heat to leave your body. Heat is a by-product of chemical reactions in your body. Some of this heat is required to maintain your core body temperature at approximately 37°C, but you usually produce more than you need. If you did not get rid of the excess heat, then your temperature would rise. This could be fatal. You lose much of your excess heat through your skin by sweating (Figure 3.4.1). Sweat also contains a very small amount of urea.

FIGURE 3.4.1 Your body gets rid of excess heat by sweating.

SciFile

That's a lot of skin!

The whole of the human skin weighs twice as much as the brain.

Kidneys

The kidneys are very important excretory organs. If you place your hands on your hips with your thumbs to the back, then your thumbs will be sitting over your kidneys. They are two bean-shaped organs about the size of a fist. The kidneys are filters that process about 50 litres of blood every hour. Figure 3.4.2 shows the position and relative size of the kidneys.

FIGURE 3.4.2 Although your kidneys are not large, they are very important.

Your kidneys have three main functions.

- They excrete urea, a waste product from the digestion of proteins.
- They control salt levels in the blood. Excess salt is removed by the kidneys and is excreted with the urine. This is important because too much (or too little) salt in the blood prevents cells from working correctly.
- They control the level of water in the body. You can tell if you are drinking enough water by the colour of your urine. If your urine is pale yellow or colourless then your urine is dilute. This means that your body has plenty of water. In contrast, strong gold-coloured urine indicates that it is concentrated and that your body has insufficient water.

Figure 3.4.3 on page 128 shows the structure of a kidney.

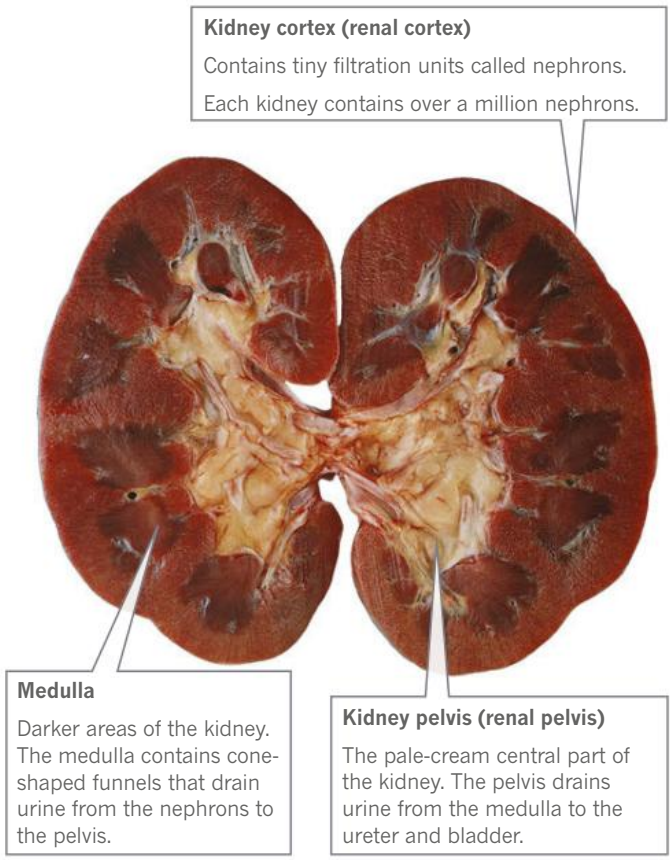


FIGURE 3.4.3 A dissected kidney

Urine

Urine is the waste material that has been filtered out of the blood by the kidneys. On average, urine is 95% water. The other 5% is urea, with small amounts of salts and pigment. The pigment comes from the breakdown of haemoglobin and gives urine its yellow colour.

Urine passes from the kidneys down narrow tubes called **ureters** and into the **bladder**, where it is stored. The bladder is a muscular bag. It can expand to hold about 500 mL of urine. About 300 mL is enough to trigger the urge to urinate—this is less than a can of soft drink.

The **urethra** is a tube that carries the urine to the outside of the body. At the end of the urethra is a sphincter muscle that controls the emptying of the bladder.

Together, the kidneys, bladder, ureters and urethra are called the **urinary tract**.

The male and female urinary tracts are shown in Figure 3.4.4.

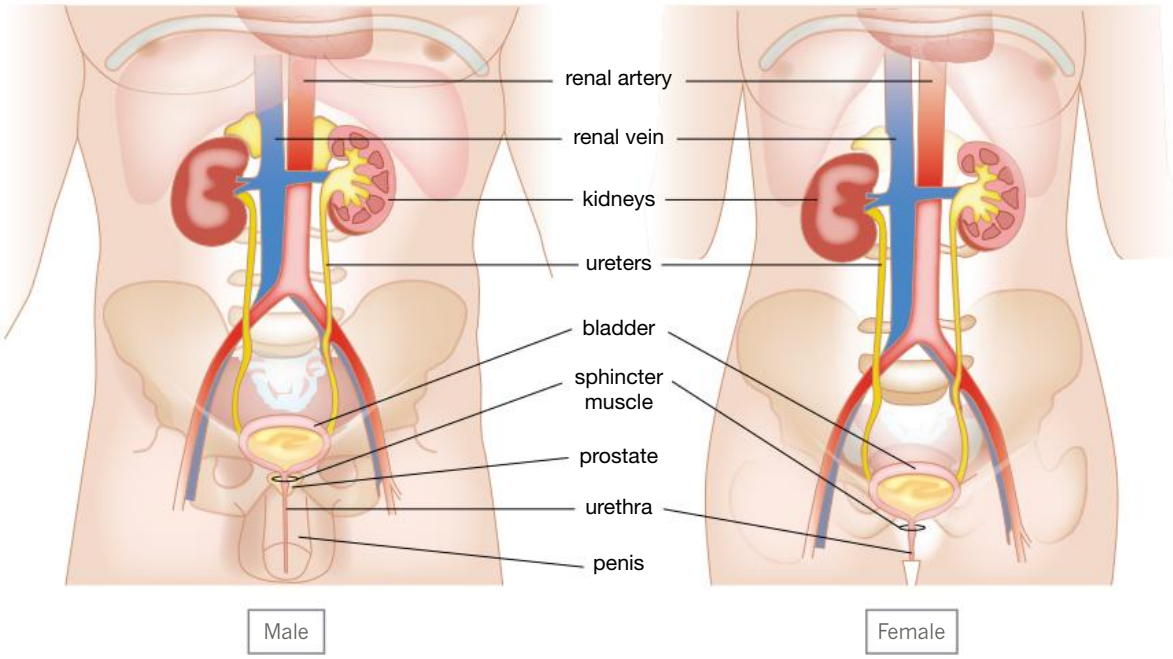


FIGURE 3.4.4 The urinary tract

Prac 1 p. 133
Prac 2 p. 134
AB 3.8

Kidney disease

More than 500 000 Australians a year consult their doctors about kidney disease and urinary tract infections. High blood pressure, kidney stones and infections are some of the causes.

High blood pressure

Your blood travels a relatively short distance from the heart to your kidneys. Very little pressure from the heartbeat is lost, so blood entering the kidneys is under pressure. This pressure helps the filtering process carried out by the kidneys. However, abnormally high blood pressure can easily damage the capillaries where the blood is filtered. This affects the functioning of the kidneys.

Kidney stones

Kidney stones occur when chemicals normally present in the urine combine to form hard crystals. If they are small enough, the crystals will pass out of the kidneys with the urine. However, larger stones can block the fine tubes within the kidney, causing pain and preventing the flow of urine (Figure 3.4.5).

FIGURE 3.4.5 The red dots in this X-ray are kidney stones.

Large kidney stones may have to be removed in an operation but more commonly they are shattered into tiny pieces using ultrasound waves. The smaller pieces should then pass naturally from the body.

Substances in the urine usually prevent kidney stones from forming. However, in some people these substances do not work and the people suffer pain and discomfort.

You can help keep your kidneys healthy by drinking. Water is the best drink (Figure 3.4.6). You should drink enough to produce about 2 litres of urine in every 24-hour period.

Infections

The structure of the urinary tract prevents any backflow of urine from the bladder, and this reduces the chance of infections of the kidneys. However, infections of the urinary tract sometimes occur. Most are caused by bacteria.

Urine is normally sterile, so the bacteria have to come from another source. They usually enter through the urethra. Most infections are caused by *Escherichia coli* (*E. coli*), a bacterium common in the digestive tract, which spreads to the urethra from the anus.

FIGURE 3.4.6 Drinking plenty of water helps to keep the kidneys healthy.

Transplants

An organ transplant is when a diseased or failing organ in one person is replaced with a healthy one from someone else. Organ transplants are highly successful and relatively common in Australia. However, there are ethical issues that need to be considered before a transplant can happen.

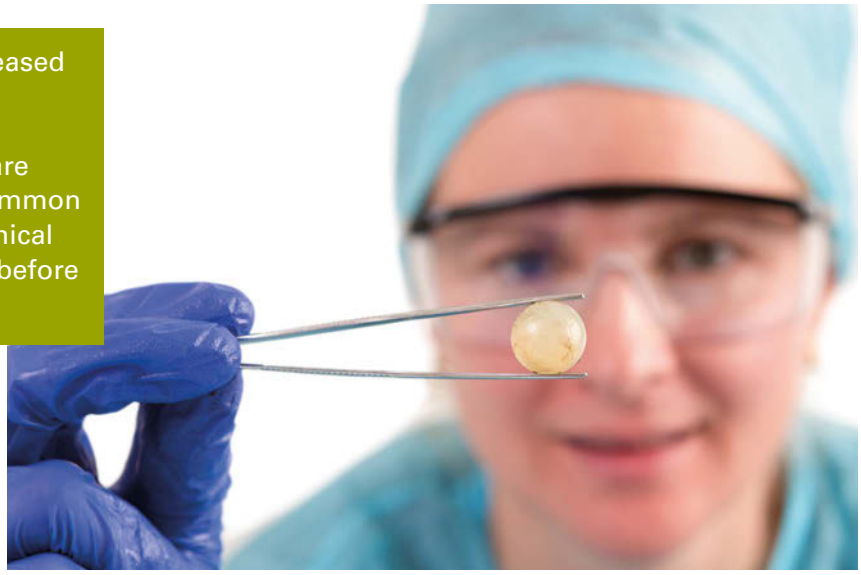


FIGURE 3.4.7 The cornea is the clear substance at the front of your eye. It is the tissue most commonly transplanted in Australia.

Organs and tissues

Organs that can be transplanted are kidneys, lungs, liver, pancreas and intestine. Sometimes, only selected tissues are transplanted. Examples are skin, heart valves, tendons and bones. The most commonly transplanted tissue is the cornea, the clear, domed surface that covers the front of your eye (Figure 3.4.7). Many of these tissues can be stored. However, without a constant supply of blood and oxygen, most organs start to break down. Within 40 minutes, many are unsuitable for transplantation. However, if a donor heart is stored correctly, it can be kept for 4 hours before transplantation. Kidneys can be stored for about 24 hours. This gives the transplant teams some time to find and prepare a suitable person who is waiting for a new organ.

The person who provides the organ or tissue for transplanting is called the **donor**. The person who receives the organ is called the **recipient**.

Living donors

Some organs and tissues can be donated by living donors. Examples are:

- kidneys—we have two kidneys, so we can donate one. The remaining kidney will grow larger and take over the function of the one that was donated.
- liver—we can donate a small part of our liver and still have enough left over to function normally.
- blood and bone marrow—these are renewed by the body anyway, so they will be quickly replaced if only small amounts are donated.

Deceased donors

Most organs and tissues for transplant are from people who have died. Death is usually declared when the heart stops beating and cannot be restarted. In some traumatic accidents, the brain is dead but the heart can be kept beating using a ventilator. Death is declared because there is no more brain activity and no chance of recovery. The heart can then be kept beating in the donor until the recipient is ready for the transplant.

The removal procedure

To be safe for transplant, the donated organs must be in good condition and not diseased. Hence, blood is tested and an autopsy may be performed to find the exact cause of death. If the organ is good, then it is removed and all its blood is flushed out to prevent blood clots forming in its capillaries. Clots would prevent the recipient's blood reaching those parts of the organ and it would die. The organ is cooled to about 4°C and all the veins and arteries are filled with preservatives. This is why the kidney in Figure 3.4.8 looks so pale.

FIGURE 3.4.8 This kidney has been cooled and the blood has been flushed from it to prepare it for transplant.

Implanting an organ

Transplanted hearts and lungs are placed in the correct position in the body. However, transplanted kidneys are often placed inside the pelvis where they are attached to blood vessels and the urinary tract. The recipient's kidneys are not usually removed unless they are so diseased that they could become a health risk.

Aftercare

The immune system fights disease by attacking and destroying bacteria and viruses. It responds to transplanted organs in the same way—it attempts to destroy transplanted organs in a process called **rejection**. Once the transplant is completed, the recipient needs to take anti-rejection drugs to prevent rejection of the new organ by their body.

Ethics and transplants

Donating organs is an ethical issue as well as a medical issue. People have different views on organ donation, depending on their family background, culture, religion and who the recipient is. For example, live donors may be willing to donate a kidney to their sick brother or sister but may not be prepared to undergo an operation for a recipient they did not know.

Donation brings immeasurable benefits to the organ recipient. The donation will either save the recipient's life or make their life much, much better.

For these reasons, many healthy people decide to donate organs or tissues on their death. They then tell close family of their decision, expecting these wishes to be carried out when they die.

Families often need to decide whether to donate organs from a deceased relative. It can be hard to make such an important decision so quickly. The decision is relatively simple if the deceased had registered as an organ donor or carried an organ donor card. Otherwise, the family will need to consider whether the deceased:

- ever mentioned their views for or against organ donation
- had a history of helping others, suggesting they would be happy to donate their organs
- would want something good to come out of their death
- had cultural or religious reasons why the body should not be interfered with after death
- had spiritual or other feelings that would stop the donation of some organs but not others (for example, they don't want their eyes touched but are happy to donate their liver).

REVIEW

1. Organ recipients need to take anti-rejection drugs for the rest of their lives. Explain why.
2. How it is possible for bone marrow or a kidney to be donated by a living person?
3. Explain why all the blood has to be flushed out of an organ that is to be transplanted.
4. List the advantages that organ transplants bring:
   a. to the recipient
   b. to the donor.
5. The parents of a young child who died in an accident have the chance to donate her organs to a number of sick children. List reasons why:
   a. they might refuse to allow this
   b. they might agree to donate her organs.
6. Australia currently has an 'opt-in' policy where you (or your family) must agree to donate organs after death. Some countries like Germany and Austria have 'opt-out' policies where your organs are automatically donated unless you have stated that you do not want to be a donor. Discuss the advantages and disadvantages of both systems.

AB 3.10

MODULE
3.4 Review questions LS

Remembering

1 Define the terms:
- a defecation
- b excretion
- c urinary tract.

2 What term best describes the following substances?
- a produced from the breakdown of amino acids
- b expelled from the urethra
- c that removes heat from the skin.

3 What is the function of the bladder?

4 Figure 3.4.9 is a diagram of the excretory system. What are the parts labelled A–D?

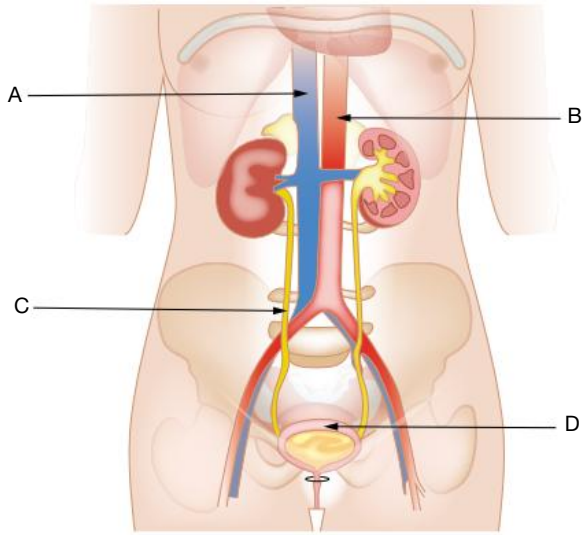


FIGURE 3.4.9

5 What wastes are excreted by the lungs?

6 List three functions of the kidneys.

7 Fill in the missing steps in the pathway followed by urine:

kidney → [ ] → bladder → [ ]

Understanding

8 On average, urine is 95% water and 5% urea and salts. Predict how the composition of urine would change if you:
- a drank very little water on a hot day
- b drank very large amounts of water
- c ate a diet high in salt.

9 Defecation is not considered to be excretion. Explain why.

10 Describe the involvement of the liver in excretion.

Applying

11 Kidneys process about 50 L of blood every hour. Your body contains about 5.5 L of blood. Calculate how often any drop of blood would pass through the kidneys in:
- a 1 hour
- b 1 day.

Analysing

12 The table below shows the composition of blood and urine. Compare the data for blood and urine and identify the substances that are:
- a more concentrated in the urine
- b not excreted by the kidneys.

Component	Percentage in blood	Percentage in urine
water	92	95
protein	7.5	0
glucose	0.1	0
urea	0.03	2
salts	0.37	3

Evaluating

13 Propose a reason for glucose not being excreted from the body.

14 Propose a reason why drinking water should reduce the chance of developing kidney stones.

15 Why do you think urine smells different depending on what you have had to eat or drink?

Creating

16 Use the following ten key terms to construct a concept map.

excretion	excretory system
urea	urine
kidneys	skin
lungs	ureter
bladder	urethra

MODULE 3.4

Practical investigations

1 • Kidney dissection

Planning & Conducting

Purpose

To dissect a kidney and look at its structure.

Timing 45 minutes

Materials

- sheep or bullock kidney
- dissecting board
- scalpel
- disposable gloves

SAFETY

Take care with sharp instruments.

Wear disposable gloves when handling the kidney.

Wash your hands thoroughly after you have completed the dissection.

Procedure

1. Place the whole kidney on the dissecting board and examine it. Look for any tubes entering or leaving the kidney. It may be possible to identify three tubes: ureter, renal artery and renal vein. (*Renal* is a word used in relation to the kidney.)
2. Use the scalpel to cut the kidney in half lengthwise as shown in Figure 3.4.10.
3. Identify the parts of the kidney as shown in Figure 3.4.3 on page 128.

Results

Draw a labelled diagram of the cut surface of the kidney.

Review

1. Compare the texture in the three different areas of the kidney.
2. Compare the kidney you have dissected with the human kidney shown in Figure 3.4.3 on page 128. How similar are the two kidneys?
3. Use this comparison to compare human excretion with excretion in sheep (or bullocks).
4. Describe the function of each part of the kidney.

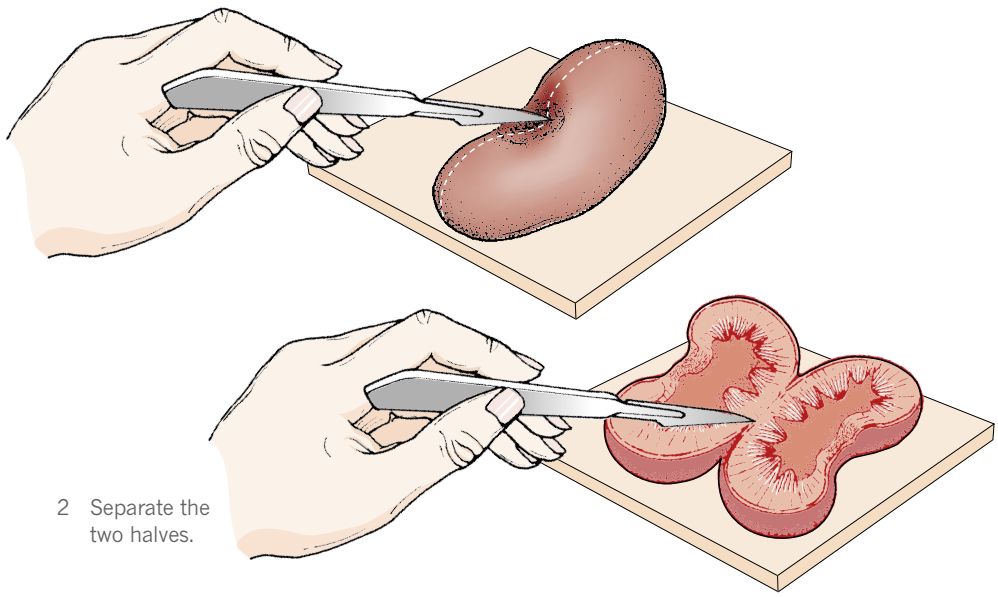


FIGURE 3.4.10

MODULE
3.4 Practical investigations

2 • Drinking and urinating

Questioning & Predicting | Evaluating

Purpose

To gather information about the relationship between drinking and urinating.

Hypothesis

Do you think the amount you drink influences the amount of urine produced each time you urinate or just makes you urinate more frequently? Before you go any further with this investigation, write a hypothesis in your workbook.

Timing 24 hours

Materials

- liquids that are normally drunk in a day
- notebook and pencil
- graph paper

Procedure

1. Construct a table like the one in the Results section. Give your table a title.
2. Use the table to record the:
   - a amount that you drink
   - b time the drink was consumed
   - c time you urinated.
3. For a 24-hour period, record the volume of all the drinks you consume and the time that you consumed them.
4. Record the times that you urinated for the same 24-hour period.

Results

1. Record your results in a table like the one shown below.

Time drink consumed	Amount drunk (mL)	Time urinated

2. Construct a bar graph with time along the horizontal axis. On the vertical axis, each bar is to represent each drink you consumed. Start each bar at the time you drank, and finish the bar at the time you urinated. Figure 3.4.11 shows how your graph might look.
3. On each bar, write the amount of liquid that you drank.

Review

On average, the adult bladder can hold between 500 mL and 1 litre of urine. Assume that your bladder is a little smaller than that of an adult and that it is not filled to capacity when you urinate. Assume that each time you urinate, the volume of urine is 300 mL.

1. Calculate the total amount you drank in the 24-hour period.
2. Calculate the total amount of urine you produced in the 24-hour period.
3. Compare the two amounts. Explain the difference.
4. a Calculate the length of time between drinking and urinating.
   b Explain any relationship you identified.
5. Not all the water in your body comes from drinking it. What are some other sources?
6. a The amount of liquid you drink is not the only factor that influences the amount of urine you produce. What factors might influence it?
   b For the day you performed this investigation, list factors that may have influenced the amount of urine your body produced.
7. On hot days, urine is sometimes much darker than on cold days. Propose a reason why.
8. a Construct a conclusion for your investigation.
   b Assess whether your hypothesis was supported or not.

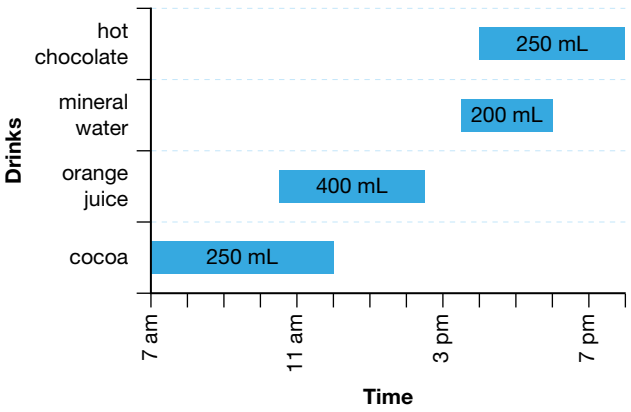


FIGURE 3.4.11

MODULE

3.5 Muscles and bones

Houses have a frame that supports the roof and keeps the walls upright. Your body also has a supporting frame—a system of bones known as your skeleton. Attached to this skeleton are your muscles. Together your bones and muscles form your skeletal/muscular system.

science 4 fun

Flexing muscles

Can you feel your muscles contract and relax?

Do this ...

1. Relax your right arm so that it hangs beside you. Wrap your left hand around your lower right arm (below the elbow) and hold onto it. Then clench your right hand into a fist. Unclench and repeat.
2. Wrap your left hand around your upper right arm (above the elbow). Clench your right fist then raise it to your chin. Lower your arm and repeat.
3. Stand near a wall and place your right hand on it. Wrap your left hand around your upper right arm as before and lean into the wall so that your elbow is bent. Lean further in, then straighten up (as though you were doing single-handed push-ups against the wall).

Record this ...

1. Describe what happened.
2. Explain why you think this happened.

The skeleton

Your **skeleton** is made up of **bones** and acts as your body's frame. The skeleton has three main functions:

- supporting your soft tissues. Without a skeleton, your skin and the organs inside your body would collapse to resemble a jellyfish stranded on the beach. You can see one in Figure 3.5.1. A jellyfish does not have a skeleton but is supported by the water in which it lives. You live on land but are surrounded by air. Air does not provide the same support as water and so you need a skeleton.

Supported by water, a jellyfish has a distinctive shape.

Out of water, a jellyfish becomes a shapeless mass of soft tissue.

FIGURE 3.5.1 A jellyfish has no skeleton and needs water to support it.

- protecting your organs. This is the main role of your **axial skeleton**, which is made up of 80 bones. It includes your skull (which protects your brain), vertebrae (which protect your spinal cord), and ribs and sternum or breastbone (which protect your lungs and heart).
- allowing movement. This is the main role of your **appendicular skeleton**, which is constructed from 126 bones. It includes your pelvis, shoulder blades and collarbones (clavicles), and the bones in your arms and legs.

Figure 3.5.2 shows your axial skeleton (shaded in yellow) and your appendicular skeleton (shaded in blue). Joints within the skeleton allow your body to move.

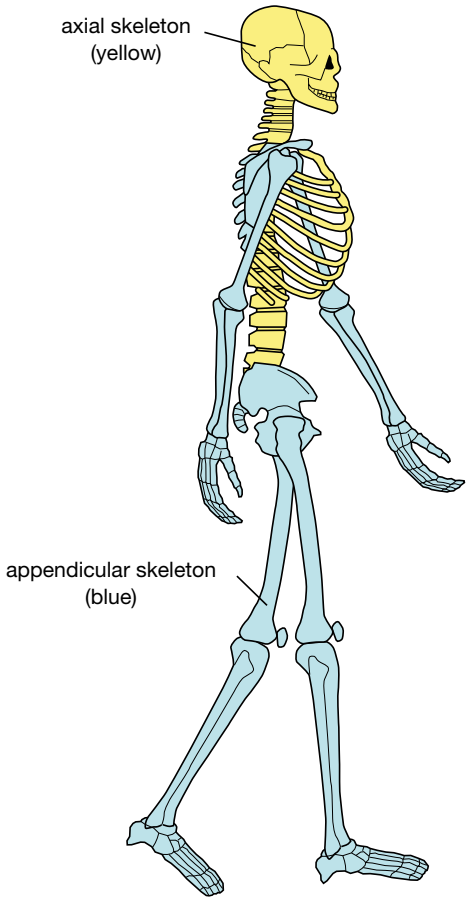


FIGURE 3.5.2 Protection and movement are provided by different parts of the skeleton.

Bones

The main bones of your body are shown in Figure 3.5.3. Bones need to be strong so that they do not snap or crumble during normal activity. Compression forces squash bones and tension forces stretch them. Your leg bones experience compression forces, squashing them when you are standing. The neck is usually under compression too, because the weight of your own head pushes it downwards. Your arms experience tension forces, stretching them whenever you carry shopping bags. Figure 3.5.4 compares compression forces with tension forces.

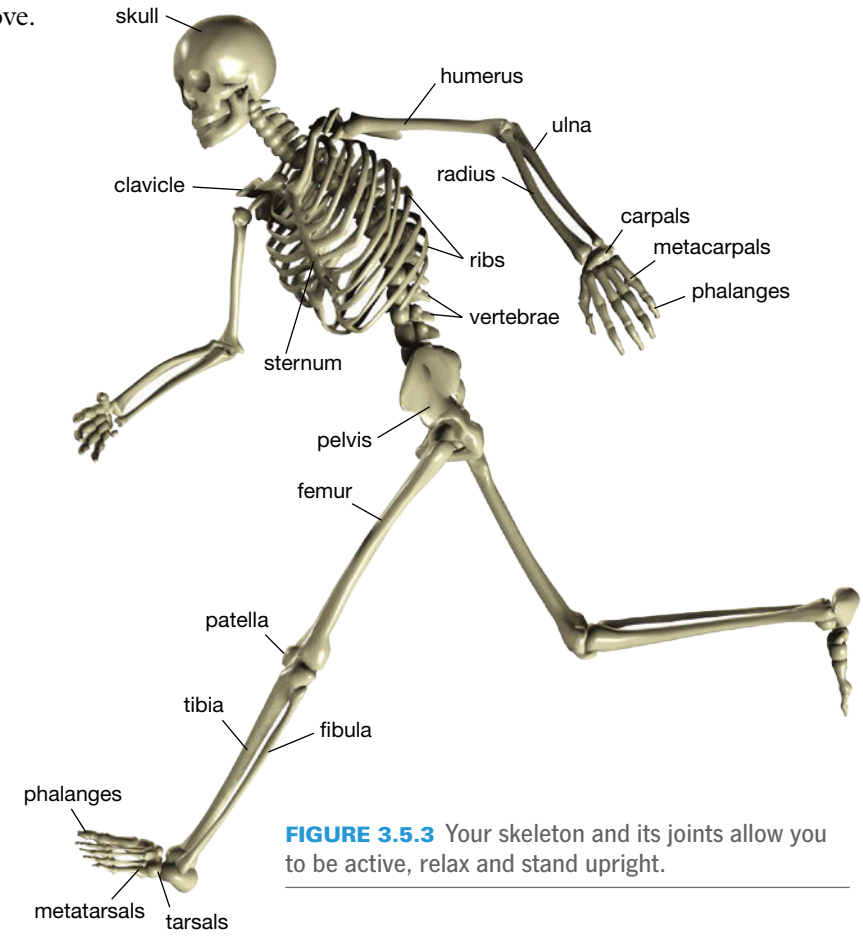


FIGURE 3.5.3 Your skeleton and its joints allow you to be active, relax and stand upright.

SciFile

Different bones

Men usually have bulkier and heavier muscles than women and so a man's bones need to be a little larger and heavier to support them. Some bones, such as the pelvis, also have a different shape. Forensic scientists can use these differences to determine the sex of a skeleton.

FIGURE 3.5.4 Your bones need to be strong enough to resist the forces that stretch them (tension) and squash them (compression).

Bones also need to be slightly elastic. They must be able to flex and twist a little and then return to their original shape and size when the force is removed from them.

Bones must also be light enough for your muscles to move. The strength and lightness of bones comes from their structure. The structure of a typical bone is shown in Figure 3.5.5. Bone tissue has two different forms.

Prac 1 p. 141

- **Compact bone** makes up the outer layer of the bone. Compact bone is dense and heavy and gives the bone much of its strength.
- **Spongy bone** resembles honeycomb. It is light yet provides a strong inner structure to the bone. Gaps in spongy bone are filled with a fatty, jelly-like material called **bone marrow**. Red blood cells and platelets are made in bone marrow, along with some white blood cells.

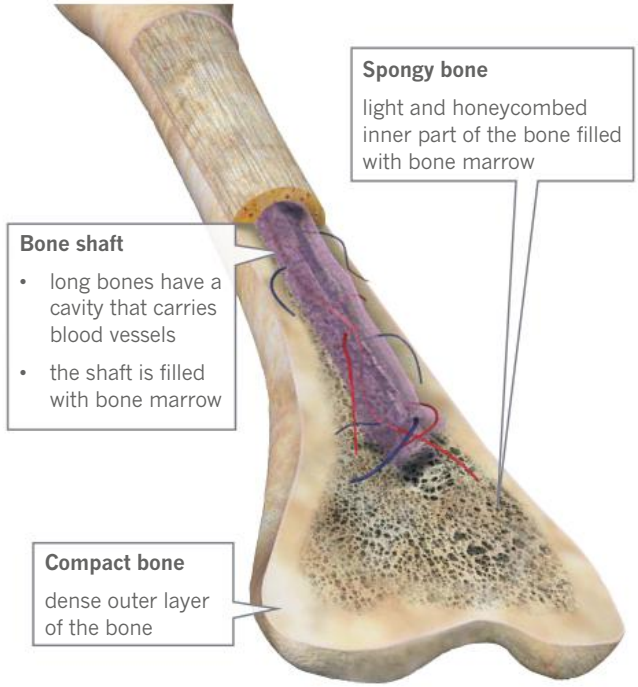


FIGURE 3.5.5 Bones are lightweight and living. This makes them easy enough for your muscles to move and allows them to renew and repair themselves.

science 4 fun

Broken bones

Bones break in much the same way as spaghetti. Does spaghetti (or bone) snap into two pieces or more when broken?

Collect this ...

- strands of dry spaghetti
- tray to collect snapped spaghetti pieces

Do this ...

1. Over the tray, flex a strand of dry spaghetti until it snaps.
2. Count how many pieces it broke into.
3. Repeat until you see a pattern in the number of pieces you get.

Record this ...

1. Describe what happened.
2. Explain why you think this happened.

FIGURE 3.5.6 Both the bones in the lower leg shown here were broken in a ski accident.

Bones are living tissue. They contain living cells that are surrounded by calcium phosphate, a substance that makes the bone hard. They also contain collagen, a material that provides elasticity. Blood vessels supply bone with the nutrients it requires. Bones are living, and hence able to repair themselves and replace worn-out cells.

Joints

A **joint** is where two bones come together. Most joints allow movement, and the type of joint determines the range of movement of the bones. Bone moving against bone would cause pain and the bone would wear down.

To protect your bones from wear, joints have:

- **cartilage**, a smooth and slippery material that covers the ends of bones that are moving against each other. It helps to cushion the impact of movement
- **synovial fluid**, which lubricates the bone ends and allows them to slide over each other freely.

These are both shown in Figure 3.5.7.

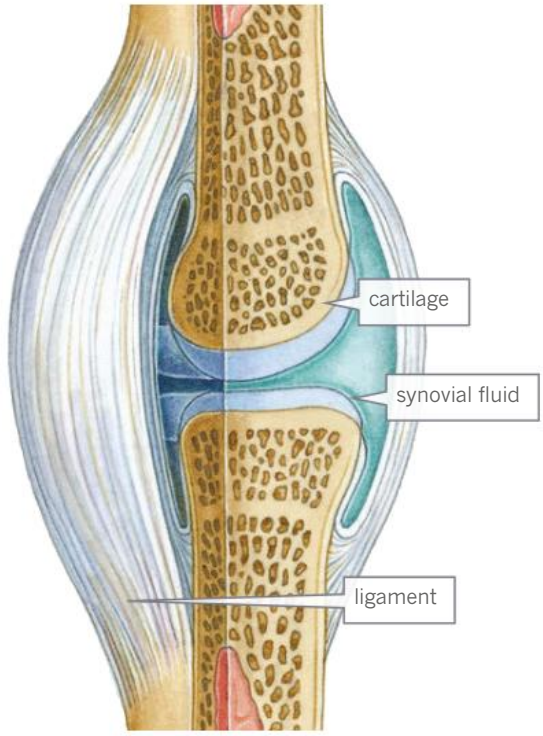
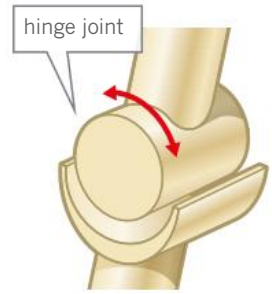


FIGURE 3.5.7 Cartilage and synovial fluid in joints ensure that the bones can move freely over one another.

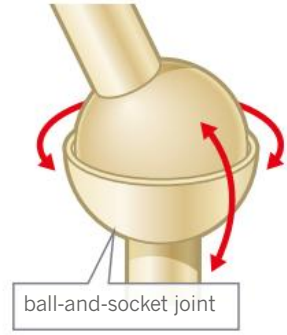
Types of joints

When you are sitting on a chair, your lower leg can move only forwards or backwards. The joint at the knee does not allow the lower leg to move from side to side. Using the hip joint, you can move your leg to make a complete circle with your toes. This is because your hip and knee are different types of joints.

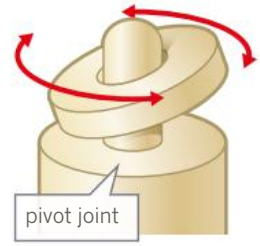
In a **hinge joint**, the ends of the bones are shaped so that movement is allowed in only one plane—backwards and forwards like the hinge of a door. There is a hinge joint between the bone of the upper arm (humerus) and the larger bone of the lower arm (ulna). Other examples are the knee joint and the joints in your fingers.



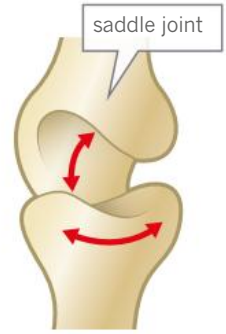
In a **ball-and-socket joint**, one bone has a ball-shaped surface that fits into a cup-shaped socket in the other bone. The bone with the ball at its end is able to complete all types of movement. You have ball-and-socket joints in your hips and shoulders.



A **pivot joint** moves by a ring-shaped bone turning around another bone shaped like a finger. A pivot joint allows a wide range of movement. The joint at the base of your skull that allows you to turn your head is a pivot joint.



A **saddle joint** allows movement in two directions but does not allow the same amount of movement as a ball and socket joint. Saddle joints are found in the ankle and the base of the thumb.



AB 3.9

Ligaments

Ligaments are bands of tough, flexible tissue that hold the bones in a joint together. Ligaments prevent the bones of the joint from moving too far apart. Figure 3.5.8 shows the ligaments in the foot.

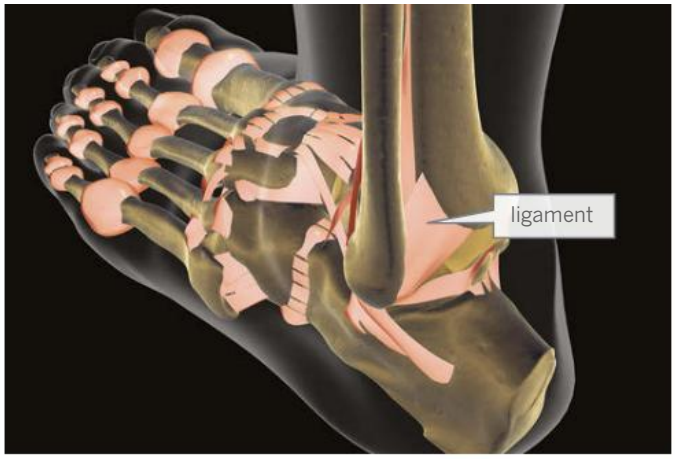


FIGURE 3.5.8 Ligaments hold all the bones of the foot together. Without them the foot would not be able to work as a single unit.

Muscles

It is your muscles that move bones. **Muscles** are tissues that are able to contract (shorten) and be stretched. You have 640 muscles, regardless of whether you are a couch potato or a body builder. Some of the main muscles are shown in Figure 3.5.9. **Tendons** are tissues that attach muscles to bones and hold the muscles in position. When activated, muscles contract, becoming fatter and shorter. They pull on the bones they are attached to, causing them to move.

Muscles can only pull. They cannot push. Therefore, another muscle is required to return the bone to its original position. For this reason, your muscles are arranged in **antagonistic pairs**. Antagonistic means that they work in opposition to each other. The biceps and triceps are antagonistic muscles in your upper arm. The biceps contracts when activated, pulling your forearm up. The biceps then relaxes. To lower the forearm, the triceps contracts. The relaxed biceps is stretched back to its original shape and the arm is straightened. This action is shown in Figure 3.5.10.

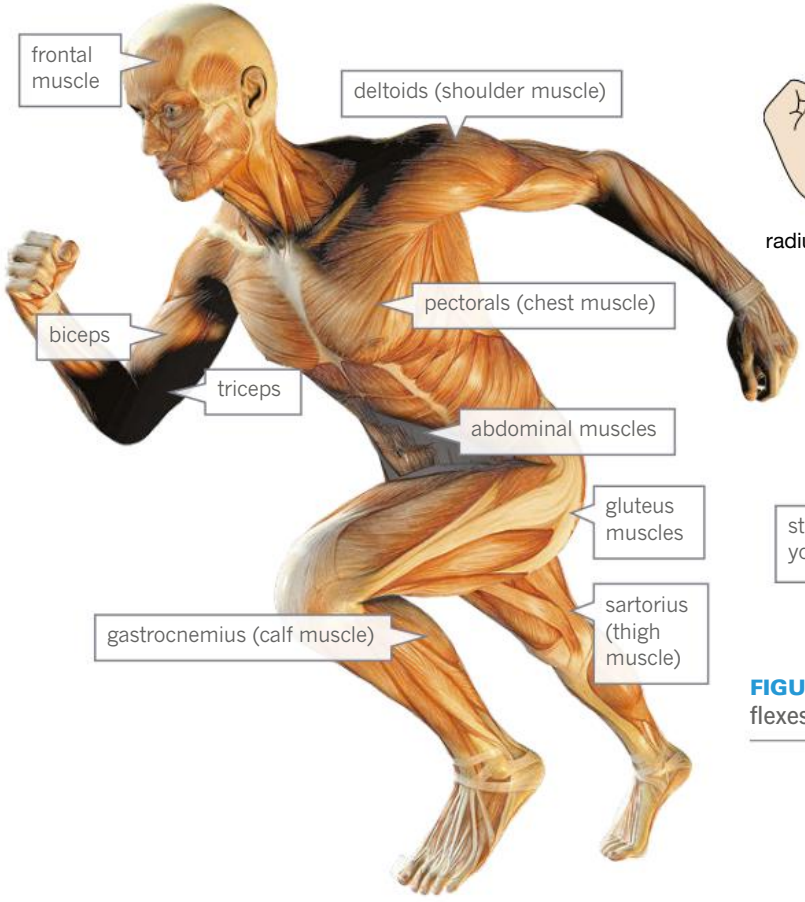


FIGURE 3.5.9 The human muscular system. The pale areas are tendons joining muscles to bones.

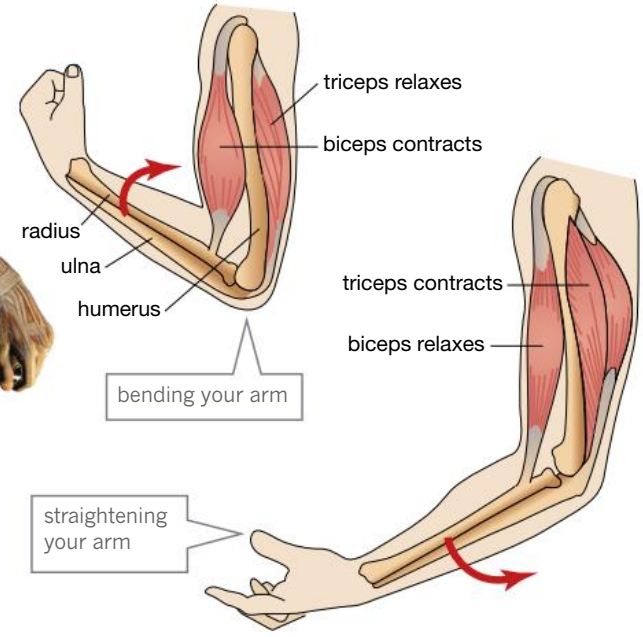


FIGURE 3.5.10 Muscles work in antagonistic pairs. The biceps flexes the arm; the triceps straightens it.

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MODULE 3.5

Review questions

Remembering

1 Define the terms:
   - a bone marrow
   - b cartilage
   - c tendons
   - d antagonistic pair.

2 What term best describes each of the following?
   - a the set of bones that allow movement
   - b honeycomb-like bone
   - c lubricating fluid in joints
   - d bands that hold bones together in a joint.

3 List the roles the skeletal/muscular system carries out in the human body.

4 How many bones are there in the adult human skeleton?

5 List the characteristics of bones.

6 How many muscles are found in the human body?

Understanding

7 The bones in your arm need to perform well under the forces of both compression and tension. Explain why.

8 Predict what the movement of your head would be like if its pivot joint was replaced with a hinge joint.

9 Describe where the following are found and what they do.
   - a ligaments
   - b tendons
   - c cartilage.

Applying

10 Identify the property of cartilage that reduces friction in a joint.

11 Use the biceps and triceps to explain why muscles need to be arranged in antagonistic pairs.

Analysing

12 Analyse Figure 3.5.7 on page 138 and predict what would happen to the joint if:
   - a cartilage wore away (osteoarthritis)
   - b excess synovial fluid built up (rheumatoid arthritis).

13 Contrast:
   - a the axial and appendicular skeleton
   - b compact and spongy bone.

14 Compare the amount and direction of movement allowed by a hinge joint and a:
   - a ball-and-socket joint
   - b saddle joint.

Evaluating

15 Propose reasons why your wrists and ankles have extra ligaments forming 'cuffs' around them.

16 Your spine extends from the base of your skull to the base of your pelvis. It holds your body upright but also allows you to flex and bend. How do you think this is achieved?

17 Arthritis is pain in the joints. What do you think might cause this pain?

18 Babies have 100 more bones than adults. What do you think happens to these 100 bones as a baby grows up?

19 Figure 3.5.6 on page 137 shows a broken tibia (the thicker bone) and broken fibula (the thinner bone).
   - a State how many pieces each of these bones has broken into.
   - b Propose reasons why the two bones broke in different ways.

Creating

20 Construct a diagram showing the position of the muscles of the leg that cause the knee to bend and straighten.

MODULE 3.5

Practical investigations

1 • Hollow bones

Questioning & Predicting | Evaluating

Long bones are hollow along their centre and can be modelled using hollow paper cylinders.

Purpose

To test whether the strength of a bone depends on whether it is hollow or not.

Hypothesis

Which do you think will be stronger: thick, hollow bones or thin, solid bones? Before you go any further with this investigation, write a hypothesis in your workbook.

Timing 45 minutes

Materials

- 9 sheets of recycled A4 paper
- 2 paper plates
- sticky tape
- 30 cm ruler
- assorted masses

SAFETY

Build your structure in a place that won't be damaged when it collapses.

Procedure

1. Copy the table from the Results section into your workbook. Give your table a title.
2. Roll three A4 sheets into identical cylinders, forming hollow tubes. Attach a few pieces of tape to stop them unrolling.
3. Measure the outer diameters of the cylinders (in millimetres). Record them in your Results table.
4. Stick the cylinders on one of the paper plates to form a triangular base, as shown in Figure 3.5.11. Stick the other paper plate on top.
5. Add masses to the top paper plate and keep adding masses until the cylinders buckle and collapse. Record the total mass that just caused the cylinders to buckle.
6. Repeat the experiment, but this time roll the A4 sheets into tighter cylinders, with a smaller diameter and with less of a hollow tube along the centre.
7. Once again, repeat but with cylinders with very thin walls and a large hollow tube down their centre.

Results

Use the table below to record your measurements.

Trial	Outer diameter (mm)	Mass that caused buckling (g)
1		
2		
3		

Review

1. All the cylinders you made had exactly the same mass. Explain why.
2. **a** Construct a conclusion for your investigation.
   b Assess whether your hypothesis was supported or not.
3. What are the advantages of having hollow bones instead of solid bones?
4. Identify animals that would benefit from having hollow bones instead of solid bones.

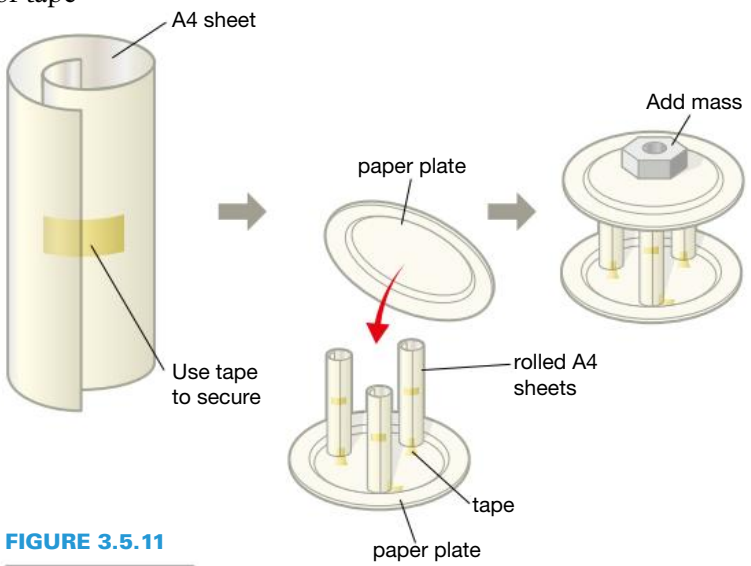


FIGURE 3.5.11

MODULE 3.5

Practical investigations

2 • Investigating muscles and bones

Planning & Conducting | Processing & Analysing

Purpose

To investigate the structure of a chicken wing.

Timing 45 minutes

Materials

- uncooked chicken wing
- disinfectant
- dissecting kit (scalpel, scissors, tweezers/ forceps)
- dissecting board
- newspaper
- access to stereo microscope

SAFETY

Take care with sharp instruments.

Wear disposable gloves while dissecting the chicken wing.

Wash your hands thoroughly after completing the dissection.

Procedure

1. Cover your workbench with newspaper and then set the dissecting board on top of it.
2. Lightly cut the skin of the wing down its length.
3. Use the tweezers to help you gently peel back the skin to expose the muscles. Record what they look and feel like and how they connect to the bones.
4. Once the muscles are exposed, flex the wing so that it opens and shuts. Record what happens.
5. Cut the muscle and fat off the wing to expose the bone. Record how the different bones of the wing connect to each other.
6. Try to break one of the bones. If successful, carefully look at the inside of the bone or its fragment, perhaps under a stereo microscope. Record what you see.

Review

1. Did you see an antagonistic muscle pair in the wing?
2. Describe the function of the muscles in the chicken wing.
3. Describe what tendons do.
4. Bird bones are extremely light and much less dense than the bones of most other animals. Propose a reason why.

• STUDENT DESIGN •

3 • Model joints

Planning & Conducting | Evaluating

Purpose

To construct models of the different joints found in the human body.

Timing 120 minutes

Materials

- selection of joint materials

SAFETY

A risk assessment is required for this investigation.

Procedure

1. Refer to page 138 and decide which type of joint you are going to build a model of.
2. Analyse the joint, how it is 'strapped' with ligaments, and what materials could represent each part.
3. Construct your model and demonstrate it to the class.
4. Use the STEM and SDI template in your eBook to help you plan and carry out your investigation.

Review

1. Describe the movement that this type of joint gives the bones attached to either side of the joint.
2. Where in your body are these types of joints most likely to be found?
3. Evaluate your model. Pick two other prac groups and evaluate their models too, identifying their strengths and weaknesses.

MODULE 3.5

Practical investigations

• STUDENT DESIGN •

4 • Muscle fatigue

Questioning & Predicting | Evaluating

Purpose

To test how quickly your hand muscles fatigue (get tired).

Hypothesis

What do you think will happen as the muscles in your hand start to fatigue? Which do you think will fatigue more quickly—your right or left hand? Before you go any further with this investigation, write a hypothesis in your workbook.

Timing 30 minutes

Materials

- springy test-tube clamp or similar
- stopwatch or access to clock or watch with second hand

SAFETY

A risk assessment is required for this investigation.

Procedure

1 Brainstorm in your group and come up with several different ways to investigate how quickly the muscles in your hands fatigue. Select the best procedure that:
   - **a** measures how many hand squeezes you (and your prac partner) can do in 30 seconds
   - **b** compares your right and left hands.

2 Write your procedure in your workbook.

3 Construct a suitable table or spreadsheet to record your results. Give your table or spreadsheet a title. It could be similar to the one shown in the Results section.

4 Before you start any practical work, assess your procedure. List any risks that your procedure might involve and what you might do to minimise those risks. Show your teacher your results table, your procedure and your assessment of its risks. If your teacher approves, then collect all the required materials and start work.

Hints

- Make sure each squeeze is exactly the same.
- Stop the exercise if your muscles haven't fatigued after 2½ minutes.
- Use the STEM and SDI template in your eBook to help you plan and carry out your investigation.

Results

1 Record the results in your table or spreadsheet.

Time (s)	Number of squeezes completed by me		Number of squeezes completed by my partner	
	R	L	R	L
30				
60				
90				
120				
150				

2 Plot a line graph showing the number of squeezes completed against time for your right hand. Place the number of squeezes on the vertical axis and time on the horizontal axis. On the same axes, plot another line for your left hand and for each hand of your prac partner.

Review

1 **a** Construct a conclusion for your investigation.
   b Assess whether your hypothesis was supported or not.

2 What do you think the term *muscle fatigue* means?

3 Why do you think some people experience muscle fatigue more quickly than others?

4 Evaluate your procedure. Pick two other groups and evaluate their procedures as well, identifying their strengths and weaknesses.

SciFile

Muscle facts

Muscles make up around half the weight of an adult male and about one-third the weight of an adult female. Your smallest muscle is the stapedius muscle in your middle ear—it is only 1 mm long!

FIGURE 3.5.12 Smiling uses twelve facial muscles, while frowning uses eleven.

MODULE 3.5

Practical investigations

STEM INQUIRY

Biometric information

Planning & Conducting | Processing & Analysing

Background

A pesticide research laboratory requires that all their scientists wear latex gloves at all times. A hand identification security system is needed to screen the scientists as they enter the toxic and controversial laboratory. Fingerprint recognition will not work here.

Timing 90 minutes

Problem

A handprint touch pad system needs to be designed that can make measurements of a person's hand and calculate ratios of these measurements to identify each individual entering the laboratory.

In designing this touch pad system, your task is to work out what measurements and ratios to use that will distinguish between different individuals. In your design proposal you must justify your approach with data you have collected and a clear explanation of your reasoning.

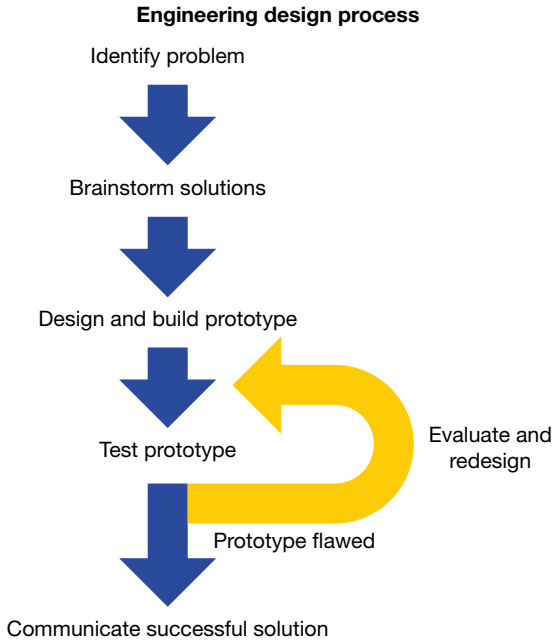


FIGURE 3.5.13 Understanding the engineering design process. Engineering involves the application of science to design, construct and maintain structures, machines and devices.

Procedure

1. Investigate the differences in a group of individual's hands.
2. Analyse the problem, identify variables and propose solutions.
3. Following an investigation, propose a series of measurements that distinguish these differences.
4. Make a decision on the basis of data collected.
5. Present the proposal in a form that enables the reader to see the relationship between the data and the conclusions reached.
6. Accurately communicate your conclusions.
7. Justify the decision in a report that describes the testing procedure and makes reference to the data collected.

Hints

- What are you trying to achieve?
- How will you systematically investigate the different parts of the hand to be measured?
- How do you standardise the method for measuring the hand dimensions?
- How will you measure these? (instruments, units)
- How many people will you need to measure, to confirm that the data collected is unique to each individual?
- Are there measurable differences between a person's left and right hand?
- Use the STEM and SDI template in your eBook to help you plan and carry out your investigation.

Materials & equipment

- Use the STEM and SDI template in your eBook to help you plan and carry out your investigation.
- measuring tape
- calipers
- calculator
- ruler
- paper to trace around each hand being measured

CHAPTER 3

Chapter review

Remembering

1 Name the body system that:
- **a** distributes heat throughout the body
- **b** gets rid of wastes produced by the body
- **c** allows the body to move
- **d** inhales and exhales gases
- **e** absorbs nutrients.

2 List these in the order that:
- **a** food will pass through as it passes through the digestive system
  large intestine, mouth, stomach, ileum, duodenum, oesophagus
- **b** inhaled air will pass through, in the respiratory system
  bronchi, trachea, nasal cavity, alveoli, pharynx, bronchiole
- **c** urine passes through, in the urinary tract
  urethra, ureter, kidney, bladder

3 Which of these statements are true and which are false?
- **a** The role of the teeth is mechanical digestion.
- **b** Your diaphragm contracts as you inhale.
- **c** Arteries carry blood towards the heart.
- **d** The urethra is the tube that expels urine from the body.
- **e** The axial skeleton protects your organs.

4 Name three organs in the excretory system.

5 Name three things produced in the bone marrow.

6 How many bones make up the following?
- **a** the axial skeleton
- **b** the appendicular skeleton.

7 What is the advantage of bone being a living tissue?

Understanding

8 Why are the lungs included in both the respiratory system and the excretory system?

9 Explain why urine is a darker colour on a hot day.

10 Describe three situations in the body where a large surface area helps the functioning of a system.

11 Major arteries are a long way from the body surface. Explain why.

12 Describe the function of:
- **a** tendons
- **b** ligaments
- **c** joints.

Applying

13 You take in about 500 mL of air in one breath, and breathe 12 times a minute. Calculate how much air you take into your body every hour.

14 Identify the organs labelled A–J in Figure 3.6.1.

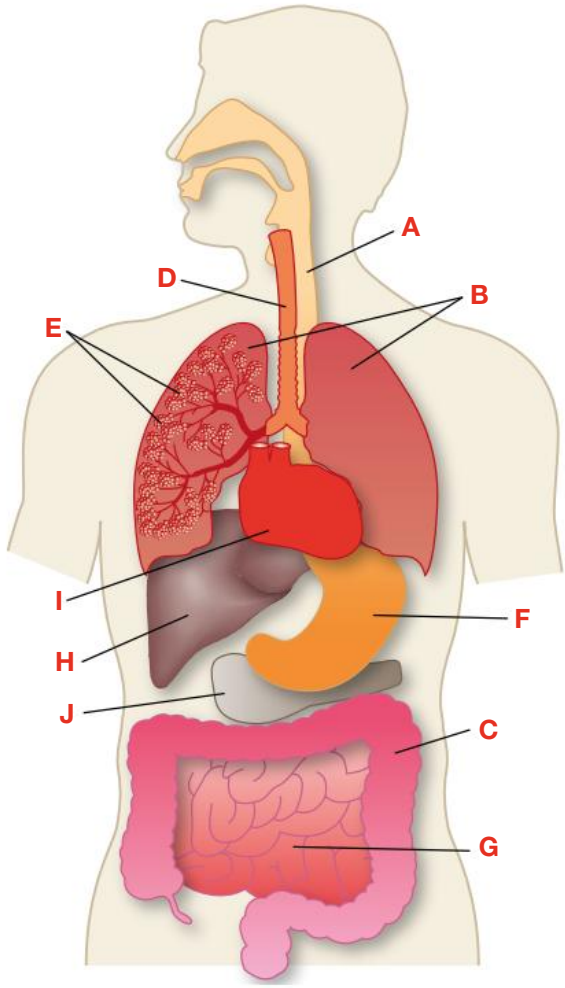


FIGURE 3.6.1

CHAPTER 3

Chapter review

15 Identify each of the following body parts.

- **a** a slippery elastic tissue found on the ends of bones
- **b** the structure that carries urine out of the body
- **c** the joint that allows movement in two directions
- **d** a tissue that can contract and be stretched but cannot expand.

Analysing

16 a Use the information in the table below to calculate the amount of oxygen that enters your blood for 1 hour while you are sleeping. Assume you breathe 12 times per minute, inhaling 500 mL of air with each breath.

b Calculate the amount of carbon dioxide you would breathe out in that time.

c i Compare the amount of oxygen and carbon dioxide breathed out during sleep and during exercise.

ii Account for any differences.

d i Compare the amount of nitrogen breathed in and out.

ii Account for any differences.

Composition of air breathed in and out during sleep and exercise

Gas	Composition of air (%)		
	Breathed in	Breathed out during sleep	Breathed out during exercise
nitrogen	78	78	78
oxygen	21	16	11
carbon dioxide	0.03	4	9.5
water vapour	a little	saturated	saturated

17 Compare the alveoli in the lungs with the lining of the small intestine.

Evaluating

18 There have been situations where people have drunk their own urine to survive in the desert when they had run out of water. Assess how this would change the composition of the urine they would produce the following day.

19 Some athletes strap their wrists, ankles, knees and shoulders when playing sport. Propose reasons why.

20 Birds have hollow bones with very little compact bone. What advantage do you think this characteristic gives them?

21 Dialysis is a process that uses a machine to filter wastes out of blood. The process is used if a person's kidneys stop working efficiently. Dialysis must take place at least three times a week and requires the person to be connected to the dialysis machine for 4–6 hours each time.

a Use this information to calculate the minimum time a person needs to be connected to the dialysis machine each week.

b Based on this calculation, what do you think are the disadvantages of kidney dialysis?

22 a Assess whether you can or cannot answer the questions on page 93 at the start of this chapter.

b Use this assessment to evaluate how well you understand the material presented in this chapter.

Creating

23 Use the following ten key terms to construct a visual summary of the information presented in this chapter.

digestion	respiration
excretion	circulatory system
heart	diffusion
glucose	oxygen
breathing	kidneys

AB 3.12

CHAPTER 3

Inquiry skills

Research

1 Processing & Analysing

Search the internet for videos or images showing:

- what happens when you breathe
- how the heart's atria and ventricles pump blood
- snake digestion
- the gill structures of fish.

2 Processing & Analysing Communicating

Find the EdHeads website and use it to:

- perform interactive surgery to repair a weakened aorta
- choose the best replacement knee
- perform interactive surgery to replace a knee or hip.

3 Processing & Analysing Communicating

Before modern technology, scientists had great difficulty finding out what happened inside the body. Alexis St Martin contributed a great deal to knowledge of the human digestive system. Find out how he was able to contribute so much.

Present your research as a report for a science magazine aimed at young teenagers.

4 Processing & Analysing Communicating

Research asthma. Find out what:

- happens in the lungs when a person has an asthma attack.
- asthma inhalers such as Ventolin® do.
- causes asthma
- a peak flow meter is and what it does
- first aid measures should be taken if someone near you has an asthma attack.

Present your research as a poster, video or PowerPoint presentation to be displayed in on the walls or TV in doctors' waiting rooms.

5 Processing & Analysing Communicating

Find out what a hamstring is, how it is torn and ways of minimising the risk of such tears when playing sport.

Present your research as a pamphlet to be given out by coaches and sport physiotherapists.

6 Processing & Analysing Communicating

Research heart transplants and heart/lung transplants. Find:

- when the first transplants were performed in the world and in Australia
- how many of each type of transplant are performed each year (on average) in Australia
- the rules that govern which donor hearts and lungs can be used
- the technologies that allowed these transplants to be performed more successfully
- who Doctor Victor Chang was and why he was so important for transplants in Australia.

Present your research in digital form.

7 Processing & Analysing Communicating

Patients with kidney failure usually need to undergo regular dialysis. Find:

- what dialysis is and what it does
- why the person undergoes dialysis and not a kidney transplant
- how frequently and for how long they need to undergo dialysis per week
- the advantages and disadvantages of dialysis.

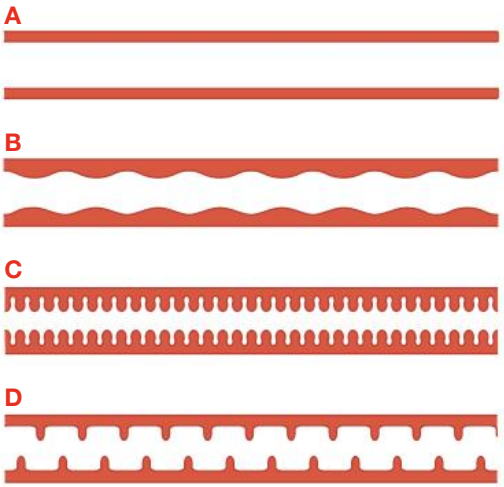
Present your findings in digital form.

CHAPTER 3

Inquiry skills

Thinking scientifically

1 The linings of the small intestines of four animals are shown below.



a Which intestine would be the most effective in absorbing nutrients from food?

b Which intestine would be the least effective in absorbing nutrients from food?

2 Figure 3.6.2 represents the lungs of a frog.

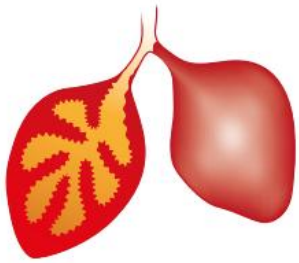


FIGURE 3.6.2

Which of the following statements best compares the structure of frog lungs with the structure of human lungs?

A Frog lungs have greater surface area than human lungs and so will be more effective in exchanging gases.

B Frog lungs have greater surface area than human lungs and so will be less effective in exchanging gases.

C Frog lungs have lesser surface area than human lungs and so will be more effective in exchanging gases.

D Frog lungs have lesser surface area than human lungs and so will be less effective in exchanging gases.

3 Figure 3.6.3 is a graph of a person's pulse rate.

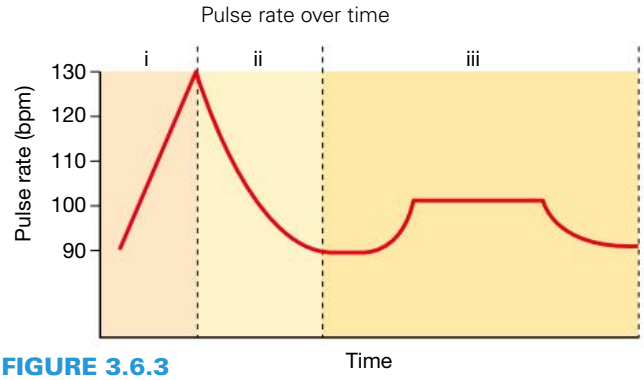


FIGURE 3.6.3

Which of the following do you think best describes what is happening in parts i, ii and iii?

A i = running, ii = resting, iii = walking

B i = walking, ii = relaxing, iii = running

C i = resting, ii = walking, iii = running

D i = running, ii = walking, iii = resting

Refer to Figure 3.6.4 for questions 4 and 5.

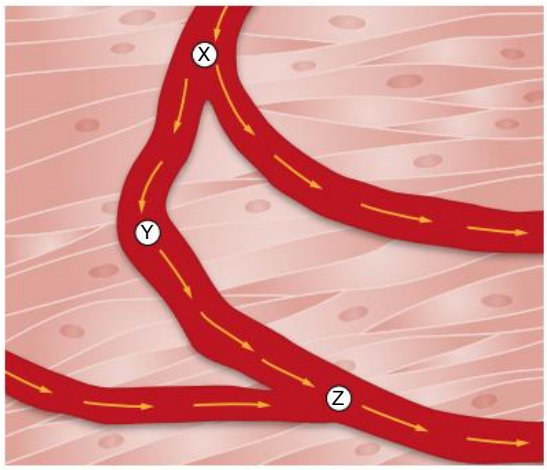


FIGURE 3.6.4

4 Where would the oxygen content in the blood be the highest in the blood vessels shown in Figure 3.6.4?

A X C Z

B Y D none of the above

5 Where would the carbon dioxide content in the blood be the highest in the blood vessels shown in Figure 3.6.4?

A X C Z

B Y D none of the above

CHAPTER 3

Glossary

alveoli: a cluster of sacs at the end of the bronchioles where gas exchange takes place; a single sac is called an alveolus

angina: severe chest pain caused by lack of oxygen being supplied to heart muscle

antagonistic pairs: pairs of muscles that work in opposition to each other

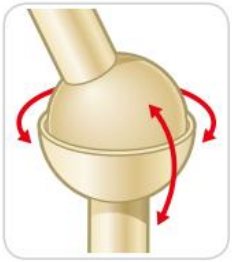
anus: a sphincter muscle at the end of the digestive tract

appendicular skeleton: the bones whose main role is to allow the skeleton to move; includes the pelvis, bones of the limbs and shoulder blades

artery: a blood vessel that carries blood away from the heart

axial skeleton: the bones whose main role is to protect the organs; includes the skull, vertebrae, sternum and ribs

ball-and-socket joint: a joint in which one bone has a ball-shaped surface that fits into a cup-shaped socket of another bone. The bone with the ball at its end is able to move in all directions.



ball-and-socket joint

bile: a greenish liquid responsible for mechanical digestion of fats

bladder: a muscular bag where urine is stored before it is expelled from the body

bolus: food rolled into a ball by the tongue

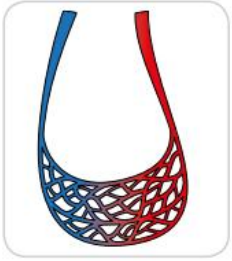
bone marrow: jelly-like material in which new blood cells are made

bones: structures that make up the skeleton

bronchi: tubes formed by the division of the trachea

bronchioles: small tubes formed by the division of the bronchi

capillary: the narrowest type of blood vessel; capillaries reach nearly every cell of the body



capillaries

cardiac muscle: the type of muscle found in the heart

cartilage: tissue with a smooth and slippery surface allowing smooth movement of a joint

cells: the building blocks of all living things

cholesterol: a fatty chemical that can cause blockages in arteries

cilia: tiny hairs lining the nostrils

circulatory system: the system that carries materials around the body; it consists of the heart, blood vessels and blood

circulatory system

compact bone: dense tissue forming the outer layer of a bone

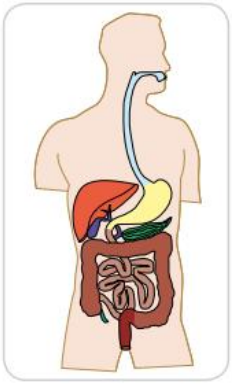
defecation: getting rid of solid waste

deoxygenated blood: blood with very little oxygen and lots of carbon dioxide

diaphragm: a sheet of muscle that separates the chest from the abdomen

digestion: the process of breaking down food into a useable form

digestive system: the system of the body where digestion takes place



digestive system

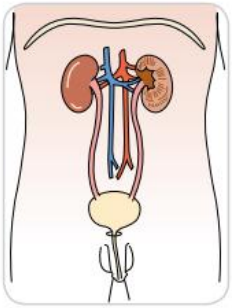
donor: someone who donates an organ or tissue for transplanting

duodenum: the first part of the small intestine

epiglottis: the flap of skin in the oesophagus that stops food entering the windpipe

excretion: getting rid of the wastes that the body has produced

excretory system: the system in the body that gets rid of wastes that the body has produced

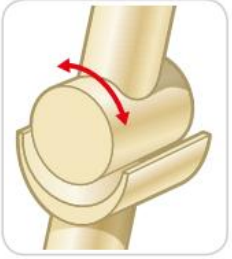


excretory system

gastric juice: a mixture of chemicals produced by cells in the stomach wall

haemoglobin: the pigment that gives red blood cells their colour

hinge joint: a joint that allows movement in only one plane



hinge joint

ileum: the second part of the small intestine and the place where absorption of food takes place

joint: the place where two bones meet

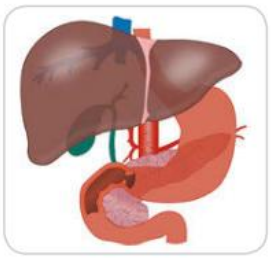
CHAPTER 3

Glossary

large intestine: the final section of the digestive tract

ligaments: fibrous bands of tissue that hold bones together in a joint

liver: the largest internal organ; it produces bile



liver

muscles: tissues that can contract and, when attached to bones, cause the bones to move

oesophagus: the part of the digestive system that connects the mouth to the stomach

organ: a structure that contains at least two different types of tissue that work together to complete a task

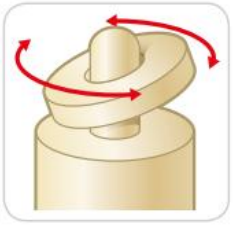
oxygenated blood: blood rich in oxygen

pancreas: an organ associated with the digestive system that produces chemicals to help the digestion of carbohydrates, fats and proteins

peristalsis: the process of pushing food through the digestive tract by alternating contraction and relaxation of muscles

pharynx: the cavity at the back of the nose, connecting the mouth and nose to the oesophagus

pivot joint: a joint like the one at the base of your skull that allows a wide range of movement



pivot joint

plaque: a mixture of cholesterol, calcium and fibrin that can build up on the inside of arteries and reduce blood flow to the heart

pulse: the regular expansion and contraction of the arteries in response to the heartbeat

recipient: someone who receives an organ or tissue for transplanting

rejection: when an organ recipient's immune system attempts to destroy the transplanted organ

respiration: the series of chemical reactions that takes place in cells to release energy

respiratory system: the system of organs and tissues that takes air into the body

saddle joint: a joint that allows movement in two directions

saddle joint

saliva: watery liquid containing a chemical that begins the digestion of starch

skeleton: bony structure that holds the body upright, protects its organs and allows movement

small intestine: the longest part of the digestive tract

sphincter: a circle of muscle

spongy bone: bone that has a honeycombed structure; makes up much of the inner structure of a bone

synovial fluid: lubricating liquid in a joint

tendons: elastic tissue that attaches the muscles to the bones

thrombus: a blood clot

tissue: a group of cells of the same type that carry out the same job in the body

trachea: the tube that carries air from the nose and mouth into the chest cavity

trachea

urea: a waste product from the breakdown of proteins

ureters: narrow tubes that carry urine to the bladder

urethra: a tube that carries urine to the outside of the body

urinary tract: kidneys, bladder, ureters and urethra

vein: blood vessel that carries blood back to the heart

vein

villi: microscopic 'fingers' that greatly increase the surface area of the wall of the small intestine

AB 3.11

CHAPTER

4 Reproduction

Have you ever wondered ...

- why animals have different sexes?
- why males and females are different?
- why there are so many different types of flowers?
- what happens during the 40 weeks of pregnancy?

LS

After completing this chapter you should be able to:

- outline how cells reproduce via cell division
- contrast asexual and sexual reproduction
- compare reproductive systems of organisms
- identify the organs and overall function of the reproductive system
- describe the structure of each organ in the reproductive system
- describe the specialised cells and tissues involved in structure and function of particular organs
- describe the impact of plant cloning techniques in agriculture
- describe how technology and modern farming techniques have improved yields and sustainability
- research the use of reproductive technologies and how they rely on scientific knowledge from different areas of science
- outline how a knowledge of cells and cell divisions has assisted in treating and controlling disease.

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AB 4.1

MODULE

4.1 Sexual reproduction

Nothing lives forever. An insect may live for only a few weeks. A tree may last thousands of years. Since every individual will eventually die, there must be a way of producing new individuals or the species would become extinct. This production of new individuals by parents is called reproduction. It is one of the most amazing processes in nature.

science 4 fun

Reproduction in the garden

Can you find examples of reproduction in the garden?

Collect this ...

- digital camera or mobile phone with camera function

Do this ...

1. Search around a garden, local bush or a park for evidence of reproduction. Evidence could be different stages in the life cycle of:
   - an insect, such as eggs, larvae, pupae or adult insects, like those shown in Figure 4.1.1
   - a plant, such as flowers, seed cases, seeds, fruits or seedlings.
2. Take photos of this evidence.

Record this ...

1. Describe what you observed, by producing a digital slide show.
2. Explain why you think your images represent reproduction.

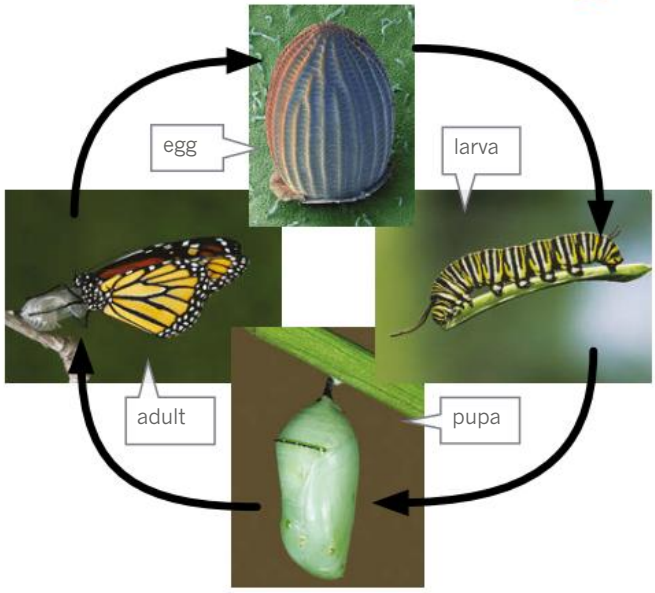

FIGURE 4.1.1 The wanderer butterfly develops in four distinct stages. All are evidence of reproduction.

Reproduction

Reproduction is the process by which parents produce new individuals. These new individuals are commonly called **offspring**.

There are two basic methods of reproduction:

- sexual reproduction—this usually requires two parents
- asexual reproduction—asexual means without sex, and so it only needs one parent.

Although most plants and animals use only one of these methods, some can use both.

Making a new individual

Sexual reproduction happens when a sperm from a male enters an egg from a female and fertilises it. The process is called **fertilisation**. Sperm and eggs are special reproductive cells, known as **gametes**. The male gamete is sperm and the female gamete is the egg. Fertilisation results in a new cell called a **zygote**. The zygote then grows by dividing to form many copies of itself. The zygote eventually grows and develops into a new individual. Although Figure 4.1.2 shows many human sperm around a single egg, only one sperm is required to fertilise it.

Many species, including humans, dogs, cattle, birds and kangaroos, undergo sexual reproduction that requires one male and one female.

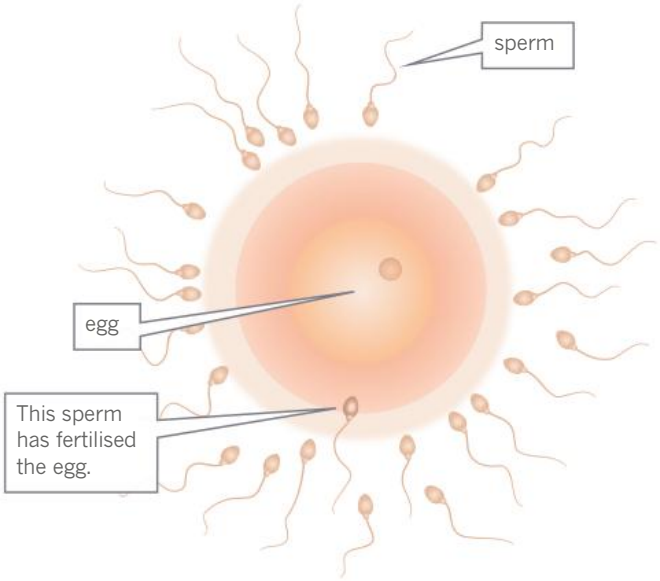

FIGURE 4.1.2 There are many sperm swimming around an egg but only one will enter and fertilise it.

Some species, such as true tapeworms, have individuals that have both male and female sex organs. They can therefore produce both sperm and eggs. Individuals with both sex organs are known as **hermaphrodites**. For example, snails, slugs and flatworms are hermaphrodites (Figure 4.1.3).

FIGURE 4.1.3 Snails are hermaphrodites—they have both male and female sex organs. They cannot fertilise themselves, so they still need two parents to reproduce.

SciFile

Sex-change fish

All barramundi are born male. At the age of 3–5 years, they then all change sex to become females!

Clownfish all start off life as males, but can change sex to female. This happens if the dominant female in an area dies. The dominant male then changes sex to female. Some wrasse fish can change sex from female to male.

barramundi

clownfish

Cell division and gametes

Cells normally reproduce by splitting into two to form two identical cells, each cell containing all the genetic information it needs. The process is called **mitosis**. It happens in almost every cell of your body and allows your body to grow and repair itself. However, sperm and eggs are formed by a different type of cell division. This process is called **meiosis** and occurs only in the male and female reproductive organs. In meiosis, each gamete splits into four cells, all different from one another.

Unlike other cells, each new gamete only has half the genetic information that a normal cell has. In order to obtain the full amount of genetic information, a sperm cell needs to fertilise an egg cell. The single fertilised cell has all the genetic information that will allow it to grow into a new individual.

This fertilised cell is known as the zygote. It then divides repeatedly by mitosis. Each cell splits in two, doubling the number of cells at each division until a new individual is formed. Every new cell in the individual comes from copying the original zygote cell formed at fertilisation. This is shown in Figure 4.1.4.

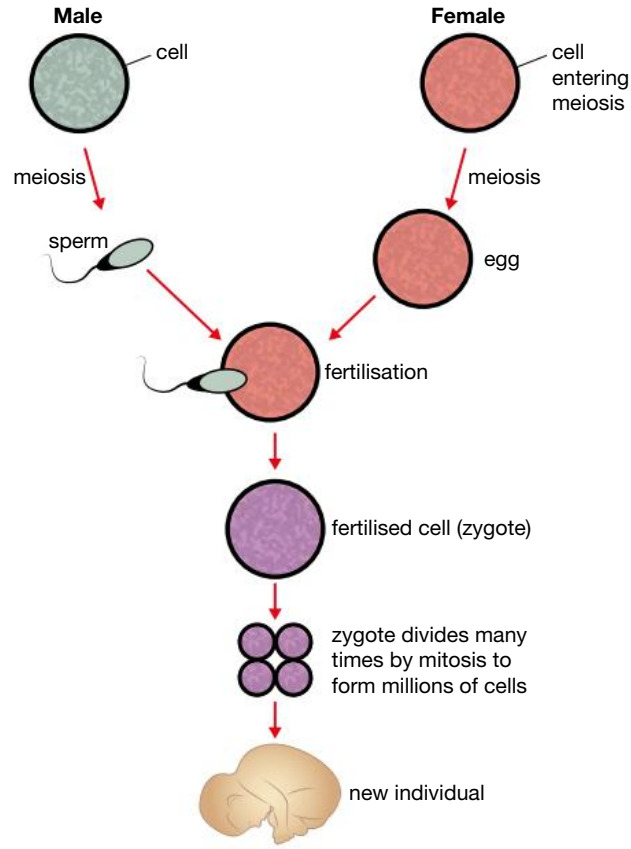

FIGURE 4.1.4 Meiosis forms gametes with only half the required genetic information. Upon fertilisation, the zygote cell has all the genetic information required to form a new individual.

Sexual reproduction in animals

There are many different types of reproductive systems in animals. Some are shown in Figure 4.1.5. Although these animals are very different, they have many similar parts that have basically the same function.

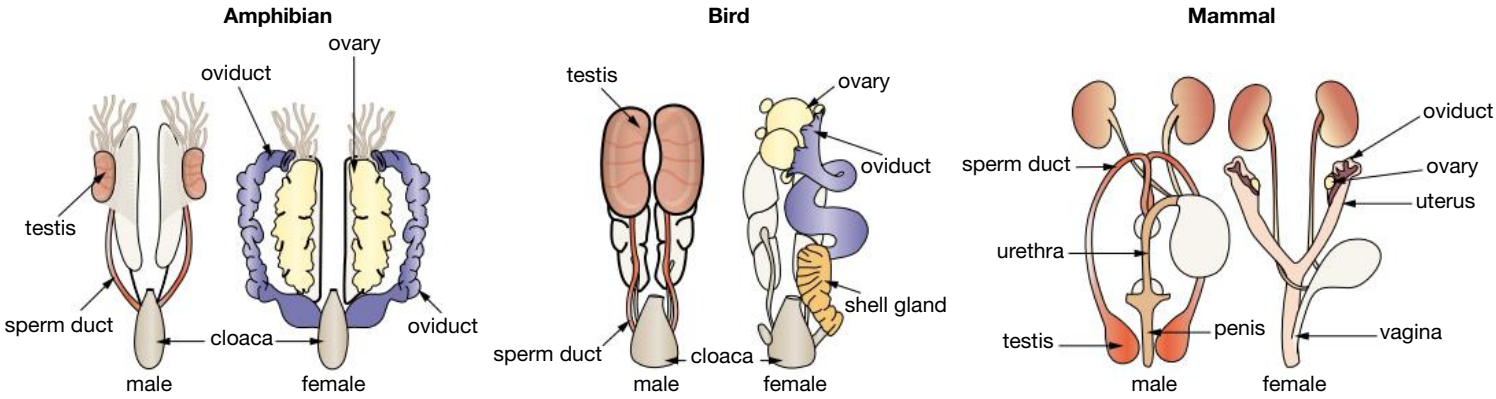

FIGURE 4.1.5 The reproductive systems in amphibians, birds and mammals have many similar parts. Here, parts with the same colour have the same function.

Males

Males have organs called **testes**, which produce sperm. Sperm pass from the testes to the outside of the body through a tube called the sperm duct. In humans and in animals like dogs, kangaroos and horses, the sperm pass out of the body through a penis.

In other animals, the sperm duct instead empties into the cloaca, which is the end of the digestive tube. The sperm then pass out through the vent, the opening at the end of the cloaca. Some animals that do this are birds, amphibians, reptiles, echidnas and platypus and some fish, such as sharks.

Females

In females, the **ovaries** make the egg cells. The eggs pass from the ovaries down tubes called oviducts. The eggs may then be fertilised outside or inside the female's body (Figure 4.1.6).

External fertilisation

External fertilisation happens outside the body. Figure 4.1.6 shows a male frog fertilising eggs laid by the female in water. Most fish reproduce externally, and so do sea urchins and jellyfish. The water stops the sperm from drying out, and the sperm can swim through it.

Internal fertilisation

Internal fertilisation happens inside the body. All land animals use internal fertilisation, as do some water-based animals. Internal fertilisation is better for land environments because sperm released into the air may dry out and die. Internal fertilsation does not require the sperm or egg to leave the bodies of the animals, and therefore prevents this from happening. **Copulation** is the act of sex and it allows a male to transfer sperm to the female. There are different ways this can happen. In mammals, the male inserts his penis into the female. In the octopus, the male transfers sperm with one of his tentacles.

The young develop

The young animal now needs time to develop. This can happen inside or outside the parent's body (Figure 4.1.7). **Development** is the change in form and structure of an individual over its life from zygote to adult. Internal development is when the young develop inside the mother's body, usually in her uterus (womb). They remain there to develop until they are born. Most mammals go through internal development. Examples are cats, dogs, cows, horse, sheep, whales, dolphins, flying foxes and humans.

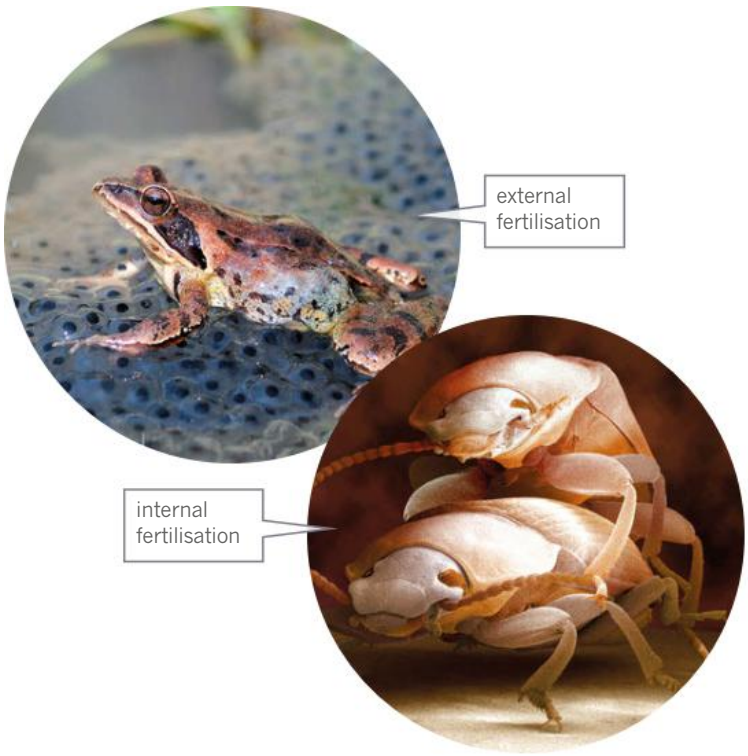

FIGURE 4.1.6 External fertilisation is used mainly by water animals such as frogs, and internal fertilisation is used mainly by land animals such as beetles.

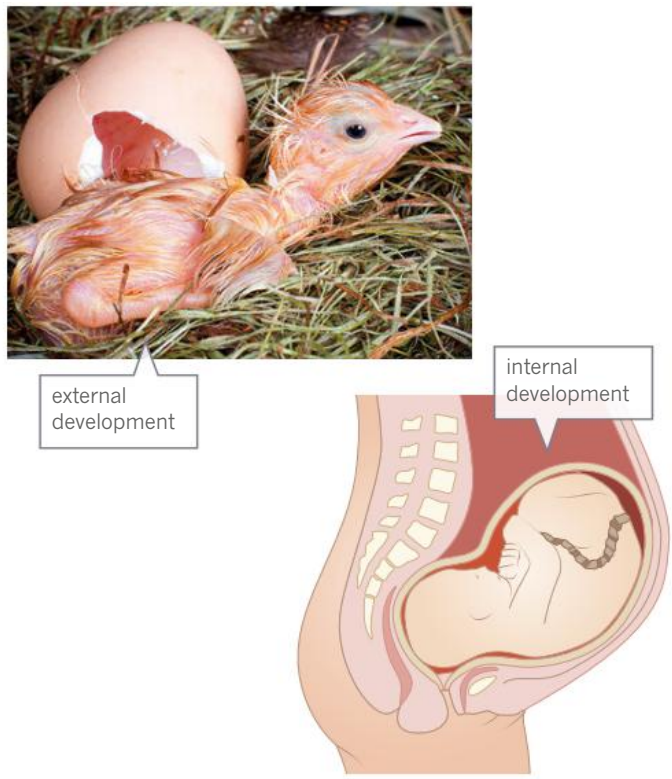

FIGURE 4.1.7 External development occurs in birds, while humans have internal development.

SciFile

Stomach breeders

The females of Queensland's gastric brooding frogs protected their young by swallowing their fertilised eggs. The female frogs did not eat while the young frogs developed in their stomach. They gave birth by vomiting out the froglets just when their legs were developing. Gastric brooding frogs haven't been found in the wild for many years and may be extinct.

External development is when the young develop completely outside the parent's body, developing inside a structure such as an egg. Spiders, amphibians, birds, fish and most reptiles undergo external development. For example, insects and birds lay eggs and the young develop inside the egg until they hatch.

Marsupials, such as kangaroos and wombats, have part internal and part external development. Marsupial young are born live but very undeveloped (Figure 4.1.8). Development then continues within the mother's pouch.

FIGURE 4.1.8 This three-day-old kangaroo joey will complete its development in its mother's pouch.

Sexual reproduction in flowering plants

Flowers are reproductive structures in plants that produce gametes and allow fertilisation to occur. This results in a seed. The structure of a typical flower is shown in Figure 4.1.9.

To form a seed:

- Pollen is produced in the anther.
- The pollen is deposited on the stigma. This transfer of pollen is known as **pollination**.
- The pollen grain develops into a long tube called the pollen tube.
- This tube grows down through the style to the ovary and into the egg.
- In the ovary, the egg is inside a structure known as the ovule. The male gamete passes down the pollen tube to join the female gamete in the ovule.

After the gametes join, a seed gradually develops.

Seeds develop in the fruit. A **fruit** is the remains of the ovary, plus all the seeds it contains. In some plants, fruit will appear as seed cases or pods. This means that fruit can be juicy like an apple or hard and dry seed cases like a gumnut.

A seed is a capsule containing a new plant, called an **embryo**. The embryo is at a very early stage of its development, supported by a food supply inside the seed.

The embryo in a seed is dehydrated (dried out) and requires water and warmth before it will grow. The seed swells up by absorbing water, and this triggers the growth of the embryo.

The embryo uses the stored food in the seed and begins to grow. The embryo then sprouts out of the seed in a process called **germination**. The embryo will begin making its own food when it reaches the sunlight above the ground. The process of a seed germinating is shown in Figure 4.1.10.

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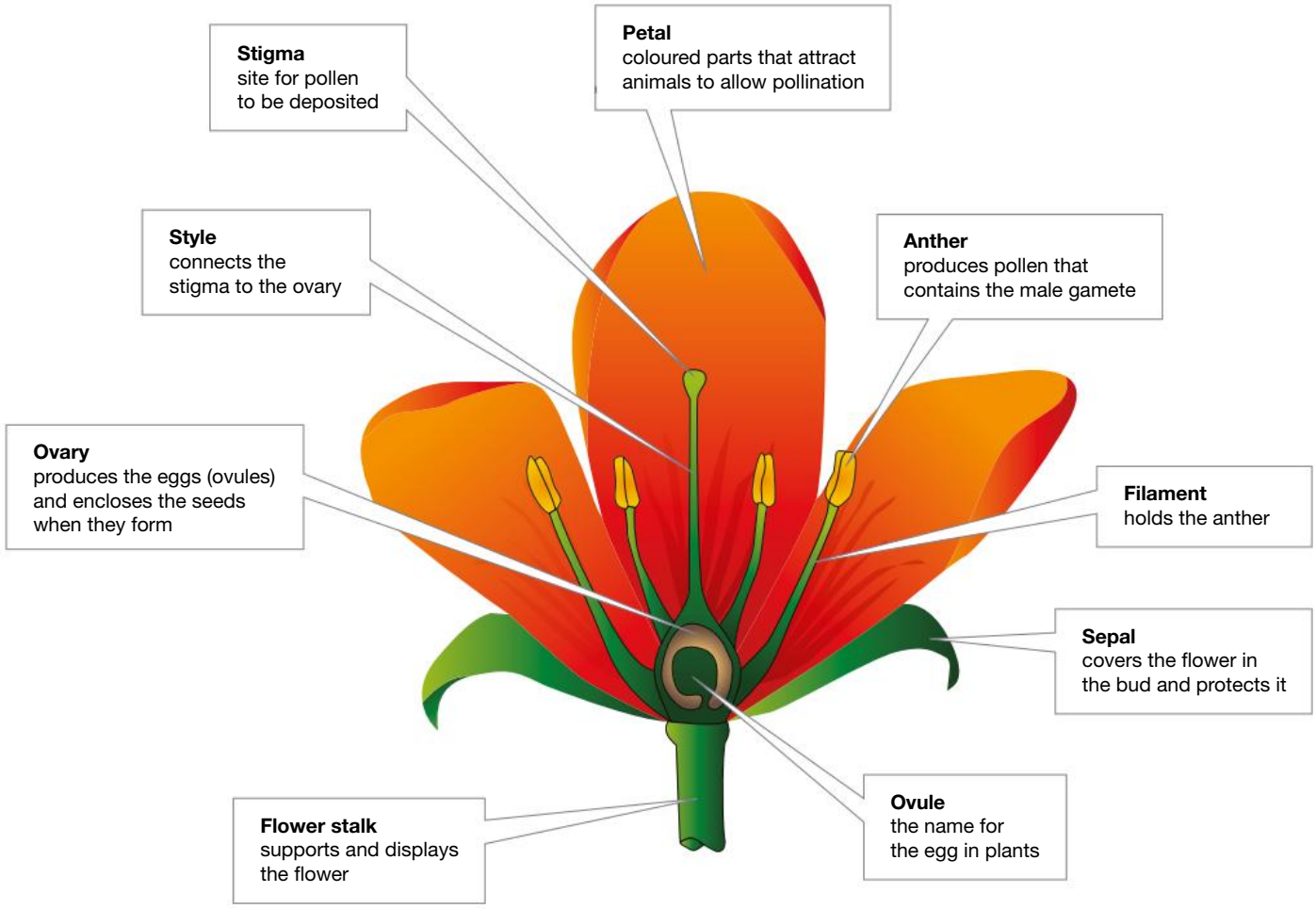


FIGURE 4.1.9 A flower is a reproductive structure.

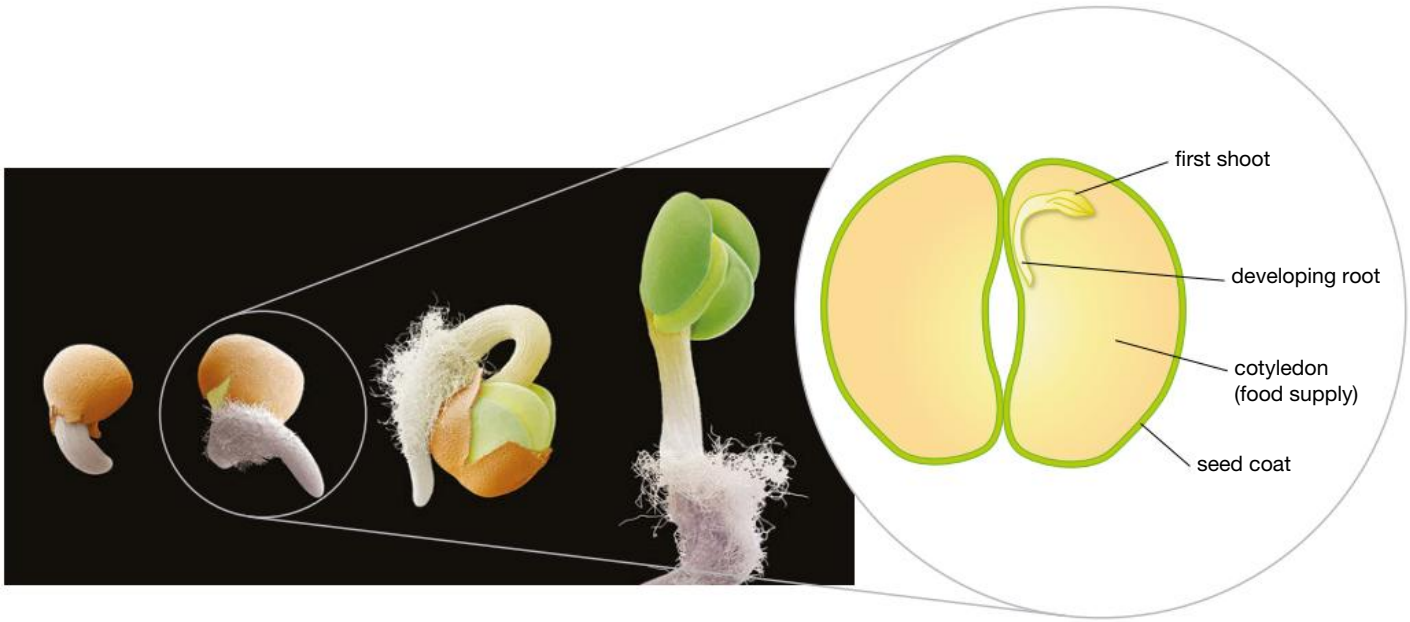


FIGURE 4.1.10 A seed is an embryo with a food supply. This seed has been split open.

Captive breeding to fight extinction

Captive breeding is the term used when animals that are normally found in the wild are bred in captivity. This means that the animals are kept and bred in cages or enclosures that provide food and protect them from other animals, disease and being hunted. Captive breeding can help to build up the numbers of animals that are facing extinction in the wild. This improves the population of that animal and chances of long-term survival of the species.

Zoos and wildlife sanctuaries play an important role in captive breeding programs. The roles of captive breeding programs are to:

- maintain healthy populations of an animal in captivity while wild populations are declining and facing threats such as habitat loss, feral animals like foxes and wild cats, and hunting
- breed animals for release into the wild once any threats to them are removed.

Scientists conduct research into reproduction to help improve the success of captive breeding programs. This research is usually done by scientists working at zoos, or by university researchers who work together with zoos. The reproductive cycle and behaviour of organisms can be very complex, and so it is important to have a good understanding of it before beginning captive breeding programs. This will help the zoo staff to keep the animals healthy and fertile, and to create the best conditions for reproduction and birth. Understanding the factors that influence the success of captive breeding programs can also increase the number of healthy offspring born in captivity over time.

The ultimate aim of any captive breeding program should be to rebuild and conserve natural populations by releasing animals that are born in captivity into the wild. For this reason, it is important that the methods and sites for release are carefully researched and planned to ensure the long-term survival and reproduction of the released animals.

Zoos Victoria has committed to wildlife conservation through its Fighting Extinction campaign. This aims to promote education, research and collaboration for the conservation of endangered species. Zoos Victoria currently has a number of captive breeding programs for threatened species. These include the orange-bellied parrot (Figure 4.1.11), the eastern barred bandicoot (Figure 4.1.12) and the helmeted honeyeater.

FIGURE 4.1.11 The orange-bellied parrot *(Neophema chrysogaster)* is critically endangered. These orange-bellied chicks were born as part of a captive breeding program at Healesville Sanctuary in Victoria. The program has been running since 1994 but the number of these parrots in the wild remains very low.

FIGURE 4.1.12 The eastern barred bandicoot *(Perameles gunnii)* was extinct in the wild on mainland Australia. Captive breeding has helped their numbers increase, and three small populations have been reintroduced to the wild.

REVIEW

1. Why do you think scientific research on reproductive biology is important for the conservation of threatened species?
2. Apart from conservation, what other reasons do you think there are for breeding animals in captivity?
3. What factors do you think zoo staff would need to consider and manage before releasing captive-bred animals into the wild?

MODULE
4.1 Review questions LS

Remembering

1 Define the terms:
- a fertilisation
- b copulation
- c embryo
- d external development
- e zygote.

2 What term best describes each of the following?
- a sperm and eggs
- b when sperm and an egg join
- c an animal with both male and female parts
- d the transfer of pollen from anther to stigma
- e when a young growing plant sprouts out of a seed.

3 Where does fertilisation take place in each of the following?
- a flowering plants
- b frogs.
- c dogs

4 What type of reproduction made you?

5 List three organisms that are hermaphrodites.

Understanding

6 a Explain what is meant by reproduction.
b Explain why reproduction is necessary.

7 Modify each of the following incorrect statements to make them correct.
- a The reproductive systems of frogs, birds and mammal share many of the same organs, however these have very different functions in each species.
- b The most important organ in males is the penis, which makes sperm.
- c In females, the oviduct makes the egg cells.
- d In all animals the eggs are fertilised inside the female in the ovary.
- e In some animals, such as frogs, the sperm pass out of the body through the penis.

8 a Group all of the following terms into two groups: *testis, ovary, oviduct, sperm duct, penis, egg, sperm, vagina*
b How did you group these terms?

9 Describe what examples of reproduction you are likely to find in a garden when doing the science4fun on page 152.

Applying

10 Identify an animal that has not been discussed in this module, that:
- a lays eggs
- b gives birth to live young
- c uses a penis to deliver sperm.

11 A female hammerhead shark living alone for many years in a tank gave birth to young. Could this have happened by sexual reproduction?

Analysing

12 Compare the process of:
- a copulation and fertilisation
- b internal and external fertilisation.

13 Figure 4.1.13 shows the reproductive system of an insect. Compare the arrangement of the organs and their functions with those of the mammal and the amphibian in Figure 4.1.5 on page 154.

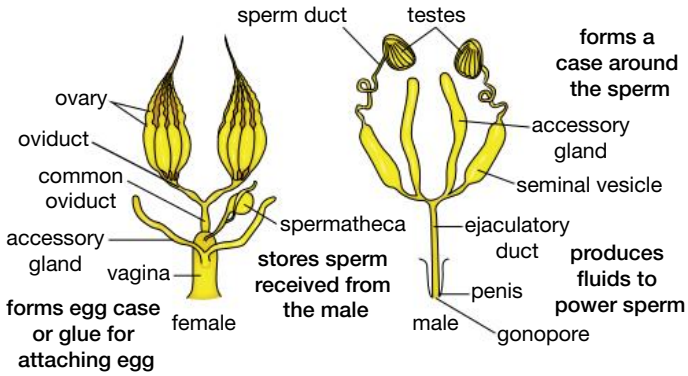


FIGURE 4.1.13

Evaluating

14 Discuss whether internal development is more likely to occur in animals that are internally fertilised or externally fertilised.

15 Whales are mammals. Their ancestors lived on land millions of years ago. The way they reproduce is very similar to their land ancestors. Discuss whether whales undergo:
- a internal or external fertilisation
- b internal or external development.

Creating

16 Design an experiment that tests whether temperature affects the breeding of a type of beetle in the laboratory.

MODULE 4.1

Practical investigations

1 • Flower structure and pollination

Processing & Analysing | Evaluating

Purpose

To identify the method of pollination of flowers using a table that relates method of pollination to flower structure.

Timing 45 minutes

Materials

- selection of flowers
- blade and forceps
- hand lens or stereo microscope
- ruler

SAFETY

Take care with sharp instruments.

Procedure

1. Collect a flower (or flower head) and take it back to your workstation. Your task is to use the table below to decide how this species is pollinated—by wind, insect, bird or mammal.
   - Use the features in the table below to help you decide.
   - You may have to pull the flower apart if necessary, and use a hand lens or stereo microscope to inspect its parts more carefully.
2. In your workbook:
   - write the flower's common or species name as a heading
   - write down its colour and size
   - draw a quick sketch of the flower (or pulled-apart flower)
   - label the features that you used to decide how the flower is pollinated.
3. Analyse its features and use them to identify the most likely method of pollination.
4. Repeat for the other species.

Results

1. Compare how you classified the flowers with how other groups classified them.
2. Record which species most groups agree on, and ones where they disagree.
3. If other groups chose a different method of pollination, then record their reasons for doing so.

Review

1. Evaluate the table. Did it work well for the flowers you tried to classify? What problems did you have when trying to classify any particular species?
2. How well did your conclusions match those of other groups?
3. Use your observations in this experiment to assess the statement: *Flowers have a structure that is suited to their method of pollination.*

Method of pollination	Flower structure/colour/size	Anther/stamens	Stigma/style
wind	• often small but many flowers in one head, often no petals, not brightly coloured • no nectar, no scent	• long stamens with large anthers exposed	• long style with exposed stigma, which has a large surface area—they often look like brushes
insect	• usually small, some with many flowers in one head, brightly coloured petals, especially blues and yellows • small amounts of nectar, strong scent • often strongly marked with 'landing guides'	• often has short stamens and small anthers, which are close to nectar source in most flowers • sticky pollen	• short style, small stigma close to nectar source
bird	• large strong flowers, often red • some have petals but many don't • lots of nectar	• often has long, strong stamens and large anthers a long way from the nectar source	• long style, smallish stigma, a long way from the nectar source
mammal	• large strong flower heads, much nectar, often not brightly coloured and hidden in plant • nectar produced at night	• strong and rigid	• strong and rigid

MODULE 4.1

Practical investigations

SPARKlab alternative available for this activity

• STUDENT DESIGN •

2 • Germination

Questioning & Predicting | Planning & Conducting

Purpose

To determine the factors affecting the germination of seeds

Hypothesis

What do you think seeds need for them to germinate—water, light, oxygen or warmth? Before you go any further with this investigation, write a hypothesis in your workbook.

Timing 60 minutes

Materials

- 1 mL vegetable oil—boiled and cooled before class
- 20 mL water—boiled and cooled before class
- 25 wheat seeds
- 5 test-tubes
- cotton wool
- labels or waterproof textas
- 100°C thermometer
- lamp
- access to dark cupboard and fridge
- digital camera or mobile phone (optional)

Procedure

1. Your task is to design an experiment that will determine whether water, light, oxygen or warmth is most important in getting seeds to germinate.
2. Brainstorm in your group and come up with different ways to investigate the problem. Select the best procedure and write it in your workbook. Draw a diagram of the equipment you need.
3. Before you start any practical work, assess your procedure. List any risks that your procedure might involve and what you might do to minimise those risks. Show your teacher your procedure and your assessment of its risks. If your teacher approves, then collect all the required materials and begin your investigation.

Hints

- Boiled (then cooled) vegetable oil will not contain any oxygen.
- Boiled (then cooled) water will not contain any oxygen.
- A 1 cm layer of oil is a barrier to air entering water.
- Wet cotton wool can provide moisture to seeds.
- Use the STEM and SDI template in your eBook to help you plan and carry out your investigation.

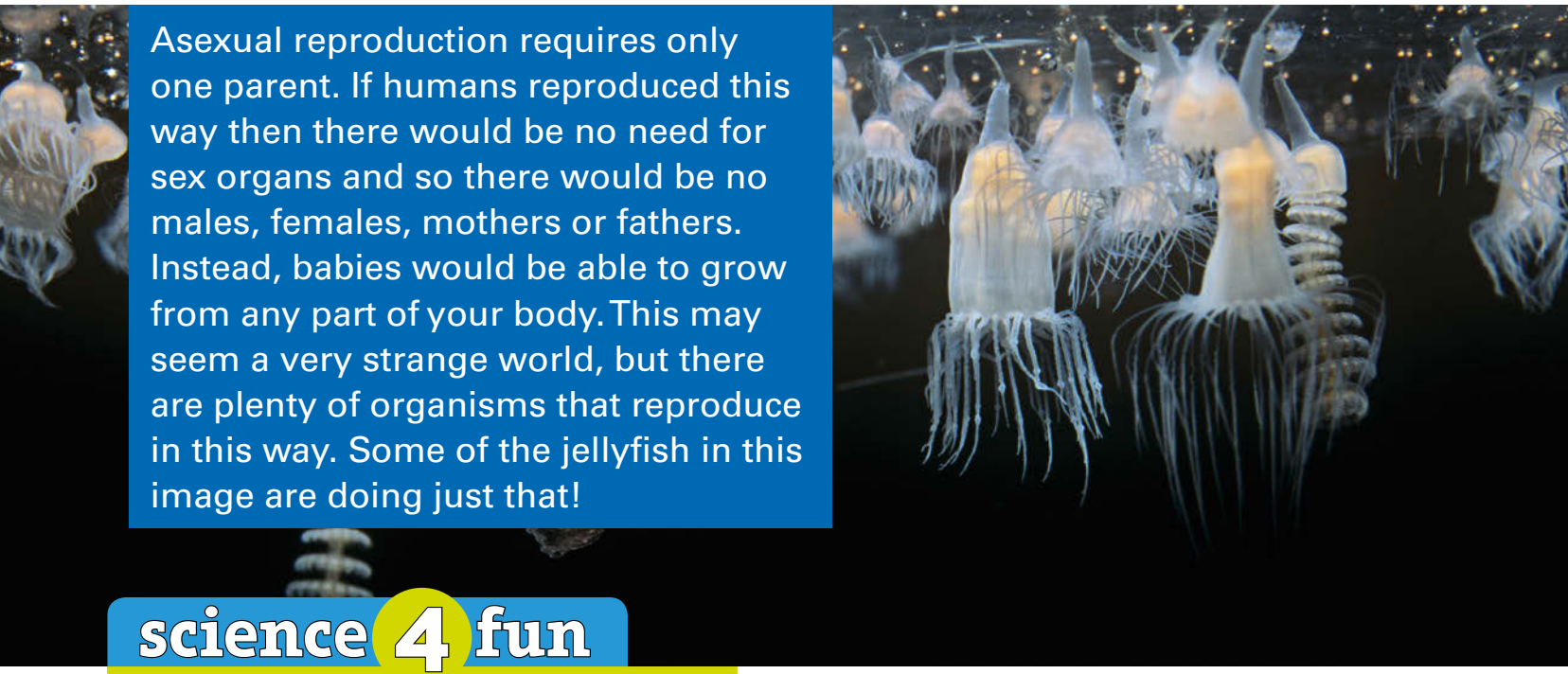
Review

1. List the containers in which seeds germinated, and the conditions in those tubes.
2. a Construct a conclusion to your investigation.
   b Assess whether your hypothesis was supported or not.
3. Compare your results with others in the class, and explain any differences.
4. Evaluate your procedure, and outline what you would do if you did the experiment again.

FIGURE 4.1.14 Seeds germinating on wet cotton wool

MODULE

4.2 Asexual reproduction



Asexual reproduction requires only one parent. If humans reproduced this way then there would be no need for sex organs and so there would be no males, females, mothers or fathers. Instead, babies would be able to grow from any part of your body. This may seem a very strange world, but there are plenty of organisms that reproduce in this way. Some of the jellyfish in this image are doing just that!

science 4 fun

Growing potatoes

Can you grow pieces of potato?

Collect this …

- 1 potato
- soil
- ice-cream container
- knife to cut potato
- chopping board

Do this …

1. Cut the potato into about 8 pieces. Each piece of potato should have 'skin' on one side.
2. Leave the pieces to dry in air for 1 day.
3. Place about 2 cm of soil in the ice-cream container. Push all the pieces of potato into the soil with the skin-side upwards. Bury the pieces so that the skin is level with the top of the soil.
4. Water the soil until it is wet, but not soaked. Over the next week keep the soil wet, and watch what happens to the potato pieces.

Record this …

1. Describe what happened.
2. Explain why you think this happened.

Asexual reproduction in animals

In **asexual reproduction**, there is no joining of egg and sperm. Instead, the young grows from part of the parent's body or from an unfertilised egg. The individual is produced by mitosis, the process in which a cell splits into two identical cells. Most species of animals reproduce sexually, with only a few species reproducing asexually. Asexual reproduction in animals can happen in a number of ways, including:

- budding
- fission
- parthenogenesis.

Budding

Hydra are small freshwater animals that grow to around 10 mm long. They are relatives of jellyfish and can reproduce both sexually and asexually. Figure 4.2.1 shows a young hydra growing from its parent. The young hydra is being formed by asexual reproduction. It grew from a bud on the side of its parent, and will soon break off the parent and lead a separate life. This method of asexual reproduction is called **budding**. Other animals that form by budding are corals and some sponges.

FIGURE 4.2.1 This young hydra was produced asexually by budding. It is still attached to its parent but has already caught a tiny water animal to eat!

Fission

Some sea stars (starfish) can reproduce asexually. They begin splitting near the mouth and divide into two. You can see in Figure 4.2.2 that each half then grows new arms. Splitting in two is a method of asexual reproduction called **fission**. The ability to regrow arms helps sea stars survive on coral reefs. Rough waves may break a sea star into pieces If the pieces have some mouth tissue attached to them then they will regrow arms to form a new, complete sea star.

Planaria are a type of flatworm that also uses fission to reproduce (Figure 4.2.3). Planaria can also regrow if they are cut into pieces.

FIGURE 4.2.2 This sea star is growing new arms after the parent split into two by asexual reproduction. The other half also regrew arms.

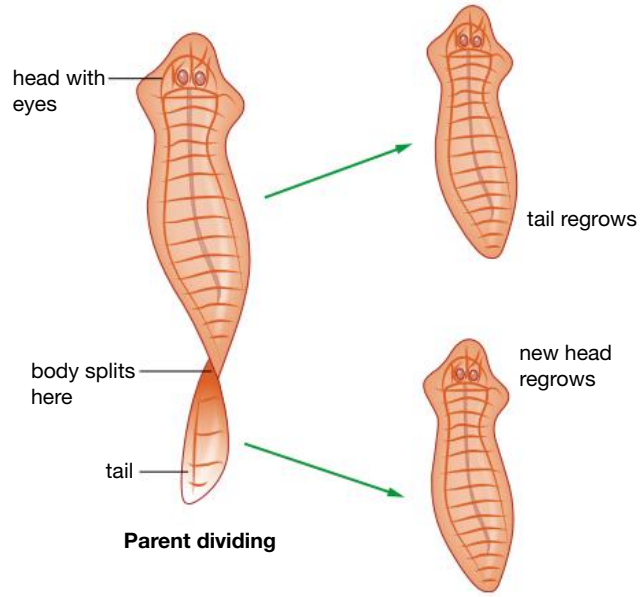


FIGURE 4.2.3 Planaria are flatworms that reproduce asexually by dividing into two. Each half then grows into a complete animal.

Parthenogenesis

Parthenogenesis is a type of asexual reproduction where offspring develop from eggs that have not been fertilised by a male. Parthenogenesis happens in water fleas, aphids, bees, and a small number of reptiles and fish (Figure 4.2.4).

AB 4.3 Prac 1 p. 169

FIGURE 4.2.4 This female water flea is giving birth to young produced by parthenogenesis.

SciFile

Males not needed

The Komodo dragon reproduces by sexual reproduction. In 2006, two dragons in different English zoos laid eggs, some of which hatched to produce living offspring. But one of the dragons had never met a male, and so sexual reproduction was not possible! The other dragon had been with a male two years previously, but testing proved that the eggs' genetics came from the mother only. In the absence of a male, these dragons had reproduced using parthenogenesis.

FIGURE 4.2.5 The Komodo dragon is the world's largest land-lizard.

Working with Science

PLANT BREEDING AND PRODUCTION

The breeding and production of healthy plants is critical to our society. We breed plants for food, textiles, furniture, housing, paper products, medicine and landscaping. Plant breeding has a long history, dating back to the start of agriculture over 10 000 years ago. Most of the food we eat today is a result of many years of selective breeding. This is the process of choosing plants that will be allowed to reproduce. This produces better crops with more food.

There are many employment opportunities for people who want to work with plants. Horticulturists, landscape gardeners, farmers, botanists, ecologists and biotechnologists are all involved in the breeding and care of plants for commercial or research purposes. Biotechnology is growing in importance and there is an increasing awareness of the need for sustainable farming and land management. Hence, there are many interesting developments in plant breeding and production technology.

There is a wide variety of jobs available to people with skills in plant breeding and so there are many ways to enter this field. Certificates (I–IV) or diplomas in horticulture, landscaping, or conservation and land management will help you gain skills to work in nurseries or landscaping businesses, or in crop production.

A Bachelor of Science majoring in botany, agriculture or biotechnology can lead you to a career in plant science research, conservation and land management, or as a consultant to farmers or food crop buyers, such as large supermarkets.

Review

1. Plants produce some of our most important resources. What five things do you use every day that are made from plants?
2. Why are the skills and technology developed by plant breeders so important?

FIGURE 4.2.6 This tulip is being pollinated by hand with a paintbrush. Collecting the pollen from one variety of tulip and using it to pollinate another variety is an artificial method of cross-pollination. This method is used to create hybrid tulip varieties.

Asexual reproduction in plants

In plants, asexual reproduction can occur by many methods, some of which are shown in Figure 4.2.7. All these methods are collectively referred to as **vegetative reproduction**.

Tuber
Stem develops many swollen parts called tubers underground. Each tuber can grow into a new plant.

Example: potato

Bulb
A swollen underground part that develops many fleshy 'leaves'.

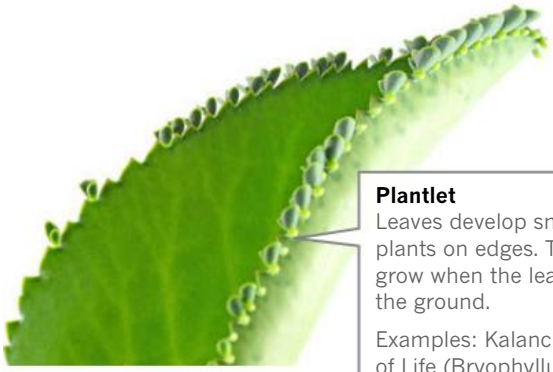
Examples: onion, daffodil, tulip, iris, lily, garlic

Rhizome
Stem grows along underground and sends up new shoots and roots at intervals.

Examples: bamboo, ginger, asparagus, lily, iris, many ferns such as bracken fern

Runner
Runners (also called stolons). Stems run along above ground and send down roots and shoots at intervals.

Examples: many grasses, strawberry, ivy, violets, spider plant (Chlorophytum)



Plantlet
Leaves develop small plants on edges. These grow when the leaf falls on the ground.

Examples: Kalanchoe, Tree of Life (Bryophyllum)

Root sucker
Roots send up new stems when they are near the surface, especially if disturbed.

Examples: Robinia, Tree of Heaven, many eucalypts

FIGURE 4.2.7 These are some of the many different methods of asexual reproduction in plants.

Cloning

Cloning is the process of producing identical individuals through reproduction. Asexual reproduction always produces clones. A **clone** is an exact 'copy' of a particular individual. Humans can produce clones using a process called **cloning**. The clone has the same features as the parent from which it was copied. This happens because the cells of the offspring came from the parent cells dividing by mitosis.

Scientists have been able to clone many species of plants and animals. The first animal cloned was a sheep named Dolly, and many others followed, such as cattle, cats, dogs and rabbits. There is no evidence that a human has been cloned.

Cloning plants

Cloning plants involves taking many small sections from one desirable plant and then growing them into complete plants. This process can then be repeated to make as many copies of the one parent plant as needed. In this way, an entire crop can be grown. The plants will all be nearly identical because each grew by mitosis from the same parent (Figure 4.2.8). Cloning can be done in several ways.

FIGURE 4.2.8 Almost all bananas now grown are of a type called Cavendish. Every Cavendish banana plant is a clone, because it is reproduced by taking cuttings from the underground stems of the plant.

Plant tissue culture

Tissue culture is a method of cloning plants that is carried out in a laboratory (Figure 4.2.9).

- The plant to be cloned is first sterilised, to kill disease-causing organisms.
- The plant is then cut into small pieces, called explants.
- The explants are placed in a dish or jar on a jelly-like material called agar. The agar contains nutrients to feed the growing cells, and plant hormones that encourage cell division.
- Each explant grows and can then be further cut into new explants.
- The process is repeated, to produce a crop of identical plants all with the same desired characteristics of the original plant.

Tissue culture is expensive but is widely used in agriculture because it is quick and can be used all year round in any climate. For this reason, it is used to produce many valuable crops. It is also used to save rare and endangered plants.

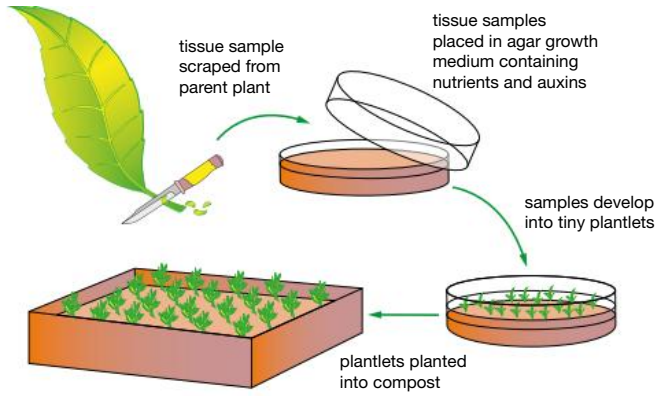


FIGURE 4.2.9 The steps used to clone one parent plant using plant tissue culture

Cell tissue culture

Cell tissue culture is a method where individual cells are cloned, instead of part of a plant. It has recently been discovered that cells don't always copy exactly. Instead, variations (slight changes) can occur. The more often cells divide, the more changes there will be. This will make some of the new plants different from the parent. In this way, plant breeders can select plants that have the characteristics they want. Such characteristics might be resistance to disease or drought, better fruit or faster growth.

Cuttings

Another cloning technique is to take cuttings. The method is similar to tissue culture, but does not need expensive laboratories and equipment. For this reason, cuttings are often used in plant nurseries, vineyards, orchards and in home gardens. The process follows simple steps:

1 Small pieces of the shoot or leaf are cut off, dipped in plant hormones (Figure 4.2.10) that will encourage growth, and placed in soil in a tray.

2 The tray is kept moist and away from direct sunlight.

3 After a few weeks, new roots grow, and eventually a complete plant develops.

4 When the plant can survive on its own, it can be sold to the public or planted in a vineyard or orchard.

FIGURE 4.2.10 This cutting is being dipped in plant hormone to encourage roots to grow. It will grow into a clone of the original plant.

Cloning in agriculture

Cloning is used in agriculture to copy a plant with a desired characteristic, and then to produce a crop of near-identical plants. Each plant in the crop then has the same desired characteristic.

Cloning can improve plants so that they produce more fruit, vegetables, seeds, oils, perfumes, flowers or medicinal drugs. In this way farmland becomes more productive. This productivity is known as its **yield**. For some crops such as wheat or grapes, yield is measured by the weight of seeds or fruit harvested per hectare of land.

For flowers sold to florists, yield is better measured as the number of flowers produced. The greater its yield the more profitable the business is.

Cloning can also be used to produce plants that are resistant to certain insects or diseases, such as fungus. The crop will survive if that insect or disease strikes the area.

Another advantage of cloning is that fruit and vegetables can be similar in appearance. For example, bananas and apples can be produced that are all roughly the same size, shape, flavour and colour. This helps when selling the crop to supermarkets, because shoppers usually want food with consistent characteristics.

Problems with cloning

When every plant in a crop is nearly identical, there is always the possibility of a disease wiping out the entire crop. If the parent plant cannot survive a disease, then the cloned crop will not survive it either. The whole crop could be lost to the disease. This does not happen with plants grown from seed because every seed is different. This means that the plants grown from the seeds are different too. If the disease strikes, then some plants will die but some will survive.

An example of a cloned crop that was destroyed by disease is the banana type called Gros Michel (Figure 4.2.11). Every plant was a clone, and all became infected by a fungus that caused Panama disease. The fungus kills the entire plant. Whole areas were devastated around the world. Since then a new banana clone called Cavendish has been produced. However, a disease related to Panama disease has recently begun destroying this banana in many places around the world.

FIGURE 4.2.11 Gros Michel was once the main banana type in the world.

Prac 2 p. 170
Prac 3 p. 171

MODULE 4.2

Review questions

Remembering

1 Define the terms:
- a asexual reproduction
- b mitosis
- c budding
- d fission
- e clone.

2 What term best describes each of the following?
- a an underground stem that grows along, sending up new plants at intervals
- b offspring developing from eggs that have not been fertilised by a male
- c the different natural methods of asexual reproduction used by plants
- d the process of producing identical individuals through reproduction
- e the amount of seeds produced by a crop per hectare.

3 What is an example of an animal that reproduces using the following methods?
- a budding
- b fission
- c parthenogenesis.

4 a List six ways that plants reproduce asexually.
b For each, name a plant that reproduces that way.

Understanding

5 Without mitosis, asexual reproduction would not be possible. Explain why.

6 Outline the benefits of using plant cloning techniques in agriculture.

7 Why is a crop of cloned plants more likely to be wiped out by a disease than a crop produced from seeds?

8 a Why have Cavendish bananas replaced Gros Michel bananas as the most common bananas sold in fruit shops?
b A new type of banana will probably be developed that will replace the Cavendish banana. Explain why.

9 Cell tissue culture does not always produce identical offspring. Explain how this can be useful for plant breeders.

Applying

10 What are the signs you might look for that would demonstrate that asexual reproduction is happening in a garden?

Analysing

11 Compare:
- a sexual and asexual reproduction
- b cloning by stem cuttings and by tissue culture.

12 What are the differences between the following?
- a budding and fission
- b parthenogenesis and budding.

Evaluating

13 Sea stars living on a coral reef may become more common after storms.
- a Propose a likely reason for this.
- b What other evidence from the reef would support your answer to part a?

14 Discuss whether tissue culture or stem cuttings would be the best way to produce clones that are almost identical.

15 Jo claims that asexual reproduction doesn't involve males and females, or sperm and eggs. Discuss whether she is right or wrong.

16 Human identical twins occur when a sperm fertilises an egg and then the zygote splits into two cells before each cell then develops into a separate baby. Assess whether identical twins are clones.

Creating

17 One plant in a garden always has more flowers on it than other plants of the same species. Design a way of producing more of these desirable plants.

18 The science4fun on page 162 shows that bits of chopped-up potato can form new plants. Design a way of extending this activity to convince someone that it is a method of asexual reproduction.

MODULE
4.2 Practical investigations

1 • Asexual reproduction in animals

Processing & Analysing | Evaluating

Purpose

To observe examples of asexual reproduction in animals.

Timing 30 minutes

Materials

- container of pond water with organisms that reproduce asexually such as water fleas, rotifers, hydra, protozoa

---

- monocular microscope
- 2 cavity slides
- 2 cover slips

Procedure

1. Place the hydra (Figure 4.2.12) on a cavity slide. Do not add a cover slip, because you will crush the animal if you do.
2. Observe your hydra under a monocular microscope under low magnification. Look for evidence that the hydra may be reproducing.
3. Carefully replace any hydra back in the container. Dip your slide into the container to do this.
4. For the other organisms, place two drops of pond water on a cavity slide and add a cover slip.
5. Use higher magnification to observe the smaller organisms. Look for water fleas, rotifers and other organisms that reproduce asexually.
6. Look for evidence that the organisms may be reproducing.

Review

1. What form of asexual reproduction does a hydra use?
2. List some of the evidence that might indicate that the hydra was reproducing.
3. Choose two animals you observed reproducing and outline the differences in their methods of reproduction.

FIGURE 4.2.12

MODULE 4.2

Practical investigations

2 • Asexual reproduction in plants

Processing & Analysing | Evaluating

Purpose

To observe examples of asexual reproduction.

Timing 30 minutes

Materials

- selection of onion, potato, African violet, tree of life (*Bryophyllum*), clove of garlic, leaf of geranium, stem of bamboo or bracken
- rooting powder
- soil

- glass jars
- toothpicks
- glass slides
- ice-cream containers
- stereo microscope
- digital camera or mobile phone with camera function (optional)

Procedure

1. Take an onion, a piece of garlic and a potato. Stick some toothpicks in them so that they can be supported on top of a jar of water and just touch the water at the bottom. Figure 4.2.13 shows how to do this using an onion. Fill each jar with water to the level shown in Figure 4.2.13.
2. Place a leaf from a tree of life or a geranium on some soil in an ice-cream container. Place a glass slide over the top of the leaf to keep it pressed against the soil. Water the soil.
3. Place the leaf stalk of an African violet in a jar of water. When roots appear, plant it in soil.
4. Cut a piece of geranium stem about 10 cm long. Remove about half the leaves. Dip the cut part of the stem in rooting powder, then place the powdered end into about 5 cm of soil in an ice-cream container. Water the soil.
5. If you have some bamboo stem or bracken stem, break about 10 cm off it and cover it in soil, watering it well.

Results

1. Place each plant sample in a cupboard and check it regularly over the next few weeks.
2. Record your observations, perhaps using a camera or a mobile phone to record the changes.

Review

1. Each plant reproduced asexually. Identify the method of asexual reproduction each plant used.
2. Evaluate your investigation and propose reasons why some plants may not have reproduced.

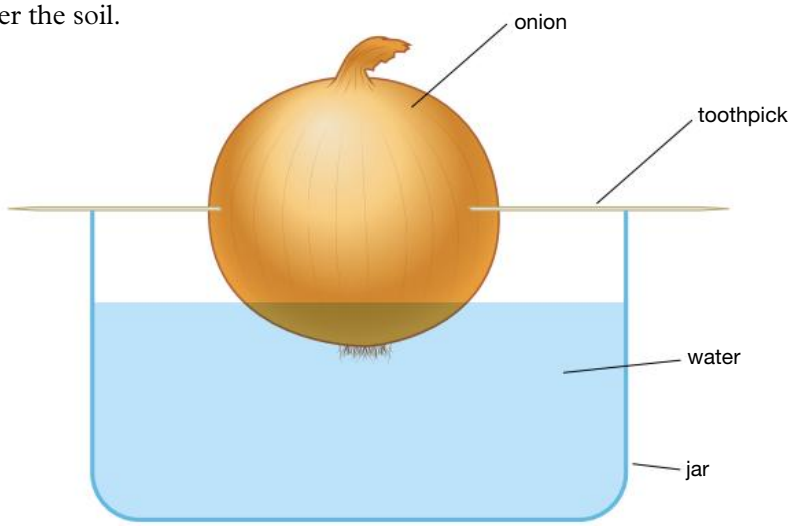


FIGURE 4.2.13

MODULE
4.2 Practical investigations

• STUDENT DESIGN •

3 • Leaf cuttings

Questioning & Predicting | Planning & Conducting

Purpose

To determine which variables affect the growth of roots from leaf cuttings.

Hypothesis

What do you think will affect the production of roots from a leaf stalk—light, soil, water or the presence of rooting hormone? Before you go any further with this investigation, write a hypothesis in your workbook.

Timing 30 minutes

Materials

- rooting hormone
- 8–10 leaves from begonia, impatiens, tradescantia or African violet
- soil–potting mix to fill 4 jars
- 1 plastic bag about 30 cm square
- 4 glass or plastic jars (about 100 mL or more)
- 4 rubber bands

Procedure

1. Your task is to find out whether light, soil, water or the presence of rooting hormone will affect the production of roots from a leaf stalk.
2. Brainstorm in your group and come up with different ways to investigate the problem. Select the best procedure and write it in your workbook. Draw a diagram of the equipment you need.
3. Before you start any practical work, assess your procedure. List any risks that your procedure might involve and what you might do to minimise those risks. Show your teacher your procedure and your risk assessment. If your teacher approves, then collect all the required materials and begin your investigation.

Hints

- The roots may take about 1–2 weeks to form.
- Cut the leaves off the plant only when you need them.
- Cover the mouth of the jar with the plastic held by a rubber band.
- The leaf stalk can be held in water by punching a small hole in the plastic and pushing the leaf stalk through the hole as shown in Figure 4.2.14.
- Use the STEM and SDI template in your eBook to help you plan and carry out your investigation.

Review

1. List the containers in which roots formed, and the conditions in those jars.
2. a Construct a conclusion to your investigation.
   b Assess whether your hypothesis was supported or not.
3. Compare your results with others in the class and explain any differences.
4. Evaluate your procedure and state what you would do if you could do the experiment again.

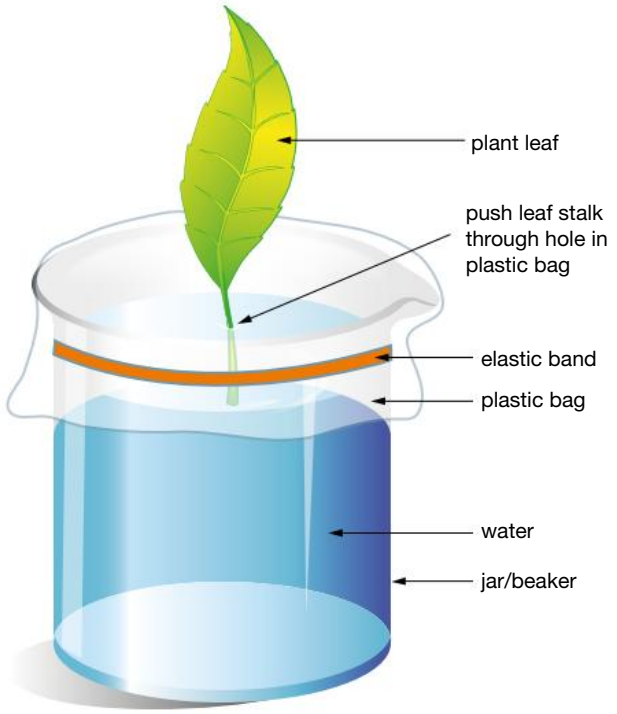


FIGURE 4.2.14

MODULE

4.3 The human reproductive system

The human reproductive system enables us to produce offspring. It also affects how humans function as an organism. Chemicals from your reproductive organs affect your behaviour, the way you grow, your appearance and how your body works.

The female reproductive system

The role of the female reproductive system is to produce a baby. Its structure is shown in Figure 4.3.1.

The ovaries are where eggs are produced. Eggs are also known as ova. A single egg is called an ovum. There are two ovaries and each is around the size of an olive. They usually release a single egg each month, alternating between left and right ovaries. The egg forms in a capsule called a follicle, which the egg then bursts out of when it has matured.

The **fallopian tubes** (**oviducts**) are tubes that the egg passes along on its way to the uterus. If the egg meets a sperm and becomes fertilised, then it is usually in one of these tubes.

The **uterus** (or **womb**) is a thick-walled muscular organ that is normally about 7 cm long and 5 cm wide. It has a lining that can change and become rich in blood vessels. A fertilised egg burrows into this lining. The baby grows and develops in the uterus until birth. The uterus can swell up to many times its normal size to allow the baby room to grow. If the egg was not fertilised, then it passes out of the uterus through the cervix.

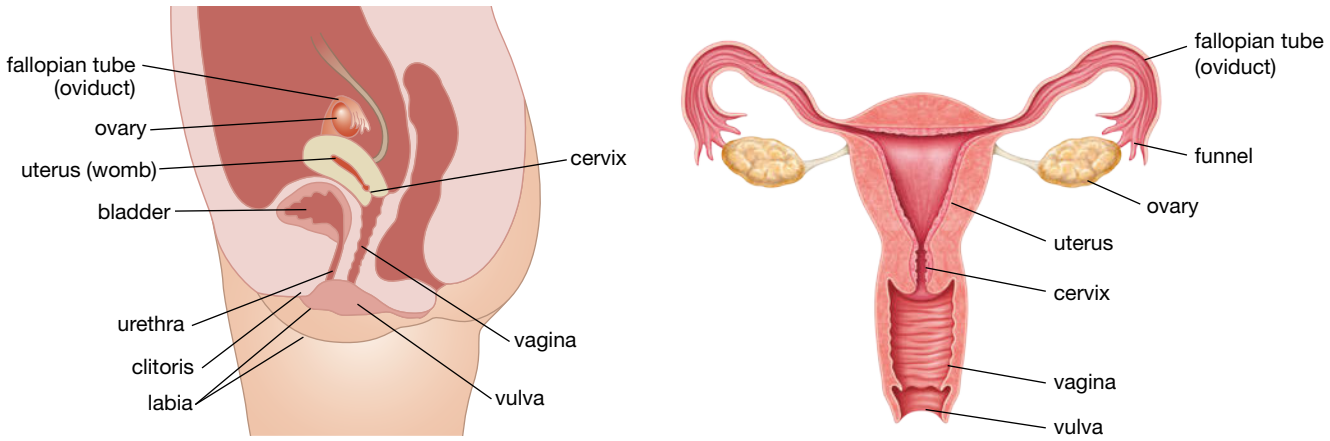


FIGURE 4.3.1 The human female reproductive system

The **cervix** is a ring of muscle that tightens to hold the uterus closed while the baby is developing. This protects the baby in the womb. The cervix opens up when the baby is about to be born.

The male's penis is inserted into the female's vagina. The **vagina** is where sperm is deposited and is also the birth canal down which the baby passes.

The menstrual cycle

Reproduction in males and females is controlled by chemicals called **hormones** that are produced in the body and travel around in the blood. One female hormone known as follicle stimulating hormone (FSH) causes the follicles to mature. A follicle is shown in Figure 4.3.2. Another hormone known as luteinising hormone (LH) makes the egg burst out of the follicle. This is called **ovulation**.

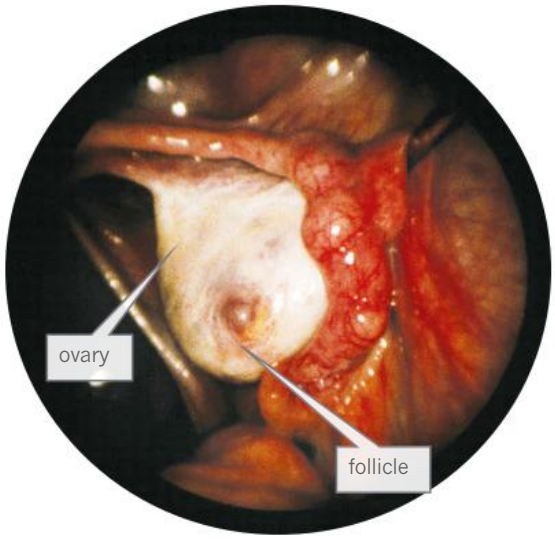


FIGURE 4.3.2 An ovary and a follicle starting to swell. The follicle will eventually burst and release an egg.

A third hormone called oestrogen makes the lining of the uterus grow thicker and increases its blood supply. Oestrogen comes from the follicles in the ovaries. The amount of oestrogen changes in a cycle over a month. These monthly changes in the body are called the **menstrual cycle**. The menstrual cycle is shown in Figure 4.3.3.

If the egg is not fertilised and implanted, then the thickened lining of the uterus breaks down. Over the next few days some blood and much of the lining of the uterus, passes out of the body. These events are **menstruation**, commonly known as a **period**.

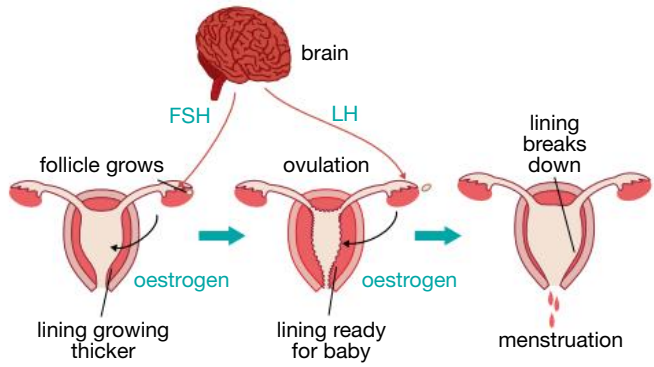


FIGURE 4.3.3 The menstrual cycle is controlled by hormones. The brain triggers the release of the hormones FSH and LH, and ovary follicles trigger the release of oestrogen.

SkillBuilder

Menstrual cycles

Menstrual cycles vary in length. A typical cycle is 28 days but the cycle can be shorter or longer, depending on the person. In this cycle, the first day of menstruation (bleeding) is counted as day 1, and typically lasts 3–7 days. Ovulation occurs at day 14 of the cycle.

You can see this in Figure 4.3.4. In some cycles, ovulation can occur as early as day 9, while in others it may be after day 20. The part of the cycle that usually stays the same is the time from ovulation to the start of menstruation. This is generally 14 days.

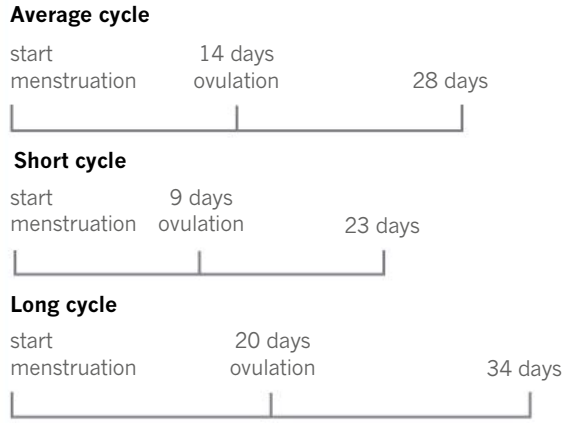


FIGURE 4.3.4 The menstrual cycle can vary in length.

Worked example

Menstrual cycles

Problem

In a 25-day cycle, on what day would ovulation most likely occur?

Solution

Thinking: Determine the number of days in the cycle.

Working: The cycle is 25 days.

Thinking: Time from ovulation to menstruation is usually 14 days, so subtract 14 from the days in the cycle.

Working: 25 – 14 = 11 days

So ovulation would have been on day 11 of the 25-day cycle.

Try yourself

Calculate the day on which ovulation would occur in a:

a 30-day cycle

b 24-day cycle.

The male reproductive system

The role of the male reproductive system is to produce and deliver sperm. Its structure is shown in Figure 4.3.5.

Sperm are produced in the two **testes** (or testicles). A single testicle is called a testis. The testicles hang outside the body in a sac called the **scrotum**.

The testes are in the scrotum, which is outside the body. This means that they are cooler than if they were inside the body. Sperm are killed or deformed if they get too hot, so being cooler ensures they are as healthy as possible. Millions of sperm are produced in tubes inside the testes. These sperm are then squeezed into a coiled tube called the epididymis, where they mature. There is one epididymis on the outside of each testis.

Muscles lining the epididymis squeeze the sperm from the inside of the male body to the outside. They are pushed into a hollow tube about 45 cm long called the **sperm duct** (**vas deferens**). This tube has muscles in its walls that squeeze the sperm along. On the way, fluid is added to the sperm from glands called seminal vesicles. This fluid contains various chemicals, such as sugars, that provide an energy source for the sperm. Fluid is also added to the sperm by the prostate gland and Cowper's gland. This mixture of sperm and other fluid is called **semen**. Semen passes out of the penis through the urethra, the same tube through which urine flows.

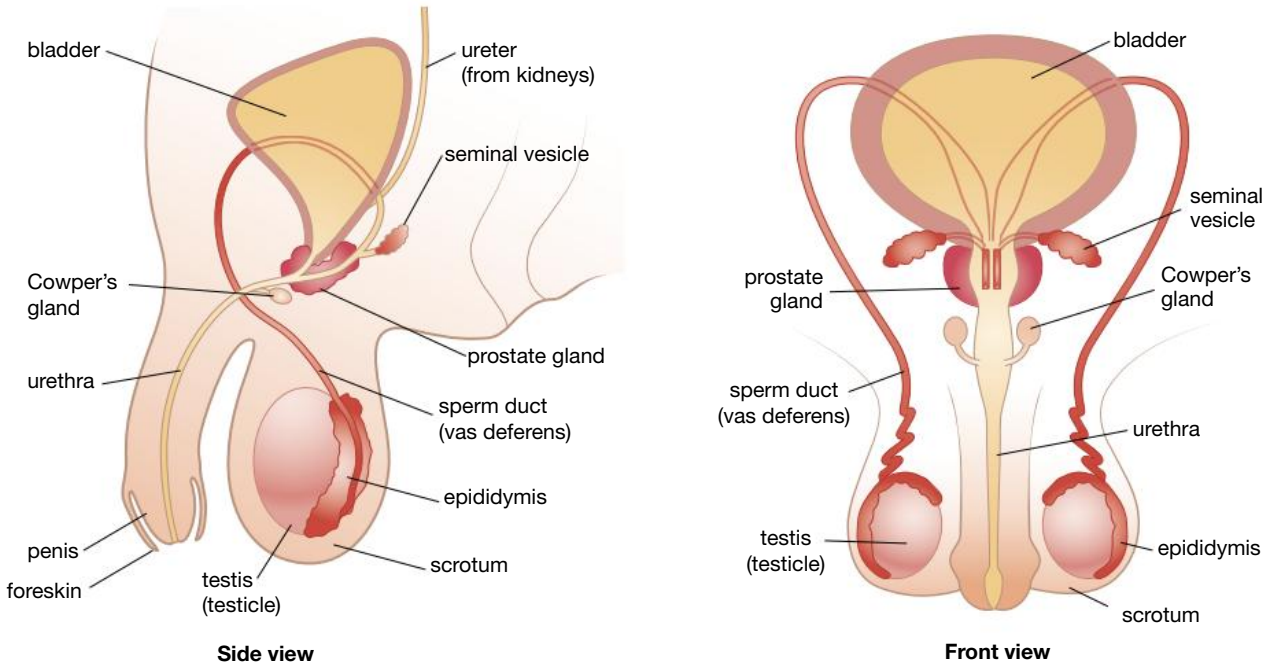


FIGURE 4.3.5 The human male reproductive system

AB 4.4

Prac 2 p. 178

Puberty

Puberty is the time in a person's life when they become sexually mature and able to reproduce. The physical changes of puberty take several years to complete. For boys, puberty is when fertile sperm are able to be produced. For girls, it is when the first ovulation occurs.

The time when puberty begins varies greatly. Girls usually begin puberty around 12 years of age, while boys are generally about 13. However, every person's body is different—you reach puberty when your body is ready.

Changes in males

The early changes of puberty in males are increased levels of some hormones such as testosterone. These lead to changes, such as:

- enlargement of the testes
- sperm formation by the testes
- growth of the penis
- the voice 'breaking' to become deeper
- hair growth on the face, arms, chest and groin
- increased muscle and bone growth and strength
- sudden increase in height and chest capacity.

These changes are shown in Figure 4.3.6.

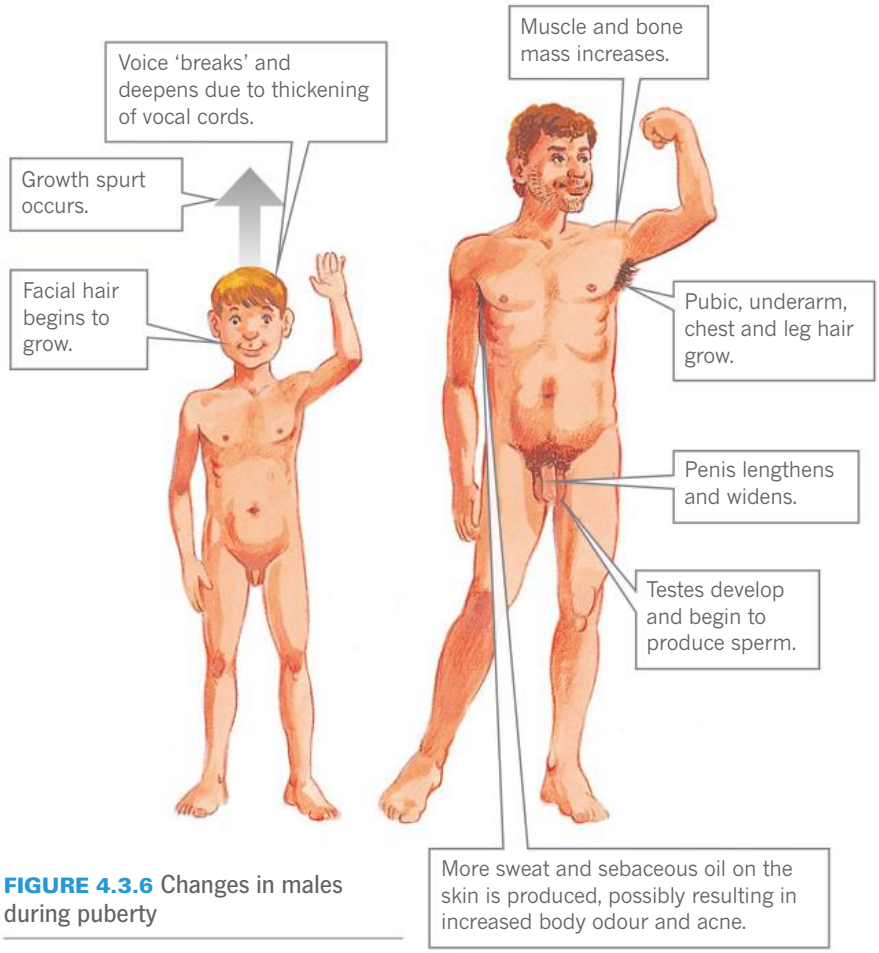


FIGURE 4.3.6 Changes in males during puberty

Changes in females

In girls, the early changes are increased levels of hormones such as FSH and LH. These hormones cause an increase in oestrogen. These hormonal changes result in changes such as:

- the breasts beginning to enlarge
- hair growth on the armpits and groin
- a sudden increase in height
- the first period
- widening of the hips
- more fat deposited around the hips.

You can see these changes in Figure 4.3.7.

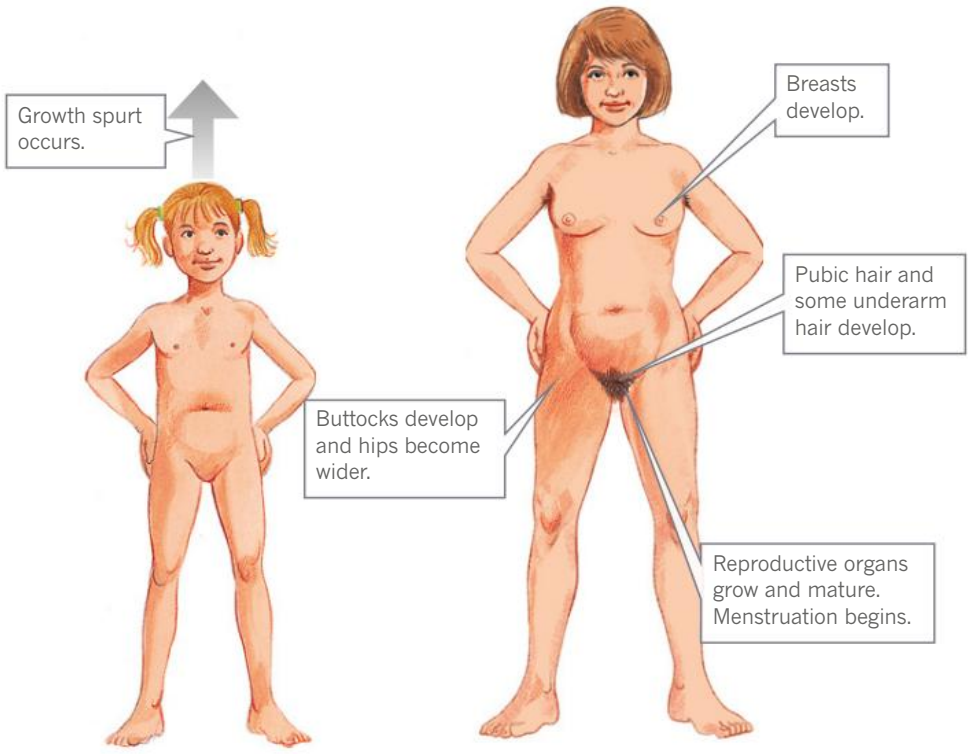


FIGURE 4.3.7 Changes in females during puberty

AB 4.5

Prac 1 p. 178

Ian Frazer and the HPV vaccine

The human papilloma virus (HPV) causes painful and unsightly genital warts in males and females. Some types of HPV also cause some cancers, mainly in women. These cancers kill about 250 000 people worldwide each year.

FIGURE 4.3.8 Ian Frazer developed a vaccine for HPV, a virus that can cause cervical cancer in women.

In 2006, Australian scientist Professor Ian Frazer (Figure 4.3.8) developed a new vaccine called Gardasil®. Gardasil® prevents about 75% of cancers of the cervix, 70% of cancers of the vagina and about 50% of cancers of the vulva. The vaccine also prevents most genital warts in males and females.

Vaccination (immunisation) is the process of injecting a chemical (called an antigen) into the body, which stimulates the body to defend itself against the chemical. The body produces several types of white blood cells that can destroy the foreign chemical. Some of these cells (called memory cells) then remain in the body. If the virus enters the body in future, the memory cells detect the chemical on the surface of the virus. The memory cells then stimulate the body to produce large numbers of white blood cells that can destroy the virus before it can multiply and damage the body. This is called the immune response.

Gardasil® is now routinely used to vaccinate (immunise) males and females between 9 and 26 years of age (Figure 4.3.9). Vaccination makes it unlikely that they will develop cancer or genital warts in the future.

FIGURE 4.3.9 Professor Ian Frazer immunises a young woman with his Gardasil® vaccine.

REVIEW

1. Name the diseases that Ian Frazer is helping to prevent.
2. State how many people die of these diseases around the world each year.
3. Explain how a person who has been immunised with Gardasil® responds if they become infected by HPV.
4. Discuss why society should support research in biological science, such as that of Professor Frazer.

MODULE 4.3

Review questions

Remembering

1 Define the terms:
- a ovulation
- b period
- c puberty.

2 What term best describes each of the following?
- a tubes down which the eggs pass to the uterus
- b changes in hormone levels in a cycle over a month
- c tubes through which sperm travel from the testes to the urethra.

3 Name the part of the male reproductive system that:
- a produces sperm
- b carries sperm to the penis
- c holds the testes
- d places sperm in the vagina
- e adds chemicals to the semen.

4 List the changes that occur in males and females during puberty.

5 What is an alternative name for each of the following?
- a fallopian tubes
- b testes
- c the uterus
- d an egg
- e the sperm duct
- f menstruation.

6 List three female sex hormones.

7 Name the main male sex hormone.

Understanding

8 a Explain what the menstrual cycle is.
- b Explain the role of hormones in the menstrual cycle.

9 Why are the testes held in a sac outside the male's body?

Applying

10 A particular woman reaches puberty at age 12 and produces one egg each month from puberty until she is 50. Calculate how many eggs she releases in her lifetime.

11 Calculate:
- a when a woman would probably ovulate if she had a 28-day menstrual cycle
- b when menstruation occurs if ovulation occurs at day 23
- c the time from menstruation to ovulation in a 36-day cycle.

12 a Identify the male reproductive part that has functions in both the reproductive and excretory systems.
- b Describe its role in each system.

Analysing

13 a Compare sperm and semen.
- b Compare ova, ovulation and oviduct.

14 Compare ovaries and testes in:
- a their position
- b the number of gametes produced.

Evaluating

15 Swelling of the prostate gland in a man often makes it difficult to urinate. Propose a reason why.

16 On hot days, the testes move away from the body and so hang lower than on cold days. Propose a reason why.

17 Infections can damage the fallopian tubes in women and the vas deferens in men, leading to scarring and potential blockages.
- a How do you think these infections will affect the chances of a woman becoming pregnant and of a man becoming a father?
- b Justify your answers.

Creating

18 Imagine you are writing for a teenage magazine. Plan an article for children who will soon be going through puberty. The article should discuss the changes that will occur and some of the emotional changes they may experience.

MODULE 4.3

Practical investigations

1 • My changing body

Processing & Analysing | Evaluating

Purpose

To identify the changes that occur during puberty.

Timing 30 minutes

Materials

- A3 sheet of paper or roll of butcher's paper
- coloured sticky note
- sticky tape, Blu-Tack® or similar

Procedure

1. Choose a partner of the same sex. Trace or draw an outline of your bodies on separate sheets of paper.
2. On these outlines, add labels to each part that changes or can be expected to change during puberty.
3. Describe the changes that occur to each body part as puberty proceeds.
4. At the bottom of your page, write down what causes these changes. Be as specific as possible, giving correct terms if possible.
5. Swap outlines with your partner and read their page. Identify any differences from yours. Discuss differences with your partner and combine the information onto one of the outlines, and stick it up on the wall to create a gallery with the other students.
6. When all the outlines in the class are up, wander around the gallery. Read all the posters and then place a sticky note on the one you think best represents all the changes that occur during puberty.
7. Tally the scores and identify which poster won.

Review

1. Evaluate the poster that won and identify what made it particularly good at explaining the changes that happen during puberty.
2. Evaluate your poster and suggest improvements you could make to it.
3. Summarise in 25 words what causes the changes that occur during puberty.

• STUDENT DESIGN •

2 • Reproduction models

Planning & Conducting | Evaluating

Purpose

To construct models of the male and female reproductive systems.

Timing 60 minutes

Materials

- As chosen by students

SAFETY

A risk assessment is required for this investigation.

Procedure

1. Construct a model of the male or female reproductive system. Your model should:
   - be 3D
   - have cutaway sections to show what the insides of different parts look like
   - clearly show its structure
   - be able to be suspended from string or cotton, or stood on a stand.
2. When all the models are complete, display them around the room.

Use the STEM and SDI template in your eBook to help you plan and carry out your investigation.

Review

Evaluate your model and suggest improvements.

MODULE

4.4 Pregnancy

Before you were born, you spent about 38 weeks in your mother's womb and were completely dependent on her for survival. In that time, all your organs such as heart, brain and lungs were formed, and eventually a whole new and unique individual was formed—you!

Copulation

Copulation is when two individuals join together for sexual reproduction. In humans it is also called **sexual intercourse**. In sexual intercourse, the penis becomes stiff and erect. It is then inserted into the vagina. The penis rubbing against the vagina causes sperm to be ejaculated (squeezed) out of the penis. The process is called **ejaculation** and it deposits several hundred million sperm near the cervix.

Sperm can swim, propelled by their tail. Their energy source is sugar in the semen. Sperm pass through the cervix and swim through the uterus into the fallopian tube. Most sperm die along the way, leaving a few hundred healthy sperm to make it into the fallopian tube where they may meet an egg. When they encounter an egg, the sperm swarm over its surface. You can see this happening in Figure 4.4.1. One sperm manages to bury its head into the egg, and the tail breaks off. When this happens, the egg surface immediately changes and becomes hard, preventing other sperms from burying into the egg and so no more sperm can enter the egg. The egg is now fertilised.

Implantation

The first cell of the new individual is called a **zygote**. The zygote begins to divide as it travels down the fallopian tube. You can see this in Figure 4.4.2 on page 180. The zygote keeps dividing until it forms a hollow ball of cells called a **blastocyst**. About five days after fertilisation, the blastocyst reaches the uterus. Then the blastocyst burrows into the wall in a process called **implantation**.

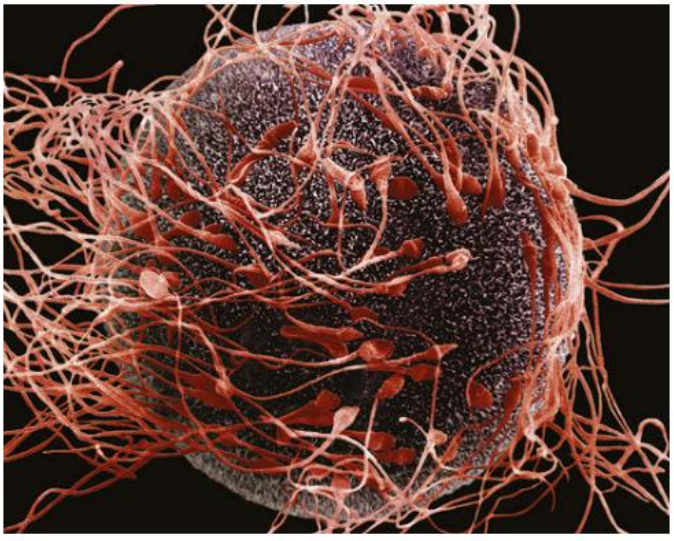


FIGURE 4.4.1 An SEM image of sperm swarming around an egg, trying to penetrate its surface

The embryo

A baby usually takes about 38 weeks to develop from fertilisation to birth. For the first 8 weeks the developing baby is referred to as an **embryo** (Figure 4.4.3). During this time, all the different types of cells, such as nerve, muscle and bone, are developing. These are being built into the different tissues, organs and systems of the body. In this critical period of development, the baby can be damaged by smoking, alcohol and other legal and illegal drugs. This is because any chemical that can affect cells could damage the embryo. Some illnesses, such as rubella, can also damage the embryo. These can cause deformities, such as missing limbs, and can also cause brain damage.

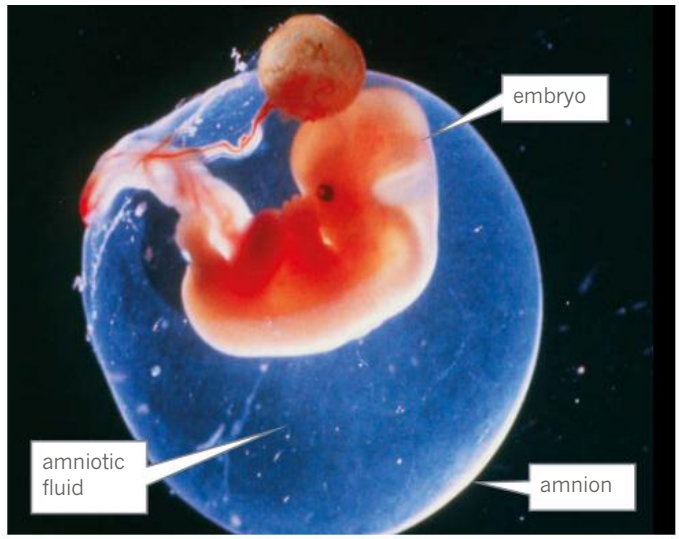


FIGURE 4.4.3 This image shows an embryo floating in protective amniotic fluid.

Amniotic fluid

The embryo floats in a fluid enclosed in a 'balloon' formed by a membrane or thin layer of living tissue. This balloon is called the amnion and is filled with **amniotic fluid**. Amniotic fluid acts as a shock absorber, protecting the embryo from bumps. It also helps keep the embryo's temperature constant.

SciFile

A fast but brief life

The fastest sperm take about 15 minutes to make their journey to the fallopian tube. Sperm can live for up to 2 days, and fertilisation is possible if the egg encounters the sperm in this time. This means that intercourse up to two days before ovulation can result in pregnancy.

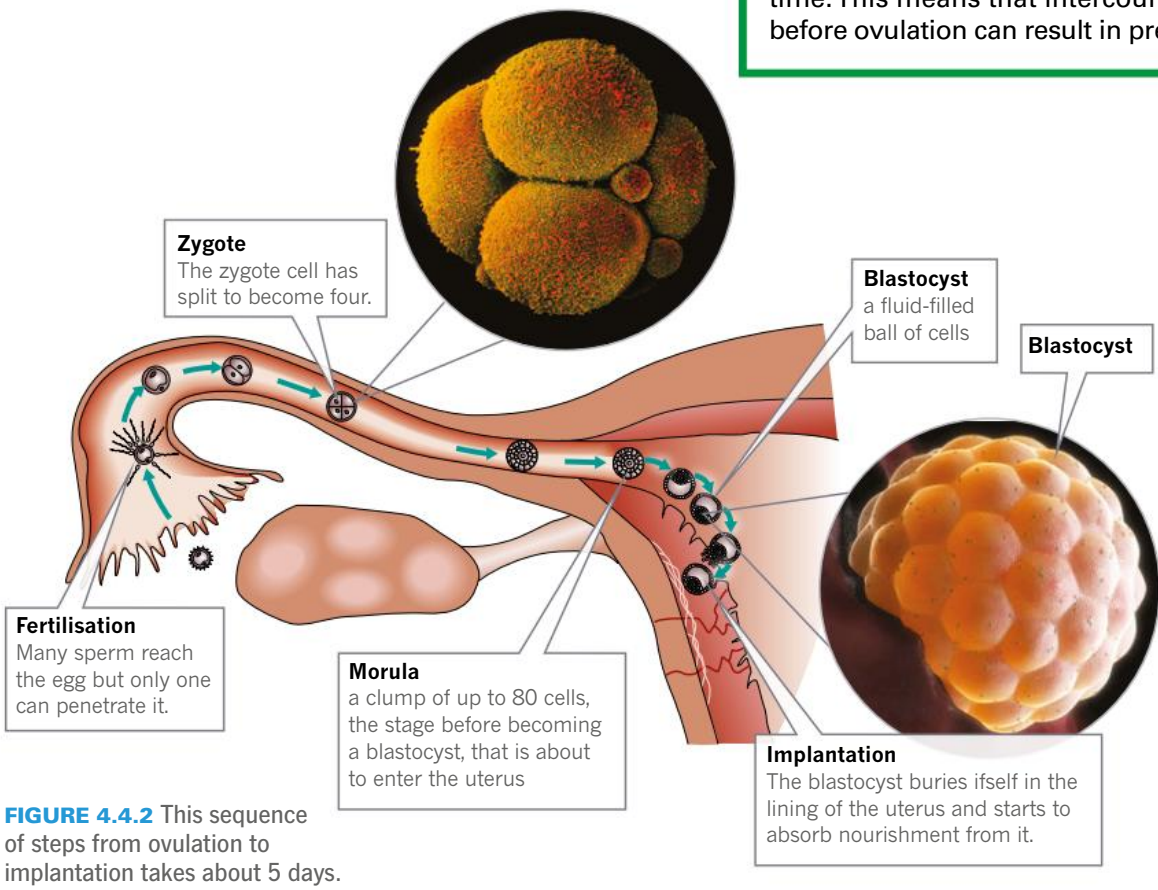


FIGURE 4.4.2 This sequence of steps from ovulation to implantation takes about 5 days.

The placenta

In its early development, the embryo is fed from a yolk sac and secretions (fluids) from the lining of the uterus. The yolk sac is similar to the yolk in a chicken's egg. Later on, the placenta develops from structures called villi. These small branching structures on the outside of the blastocyst develop into the placenta (Figure 4.4.4). The **placenta** is a highly folded series of membranes and blood vessels. It allows nutrients and oxygen from the mother to enter the baby. It also allows the embryo's waste materials such as carbon dioxide to enter the mother's blood so her body can remove it.

Figure 4.4.5 shows how the placenta is connected to the embryo by the **umbilical cord**. This contains blood vessels from the embryo. The blood supplies of the mother and embryo do not mix together. They are kept apart by a membrane. The materials to be exchanged between the mother and embryo pass across this membrane.

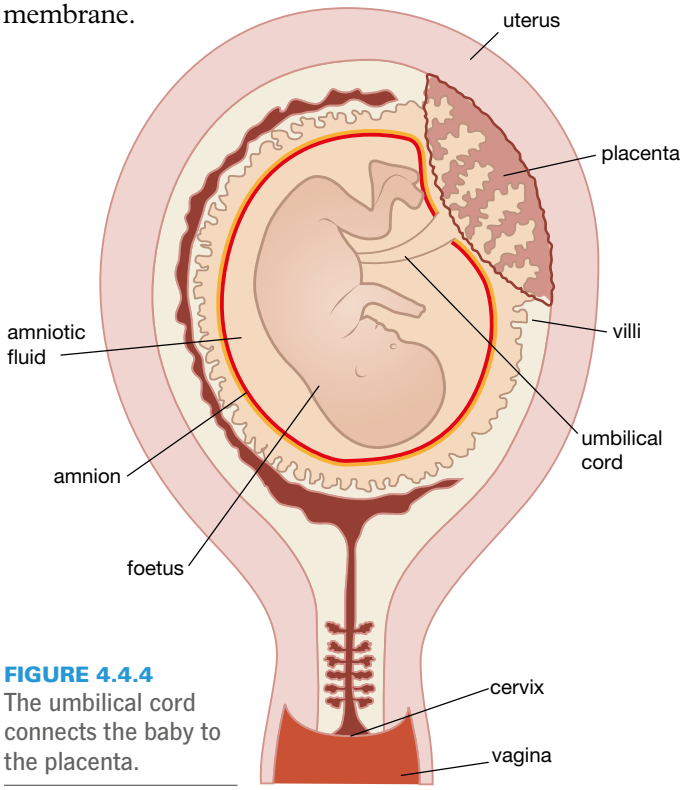


FIGURE 4.4.4 The umbilical cord connects the baby to the placenta.

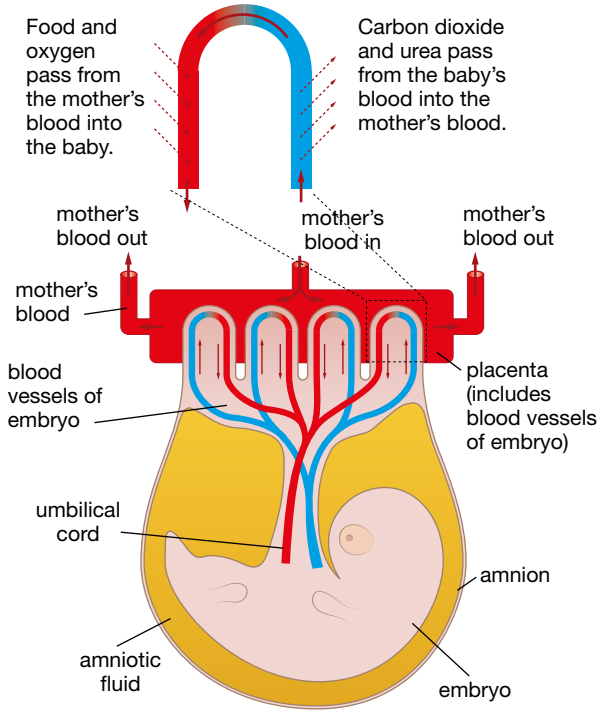


FIGURE 4.4.5 The placenta allows exchange of materials between the mother and the developing baby.

The foetus

Most of the major organs and systems have been formed when the embryo is about 9 weeks old. By now, its external appearance looks more human-like. It increases in size and the organs mature so they can function at birth. The developing baby is now called a **foetus**.

AB 4.6 AB 4.7 AB 4.8

Gestation

The period during which the baby develops in the uterus is known as the **gestation** period.

A baby develops for about 266 days (38 weeks) from fertilisation to birth. However, because menstrual cycles vary in length, doctors can't be sure when ovulation actually occurred. So, they usually talk about 'weeks pregnant'. These are counted from the start of the last menstrual cycle. Since this is about 14 days before fertilisation, birth is at '40 weeks', or 280 days, from the last menstruation. So a doctor talking about 'weeks pregnant' is referring to the weeks since the last menstrual period.

SciFile

Belly buttons

The umbilical cord joins the embryo in its abdomen. Your 'belly button' is where your umbilical cord joined you to your mother in the womb.

Birth

Birth is part of the process called **labour**, which can last for a few hours to a day or more. The first sign of labour is pain in the abdomen. This is due to the uterus contracting and relaxing. These contractions come and go but gradually get stronger, more painful and come closer together. When the contractions are regular and a few minutes apart, birth is not far away. The cervix dilates, relaxing and widening and causing the amniotic sac to burst. The baby then begins to pass through the cervix. As Figure 4.4.6 shows, the head usually goes through first. Then the baby is born. This may take from 10 minutes to a few hours. The umbilical cord is cut and tied. A short time after the baby is born, the placenta is expelled from the mother. This is called the **afterbirth**.

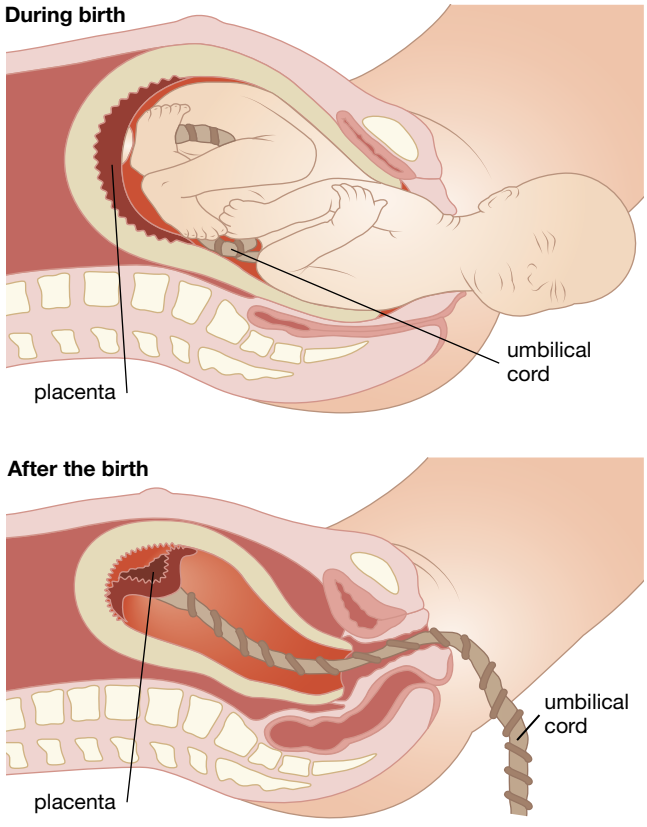


FIGURE 4.4.6 Labour involves birth of the baby and expulsion of the afterbirth.

STEM 4 fun

Reproduction animation

PROBLEM

Create an animation about human reproduction.

SUPPLIES

- computer access, camera, art materials such as markers, modelling clay

PLAN AND DESIGN

Create a computerised animation of one of the following:

- the female menstrual cycle
- fertilisation and implantation
- embryo growth after implantation
- the process of childbirth.

Design a storyboard for the sequence of your animation. What do you need to research to solve the problem? Make a list of materials you will need and steps you will take.

CREATE

Follow your plan. Create your drawings and models, then record your animation.

IMPROVE

What works? What doesn't? How do you know it solves the problem? What could work better? Modify your design to make it better. Test it out.

REFLECTION

1. In what career do these activities connect?
2. How did you use mathematics in this task?
3. What did you do today that worked well? What didn't work well?

SciFile

Pregnancy tests

In a pregnancy test, a woman urinates on a stick. The stick contains a detector for the hormone human chorionic gonadotropin (hCG). hCG is produced by the blastocyst, so if the woman is pregnant, hCG will be present in her urine. If hCG is present, two lines appear on the tester shown here.

Drugs and pregnancy

Research over the past fifty years has shown that some drugs and chemicals can damage the developing baby during pregnancy.

Thalidomide

In the 1960s, Australian scientist Dr William McBride noticed that a large number of children were being born with birth defects such as missing or shortened limbs, like those of the girl shown in Figure 4.4.7. When Dr McBride investigated the medical histories of the mothers, he found that they had been taking a pharmaceutical drug called thalidomide. The drug was prescribed by doctors to help relieve nausea and vomiting during pregnancy, symptoms called morning sickness. Further research by Dr McBride showed that thalidomide crossed the placenta and entered the embryo as it developed. It affected cell division, resulting in missing or deformed limbs. Thalidomide was then banned for use by pregnant mothers.

Under certain circumstances, thalidomide is still an effective drug. It has been shown to:

- slow cell division in cancer cells, preventing their spread
- help cure multiple myeloma, a cancer of the white blood cells
- ease the pain and halt the progression of leprosy, a bacterial disease that damages nerves, causing weakness and inability to use arms and legs.

In most of these cases, thalidomide is prescribed by specialist doctors to ensure that it is not taken by pregnant women.

Despite this, it is estimated that there have been over 7000 cases of thalidomide-affected babies born in Brazil in the past twenty years. Some of these cases are because doctors have prescribed thalidomide as a treatment for leprosy to women who were unaware they were pregnant. Brazil is the world's largest user of thalidomide, with over 300 000 leprosy patients in that country.

FIGURE 4.4.7 Deformed and shortened arms and legs are typical symptoms of thalidomide taken by the mother during pregnancy.

Alcohol

Drinking while pregnant can have consequences for the baby. Research has shown that alcohol crosses the placenta and that high alcohol intake can cause a condition known as fetal alcohol syndrome (FAS). Babies born with FAS can have low birth weight, a smaller head, small eyes, flattened face and nose, and heart defects.

Children with FAS are affected for life and cannot be cured. FAS can result in serious problems such as:

- low intelligence, poor memory and learning difficulties (due to damage to the growing brain)
- behavioural problems such as attention deficit hyperactivity disorder (ADHD). However, not all ADHD is due to FAS
- increased risk of mental illness.

Smoking

Research has shown that smoking damages both the mother and her unborn baby, because many chemicals from cigarettes can cross the placenta. Smoking can cause:

- death of the foetus in the womb
- miscarriage (expulsion of the foetus from the womb)
- premature birth
- slower growth and development
- increased risk of cleft lip and cleft palate
- lower birth weight
- twice the risk of sudden infant death syndrome (SIDS).

Other drugs

Many other legal and illegal drugs and chemicals have been shown to damage an unborn baby. These include:

- cocaine
- high doses of vitamin A
- some antibiotics.

Legal drugs such as aspirin and antibiotics have warnings printed on their labels indicating whether there is a risk of damage to the unborn child if taken during pregnancy.

An ultrasound scan may be used to detect abnormalities and monitor the growth of the foetus (Figure 4.4.9).

Review

1. Explain how thalidomide causes birth defects.
2. Propose reasons why a specialist doctor might give a patient thalidomide.
3. Explain how a foetus could be affected when a pregnant woman drinks a lot of alcohol.
4. List four permanent effects of foetal alcohol syndrome on children.
5. What would you recommend pregnant women do about smoking, drinking alcohol or taking other drugs?
6. Give an example of how research on cells has helped doctors provide better medical care.

Prac 1
p. 186

FIGURE 4.4.8 Alcohol and smoking can do great harm to a developing foetus.

FIGURE 4.4.9 An ultrasound allows doctors to check for any physical deformities or threats to the health of the foetus.

MODULE 4.4

Review questions

Remembering

1 Define the terms:
- **a** copulation
- **b** ejaculation
- **c** implantation
- **d** blastocyst
- **e** placenta
- **f** labour.

2 What term best describes each of the following?
- **a** the cell formed by fertilisation
- **b** the place where fertilisation occurs
- **c** the site of implantation
- **d** fluid surrounding the embryo
- **e** the connection between the embryo and the placenta
- **f** the time period from fertilisation to birth.

3 List the major events from fertilisation to implantation.

4 What are the signs that labour is occurring?

5 What should happen after the cervix dilates during birth?

Understanding

6 What is the purpose of amniotic fluid?

7 What are the functions of the placenta?

8 Explain what prevents mixing of the blood supplies of the mother and the foetus.

Applying

9 Calculate the date the baby should be born if:
- **a** a woman last had a period on 1 January and is pregnant
- **b** a zygote was formed on 1 January.

Analysing

10 Compare:
- **a** an embryo and a foetus
- **b** labour and birth.

11 What is the difference between each of the following?
- **a** the placenta and the umbilical cord
- **b** fertilisation, implantation and pregnancy.

Evaluating

12 A pregnant woman complains that she feels sick every morning. She wants to use a natural remedy that a friend suggested. What would you recommend she do, and why?

13 A baby's skull bones do not lock together to make the skull rigid until well after birth. Why do you think this is an advantage in childbirth?

14 To induce labour is to make it happen so that the baby can be born. Labour is induced when a chemical called oxytocin is injected into the mother. What effect do you think the chemical has on the uterus?

Creating

15 Construct a diagram of a developing foetus and the uterus. Label each part of the diagram with its function in reproduction.

16 Plan a survey that would determine how much primary school students know about their 'belly button'.
- **a** List the questions you wish to ask.
- **b** State how many students you would include in your survey.
- **c** Outline how you would conduct your investigation—for example, would it be a paper quiz or interview, or something else?
- **d** List possible problems the investigation could create.
- **e** State what you would tell students after you have collected the results.

MODULE
4.4 Practical investigations

• STUDENT DESIGN •

1 • Interview a mother

Planning & Conducting | Evaluating

Purpose

To interview a mother about her experiences of pregnancy and the advice she received.

Timing 30 minutes

Materials

- paper and pen or recording device such as the video function on a mobile phone

Procedure

1. Design an interview with a woman who has been a mother—either your own mother, or someone you know. Scientists must always be ethical and so it is important that the woman agrees to participate freely. Your aim is to find out what advice the mother received before pregnancy, what she wished she had known, and what advice she would like to pass on to young women.
2. After compiling your list of questions, discuss them with another student to get their opinion on them. Check with your teacher that your questions are good ones.
3. Show the questions to the mother and ask her if she could help you. Tell her that her name will not appear in the report and that her answers will not be shown to anyone else other than your teacher. It would be best if you could actually talk to her and write out or record what she says. If she doesn't want to talk about it, but would be happy to write out some answers, then accept the offer. Don't hassle her to tell you things. Some things may be personal.
4. Obtain the answers to your questions by interview or in writing from the person. Make sure that you keep your promises about her privacy.

Hints

The first step is to think about the questions you should ask the woman, and write these down. Some examples are:

- How did you find out what to expect in pregnancy?
- What advice had you received about your diet during pregnancy?
- What was the hardest thing about pregnancy?
- What did you find hardest about looking after a baby?
- What advice would you give about seeking help from healthcare workers during and after pregnancy?
- What is the main thing you wished you had known before the birth and after the birth?
- Use the STEM and SDI template in your eBook to help you plan and carry out your investigation.

Review

Assess what you have learnt in this activity, including any lessons that could help if you become a parent in the future.

CHAPTER 4

Chapter review

Remembering

1 State the term for the following:
   - a reproduction not involving joining of sex cells
   - b production of offspring by unfertilised eggs
   - c sex cells that must join together in sexual reproduction
   - d the human organ that produces male gametes
   - e the human organ that produces female gametes.

2 What are the following times?
   - a the length of human gestation in weeks and days
   - b the average age for the start of puberty in girls and boys
   - c the length of time a sperm can live in the oviduct
   - d the number of the day when ovulation occurs in a typical 28-day menstrual cycle.

3 List five different methods of asexual reproduction, and for each name an organism that reproduces that way.

4 What does the term *clone* mean?

Understanding

5 Why is cloning a useful process in agriculture?

6 Explain the important role of the lining of the uterus in human reproduction.

7 Describe how you could clone a small shrub at home.

8 Describe how you could grow a daffodil, onion or potato plant at home and demonstrate that it has reproduced.

9 Outline the role of cell division in sexual and asexual reproduction.

Applying

10 Animals such as humans, dogs, sheep and horses are classified into a group called placental mammals. The echidna and platypus are classified into a different mammal group called monotremes because they lay eggs. Identify the key difference between these two mammal groups.

11 Identify the structure in a pregnant woman that allows the embryo's carbon dioxide to enter the mother's circulation.

Analysing

12 Discuss how important asexual reproduction is in animals is compared with plants.

13 Compare the structures involved in sexual reproduction in plants and animals.

14 What is the major difference between sexual and asexual reproduction?

15 Compare the roles of the male and female reproductive systems in humans.

16 Choose three characteristics of boys and girls that change over puberty and classify them into:
   - changes that have an essential role in reproduction
   - changes that may assist in reproduction but are not essential
   - changes that do not have an obvious role in reproduction.

17 Compare cell division in sexual and asexual reproduction.

Evaluating

18 Why is it a good idea to be careful which drugs or medications are taken during pregnancy?

19 a Assess whether you can or cannot answer the questions on page 151 at the start of this chapter.
   b Use this assessment to evaluate how well you understand the material presented in this chapter.

Creating

20 Use the following ten key terms to construct a visual summary of the information presented in this chapter.

sexual reproduction	asexual reproduction
flower	meiosis
reproductive system	fertilisation
placenta	pregnacy
clone	foetus

AB 4.10

CHAPTER 4

Inquiry skills

Research

1 Processing & Analysing Communicating

Three-part inquiry question

Select your entry point and complete the relevant parts of this inquiry.

As a zygote develops into a new individual, the arms, legs, brain and other organs must develop. All the parts of the body develop at different rates and at different times.

a Draw a timeline that shows the development of the arms, legs, eyes, ears, heart, brain and spinal cord. Make sure you mark on your timeline the point when the developing baby's heart starts to beat and when it begins to suck its thumb.

b i Research has shown that newborn babies show a preference for the voice of their mother over most, or even all, other sounds. Consider your timeline. Can you explain why this preference might be the case?

ii How might this preference be affected if the mother caught rubella (also called German measles) during week 6 of her pregnancy, or in week 21? Explain why.

c X-rays can be extremely damaging to a developing embryo, but much less damaging to the foetus in the last 6 months of development. Explain this difference.

2 Processing & Analysing Communicating

Research the impact of plant cloning techniques in vineyards or fruit production. Find:

- images of the techniques used to propagate the plants, such as cuttings, grafting and layering
- why asexual reproduction is used, rather than allowing the crop to reproduce sexually
- how beneficial the cloning techniques have been
- specific examples of each cloning technique.

Present your findings in digital form or as a poster.

3 Processing & Analysing Communicating

Mammals are classified into three main groups on the basis of their method of reproduction—the placentals, marsupials and monotremes.

a Briefly outline in words these three methods of reproduction, using examples of animals from each group.

b Present diagrams identifying the major differences in the reproductive structures and methods of these three major groups of mammal.

4 Processing & Analysing Communicating

Jellyfish reproduce in a complex cycle that involves both sexual and asexual reproduction. Research how jellyfish reproduce, and find:

- an image of their reproductive cycle
- the function of polyps
- which parts of the cycle involve sexual reproduction and which involve asexual reproduction.

Present your research as a poster.

5 Processing & Analysing Communicating

Research how reproductive technologies are used to assist humans in having children. Find:

- information regarding the basic procedures that are available, and which patients each method is aimed at helping. Procedures to investigate include in-vitro fertilisation (IVF), embryo transfer, artificial insemination (AI), donor eggs, surrogacy and intracytoplasmic sperm injection (ICSI)
- images to help explain each procedure
- why some people are opposed to the use of such technologies.

Present your research in digital form.

6 Processing & Analysing Communicating

Research the labels on any five common legal drugs that may be in your medicine cabinet at home. Some typical drugs are aspirin, Panadeine®, paracetamol (Panadol®), ibuprofen (Nurofen®), Zyrtec® (or other allergy relievers). Look at the labels and find warnings for pregnant women.

- Take digital photos of the warnings.
- Research to find the reasons why each warning is on the packet.
- Explain why pregnant women should always read warning labels on packets.

Present your research in digital form.

CHAPTER 4

Inquiry skills

Thinking scientifically

Questions 1 and 2 are based on the following graph. Various studies have investigated whether the sex of reptile embryos can be changed by incubating the eggs at different temperatures. Consider the graph in Figure 4.5.1.

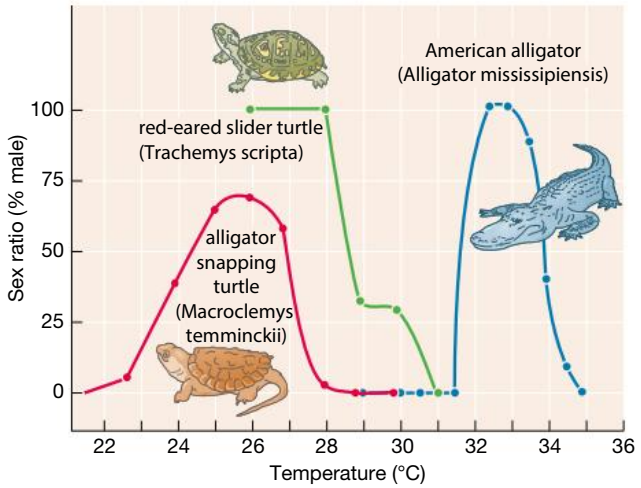


FIGURE 4.5.1 The effect of temperature on the sex of newly hatched offspring of three reptile species: the American alligator (*Alligator mississippiensis*), the red-eared slider turtle (*Trachemys scripta elegans*) and the alligator snapping turtle (*Macroclemys temminckii*).

1 Which of the following is a suitable conclusion based on the graph?
- **A** Reptiles only reproduce at a particular temperature.
- **B** In some reptiles, a male embryo can later change sex to a female embryo if it gets hotter.
- **C** The sex that an embryo becomes depends on the temperature at which the egg was developing.
- **D** The sex ratio of a reptile is different for different species.

2 Consider an area where alligators lay eggs. Imagine there is a long-term change in environmental temperatures. If temperatures remained at 29°C from laying to hatching, which of the following is a long-term problem that may occur for alligators in the area?
- **A** It will be too hot for alligators to survive so they will move to other areas.
- **B** Breeding will eventually stop in the area as no males are being born.
- **C** The sex ratio of the alligators will be zero so no young are being born in the area and the population will all die out.
- **D** It will be too cold for alligators to lay eggs so the population will die out or move to another area.

3 Bats are like humans in that they are placental mammals. Which of the following should occur in the life cycle of a bat?
- **A** Bats would lay eggs in nests, like birds.
- **B** Bats would give birth to live young and carry them in a pouch like marsupials.
- **C** Bats would give birth to babies that go through a metamorphosis like butterflies.
- **D** Bats would develop in a uterus with the foetus connected to the mother by an umbilical cord.

Questions 4 and 5 refer to the following table listing some reproductive structures in a human and a flowering plant.

Pair number	Human part	Flowering plant part
1	testis	stigma
2	uterus	seed
3	sperm	pollen
4	egg	anther
5	foetus	ovule
6	fallopian tube	fruit

4 Which of the following pairs in the table names parts that have the same role in human reproduction as they do in plant reproduction?
- **A** pair 1
- **B** pair 2
- **C** pair 3
- **D** pair 6

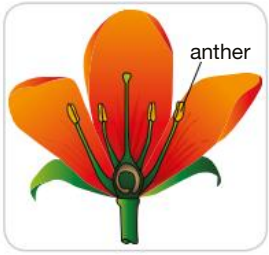
5 Which of the following pairs in the table names parts found in the female human and the female part of the flower?
- **A** pair 1
- **B** pair 3
- **C** pair 4
- **D** pair 5

CHAPTER 4

Glossary

afterbirth: placenta expelled from the mother after birth

amniotic fluid: fluid surrounding the embryo that acts as a shock absorber and helps to maintain a constant temperature



anther

anther: the part of a flower that produces pollen

asexual reproduction: a form of reproduction where only one parent produces the offspring and no joining of sperm and eggs is involved

asexual reproduction

blastocyst: a hollow ball of cells that develops into an embryo

blastocyst

budding: a form of asexual reproduction, where the offspring grows from part of the parent's body then detaches from the parent

bulb: a swollen underground part of a stem that has fleshy 'leaves' and can grow into a new plant

cervix: part of the uterus that keeps it closed while the baby is developing

clone: a copy of a particular individual.

cloning: the process of producing identical individuals through reproduction

copulation: two individuals joining together for sexual reproduction

development: changes in form and structure in an individual over its life, from zygote to adult

ejaculation: the process of sperm being squeezed out of the penis

embryo: a developing offspring at a very early stage of development, before the major organ systems are formed

fallopian tubes (oviducts): tubes down which the egg passes and where fertilisation occurs

fertilisation: the joining of gametes

fertilisation

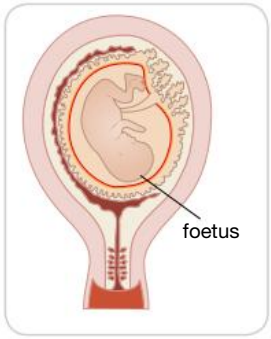
filament: flower structure holding the anther

fission: asexual reproduction by splitting in two

flower: the reproductive structure in plants that makes male sex cells and female sex cells

flower stalk: supports and displays the flower

foetus: the stage of development when most of the major organs and systems are present



foetus

fruit: the structure that the ovary of a flowering plant turns into as the seeds ripen

gametes: reproductive cells; sperm in males and eggs in females

germination: when the young growing plant sprouts out of the seed

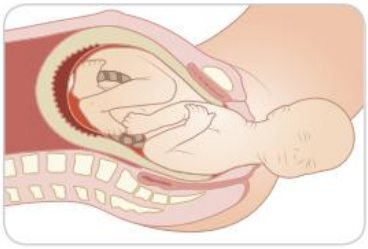
gestation: the time from fertilisation to birth

hermaphrodite: an individual with both male and female sex organs

hormones: chemicals that are produced in the body and control reproduction and physical characteristics

implantation: when the blastocyst burrows into the lining of the uterus

labour: the process leading to birth, from the first contractions of the uterus to expulsion of the afterbirth


labour

meiosis: the process that forms sex cells, when a cell nucleus divides into four nuclei

menstrual cycle: regular monthly changes in the hormones and reproductive organs of adult females

menstruation: a period

mitosis: when the cell nucleus divides into two new nuclei

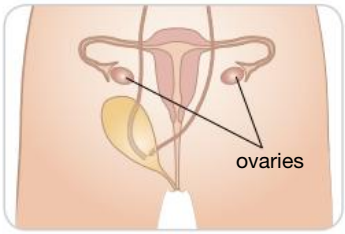
mitosis

offspring: individuals produced by reproduction

CHAPTER 4

Glossary

ovaries (ovary): organs that produce eggs (or ova)



ovaries

ovulation: when the egg bursts out of the follicle

ovule: name for the egg in plants

parthenogenesis: a form of reproduction where offspring develop from eggs that have not been fertilised by a male gamete

period (menstruation): the shedding of blood and dead tissue from the lining of the uterus

petal: coloured parts of a flower that attract animals for pollination

placenta: membranes of the foetus and mother that allow nutrients and oxygen to be exchanged and waste to be removed

plantlet: small plants on a leaf that can grow into new plants

pollination: the transfer of pollen from anther to stigma

puberty: the time of life in humans when physical changes bring sexual maturity

reproduction: the process of parents producing new individuals, or offspring

rhizome: an underground stem that grows along underground, sending up new plants at intervals

root sucker: a new plant growing from roots of an existing plant near the surface

runners: stems that run along the ground surface, forming new plants at regular intervals

scrotum: a sac that hangs outside the body and contains the testes

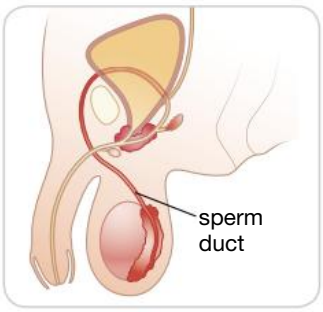
semen: a mixture of sperm and other fluid released from the penis

sepal: small leaf-like structures covering and protecting a flower bud

sexual intercourse: a male and a female copulating

sexual reproduction: the process of a sperm and an egg joining together and then growing into a new individual

sperm duct (vas deferens): a tube carrying sperm from the testes to the urethra



sperm duct

stigma: the flower part that receives the pollen

style: the flower part that connects the stigma to the ovary

testes: organs that produce sperm; (plural of testis)

tuber: a swelling on a stem, usually underground, that can grow into a new plant if detached

umbilical cord: joins the embryo to the placenta

uterus (womb): the organ in which the foetus grows and develops

vagina: the organ that allows the male penis to be inserted to deposit the sperm; also acts as the birth canal down which the baby passes

vegetative reproduction: natural methods of asexual reproduction used by plants, including bulbs and runners

yield: the amount of the desired part of the plant that is produced from the area planted or number of plants grown

zygote: the first cell of the new individual after fertilisation

AB 4.9

CHAPTER

5 Energy

Have you ever wondered...

- why car engines get hot?
- what the energy stars on a new refrigerator mean?
- what insulation does in a house?
- how sounds get to you?
- why rainbows form?

LS

After completing this chapter you should be able to:

- describe kinetic energy as the energy of movement
- describe potential energy as stored energy, such as gravitational, chemical and elastic energy
- investigate different forms of energy in terms of the effects they cause
- outline how heat energy is often produced as a by-product of energy transfer
- use flow diagrams to show changes between different forms of energy
- investigate how energy efficiency can reduce energy consumption
- outline how engineers improve energy efficiency
- *investigate energy transformations in devices, such as a catapult or a water wheel*
- *describe how sounds are produced by different musical instruments*
- *measure the speed of sound*
- *use a wave model to describe the measured properties of sound, wavelength and frequency*
- *outline how images can change when the arrangement of the mirrors or lens is altered*
- *explore the mechanism of the human eye and corrective technologies*
- *observe and list the order of colours in the visible spectrum*
- *describe the different types of radiation in the larger spectrum of radiation.*

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AB 5.1

MODULE

5.1 Energy around you

As a roller-coaster speeds downwards, the wheels of the rolling cart heat up. As a passenger, you feel the wind rushing past you, your hair flies around and you probably scream! Energy is needed to make all these things happen. Energy exists in many different forms, from electrical energy to sound, light and heat energy. Energy can change forms, but it is never lost.

science 4 fun

Making spiders

YES

Can you release energy by mixing two substances together?

Collect this ...

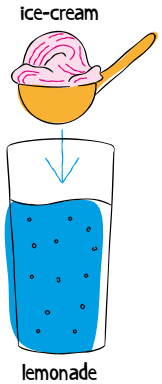
- lemonade
- ice-cream
- spoon

SAFETY

Do not eat food prepared in the science laboratory.

Do this ...

1. Half-fill a glass with lemonade.
2. Add a scoop of ice-cream.
3. Give it a stir.



Record this ...

1. Describe what happened.
2. Explain why you think this happened.

Energy makes things happen

On a typical day, many things happen around you. People walk and drive around in cars, birds chirp, leaves fall from trees, clothes dry on the clothesline and you watch a film clip on a smartphone. Each of these activities needs **energy**. It is hard to explain what energy is, because you can't see it or weigh it. Instead, you can observe what energy does. Energy is needed to move or heat something, to make noise or light, or to change an object's shape. Energy makes things happen.

SciFile

Counting calories

You may have heard of a unit of energy called the calorie. This unit is used in some countries of the world, particularly to measure food energy. One calorie (cal) is the amount of energy needed to raise the temperature of 1 gram of water by 1°C. This is about 4.2 joules.

SkillBuilder

Measuring energy

Energy is measured using a unit called the joule (symbol J). You use one joule of energy when you lift a 1 kilogram (kg) bag of potatoes 10 centimetres (cm) off the floor. Lifting 1 kg of potatoes isn't too hard, which shows that a joule is a small amount of energy. In fact, a joule is so small that energy is often measured in batches of 1000 joules. A batch of 1000 joules is known as a kilojoule (kJ). If you lifted 1 kg of potatoes 10 cm with 1 J of energy, then you could lift them 100 metres with 1 kJ of energy!

Food energy is commonly measured in kilojoules (kJ). Even larger amounts of energy, such as electrical energy, are measured in megajoules (MJ).

1 kJ = 1000 J **1 MJ = 1 000 000 J**

Worked example

Measuring energy

Problem 1

Calculate how many joules of energy are contained in:

a 2 kJ **b** 3.5 MJ

Solution

Thinking: Determine the factor to multiply with

Working:

a 1 kJ = 1000 J so multiply by 1000 therefore 2 kJ = 2 × 1000 = 2000 J

b 1 MJ = 1 000 000 J so multiply by 1 000 000 therefore 3.5 MJ = 3.5 × 1 000 000 = 3 500 000 J

Problem 2

Calculate how many megajoules of energy are contained in:

a 4 800 000 J **b** 5 700 000 000 J

Solution

Thinking: Determine the factor to divide by.

Working:

a 4 800 000 J = 4 800 000 ÷ 1 000 000 = 4.8 MJ

b 5 700 000 000 J = 5 700 000 000 ÷ 1 000 000 = 5700 MJ

Try yourself

1 Calculate how many joules of energy are contained in:
a 6 kJ **b** 1.8 MJ

2 Calculate how many kilojoules of energy are contained in:
a 4000 J **b** 16 400 J

Forms of energy

As Figure 5.1.1 shows, there are many different forms of energy.

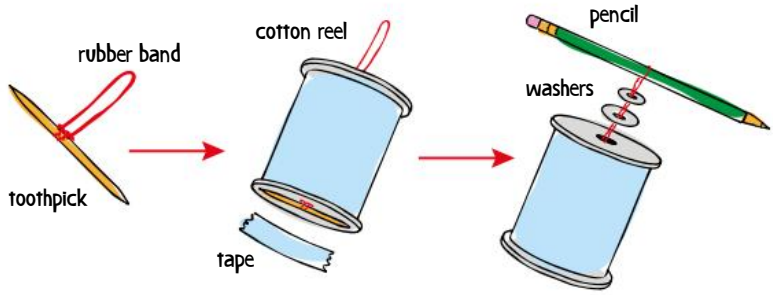
- **Kinetic energy** is the energy of movement. Anything that moves has kinetic energy. The faster an object moves, the more kinetic energy it has.
- **Heat energy** can come from the Sun, flames, chemical reactions, electrical devices or even from a person or animal. Heat warms, burns, dries, melts, and makes hot-air balloons rise.
- **Light energy** comes from the Sun, light globes, fires and animals such as glow-worms. Without light energy, the world would be a very dark place.
- **Sound energy** is the energy that air has when it is vibrating. Your ears and brain interpret the vibrating of air as sounds. Sound comes from your voice, musical instruments, cars and power tools.
- **Electrical energy** is produced by power stations, solar cells, batteries and lightning. Electrical energy powers your TV, phone, microwave and toaster.

FIGURE 5.1.1 All these common forms of energy make things happen.

science 4 fun

Creepy crawly

What happens when you twist a rubber band?



Collect this ...

- rubber band
- cotton reel
- part of a toothpick or match smaller than the diameter of the cotton reel
- masking tape
- 2 metal washers
- a pencil or a piece of dowel longer than the diameter of the cotton reel

Do this ...

1. Loop a rubber band around the toothpick and through the cotton reel as shown. Tape the toothpick to the cotton reel.
2. Insert the rubber band through the metal washers and loop the end around the pencil.
3. Twist the pencil to wind up your creepy crawly.
4. Place it on a smooth surface and let it go!

Record this ...

1. Describe what happened.
2. Explain why you think this happened.

Stored energy

Not all forms of energy are as obvious as those discussed so far. Many of the objects around you have stored energy or **potential energy**. Petrol in a car's fuel tank and books on a shelf both have potential energy. They are not using energy at the moment but have stored energy. Stored energy gives objects the potential to make things happen: the books can fall off the shelf and the petrol can burn.

One form of potential energy is the **chemical energy** your body gains from eating food. This energy enables you to run, play sport, heat your body and keep your heart beating. The foods that you eat originally obtained energy from the Sun. Plants capture light from the Sun and convert it into chemical energy in the form of simple sugars. This happens in a process called **photosynthesis**. Plants such as wheat make sugars and then convert them into starch for storage. When you eat the plants, their seeds, nuts or grains (or eat animals that have eaten them), your body uses the chemical energy from these simple sugars and starch as your energy source. Figure 5.1.2 shows the energy content available from one type of breakfast cereal.

NUTRITION INFORMATION (Average)

SERVING SIZE: 30G (APPROX. 1 CUP) SERVINGS PER PACKAGE: 16

	PER SERVE	PER 100g	30g with 2/3 cup (170mL) Whole Milk	30g with 2/3 cup (170mL) So Good™
Energy (kJ)	459	1530	930	920
(Cal)	110	366	222	220
Protein (g)	2.3	7.6	7.9	8.1
Fat -Total (g)	0.1	0.4	6.6	5.9
-Saturated (g)	<0.1	0.2	4.3	0.7
Cholesterol (mg)	0.0	0.0	22.1	0.0
Carbohydrate				
-Total (g)	24.0	80.0	32.0	33.0
-Sugars (g)	2.8	9.3	10.8	6.0
Dietary Fibre (g)	0.9	3.1	0.9	0.9
Sodium (mg)	234	780	304	311
Potassium (mg)	41	136	299	327
Thiamin (mg)	0.55 (50%)*	1.83	0.58	0.65
Riboflavin (mg)	0.42 (25%)*	1.42	0.76	0.72
Niacin (mg)	2.5 (25%)*	8.3	2.5	2.5
Folate (µg)**	100 (50%)*	333	108	105
Iron (mg)	3.0 (25%)*	10.0	3.0	3.9

*=Percentage of Recommended Dietary Intake (RDI)

FIGURE 5.1.2 For a healthy lifestyle, the energy you put into your body from food should be about the same as the energy you require for your body to function.

Figure 5.1.3 shows four different types of potential energy.

- **Gravitational potential energy** is energy stored in an object when it is above the ground. The greater the height of an object the more gravitational potential energy it has. For example, the higher a water slide, the more gravitational potential energy you have at the top and the more kinetic energy you will have on the way down!
- **Chemical energy** is energy stored in substances. This energy is released by your body when you digest food, and by cars when fuel is burnt. Wood, paper, apples, petrol and batteries all contain chemical energy.
- **Elastic potential energy** is energy stored in a stretched or squashed spring. Stretched rubber bands also store elastic potential energy, which is released when they are let go.
- **Nuclear energy** is energy stored inside the tiny atoms that make up all matter. Nuclear energy is released in a nuclear power plant, when a nuclear bomb explodes, and inside the Sun. Nuclear reactions produce heat and light.

Prac 1 p. 203
AB 5.2

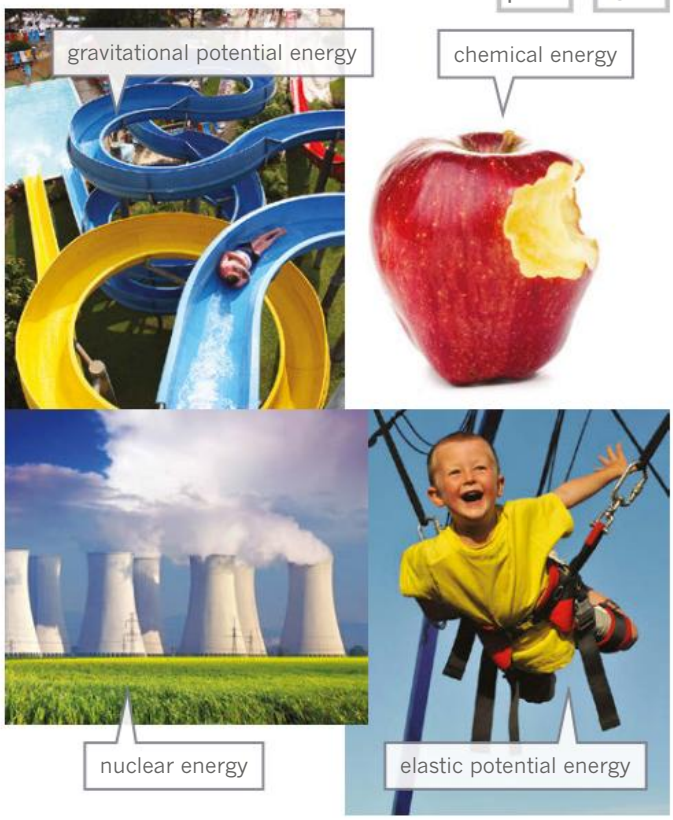


FIGURE 5.1.3 Objects that store potential energy may release the energy in different forms at a later time. When stored energy is released, things happen.

Working with Science

RENEWABLE ENERGY ELECTRICIAN

In Australia, there are growing concerns about the impact of climate change and pollution and the fact that one day non-renewable resources like coal and oil will run out. As a result there is a need for the development of renewable energy technology. People who are skilled in working with this technology are an important part of moving to a more sustainable energy future. There are various employment and training pathways you can take to gain skills in working with renewable energy technology.

Electricians are an important part of the renewable energy industry and there are many employment opportunities in Australia. Electricians maintain, repair and install electrical systems and equipment, and so are essential in our technology-dependent society (Figure 5.1.4). To become a qualified electrician, you need to complete an apprenticeship in Electrotechnology (Certificate III). Electricians need to have good communication and problem-solving skills, and enjoy technical tasks and working independently. To gain specialist electrical skills in working with renewable energy technology, such as solar panels, you will need to complete a Certificate IV in Electrical: Renewable Energy. This qualification will give you the skills to work in and contribute to the important area of renewable energy, with a promising job outlook for the future.

FIGURE 5.1.4 An electrician inspects cables for a set of solar panels. Electricians have many important roles in the renewable energy industry.

Review

Electricians qualified to work with renewable energy technology will be in great demand in the future. Propose reasons why.

Energy transfer

Energy can be passed from one object to another. This is known as **energy transfer**. For example, when you kick a ball, kinetic energy from your foot is transferred to the ball, causing the ball to move. You can see this in Figure 5.1.5.

FIGURE 5.1.5 Kinetic energy is transferred from the person's foot to the ball.

Heat transfer

Kinetic energy is not the only type of energy that can be transferred. When you stand in front of a heater, heat energy is transferred from the heater to you, warming you up. Heat energy can be transferred in three ways:

- conduction
- convection
- radiation.

Often heat is transferred using a combination of these methods. Figure 5.1.6 shows an example.

Conduction

When you consume hot soup, you feel the heat of the soup as it warms your mouth and passes down your throat. Heat has been transferred from the soup to you. This type of heat transfer is called conduction. **Conduction** happens between two objects that are in contact. Heat transfers from the hotter object into the cooler one, until they are both the same temperature.

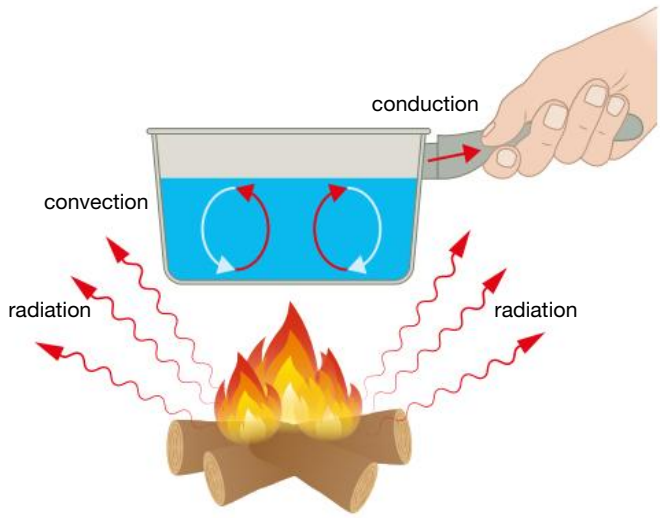


FIGURE 5.1.6 Radiant heat is released in waves from the fire. The liquid in the saucepan is heated by convection currents. Heat from the saucepan handle is transferred by conduction to the person holding it.

Conduction explains why you get burnt if you touch a hot tripod or stovetop. Conduction also explains why a can of lemonade feels cold. The can feels cold because heat transfers away from your warm hand into the metal of the can and the cold drink inside. In this way, conduction makes your hand get colder and the can and lemonade warmer.

Prac 2
p. 204

Convection

You don't need to touch a heater in a room to feel heat transfer. This is because heat can flow through liquids and gases. This process is called **convection**. It is convection that causes heat to rise, making it hotter near the ceiling than down on the floor, and it is convection that spreads heat from ducted heating vents through the rooms of a house. Convection also spreads heat through soup being heated in a saucepan.

Radiation

Heat radiates (spreads outwards) from any hot object. This type of heat transfer is called **radiation**. Radiant heat is transferred as a wave that can travel even through the vacuum of space. This explains why you feel the heat of the Sun when you are outside. However, radiation is easily blocked. If you stand in the shadow of a tree it feels cooler, because the radiant heat of the Sun cannot get to you.

Energy transformation

Energy can be transferred from one object to another. Energy can also be changed, or transformed, from one type of energy into another type of energy. Whenever you watch TV, listen to music or play on a games console, you are relying on **energy transformation**. Tablets, TVs and phones convert electrical energy into sound, light and heat energy. Figure 5.1.7 shows some energy transformations using an **energy flow diagram**.

Sometimes a number of different energy changes happen all at once. Imagine that you accidentally knock a glass off a table. The glass falls and smashes on the floor below. The glass initially has gravitational potential energy. When it is falling, this energy is changed into kinetic energy and some heat energy. When it hits the floor, some of the kinetic energy is transferred to the pieces of glass that break and fly off in all directions.

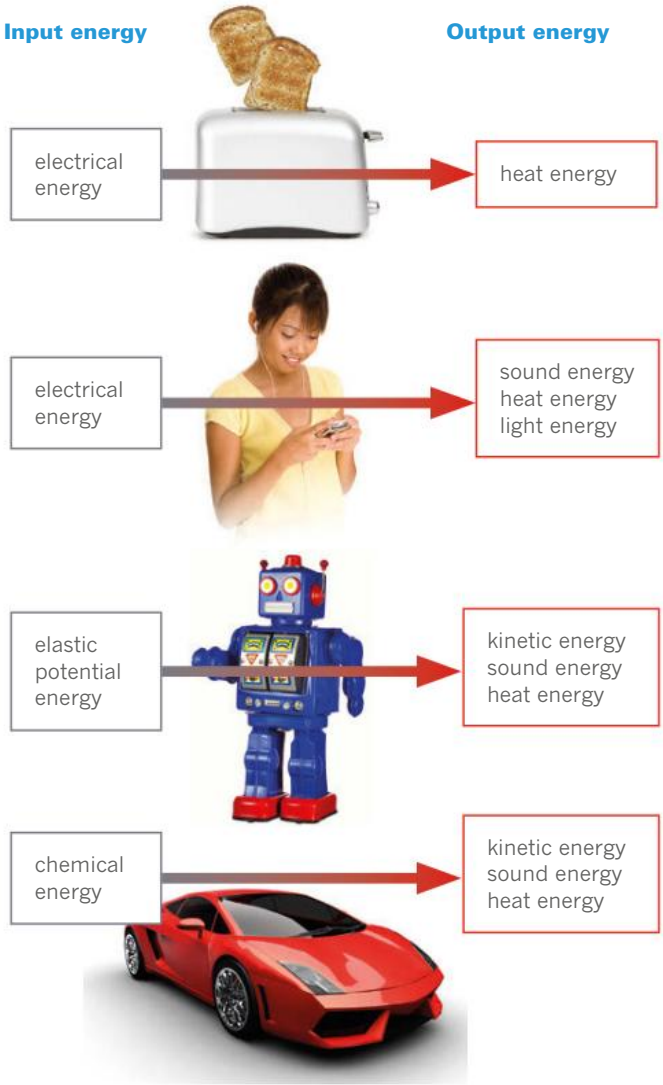


FIGURE 5.1.7 The arrow shows the source of energy and the form of energy into which this is transformed.

Some kinetic energy is converted into heat energy and the sound of glass smashing.

A solar cell converts light energy into electrical energy. This energy can then be converted into many different types of energy. Figure 5.1.8 shows an energy flow diagram for the energy changes involved in using a solar-powered electric fan.

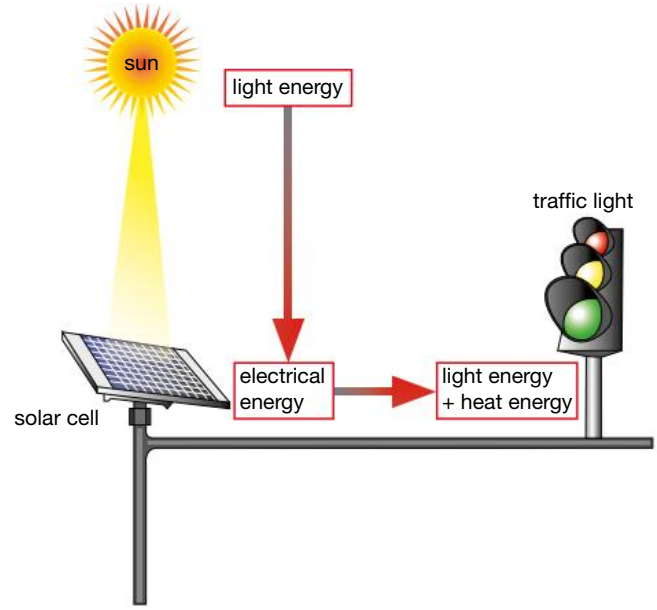


FIGURE 5.1.8 A solar cell converts light energy from the Sun directly into electrical energy. This electrical energy is converted into the light and heat energy in the traffic light.

The law of conservation of energy

Sometimes it looks as though energy disappears. For example, when you kick a ball, the kinetic energy you give the ball seems to be lost when the ball stops moving. The ball's kinetic energy has instead been converted into other forms of energy, such as heat and sound energy.

The **law of conservation of energy** states that energy can never be created or destroyed. Instead, the energy is conserved, or kept, as it is converted from one form to another.

This means that:

- energy might be passed on or wasted, but it is never lost
- if one object wastes energy, then it is always gained by another object, usually as heat.

Prac 3 p. 205
AB 5.3

SCIENCE AS A HUMAN
ENDEAVOUR

Use and influence of science

CETO 6 and the Perth wave farm

Waves are made of moving water and so waves carry kinetic energy with them. This energy can be converted into electrical energy and used to provide fresh water that can then be pumped into reservoirs.

Waves are a renewable source of energy. Other forms of renewable energy, like solar and wind, depend on the sun shining or the wind blowing. However, waves always happen and so provide a reliable and constant source of energy throughout the day and night, in all weather conditions and seasons. With Australia's long coast, it is estimated that waves could provide a third of all our energy needs.

FIGURE 5.1.9 An artist's impression of the Perth wave farm. The three CETO 6 wave energy converters currently generate enough electricity to power 2000 homes. They also power a desalination plant that provides fresh water.

Although waves are a promising source of renewable energy, the development of wave farms and wave technology has been much slower than with solar and wind technology. For example, the first experimental wave farm only began operating in the United Kingdom in 2003.

Off the coast of Perth in Western Australia, the world's first wave farm that can generate both renewable electricity and fresh water was installed in 2015 (Figure 5.1.9). The wave farm is currently made up of three buoys that are anchored to the seabed. Unlike other wave farms, the Perth buoys are below the surface of the sea. This shelters them from storm damage and hides them from view. The movement of the waves causes the buoys to rise and fall, driving pumps and electrical generators within them. Kinetic energy from the movement of the pumps is then converted into electricity, which is delivered to shore through underwater cables. The power is then transferred to the electricity grid as well as powering a desalination plant that removes salt from sea water and supplies fresh water.

Figure 5.1.10 on page 200 shows how it works. The wave energy converter used at the Perth wave farm is called CETO 6, after the ancient Greek sea goddess Ceto. The wave farm currently generates enough electricity to power 2000 homes. Plans for the installation of wave farms near Portland, Victoria and Port MacDonnell, South Australia are under way, along with plans for a larger wave farm off the coast of Western Australia.

REVIEW

1. Why do you think it is important that we continue to research and develop renewable energy technology?
2. List five other sources of renewable energy.
3. Australia is an ideal place for many types of renewable energy technology. What environmental factors do you think make Australia a good place for renewable energy?

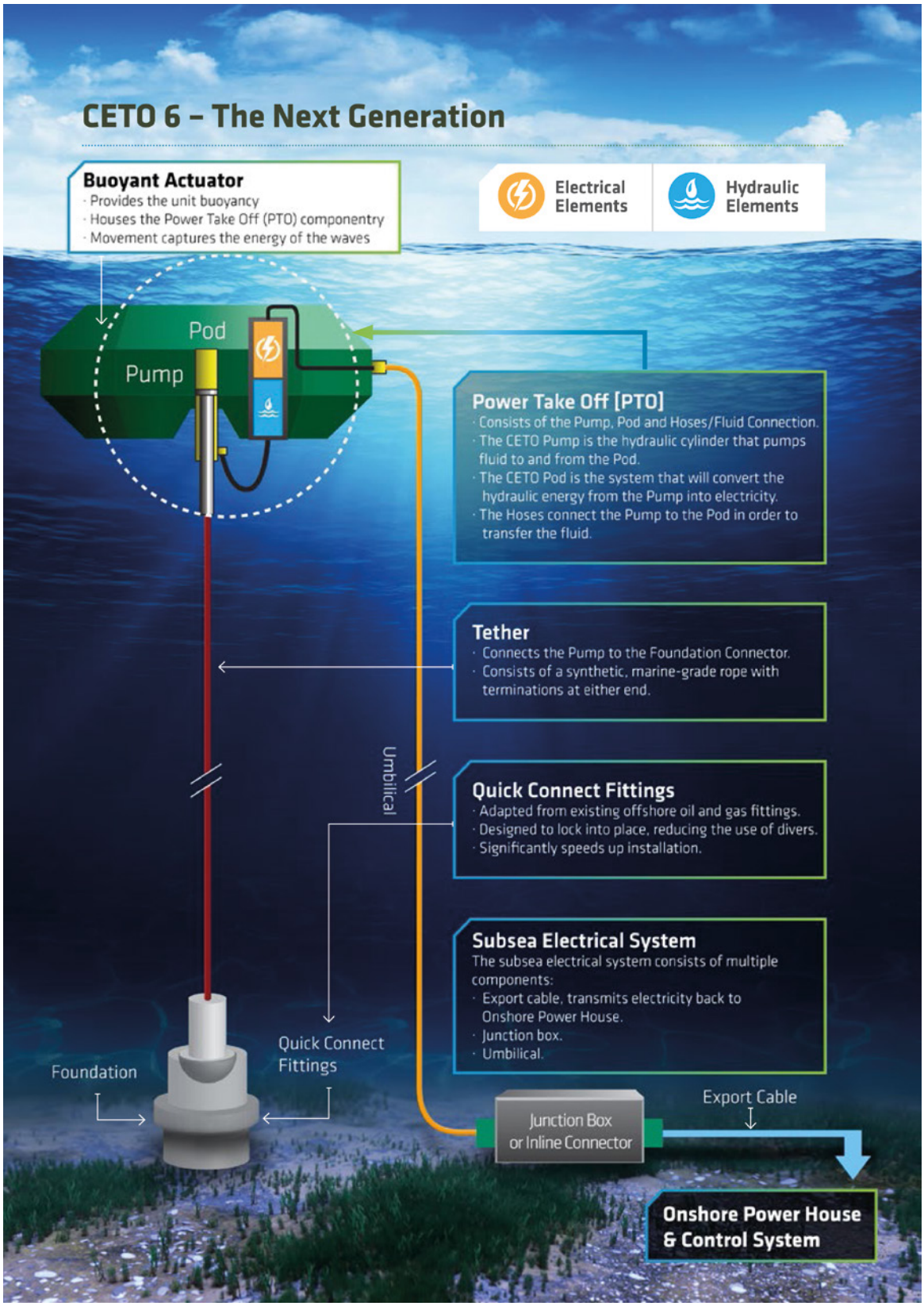


FIGURE 5.1.10 The CETO 6 wave energy converter is unlike many other wave energy converters, as it sits under the surface of the water and contains pumps and generators within its buoy.

MODULE 5.1

Review questions LS

Remembering

1 Define the terms:
- a gravitational potential energy
- b elastic potential energy
- c energy transformation.

2 What term best describes each of the following?
- a the energy of movement
- b a type of heat transfer that involves liquids and gases
- c energy produced by power stations, solar cells, batteries and lightning.

3 Recall what you know about energy by matching the following types a–e with their descriptions i–v.
- a kinetic energy
- b sound energy
- c elastic potential energy
- d gravitational potential energy
- e light energy
  - i in vibrating air particles
  - ii in a stretched or squashed spring
  - iii in objects positioned above the ground
  - iv released from glow-worms
  - v in a moving object.

4 List the three ways that heat can be transferred.

Understanding

5 Describe the three ways that heat can be transferred, giving an example of each method.

6
- a State the law of conservation of energy.
- b Explain what this law means, using an example.

7 Petrol, kerosene and oil are all types of fuel. Which type of energy do these fuels possess?

Applying

8 Identify the key type of energy possessed by a:
- a seatbelt buckle that has been in the sun all day
- b shopping trolley rolling across the floor
- c marshmallow
- d golf ball hit along the ground
- e lawnmower filled up with petrol
- f bird resting in its nest on a tree branch.

9 Identify the *major* method of heat transfer in each of the following situations.
- a Taylah boils a kettle of water to make a cup of tea.
- b Mein sits on a deckchair by a pool and feels the Sun's heat.
- c Emmaline opens the metal gate at the front of her house and feels that the gate is hot.

10 Calculate how many joules of energy are in:
- a 3 MJ
- b 7500 kJ.

11 Calculate how many megajoules are in:
- a 2 500 000 J
- b 5000 kJ.

12 Identify the types of energy that caused the changes in the 'Making spiders' science4fun on page 193.

13 Use a diagram to show the energy transformations that occurred in the science4fun 'Creepy crawly' on page 195.

14 Your body needs a source of energy. Use Figure 5.1.11 to list four different ways that the chemical energy in food can be used by your body.

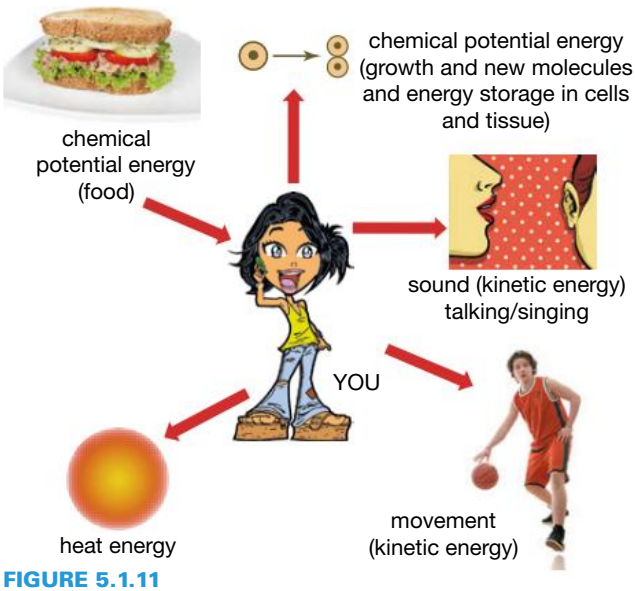


FIGURE 5.1.11

MODULE
5.1 Review questions

15 Use your knowledge of energy transformations to match the situations a–d with the appropriate energy transformations i–iv.

- **a** A girl toboggans down a slope.
- **b** You ride a bike.
- **c** A wind-up toy car travels across the floor.
- **d** Wood burns in a fire.
  - **i** chemical energy → kinetic energy + sound energy + heat energy
  - **ii** gravitational potential energy → kinetic energy + sound energy + heat energy
  - **iii** chemical energy → heat energy + light energy + sound energy
  - **iv** elastic potential energy → kinetic energy + sound energy

Analysing

16 The following objects have potential energy. Classify each one as an example of gravitational potential energy, chemical potential energy or elastic potential energy.

- **a** a piece of chocolate cake
- **b** a stretched spring
- **c** a glass of cola
- **d** an empty coffee mug on a table
- **e** a teaspoon of sugar
- **f** a cardboard box
- **g** a 9-volt battery
- **h** a painter at the top of a ladder
- **i** a banana
- **j** a squashed tennis ball.

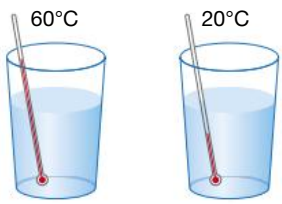
17 What are the similarities and differences between heat transfer by conduction and heat transfer by convection?

Evaluating

18 Consider each pair of objects shown in Figure 5.1.12.

- **a** Identify which type of energy they possess.
- **b** Identify which (A or B) has more energy.
- **c** Justify your response.

i



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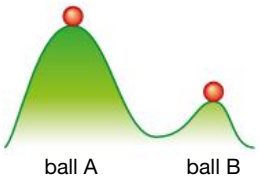

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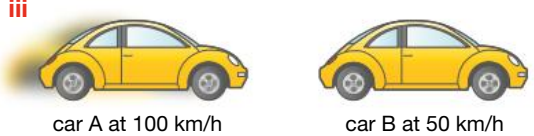


FIGURE 5.1.12

MODULE 5.1

Practical investigations

1 • Making a spinning snake

Planning & Conducting | Processing & Analysing

Purpose

To observe how heat can cause a change.

Timing 30 minutes

Materials

- square of aluminium foil
- 15 cm length of strong cotton
- retort stand and clamp
- Bunsen burner and bench mat
- matches

Procedure

1. If your aluminium foil is thin, then fold over a piece to double its thickness.
2. Cut a spiral shape from your piece of foil about 8 cm in diameter, as shown in Figure 5.1.13.

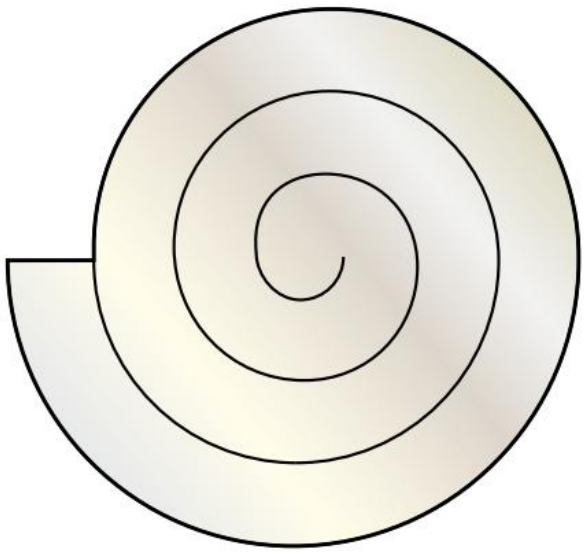


FIGURE 5.1.13

3. Make a small hole in the tip of your spiral, and tie a piece of strong cotton from the tip to a clamp as shown in Figure 5.1.14.

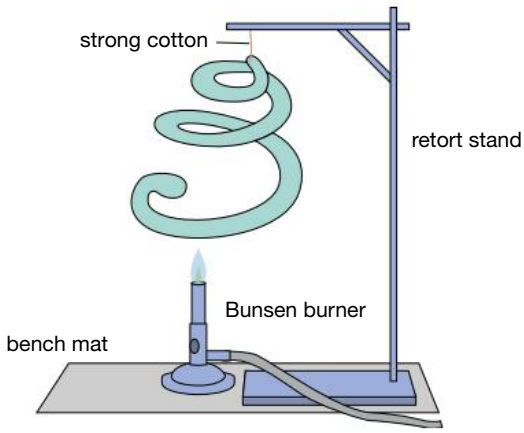


FIGURE 5.1.14

4. Position a Bunsen burner underneath the spiral. Make sure that the flame will not touch the spiral.
5. Light the Bunsen burner and adjust it to produce the blue flame.
6. Observe the spiral.

Results

List the changes that happened to your foil spiral.

Review

1. Which source of energy caused these changes to occur?
2. How do you think this source of energy might have caused the changes you observed?
3. Propose a reason why the spiral was made from aluminium foil instead of paper.
4. The circulating air that caused this change is called a convection current. Describe situations in which convection currents might occur.

MODULE 5.1

Practical investigations

SPARKlab alternative available for this activity

2 • Investigating heat

Planning & Conducting | Processing & Analysing

Some materials are better conductors of heat than others. To keep a hot drink warm, you would try to choose a cup made from a material that is a poor conductor of heat. In this way, your drink will lose minimal heat. A poor conductor is a good insulator. It insulates the drink, stopping its heat from transferring to its surroundings.

Purpose

To compare how effectively different substances conduct heat.

SAFETY

A risk assessment is required for this investigation. Be careful when handling hot liquids.

Hypothesis

Which material do you think will be the poorest conductor of heat and so the best insulator—metal, polystyrene or ceramic? Before you go any further with this investigation, write a hypothesis in your workbook.

Timing 45 minutes

Materials

- supply of hot water
- polystyrene cup
- metallic mug
- ceramic coffee mug
- thermometers or temperature probes and data logger

Procedure

1. Construct a table similar to the one below in your workbook. Alternatively, construct a spreadsheet with similar columns. Give your table or spreadsheet a title.
2. Carefully pour 100 mL of hot water into each cup or mug. Make sure that the water poured into each is at the same temperature.
3. Place a temperature probe or thermometer into each cup or mug.
4. Record the starting temperature using the data logger or thermometer and take measurements for 10 minutes.

Results

1. Plot a line graph showing the temperature of the water in the cup over 10 minutes. Alternatively, use your spreadsheet to plot the line graph for you.
2. On the same set of axes, use different colours to plot line graphs for each mug you tested.

Review

1. To be a fair scientific test, the three containers used in this experiment should be the same thickness and have the same diameter opening at the top. Explain why these factors are important.
2. Which material is the following?
   a. best conductor of heat
   b. worst conductor of heat.
3. A pool blanket is used to trap heat within a swimming pool. Do you think the blanket should be made from material that is a good or a poor conductor of heat?
4. a. Construct a conclusion for your investigation.
   b. Assess whether your hypothesis was supported or not.

Time (minutes)	Temperature of water in		
	Polystyrene cup (°C)	Metallic mug (°C)	Ceramic coffee mug (°C)
0			
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

MODULE 5.1

Practical investigations

3 • Energy transformations

Planning & Conducting | Processing & Analysing

Purpose

To observe how different types of energy can cause a change.

Timing 30 minutes

Materials

- matches
- torch
- tennis ball
- phone
- pop ball
- 50 g hanging mass
- retort stand and clamp
- 40 cm long piece of string
- small wind-up toy

SAFETY

Make sure no one is standing too close to the hanging mass when it is released.

Procedure

1. Copy the table shown in the results section below. Allow plenty of room to complete the last column. Give your table a title. As you complete each task listed below, record your observations in the table.
2. Turn on a phone to play music for a few seconds, then turn it off.
3. Compress a pop ball and leave it on a bench as you watch it.
4. Light a match and then carefully blow it out.
5. Turn on a torch and see what happens. Switch the torch off.
6. Suspend a hanging mass from a retort stand. Pull it about 10 cm upwards in an arc, then carefully release it and allow the mass to swing.
7. Wind up a toy and release it on a bench top.

Results

Situation	Initial type of energy present	Describe any changes that you observed	Draw an energy flow diagram for this situation
a phone plays music for 5 seconds			
a pop ball is compressed			
a match is struck			
a torch is turned on			
a mass is released from a pendulum			
a wind-up toy is wound and released			

Review

1. In which situations tested was the initial source of energy potential?
2. Identify which energy transformation was the most complex in terms of its energy flow diagram.
3. Which form of energy do all of these transformations become?

MODULE
5.2 Energy efficiency

Energy resources are in constant demand in today's world. Society is faced with the challenge of designing devices that make better use of the energy that is supplied to them. Advances in technology such as this hybrid car are vital in reducing energy consumption in the future.

science 4 fun

Hot stuff!

Does friction produce heat?

Collect this ...

- bike tyre or inflatable ball
- hose or needle attachment that fits the bike tyre or ball
- pump

SAFETY

Do not over-inflate balls or tyres.

Do this ...

1. Fit the hose to the bike tyre or the needle into the ball.
2. Pump up the tyre or ball.
3. Undo the hose or needle attachment.
4. Feel the end of the hose or needle.

Record this ...

1. Describe what happened.
2. Explain why you think this happened.

Useful and wasted energy

Any object that moves, or has moving parts, has kinetic energy. A child pushing a toy car gives the car kinetic energy. When the child stops pushing, the car keeps moving along the ground. However, friction between its wheels and the ground produces heat energy. Eventually, the car will stop moving because all of its kinetic energy has been converted into heat energy. This heat energy is wasted energy. The energy has been transformed into a form that is not useful for the car.

Likewise, a light globe like the one in Figure 5.2.1 quickly gets hot, releasing heat energy. This is wasted energy because you don't use a light globe for its heat. Instead, you want the light energy it produces.

FIGURE 5.2.1 The useful energy you want from a light globe is light energy. The heat released is wasted energy.

Most energy conversions waste some energy. This 'wasted' energy is usually released as heat and perhaps some sound. For example, you can feel unwanted heat coming from computers, TVs and light globes. This heat wastes some of the electrical energy used to operate the appliance, making it more expensive to run. Some examples of energy conversion and wasted energy are shown in Table 5.2.1.

TABLE 5.2.1 Examples of energy conversions

Example	Initial energy	Useful energy produced	Wasted energy
using an electric toothbrush	electrical energy	kinetic energy	heat and sound energy
playing cricket	chemical energy from food digested	kinetic energy of moving cricket bat and ball	heat and sound energy
using an iPad	chemical energy from batteries	sound and light energy	heat energy
using a torch	chemical energy from batteries	light energy	heat energy

Energy efficiency

Any device, such as a car or a computer, requires some form of energy to make it run. The energy that it needs to operate is called its input. The output is useful energy.. Unfortunately, unwanted forms of energy are released too, usually as heat. **Energy efficiency** is a measure of how much input energy is converted into useful output energy. When there is a lot of useful output energy, and not much input energy, the device is energy efficient. If a lot of the input energy is wasted, then the device is inefficient.

For example, in an electric fan, electrical energy is converted into the kinetic energy of the fan blades, which produces a breeze. If all the electrical energy was converted into kinetic energy, then the fan would be 100% energy efficient. In reality, an electric fan wastes some of its electrical energy by converting it into sound and heat. This makes it inefficient.

Figure 5.2.2 compares the efficiency of a car with that of a bike. Cars are inefficient because only about a quarter of the chemical energy supplied by petrol goes into making the car move. Bikes are much more efficient—around 95% of the energy from your muscles is converted into the kinetic energy of movement.

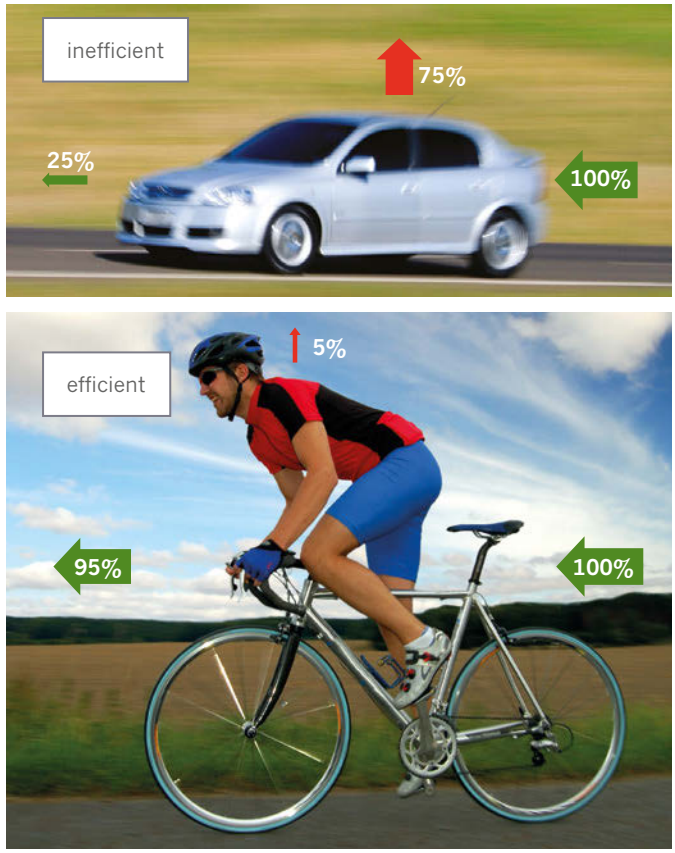


FIGURE 5.2.2 Riding a bike uses energy far more efficiently than driving a car.

Figure 5.2.3 compares the typical percentage energy efficiencies of some energy converters.

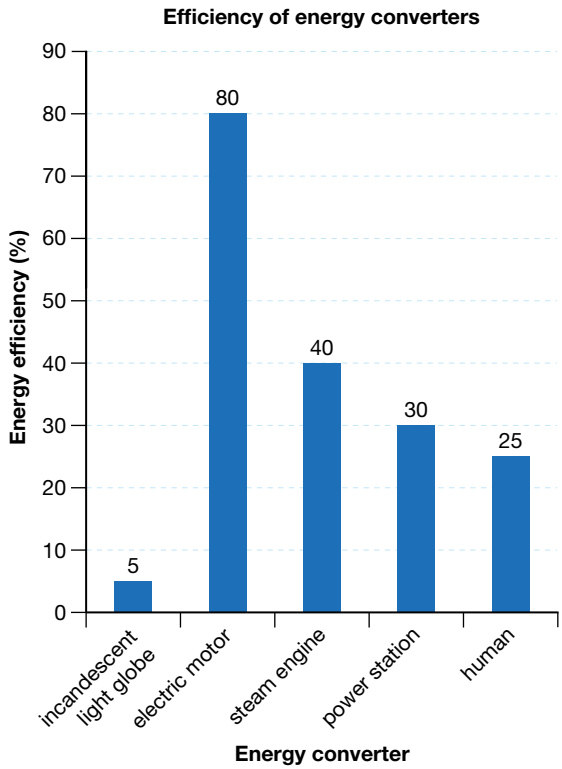


FIGURE 5.2.3 Typical energy efficiencies of some energy converters

SkillBuilder

Calculating efficiency

Efficiency measures how much energy is converted into useful forms in a device. Efficiency is expressed as a percentage. The higher the percentage, the higher the efficiency. A device that is 100% efficient converts all its energy into useful forms and wastes no energy. If a device is 60% efficient, then 60% of its energy is converted into useful forms, with 40% of its energy being wasted.

$$\text{energy efficiency} = \frac{\text{useful energy output}}{\text{total energy input}} \times 100$$

SciFile

Generating waste

Most of our energy needs are met by electricity produced by burning coal. It is estimated that 65–70% of the energy produced when coal is burned is transformed into heat. Heat is lost in every part of the process of generating, transmitting and distributing electrical energy. Not an efficient use of resources!

Worked example

Calculating efficiency

Problem

In 5 minutes, a particular battery-operated remote-controlled car used 1800 J of chemical energy. Of this chemical energy, it converted:

- 450 J into kinetic energy
- 300 J into sound energy
- 1050 J into heat energy.

Given that the useful energy output of this device is kinetic energy, calculate the percentage energy efficiency of the car.

Solution

Thinking: Identify the useful form of energy output.

Working: The useful form of energy is the 450 J of kinetic energy.

Thinking: Express the useful form of output energy as a ratio compared with the total energy input.

Working: $\frac{450}{1800}$

Thinking: Convert this into a percentage to calculate energy efficiency.

Working: $\text{Energy efficiency} = \frac{450}{1800} \times 100$

$= 25\%$

Try yourself

Jim mows a section of grass. In 2 minutes the lawnmower used 3200 kJ of chemical energy from the petrol in its engine.

Of this chemical energy, the mower converted:

- 800 kJ into kinetic energy
- 1200 kJ into sound energy
- 1200 kJ into heat energy.

Given that the useful energy output of this device is kinetic energy, calculate the percentage energy efficiency of the lawnmower.

Prac 1 p. 217
AB 5.4

Energy rating labels

Household appliances vary in their energy efficiency. By purchasing appliances that are more efficient, your household will save energy and save on running costs. Look around shops selling electrical appliances and you will see that most large appliances carry a red and yellow **energy rating label**. A sample label is shown in Figure 5.2.4.

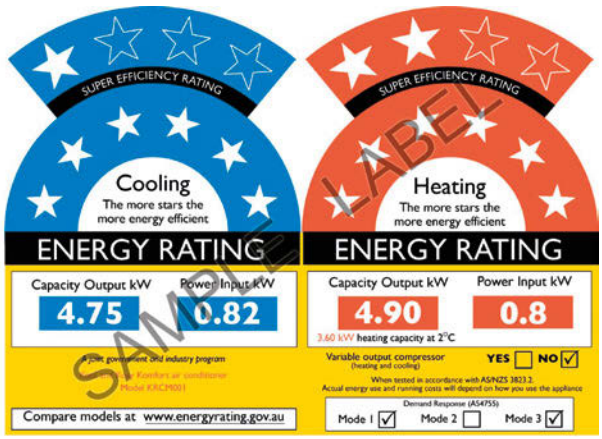


FIGURE 5.2.4 Appliances labelled up to 6 stars are said to be 'efficient'. Those with more than 6 stars are 'super-efficient'.

Energy efficiency is shown by the number of stars on the label. The more stars (usually from 1 to 10) that are shaded on the energy rating label, the greater the energy efficiency of the appliance. You can determine which models are the most energy efficient by comparing the number of stars. The number found on the label provides the customer with an estimate of the amount of energy (usually listed in kilowatt hours per year) needed to operate the appliance for one year. The higher the number, the more energy is needed and the more the appliance will cost to run.

Prac 2 p. 218
AB 5.6

SciFile

Comparing labels

The energy rating label was first used in New South Wales and Victoria in 1986. Today, any household refrigerator, freezer, television, washing machine, clothes dryer, single-phase air conditioner or dishwasher sold in Australia must carry an approved energy rating label. It's the law!

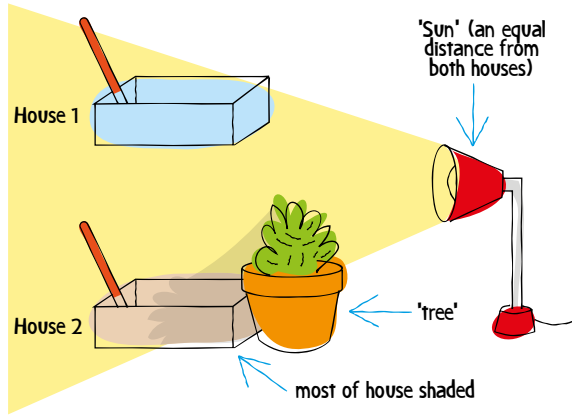
science 4 fun

Shading a house

What difference does shade make to the temperature inside a house?

Collect this ...

- 2 identical shoeboxes
- incandescent desk lamp (sunlight will do on a warm day)
- pot plant or branch with leaves propped up in a pot with dirt
- 2 thermometers or temperature probes



Do this ...

1. Position the two shoebox 'houses' an equal distance from the desk lamp (or outside in a sunny position).
2. Place the pot plant or branch close to one 'house' so that it is shaded as much as possible.
3. Measure the temperature inside each 'house' every 5 minutes for an hour.

Record this ...

1. Describe what happened.
2. Explain why you think this happened.

Efficient housing

Living in an energy-efficient house makes it easier for households to reduce energy use. It is estimated that about half of the energy costs of running a house are to keep it warm in winter and cool in summer. Heat naturally flows from regions of higher temperature to regions of lower temperature. In winter, the warm air from a heater or heating system can flow through any cracks or gaps in the walls to the cool air outside or into the cooler garage. Alternatively, heat can rise up into the roof space. This means that a lot of energy is needed to keep a leaky house warm in winter. Similarly, in summer, the warm air outside will naturally flow into a cool house. To keep the house cool, air conditioners might be used. However, they use a lot of energy, making them expensive to run. Adding **insulation** to ceilings and between the walls of a home reduces the heat flowing outside in winter and inside in summer. This makes heating and cooling more effective and makes a house more comfortable.

The **National House Energy Rating Scheme** uses computer simulations to provide a star rating for the built exterior shell of a house. A rating of zero stars means that the house is poorly designed and does little to protect those living there from heat in summer and cold in winter. A house rated at 10 stars probably won't need any heating or cooling because it remains at a comfortable temperature all year round.

Improvements in house design can be achieved by:

- considering the orientation of windows—in Australia this usually means placing large windows along the northern and eastern sides of the house, with small or no windows on the hot western side and the cooler southern side
- considering the orientation of the house on the block of land—in Australia, this usually means having living areas facing north and other rooms (such as the bathroom) facing south
- tinting or shading west-facing windows
- including coverings such as eaves, verandas or pergolas over the north- and west-facing windows
- insulating the floor, walls and roof to reduce energy losses.

Building regulations throughout Australia require new homes to be built to specific minimum energy standards. Figure 5.2.5 shows design features that make a house more energy efficient.

Prac 3 p. 219
AB 5.5

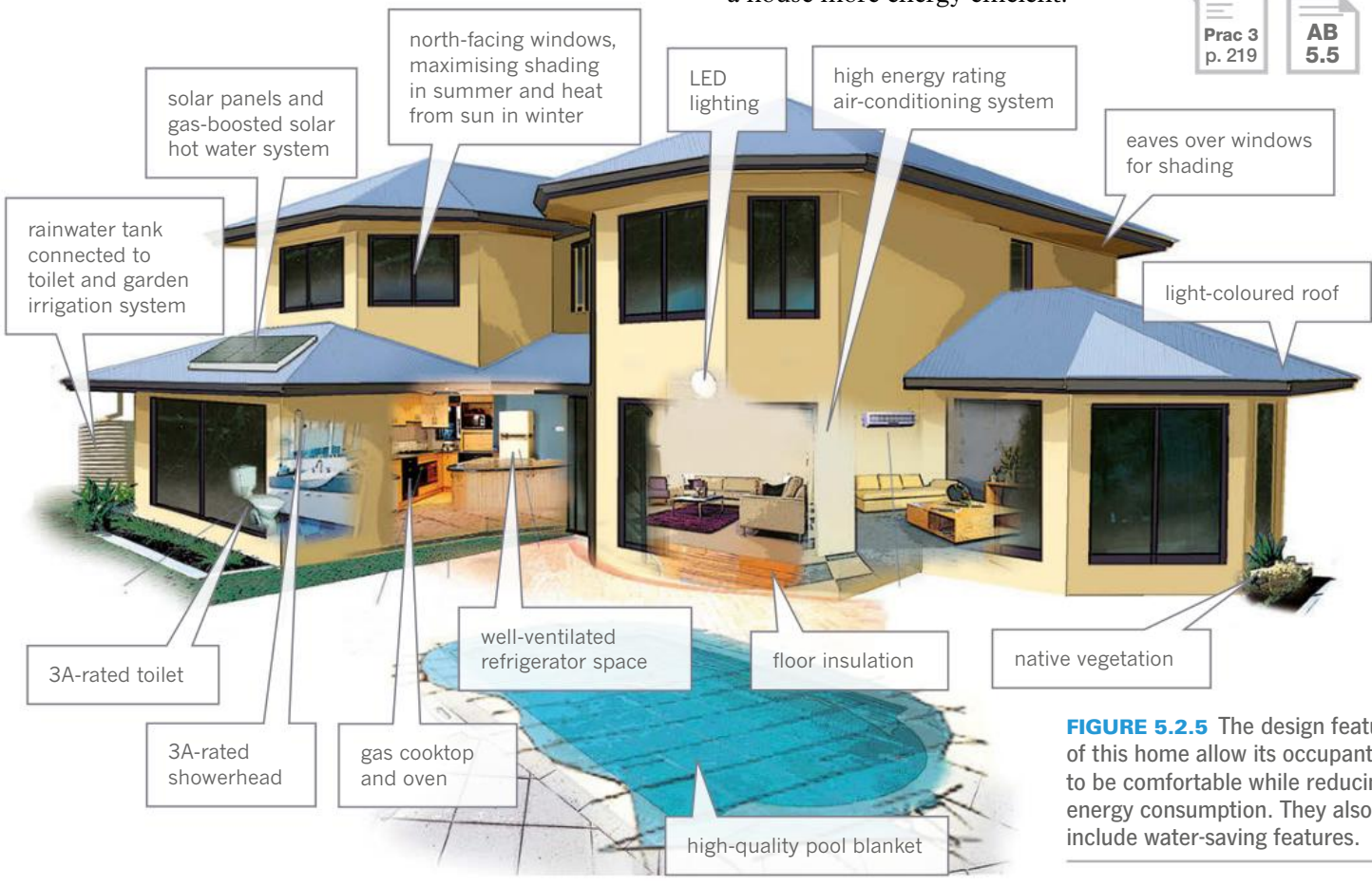


FIGURE 5.2.5 The design features of this home allow its occupants to be comfortable while reducing energy consumption. They also include water-saving features.

SciFile

How much energy is that?

Energy rating labels display the typical amount of energy an appliance will use over one year. This value is stated in kilowatt hours (kWh). One kilowatt hour is equal to 3 600 000 joules of energy. This can also be written as 3.6 megajoules (MJ).

Innovative design

The need to save energy has led to new and innovative designs to increase efficiency. Some of these ideas include regenerative braking, interior cooling in parked cars, magnetic refrigeration, LED lighting, more efficient photovoltaics and dry washing machines.

The **regenerative braking** system of a hybrid car captures some of the vehicle's kinetic energy as the car slows down. Stored in a battery, this energy is then used to power the car's electric motor when needed. Elevator (lift) manufacturers are investigating how to use this idea to save the energy used by lifts.

If you have ever looked at a car engine, then you have probably noticed that there are belts used to transfer energy to the alternator and to the air conditioner. Sometimes a fan belt is used to turn a fan that cools the engine. However, most new cars now rely upon an electric motor instead of belts to turn the fan. A beltless engine reduces car maintenance, engine noise and heat loss due to friction. Lighter cars are also being built from materials such as carbon fibre, plastics and aluminium. All these changes improve the efficiency of the vehicle. Figure 5.2.6 shows an example.

FIGURE 5.2.6 New technology has made this car 109 kg lighter than the previous model. Although the new model is larger, energy efficient design features enable it to use 23% less fuel.

Some luxury cars now incorporate solar cells on the roof of the car. These cells power interior fans that prevent the inside of the car from getting too hot when the car is parked. This reduces the need for air conditioning when the car is being driven.

Light-emitting diodes (LEDs) produce very little heat and are extremely energy efficient. They are used in traffic lights, torches and household light fittings. LED televisions use LEDs to backlight an LCD screen. The high efficiency of LEDs has improved the energy efficiency of these televisions. Figure 5.2.7 shows the spectacular use of coloured LEDs to light a building.

FIGURE 5.2.7 Over 20 000 LEDs were installed on Council House in the city of Perth. This energy-efficient lighting display is controlled by computer.

The development of aircraft design

For thousands of years, humans have wanted to fly. From flying kites and gliders, curious people learned which wing shapes were needed to provide a lift force. Aircraft design has developed greatly since the Wright brothers' first flight in 1903.

FIGURE 5.2.8 Otto Lilienthal died in 1896 after losing control of a glider like this one in a strong wind.

400 BCE
Kites were flown in China.

1480 CE
Leonardo da Vinci (1452–1519) drew diagrams of a machine with wings that he thought could help people fly. He called his machine an 'ornithopter'.

1799
British scientist Sir George Cayley (1773–1857) discovered many of the principles of flight. He experimented with the shape of the wings on a glider that would allow smooth air flow.

1891–1896
German engineer Otto Lilienthal (1848–1896) made over 2000 flights in monoplane and biplane gliders that he had designed. His gliders, like the one in Figure 5.2.8, were the first to travel long distances.

1903
American brothers Orville and Wilbur Wright tested different shapes of aircraft wings in a wind tunnel to assist them in designing their gliders.

In 1902, the brothers built the Wright Glider. They made almost 1000 flights testing the controllable glider, and were able to stay in the air for up to 26 seconds. The Wright brothers built a new aircraft with an engine and in 1903, Orville Wright flew 36.5 metres in *The Flyer* (Figure 5.2.9). By 1905 the brothers had achieved a flight of 39.4 kilometres.

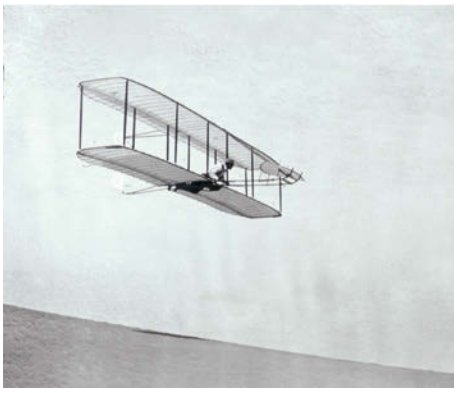


FIGURE 5.2.9 Orville Wright (1871–1948) lying on the lower wing of *The Flyer*

Early 1900s
During the first few decades of the 1900s, the bodies of aircraft were enclosed to reduce drag forces when in flight. Aircraft were made from stronger and lighter materials such as aluminium. Figure 5.2.10 shows US aviator Charles Lindbergh, who made the first flight across the Atlantic Ocean in 1927, from New York to Paris. Australian aviator Charles Kingsford Smith (1897–1935) made the first flight across the Pacific Ocean between the USA and Australia in 1928.

FIGURE 5.2.10 Charles Lindbergh (1902–1974) made the first solo flight across the Atlantic Ocean.

SCIENCE AS A HUMAN ENDEAVOUR

1937

British pilot Frank Whittle (1907–1996) designed the first turbo jet engine, which was used to power an aircraft in 1941. The jet engine shown in Figure 5.2.11 enabled aircraft to travel at much higher speeds than propeller aircraft.

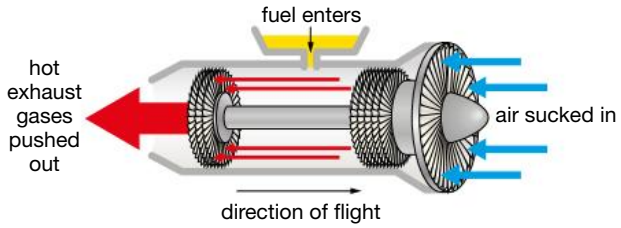


FIGURE 5.2.11 Fuel burns compressed air inside a jet engine. Hot exhaust gases are expelled at high speed, providing the forward thrust that propels the aircraft.

1950s

Aviation boomed following World War II. Most aircraft were built with piston engines and propellers to provide thrust for flight. From the 1950s, passenger jets such as the Boeing 707 were manufactured.

Now

The engines of passenger jets such as the Airbus A380 shown in Figure 5.2.12 have become more efficient, and the composite materials used to construct the aircraft are lighter than materials used in the past.

FIGURE 5.2.12 The use of carbon-fibre reinforced plastic in the structure of this modern aircraft increases fuel efficiency and reduces greenhouse emissions.

Given that a typical passenger jet has a mass of around 300 tonnes, it is not surprising that a vast amount of fuel is needed to make it fly. *Solar Impulse* is a Swiss project that aims to fly around the Earth by a piloted fixed-wing aircraft using only solar power. Figure 5.2.13 shows the structure of the aircraft *Solar Impulse 2*. Made from lightweight carbon fibre and foam layers, the aircraft and its sole pilot have a mass of only 2.3 tonnes. The long wing span maximises the area needed for over 17 000 photovoltaic cells that generate power. The aircraft must reach altitudes of 9 km by day to generate sufficient energy to allow it to glide at night. The energy generated by day is stored in lithium-ion batteries. Although the batteries have caused problems by overheating, the project is showing encouraging signs for harnessing solar power for future generations.

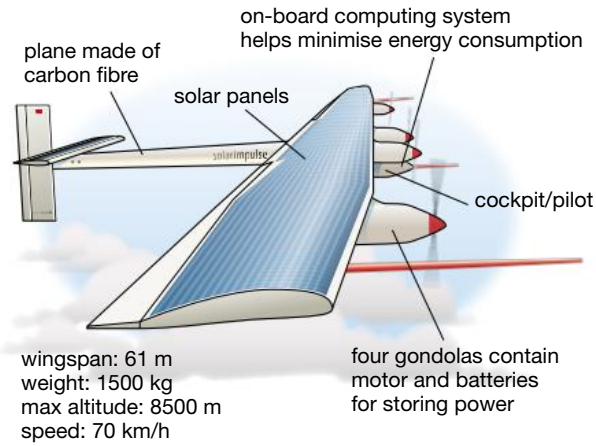


FIGURE 5.2.13 The *Solar Impulse 2* is powered using only solar energy.

REVIEW

1. Why would flying in a glider in the time of Otto Lilienthal be dangerous?
2. How did the Wright brothers' aircraft *The Flyer* differ from earlier models?
3. Why do you think enclosing the body of an aircraft allows it to travel faster?
4. In examining key steps in the development of aircraft design, identify what you consider to be the top five breakthroughs.
5. Given the vast amounts of fuel currently needed to fly by aeroplane, should this form of travel be banned? Propose an argument for or against this form of travel.

MODULE 5.2

Review questions

Remembering

1 Define the terms:
- a energy efficiency
- b energy rating label.

2 What term best describes each of the following?
- a the type of energy most often listed as wasted energy in an energy conversion
- b a highly efficient source of lighting
- c material placed in the ceiling and between walls of buildings to reduce heat loss.

3 What is the useful type of energy produced in an electric toothbrush?

4 List the types of appliances that must carry an energy rating label in Australia.

5 Refer to Table 5.2.1 on page 207 and list the wasted forms of energy that occur when you:
- a listen to music on a phone
- b play cricket.

Understanding

6 Describe how heat losses reduce the efficiency of a device.

7 Explain what the star rating in Figure 5.2.4 on page 209 tells a consumer about the energy efficiency of this appliance.

8 Describe three ways in which the house shown in Figure 5.2.5 on page 210 reduces household energy consumption.

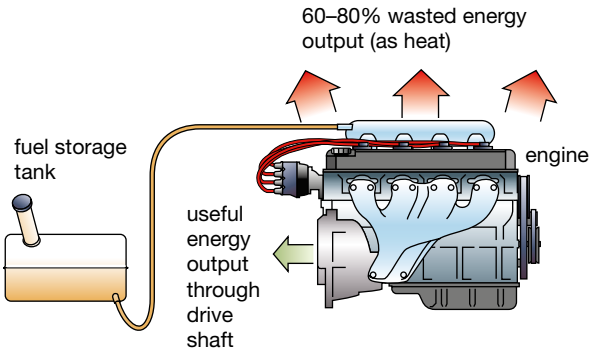
9 How can adding insulation to a house and sealing gaps reduce the energy costs of heating and cooling the house?

10 How can regenerative braking make a car more energy efficient?

Applying

11 In the science4fun on page 206, the kinetic energy of the pump action pushes air into the ball.
- a Identify which force is always produced when two surfaces move across each other.
- b Explain why this force produces heat.
- c Discuss whether the production of heat makes the pump more or less efficient.

12 a Use the information in Figure 5.2.14 to rank the different engines from most to least efficient.
- b If 100 MJ of energy is supplied to a jet turbine, calculate the amount of energy that is converted into useful energy required to fly the jet.
- c Calculate the percentage of energy that is wasted in a typical petrol engine.



Efficiency:

petrol engine	25%
diesel engine	35%
jet turbine	30%
steam engine	40%

FIGURE 5.2.14

Analysing

13 Classify the method of heat transfer that is blocked by the 'tree' in the science4fun on page 209—is it conduction, convection or radiation?

14 In 10 minutes, a power saw used 6050 J of electrical energy. It converted:
- 1210 J into kinetic energy
- 1520 J into sound energy
- 3320 J into heat energy.

a Identify the useful output energy from the saw.
- b Calculate percentage energy efficiency of the saw.

15 A phone docking station is supplied with 2000 J of electrical energy. Of this, 900 J is converted into heat energy, 300 J is converted into kinetic energy of the sound system and the remaining energy is converted into sound. Calculate the:
- a number of joules of sound energy produced
- b percentage efficiency of the device for converting electrical energy into sound energy.

16 An apple that falls from the top of an apple tree hits the ground at a greater speed than an apple that falls from near the base of the tree. Analyse why this happens.

MODULE 5.2

Review questions

Evaluating

17 A car is a very inefficient machine.
- **a** List which forms of wasted energy are produced.
- **b** Cars would soon overheat if they didn't have a radiator. What do you think the purpose of a radiator is?

18 In a coal-fired power plant, coal is burned to heat water. The heated water produces steam, which is used under high pressure to turn a turbine. Electricity is generated when the turbine turns inside a magnetic field.
- **a** The source of energy used in this case is coal. What type of energy does coal possess?
- **b** What is the useful output energy of the power plant?
- **c** Why do you think the average efficiency of a coal-fired power plant is only around 33%?
- **d** Of every 100J of energy input into a typical coal-fired power plant, calculate how many of joules of energy are converted to heat.
- **e** Calculate the number of joules that are converted into useful energy from every 100J input into a typical coal-fired power plant.

19 Table 5.2.2 compares the features of existing incandescent globes with those of compact fluorescent globes and LEDs. Refer to this table to complete the following.
- **a** Which type of individual bulb costs the least to buy?
- **b** What is the typical number of hours that an LED will operate before it needs to be replaced?
- **c** Rank the three types of lighting from least to most in terms of average cost to run per hour.
- **d** Which type of lighting would you consider to be most cost effective to install in a new home?

20 A typical passenger car is around 20–30% efficient. This means that over half of the energy input to a car is converted to other, non-useful forms of energy. Predict what a car would be like if it was 100% efficient. In your response, discuss the ways that it would differ from a normal car in terms of what it would look, sound and feel like as a car.

Creating

21 Construct a flow diagram to show the energy changes that happen when you:
- **a** ring a doorbell
- **b** light a match
- **c** fall over.

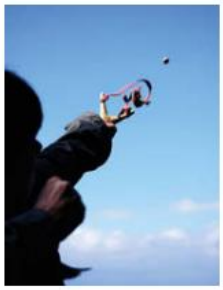
TABLE 5.2.2 Features of incandescent, CFL and LED light globes

Comparing light globe features	Incandescent	CFL (compact fluorescent light)	LED (light-emitting diode)
life span (hours)	1500	10 000	50 000
bulb cost	$1.50	$3.00	$30.00
wattage (W)	60W	14W	6W
cost to run per hour ($0.30 per kWh)	$0.02	$0.004	$0.002
running cost over 50 000 hours	$900	$210	$90
bulbs need for 50 000 hours use	33	5	1
replacement cost total	$50	$15	$0
total 50 000 hour lighting cost	$950	$225	$90

MODULE
5.2 Review questions

22 Figure 5.2.15 shows three situations in which energy is transformed. Create an energy flow diagram to show the nature of the changes in each device.

a



catapault

b

solar toy car

c

electric toothbrush

FIGURE 5.2.15

23 Construct an advertisement for a new energy-efficient appliance. Outline how your appliance will save energy and why people should buy it.

24 Use Figure 5.2.16 to construct a flow diagram to show the energy changes that occur when you vacuum the floor using electricity from a wind generator.

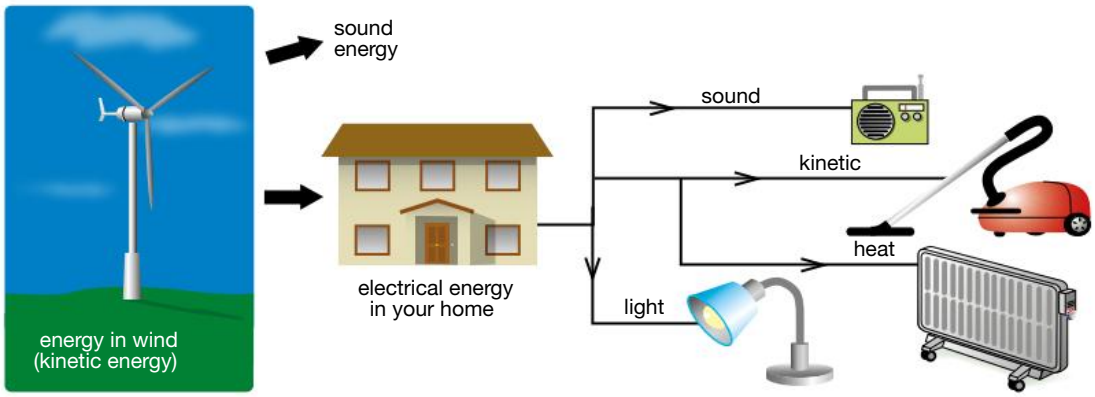


FIGURE 5.2.16

25 Water wheels are ancient devices used to transform the energy of moving water into mechanical energy. Water wheels were used to mill flour, grind wood to a pulp and crush ore or other materials. There are four basic water wheel designs. The horizontal water wheel uses the horizontal flow of water to turn a wheel. A vertical water wheel can be used as an overshot wheel. This type of wheel is shown in Figure 5.2.17. It uses falling water to turn the wheel. Create an energy flow diagram to show how an overshot water wheel operates.

FIGURE 5.2.17

MODULE 5.2

Practical investigations

1 • Building a kettle

Planning & Conducting | Processing & Analysing

Purpose

To build a model kettle or jug and study its energy transformations.

Timing 45 minutes

Materials

- 40 cm nichrome wire
- pencil
- 150 mL beaker with cardboard lid
- connecting wires with alligator clips stripped of plastic covering
- power supply
- thermometer (or data-logging temperature probe)
- bench mat

SAFETY

Do not touch the nichrome wire while it is hot, as it can give a nasty burn. Let it cool completely on a bench mat before packing it away.

Do not let the alligator clips touch each other, as this could cause a short circuit.

Plastic can melt, so ensure the alligator clips do not have plastic covering the metal clip.

Procedure

1. Construct a table similar to the one shown in the Results section, in your workbook. Alternatively, construct a spreadsheet with similar columns. Give your table or spreadsheet a title.
2. Make a heating element as shown in Figure 5.2.18 by winding the middle section of the nichrome wire around a pencil. Leave 10 cm of straight wire at each end as connecting leads. Remove the pencil.

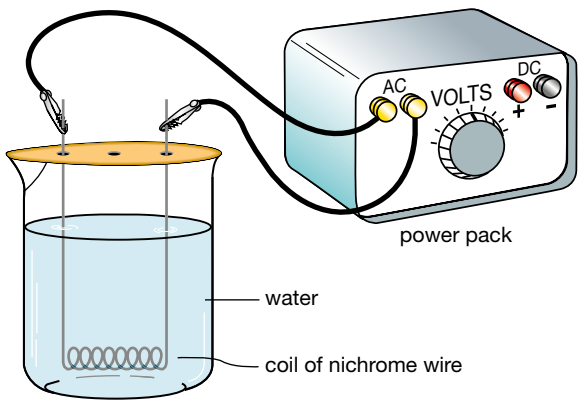


FIGURE 5.2.18

3. Add about 100 mL of water to the beaker.
4. Place the heating element in the beaker, making sure it is completely covered by water.
5. Connect the element to the power supply by threading the wires through the cardboard lid.
6. Set the power pack to 4 volts and switch the power supply on.
7. Record the temperature of the water every minute for 10 minutes in your table.

Results

1. Record all temperatures in your Results table.

Time (min)	Temperature (°C)
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

2. Construct a line graph, or use your spreadsheet to construct a line graph, showing the rise in water temperature against heating time. Save a copy of your graph in your prac report.

Review

1. Use your graph to predict how long it would take for the water to boil.
2. What is the energy source for your kettle?
3. Name the form of energy it was converted into.
4. Identify three household appliances that rely on the same energy transformation as this kettle.
5. If this kettle was graded for an energy rating label, it would probably have a rating of zero or one star.
   - a Explain why the kettle would not have a high star rating.
   - b Describe two ways of changing the kettle's design to make it more energy efficient.

MODULE 5.2

Practical investigations

SPARKlab alternative available for this activity

2 • Effect of double-glazing on heat loss

Planning & Conducting | Processing & Analysing

Purpose

To investigate the effect of double-glazing in preventing heat loss.

Timing 45 minutes

SAFETY
Be careful when handling hot liquids.

Materials

- hot water
- 2 × 100 mL beakers
- cling wrap
- 4 cardboard discs of the same size, slightly larger in diameter than a 250 mL beaker
- stopwatch
- 2 thermometers (or data-logging temperature probes)

Procedure

1. Construct a table similar to the one in the Results section in your workbook. Alternatively, construct a spreadsheet with similar columns. Give your table or spreadsheet a title.
2. Position each beaker on a cardboard disc. Punch identical holes in the centre of the two remaining discs to fit a thermometer or probe as shown in Figure 5.2.19.

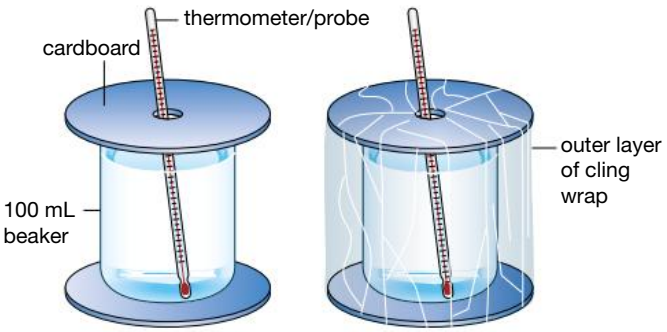


FIGURE 5.2.19

3. Carefully add 80 mL of hot water to each beaker. (Ensure the water is the same temperature in each.)
4. Place the cardboard discs on top of each beaker and insert the thermometers or temperature probes. Wrap a couple of layers of cling wrap over the beaker to cover the beaker and the cardboard discs, as shown in Figure 5.2.19. Make a small hole to allow the thermometer to sit in the water.
5. Record the temperature in each beaker every minute for 10 minutes.

Results

Record all temperatures in your Results table.

Time (min)	Water temperature in beaker without cling wrap (°C)	Water temperature in beaker with cling wrap (°C)
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Review

1. Show on the same set of axes how the temperature varied in each beaker. Plot the graphs yourself or use your spreadsheet to do this and save a copy to your report.
2. State whether the layers of cling wrap had an effect on the heat loss from the beaker.
3. Explain how double-glazing windows can reduce energy losses from a house.
4. List possible ways in which the design of this experiment could be improved.

MODULE 5.2

Practical investigations

• STUDENT DESIGN •

3 • Investigating the efficiency of bouncing balls

Questioning & Predicting | Processing & Analysing

When a ball is dropped from a height, its gravitational potential energy is converted to kinetic energy and heat. As the ball bounces (rebounds) from the floor, some of the ball's kinetic energy is converted back into gravitational potential energy. This process continues until all the initial gravitational potential energy has been converted into other forms of energy. The efficiency of the first bounce of the ball can be calculated as:

$$\text{Efficiency} = \frac{\text{rebound height of first bounce}}{\text{initial height above ground}} \times 100\%$$

Purpose

To calculate and compare the efficiency of bouncing balls.

Hypothesis

Which type of ball do you think will be the most efficient and will rebound to greater heights when dropped—a table tennis ball, a squash ball, a hi-bounce ball or some other type? Before you go any further with this investigation, write a hypothesis in your workbook.

Timing 45 minutes

Materials

As chosen by students but likely to include:

- a range of balls of different types, such as table tennis, squash, tennis, hi-bounce
- equipment to measure the height of a bounce, such as video equipment, motion sensors or metre rulers.

SAFETY

A Risk Assessment is required for this investigation.

Procedure

1. Design an experiment to measure the rebound height of a range of different types of balls.
2. Brainstorm in your group and come up with several different ways to investigate the problem. Select the best procedure and write it in your workbook. Draw a diagram of how you intend to run your experiment.
3. Before you start any practical work, assess your procedure. List any risks that your procedure might involve and what you might do to minimise those risks. Show your teacher your procedure and your assessment of its risks. If your teacher approves, then collect all the required materials and start work.

Use the STEM and SDI template in your eBook to help you plan and carry out your investigation.

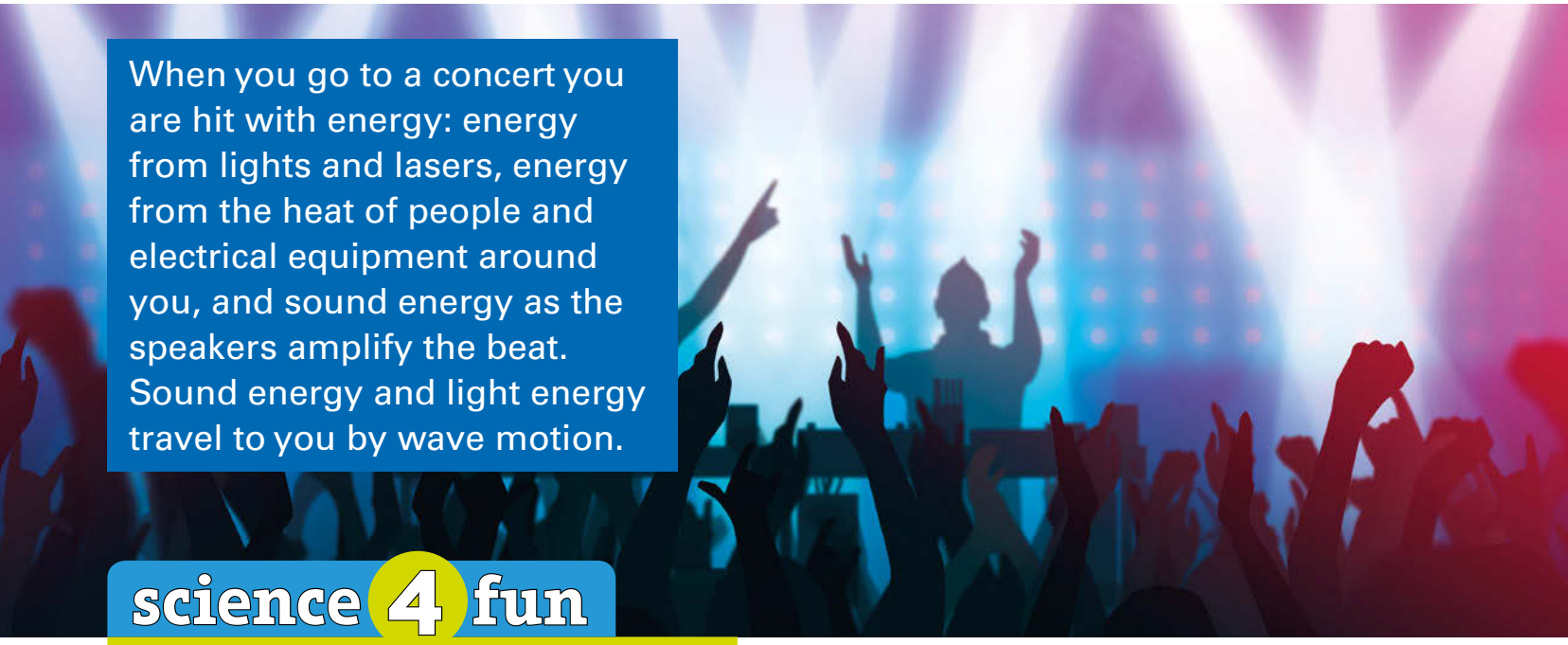
Results

1. Construct a table to display your results.
2. Use your drop height and measured rebound heights to calculate the efficiency of each ball.

Review

1. a Construct a conclusion for your investigation.
   b Assess whether your hypothesis was supported or not.
2. Identify sources of error in your investigation.
3. What are the strengths and weaknesses of your procedure? Choose two other groups and evaluate the strengths and weaknesses of their procedures.
4. How could your procedure have been improved?
5. Squash balls get very hot after a short time in play. Use your results from this investigation to explain why.
6. List the balls in order from the one you predict will be the hottest after a bounce to the one that will be coolest.

MODULE
5.3 Sound energy



When you go to a concert you are hit with energy: energy from lights and lasers, energy from the heat of people and electrical equipment around you, and sound energy as the speakers amplify the beat. Sound energy and light energy travel to you by wave motion.

science 4 fun

Hear this!

Sound vibrates air particles as it travels through them. What happens to a sound wave when you push air particles closer together?

Collect this …

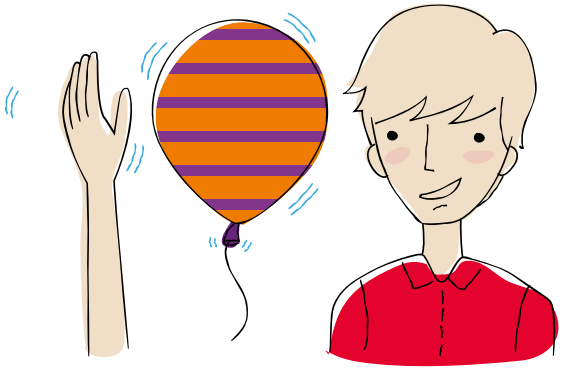
- balloon

Do this …

1. Blow up the balloon and tie off the end.
2. Hold the balloon close to one of your ears.
3. Have a partner lightly tap on the other side of the balloon.

Record this …

1. Describe what you heard.
2. Explain what you think made this happen.



Sound waves

Sound is a type of energy produced by vibrations. When you pluck a string on a guitar, you start the string vibrating. The vibrating string pushes on nearby air particles. These air particles in turn push outwards on other air particles. The energy of the original vibration extends outwards in all directions, just like ripples spreading outwards from a stone dropped into a pond (Figure 5.3.1).

FIGURE 5.3.1 The ripples in a pond spread outwards in all directions from a disturbance. Sound waves behave in a similar way.

A 'Mexican wave' at a sporting event is a flow of energy around a stadium. You can see it in Figure 5.3.2. Each person in the crowd stands up, lifts their arms and sits down again. The wave spreads but no one actually moves around the stadium. They all stay in the same spot—the energy is transferred from one to another until it has passed around the stadium. The Mexican wave is an example of **wave motion**, in which a wave transfers energy without an overall transfer of matter.

FIGURE 5.3.2 In a Mexican wave, the energy of the crowd spreads as people stand up and sit down, one after the other.

Vibrating air particles have kinetic energy. This kinetic energy is transferred from air particle to air particle as a sound wave travels. As for each person taking part in a Mexican wave, the kinetic energy of the air particles is transferred from one to another as the sound wave travels. The air particles themselves do not travel with the sound wave but stay in the same spot. In the case of the sound from a guitar, kinetic energy moves along the sound wave, not the particles of air themselves (Figure 5.3.3).

FIGURE 5.3.3 A vibrating guitar string pushes on the air particles around it. These particles of air vibrate and transfer sound energy along a sound wave.

AB 5.7

Sources of sound

For a sound to be produced, an object must be vibrating. Figure 5.3.4 gives some examples of objects that vibrate to make some common sounds.

FIGURE 5.3.4 Something needs to vibrate for a sound to be produced.

SciFile

Long distance love call

Crickets produce sounds to attract a mate, establish territory and scare off competitors. If a male cricket wishes to attract a female, then it pulls the hardened base of one wing across the ridged base of the other wing. The sound can reach female crickets one kilometre away!

What happens to sound energy?

As a sound wave travels through a material, the particles of that material vibrate. When a sound wave hits a flat and solid surface, like a brick wall, it can be reflected. If a sound wave is reflected, then you hear an **echo**.

When a sound wave hits a soft surface, like a curtain, carpet or foam, some of the kinetic energy is absorbed. This kinetic energy creates friction, and sound energy is converted into heat within the surface. Classrooms and concert halls usually have coverings, such as carpet, wall panels or ceiling tiles, that are positioned to absorb sound energy and reduce echoes.

Sometimes a sound hits a rough surface. This scatters the sound and spreads out its energy in many directions. In this case the sound is diffused and is muffled. Figure 5.3.5 shows three different ways that sound can interact with a surface.

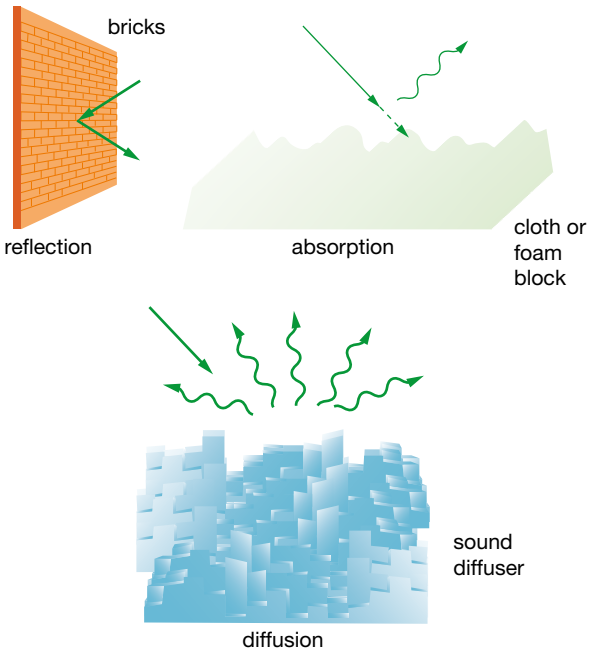


FIGURE 5.3.5 Sound can be reflected, absorbed or diffused depending on the surface it strikes.

Some sound is usually transmitted. This means that some of it passes through a surface. The amount of sound transmitted depends upon the surface itself. Not much noise will be heard between two classrooms separated by a brick wall. If the separation between the classrooms is a curtain or a thin plaster sheet, then more sound will be transmitted.

The science of sound is called **acoustics**. Acoustical engineers design spaces in which we can hear the sounds we want to hear, and not hear the sounds we don't want to hear. In a movie theatre, we all want to hear an actor on the screen but not someone opening a lolly wrapper in the back row.

STEM 4 fun

Echoes

PROBLEM

How far do you need to be from a wall to hear a sound clearly reflected as an echo?

SUPPLIES

- 2 flat pieces of wooden board about 30 cm long and 5 cm wide
- a large flat brick or a concrete wall outside

PLAN AND DESIGN Design the solution. What information do you need to solve the problem? Draw a diagram. Make a list of materials you will need and steps you will take.

CREATE Follow your plan. Draw your solution to the problem.

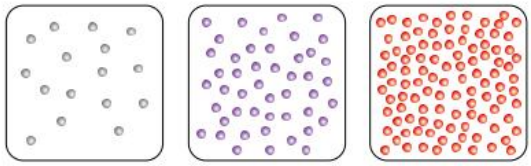
IMPROVE What works? What doesn't? How do you know it solves the problem? What could work better? Modify your design to make it better. Test it out.

REFLECTION

1 What area of STEM did you work in today?
2 What field of science did you work in?
3 How did you use mathematics in this task?

Frequency, wavelength and speed

Figure 5.3.6 compares the speed of sound in a gas, a liquid and a solid. Sound travels at about 340 m/s through air. This explains why it can take several seconds to hear the sound of thunder produced by lightning that is some distance away. The speed that a sound travels depends upon the material the sound travels through. The more closely the particles of the material are packed together, the faster a sound will travel through it. It is not possible for sound to travel in space, because in space there is no material or particles to vibrate and transfer energy.



	gas	liquid	solid
medium:	air at 20°C	water at 25°C	iron
speed of sound:	343 m/s	1493 m/s	5130 m/s

FIGURE 5.3.6 Sound travels much faster through a solid than through a gas, because the particles in the solid are spaced much more closely.

Our ears respond to differences between sound waves. The pitch of a sound is how low or high the sound appears to us. The growling of a dog sounds low in pitch, while the chirping of a bird is a high-pitched sound. The **pitch** of a sound depends upon how quickly the particles vibrate in a sound wave. The faster the particles vibrate, the higher the pitch of the sound. The number of waves that travel past a given point per second is called the **frequency** of a wave. Frequency is measured in a unit called hertz (Hz). A high-pitched sound has a higher frequency than a low, deep-pitched sound. The length of one wave is called the **wavelength**. As wavelength is a distance, it is measured in metres. A high-pitched sound has a shorter wavelength than a low-pitched sound. The pitch, wavelength and frequency of a dog growling and a bird chirping are compared in Figure 5.3.7.

Some sounds are fairly quiet—think of leaves rustling in the breeze. Other sounds are very loud—think of an aircraft taking off. The distance that each particle in a material moves as it vibrates back and forth determines the loudness of a sound. Sounds with more kinetic energy have particles that move further as they vibrate than sounds of lower energy.

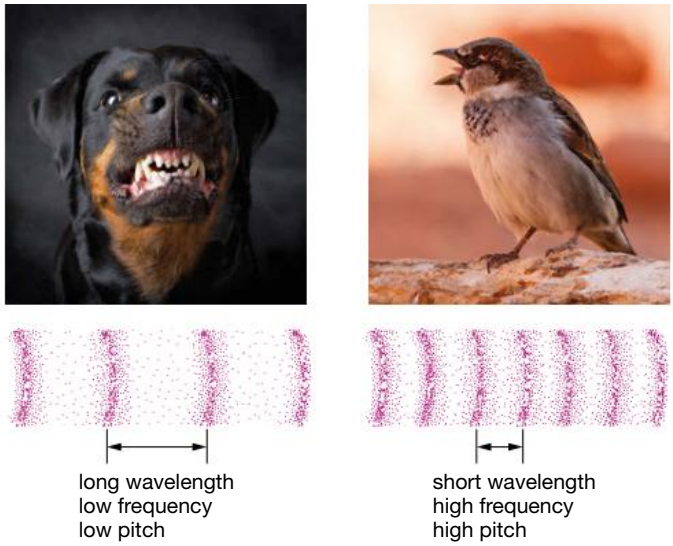


FIGURE 5.3.7 The pitch or frequency of a sound depends on its wavelength.

This difference in energy is heard as a difference in volume. If you blow hard on a whistle then you will produce a much louder sound than if you blow softly. **Loudness** is measured in a unit called the decibel (dB). The loudness of some common sounds is shown in Figure 5.3.8.

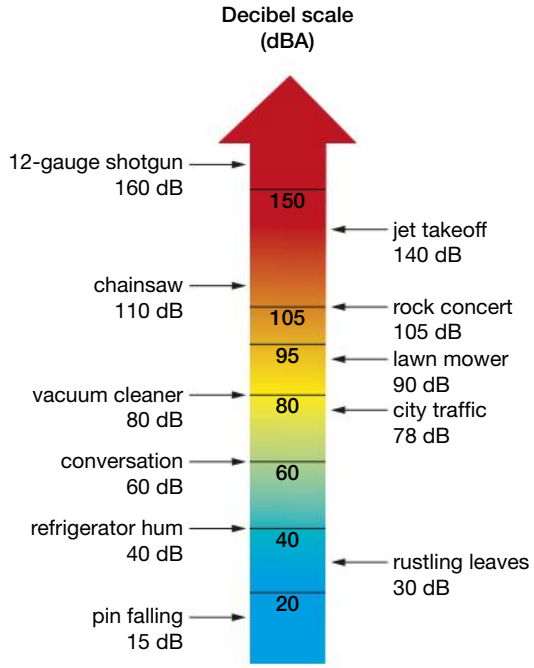


FIGURE 5.3.8 Loudness is measured using the decibel scale (dB).

Prac 1 p. 225
Prac 2 p. 226
Prac 3 p. 227

MODULE
5.3 Review questions

Remembering

1 Define the terms:
   a wave motion b acoustics.

2 What term best describes each of the following?
   a the number of waves that pass a point in one second
   b the scale used to measure loudness.

3 What unit is used to measure the following quantities?
   a wavelength b frequency.

4 What vibrates to produce sound in the following?
   a vocal cords b drum c trumpet.

5 Refer to Figure 5.3.8 on page 223 and state the loudness in decibels of the following:
   a vacuum cleaner b rock concert
   c rustling leaves.

Understanding

6 Explain why a sound wave can be compared to the spread of ripples of water from a stone dropping into a pond.

7 You hear a bell ringing. Describe how the sound of the bell reaches your ears.

8 Explain why sound can be considered a type of kinetic energy.

9 Why is it not possible for sound to travel through empty space?

10 Why is sound transmitted easily through plaster walls but not through brick walls?

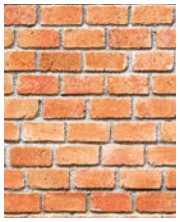
11 Group the following into high-pitched sounds and low-pitched sounds.
ambulance siren *jackhammer*
someone screaming *bass guitar.*

Applying

12 Use Figure 5.3.8 on page 223 to identify sounds that would be:
   a painful, given that sound louder than 120 dB will produce pain
   b dangerous, given that sound louder than 80 dB will damage your hearing with repeated exposure.

13 Look at the STEM4fun activity on page 222. List any animals that hunt using echoes.

14 For each surface shown in the following images, indicate whether it would mainly reflect sound, absorb sound or diffuse sound.

a
b 
c

Evaluating

15 A clarinet has a very thin piece of bamboo in its mouthpiece. Propose a reason why it is there.

16 a Which sound would have its particles vibrating fastest—the sound of a lawnmower or the sound of a ticking clock?
   b Justify your answer.

17 The 1979 film *Alien* included the line, 'In space, no one can hear you scream'.
   a Assess this statement and decide whether it is true, false or a bit of both.
   b Justify your response.

18 Energy cannot be created or destroyed, yet a sound is never heard forever. What do you think happens to the energy of a sound?

19 A new performance space is built at a school. The builders install rows of wooden seating on a polished wooden floor and a cement roof. The students find the space very noisy, with many unwanted echoes. Recommend three improvements that would improve the acoustics of this venue.

20 Table 5.3.1 shows the speed of sound as it travels through different materials.

TABLE 5.3.1 Speed of sound through different materials

Material	Speed of sound (m/s)
air (20°C)	343
air (0°C)	331
sea water	1533
copper	3560
glass	5640
diamond	12 000

Draw five conclusions from the data in Table 5.3.1.

MODULE
5.3 Practical investigations

1 • Chicken sounds

Planning & Conducting | Processing & Analysing

The sound of a tuning fork is much louder when it is placed on a hard surface or a wooden box. The surface vibrates at the same frequency as the tuning fork, moving more air particles and making the sound louder. All musical instruments use a surface called a sound board to magnify their vibrations and increase their sound. In this experiment, the cup acts as a sound board to make the sound produced by the string much louder.

Purpose

To construct a device that produces amplified sound.

Timing 45 minutes

Materials

- plastic drinking cup
- piece of string or cotton about 40 cm long
- sheet of paper towel
- phone or device to record audio
- nail
- paperclip
- small piece of cloth or tissue

Procedure

1. Use the nail to pierce a small hole in the centre of the base of the cup.
2. Tie one end of the string to the paperclip.
3. Thread the other end of the string through the hole in the base of the cup, as shown in Figure 5.3.9a.
4. Fold the paper towel over a couple of times to make a rectangular strip.
5. Hold the paper towel strip under a light stream of water to make it damp.
6. Hold the cup in one hand and, with the other hand, wrap the paper towel around the string so that it hangs just below the cup.
7. Pull on the paper towel in short bursts so that it slides on the string and makes a sound, as shown in Figure 5.3.9b.
8. Experiment with the way you pull on the paper towel to make your device sound like a clucking chicken! Use a device to record a few seconds of the sound produced.
9. Stuff a piece of cloth or tissues inside the cup and record the audio of the clucking sound again.

Review

1. If you were to pull on a piece of string with damp paper towel, then the sound produced would be very soft. Explain why the device you have built produces a loud sound.
2. a Compare the loudness of the sound produced in the device with and without the material stuffed inside the cup.
   b Explain this finding.
3. A guitar or a violin uses a sound board made of wood to increase or amplify the sound made from the vibrating strings. Explain how the sound board makes the sound louder.

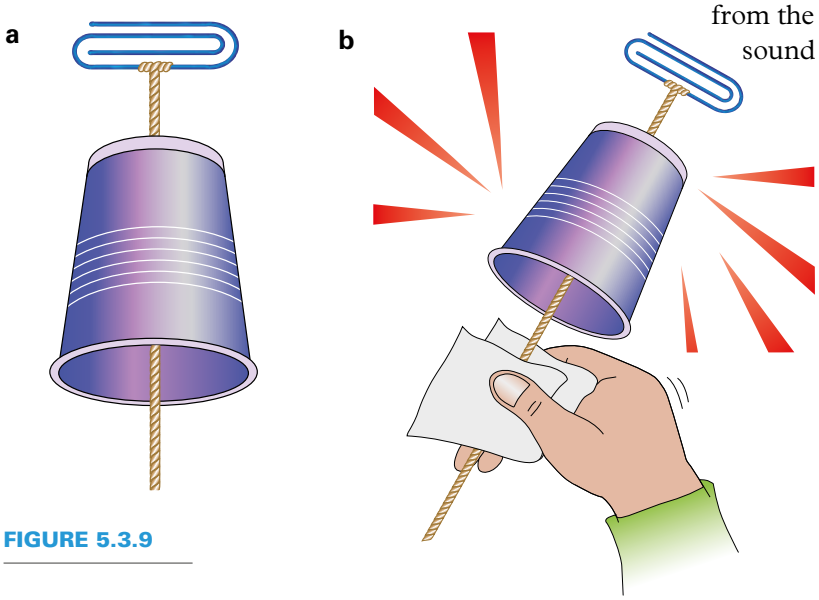


FIGURE 5.3.9

2 • Making a speaker

Planning & Conducting | Questioning & Predicting

A docking station can be used to amplify the sound produced by a portable music device or phone. In this experiment you will make a device that increases the loudness of sound from a phone.

Purpose

To construct a device that will amplify the sound produced from a phone.

Timing 45 minutes

Materials

- cylindrical cardboard container such as a Pringles can
- box cutter knife or scissors
- 2 large binder clips
- paint or coloured paper for decoration
- phone
- permanent marker
- masking tape

Hypothesis

Which do you think would make a louder sound: a phone playing music while resting on a bench, or a phone playing music while inserted into a cardboard cylinder? Before you go any further with this investigation, write a hypothesis in your workbook.

Procedure

1. Lay the cylinder flat on a bench. Carefully mark the width of the phone on the cylinder with permanent marker.
2. Carefully cut a slot in the can to fit the phone. To make sure the phone fits snugly, cut a smaller hole at first and increase as needed to fit the phone.
3. Tape the two binder clips to each side of the can to keep the cylinder from rolling, as shown in Figure 5.3.10.
4. Decorate your can using spray paint or by attaching coloured paper to the outside.
5. Play some music from your phone, then insert it into your speaker to hear whether the volume of sound changes.

Review

1. Describe any improvements you could make to the design of this speaker to amplify the sound further.

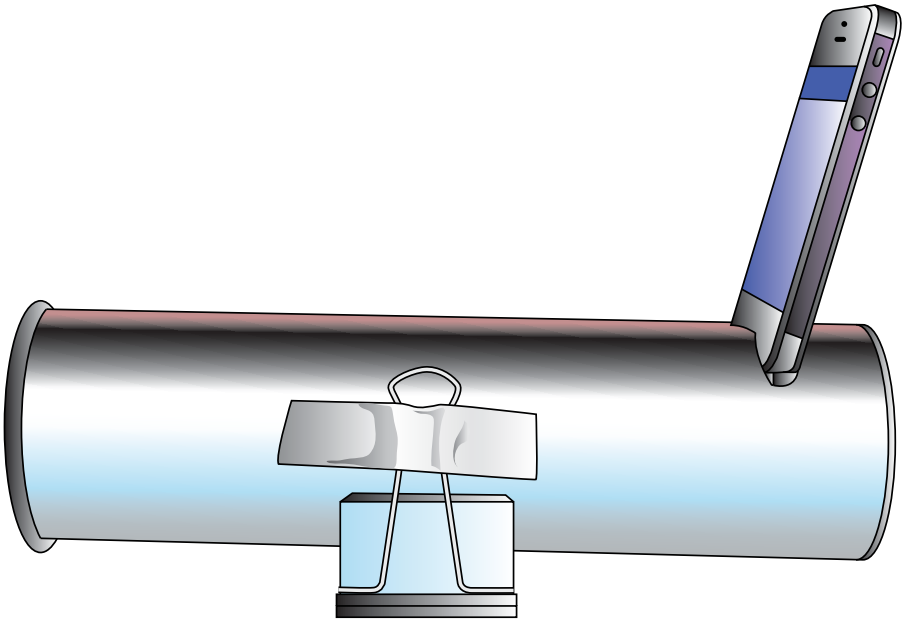


FIGURE 5.3.10

MODULE
5.3 Practical investigations

• STUDENT DESIGN •

3 • Seeing sounds

Planning & Conducting | Questioning & Predicting

Purpose

To watch materials vibrate to sound coming from a speaker and investigate how the sound changes their shape or formation.

SAFETY

A Risk Assessment is required for this investigation.

Materials

Variety of materials to test, for example:

- oobleck (cornflour mixed with water)
- milk
- salt
- Smarties™ or M&Ms™

- large speaker cone through which music can be played
- garbage bag

Procedure

1. Design an investigation to test how a range of materials respond to the vibrations of sounds from a speaker.
2. Lay a large speaker on the floor so that the speaker cone points upwards, and cover the speaker with a protective layer such as a garbage bag.
3. Research this experiment on the internet and decide which materials to test and which types of sounds will be most effective.
4. Write your procedure in your workbook.
5. Before you start any practical work, assess your procedure. List any risks that your procedure might involve and what you might do to minimise those risks. Show your teacher your procedure and your assessment of its risks. If your teacher approves, then collect all the required materials and start work.

Use the STEM and SDI template in your eBook to help you plan and carry out your investigation.

Results

Record your observations using video of each material tested on the speaker.

Review

1. Which materials were the most effective in showing the nature of the sound from the speaker?
2. Explain why you think these materials worked best.
3. What do your findings tell you about sound?
4. Evaluate your procedure and identify ways it could be improved if you were to repeat the experiment.

MODULE

5.4 Light energy

Light floods our eyes and allows us to see the world around us. White light can split into all the colours of the rainbow. Light bounces off surfaces or bends as it travels through materials to form images. We see these images when we look in a mirror, a microscope, a telescope or a magnifying glass. Light is one small part of a spectrum of radiation produced by the Sun. It is the only part of this spectrum that we can see.

science 4 fun

Forming an image

YES

Collect this ...

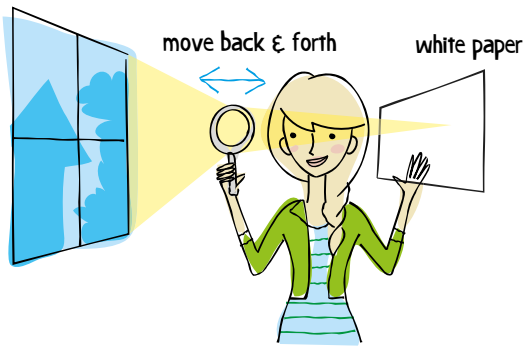
- magnifying glass
- sheet of white paper

Do this ...

1. Hold the magnifying glass in front of a light source, such as sunlight through a window, a candle or a light globe.
2. Hold the sheet of paper as a screen in one hand and the lens in the other.
3. Try to focus an image on the sheet of paper by moving the lens back and forth.

Record this ...

1. Describe what happened.
2. Explain why you think this happened, using a diagram to assist your response.



Light waves

Like sound, light travels as a wave. Light travels much, much faster than sound. In fact, nothing can travel faster than light. Light travels at about 300 million metres every second. This means light would be able to travel around the equator seven and a half times in just one second!

The nature of light is very complex and has been debated by scientists for centuries. Light does not need a material to travel through, and so it can reach Earth from the Sun through empty space (Figure 5.4.1).

FIGURE 5.4.1 Sound needs something to travel through, but light does not—it can travel through space.

Electromagnetic radiation

Energy released from the Sun is called **electromagnetic radiation**. Light is a form of electromagnetic radiation. In addition to the visible light that can be seen, radiation from the Sun includes gamma rays, X-rays, UV radiation, infrared radiation, microwaves and radio waves. The complete range of radiation released from the Sun is called the **electromagnetic spectrum** and is shown in Figure 5.4.2. All types of electromagnetic radiation travel as waves at the speed of light.

The wavelength of these different forms of electromagnetic radiation varies considerably. The length of one radio wave can be the length of a shopping centre, whereas the length of one gamma wave is smaller than the tiny particles that make up matter.

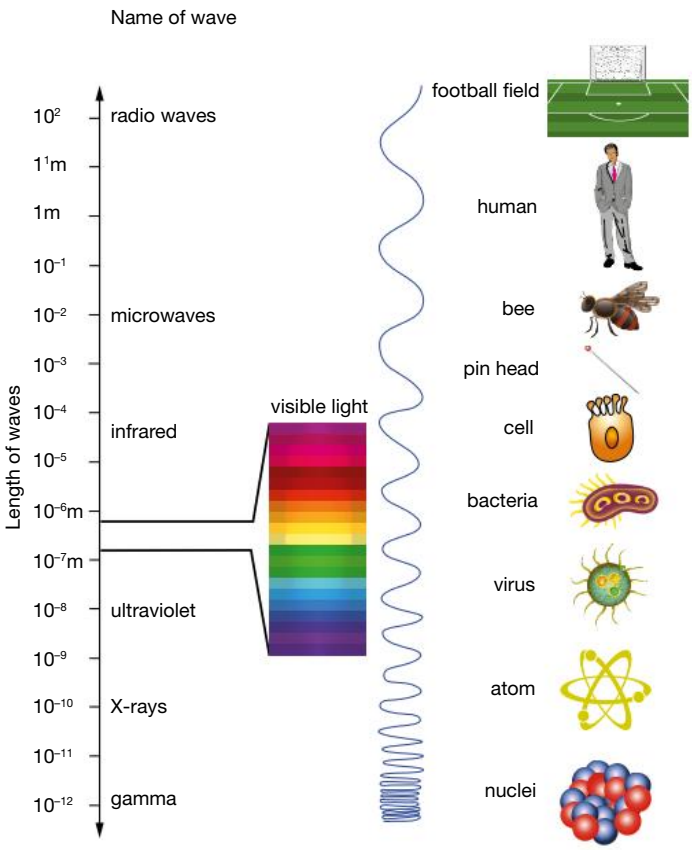


FIGURE 5.4.2 Most of the waves in the electromagnetic spectrum are invisible to us. The waves are all types of light—the only difference is in their wavelength and frequency.

Dispersion of light

Visible light is part of the larger electromagnetic spectrum but visible light is made up of a spectrum too. This spectrum is made up of all the different colours that we can see. It forms the rainbow seen in Figure 5.4.3.

FIGURE 5.4.3 Tiny water droplets left in the air after rain have split white light from the Sun into the colours of this rainbow.

A rainbow happens because a water droplet has split white light from the sun into different colours, which then fan out in slightly different directions. A similar rainbow effect is sometimes seen when light passes through crystal in a chandelier or a glass. This splitting of white light into colours is called **dispersion**.

This rainbow of colours is called the **visible spectrum** and can be seen in Figure 5.4.4. In order, the colours of the visible spectrum are: red, orange, yellow, green, blue, indigo and violet. A simple way of remember this is to remember ROY G BIV. Red light has the longest wavelength and the lowest frequency. As you move through the spectrum towards the violet end, the wavelength of light decreases and the frequency increases.

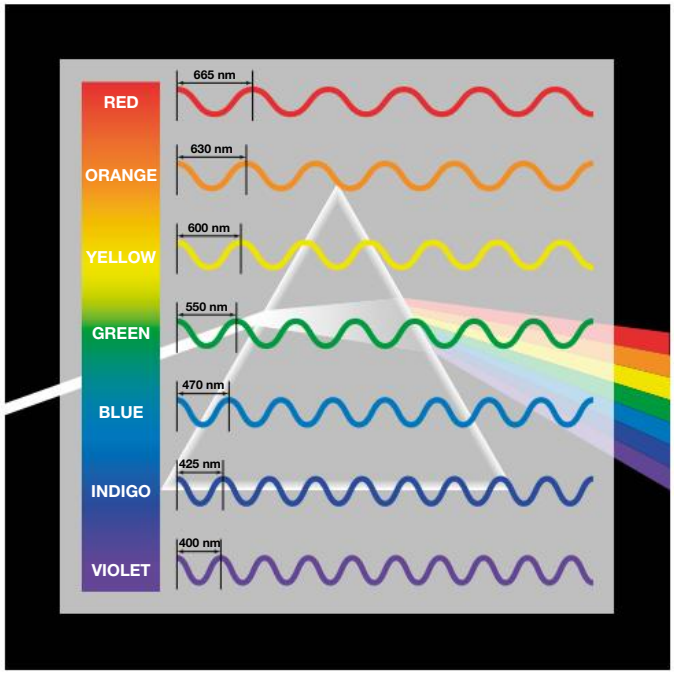


FIGURE 5.4.4 This glass prism is dispersing white light into its colours. Each colour has waves of slightly different length.

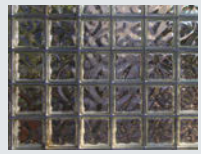
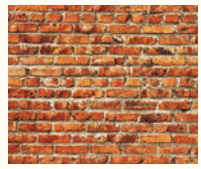
What happens to light energy?

When light hits a surface, it acts much like sound energy. It may be:

- transmitted through the substance
- reflected from the surface
- absorbed into the substance.

Table 5.4.1 outlines examples of each of these three situations.

TABLE 5.4.1 Transparent, translucent and opaque materials

Light hits a surface and:	This material is called:	Examples
• almost all light is transmitted through the substance • a clear image can be seen through the substance.	transparent	clear glass, shallow water
• some light may be reflected, and light that passes through is scattered • an image seen through the substance is fuzzy.	translucent	tissue paper, fingernails, frosted glass 
• light is either reflected from or absorbed into the substance • no light is transmitted • no image can be seen through the substance.	opaque	brick, piece of wood, desk, football 

Reflection of light

Light energy can bounce or reflect off surfaces. This is called **reflection**. Light reflects off a surface at the same angle that it hit the surface, just like a ball bouncing off a wall (Figure 5.4.5). When light hits objects around us, it reflects or scatters from these objects into our eyes, allowing us to see them. This is why we see things like books, clothing and people. If a surface is very smooth, then the reflection of light instead produces an **image**. You see an image whenever you look into still water, polished glass or a mirror (Figure 5.4.6).

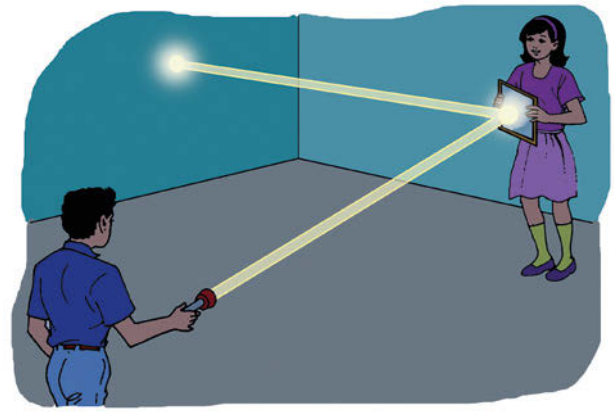


FIGURE 5.4.5 Light reflects from a mirror at the same angle that it hits it.

FIGURE 5.4.6 When light reflects from a very smooth surface such as a mirror, an image is produced. This baby's image is back to front and lies the same distance behind the mirror as the baby is in front of it.

Mirrors

Most mirrors are flat. These are called **plane mirrors**. Mirrors can also be curved. Mirrors in amusement parks can bulge inwards and outwards to produce distorted images. You have probably seen similar distorted images when looking at each side of a soup spoon. A mirror that bulges outwards is called a **convex mirror**. Convex mirrors produce small images that show a wide angle of view. These types of mirrors are useful as car rear view mirrors or as security mirrors, as can be seen in Figure 5.4.7 on page 231.

A mirror that caves inwards is called a **concave mirror**. These mirrors can be used to magnify an object when used at a close distance (Figure 5.4.8 on page 231). For this reason they are used by dentists to examine teeth, or as make-up or shaving mirrors. Concave mirrors are also used in torches, car headlights and astronomical telescopes. When used in this way, a concave mirror focuses light to a point.

FIGURE 5.4.7 The wide-angled image from a convex mirror makes it useful as a security device.

FIGURE 5.4.8 When an object is close to a concave mirror, a magnified image is formed.

Prac 1 p. 237
Prac 2 p. 238

SciFile

Mirror on the Moon

In 1969, Neil Armstrong and Buzz Aldrin travelled in *Apollo 11* to the Moon. There they left a device called a corner reflector. Researchers have used the reflection of laser light from the device to accurately measure the distance from the Earth to the Moon, and have discovered that this distance increases by 4 cm each year.

Refraction of light

Light slows down when it travels into different materials, such as water or glass. When light slows down, its path is bent. Light bends, or refracts, when it passes through a new substance. This bending of light is called **refraction**.

The refraction of light produces unusual effects, like the glue stick viewed through a trough of water seen in Figure 5.4.9.

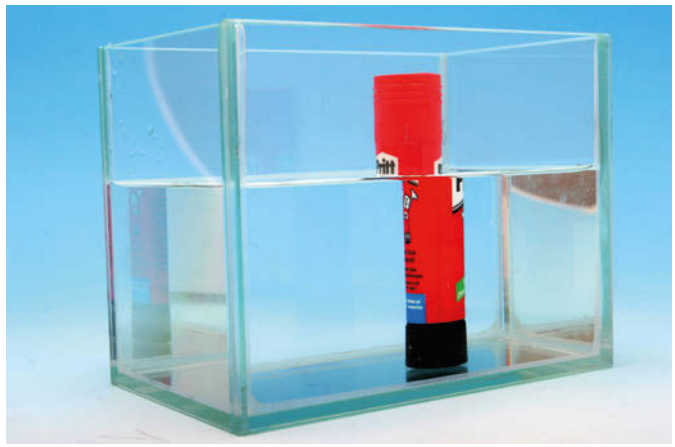


FIGURE 5.4.9 This glue stick appears disjointed because light travels more slowly through water than air. As a result, its path is refracted or bent.

Explaining dispersion

Refraction also explains dispersion. When white light passes through a water droplet in the sky, each colour slows down by a slightly different amount, and so the different colours travel through the water at slightly different speeds. As a result, each colour is bent a little bit differently. This splits the white light into the colours that make it up.

Prac 3 p. 239

Lenses

Lenses are specifically shaped pieces of plastic or glass that are designed to bend light in a particular way. A **convex lens** bulges outwards in the centre. This type of lens bends light together. A convex lens can be used as a magnifying lens when placed close to an object, as shown in Figure 5.4.10.

FIGURE 5.4.10 The convex lens used close to the eye acts as a magnifying glass.

When the object is placed further away, a convex lens can produce an image on a screen. This is how you see a movie at the cinema—it is projected onto a screen.

A lens that caves inwards is called a **concave lens**. This type of lens spreads light apart. These lenses always produce small and upright images (Figure 5.4.11).

FIGURE 5.4.11 The image of this man's face is small because it is produced using a concave lens.

AB 5.8

The eye

Your eye forms an image using a convex lens. The convex lens in your eye focuses light onto a point on the retina, which is found at the back of your eyeball (Figure 5.4.12).

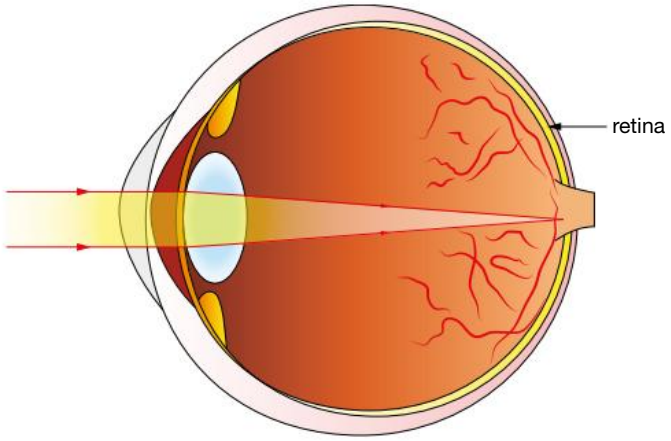


FIGURE 5.4.12 Together with the cornea, or outer covering of the eye, the convex lens inside your eye brings light to a point at the retina.

If light is focused in front of or behind the retina, then your sight will be blurry when looking at things up close or further away. If your eyeball is too long then light is focused in front of the retina. This problem is called short-sightedness or myopia. If your eyeball is too short, light is focused behind your retina. This problem is called long-sightedness or hyperopia.

Glasses or contact lenses are lenses that can be prescribed and used to adjust the focus of your eyes back to the correct position. A concave lens is used to treat short-sightedness (5.4.13) and a convex lens is used to treat long-sightedness (Figure 5.4.14).

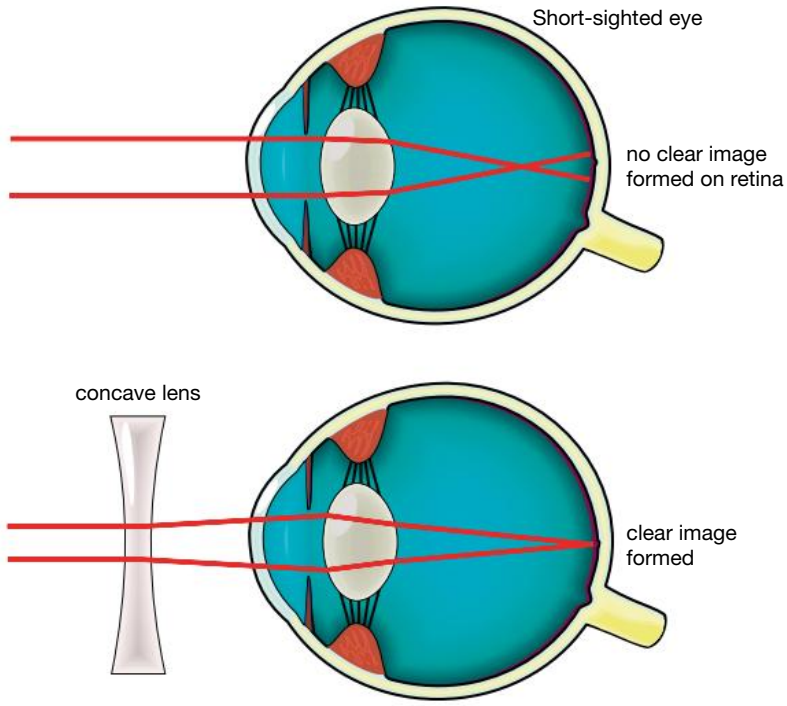


FIGURE 5.4.13 A concave lens is used to treat short-sightedness.

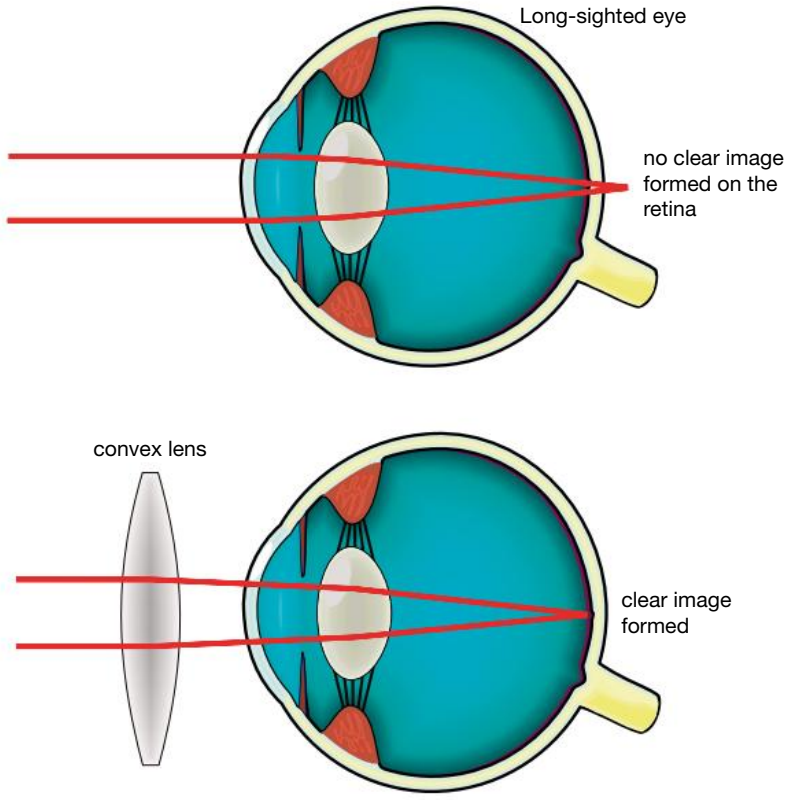


FIGURE 5.4.14 A convex lens is used to treat long-sightedness.

SCIENCE AS A HUMAN ENDEAVOUR

Use and influence of science

Lighting the world

In 2014, three Japanese scientists were awarded the Nobel Prize in Physics for their work in developing the blue LED. An example is shown in Figure 5.4.15. The Nobel Prize is awarded for inventions that most benefit society.

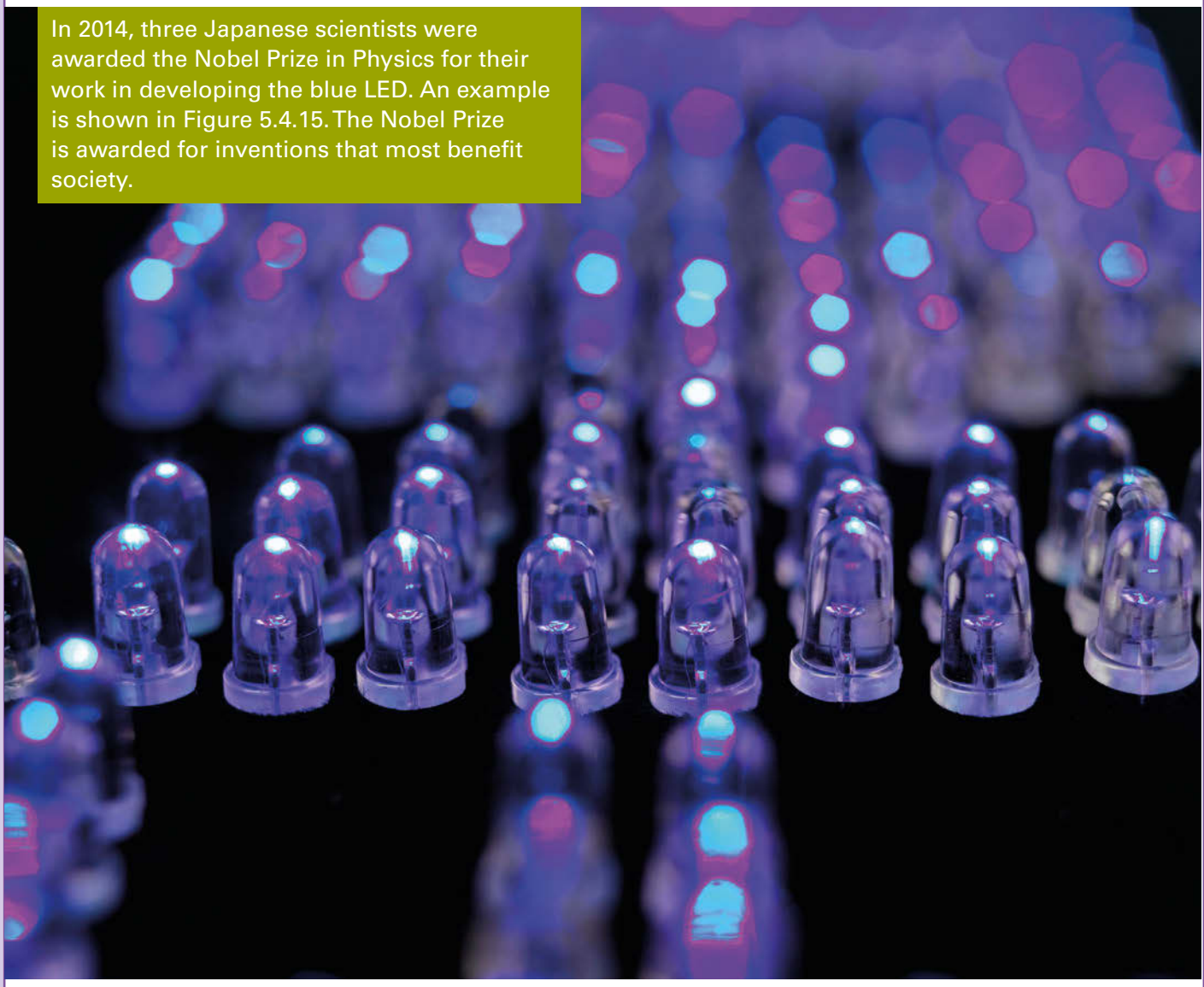


FIGURE 5.4.15 The invention of blue LED light has changed the way we light the world.

Red and green LEDs (light emitting diodes) had been around for decades. Red, green and blue LED light are all needed to produce the much desired white LED light. White LED lighting is energy efficient, long lasting and does not contain the harmful mercury that is found in fluorescent tubes. Discovering how to produce blue LED light was difficult and complex. Many researchers tried without success. While working at Japan's Nagoya University in 1992, Isamu Akasaki and Hiroshi Amano successfully produced the blue LED after many trials and many attempts to refine their experimental method.

In the same year, Shuji Nakamura, working at Nichia Chemicals in Japan, independently produced blue LED using a different approach. These scientists developed revolutionary solutions to problems that had previously been unsolvable.

SCIENCE AS A HUMAN ENDEAVOUR

For their work, Akasaki, Amano and Nakamura (Figure 5.4.16) were jointly awarded the Nobel Prize in Physics. In awarding the scientists the prize, the Nobel committee said that they succeeded where everyone else had failed.

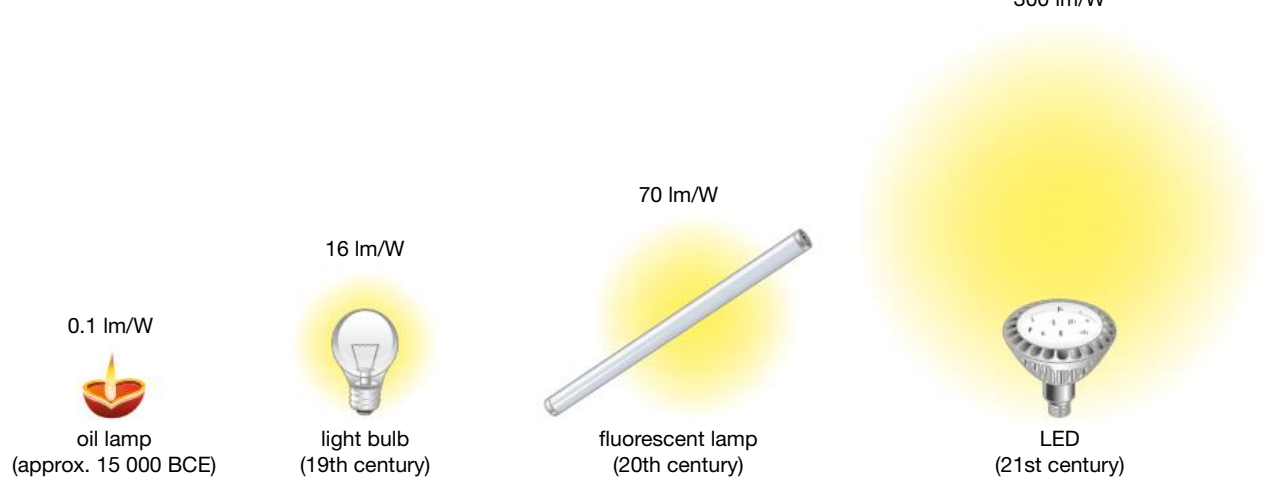
FIGURE 5.4.16 The three joint winners of the 2014 Nobel Prize for Physics: Akasaki, Amano and Nakamura.

LED lighting is far more energy efficient than forms of lighting used in the past. Figure 5.4.17 compares the brightness of various light sources. It is estimated that one-quarter of the world's energy is used to produce light. In increasing the efficiency of lighting using white LEDs, the scientists who developed blue LEDs have forever changed the way the world uses energy for lighting.

REVIEW

1. Which three colours of LEDs must be combined to produce white LED light?
2. Compare the efficiency of white LEDs with earlier light sources.
3. What proportion of the world's energy is estimated to be used to power lights?
4. Predict the effect that the development of highly energy efficient white LED lighting will have for 1.5 billion people living in areas of the world that are not connected to an electricity grid.
5. Developing blue LED light occurred only after thousands of experiments. Discuss the qualities needed by its inventors.
6. Engineers use their knowledge of science and mathematics, in addition to their own creativity and thinking skills, to develop solutions to contemporary problems. The scientists who developed the blue LED engineered a solution to the problem they wanted to solve. Propose three other areas in which there is a need for engineering solutions for the future.

FIGURE 5.4.17 Brightness of light is measured in lumens(lm). This diagram compares the brightness of light in lumens produced per watt of electrical power. The LED produces far more light per watt than the other light sources.



MODULE
5.4 Review questions

Remembering

1 Define the terms:
- **a** reflection
- **b** visible spectrum
- **c** concave.

2 What term best describes each of the following?
- **a** the complete range of radiation released from the Sun
- **b** a flat mirror
- **c** the bending of light.

3 What is the speed of light in air?

4 What is an example of a type of radiation in the electromagnetic spectrum that has:
- **a** a long wavelength?
- **b** a short wavelength?

5 Name the process shown in Figure 5.4.18.

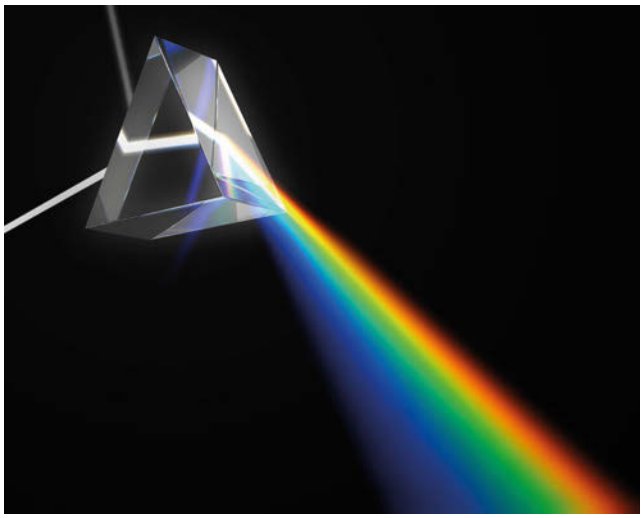


FIGURE 5.4.18

6 List what light can do when it strikes a surface.

Understanding

7 List the colours of the visible spectrum in order.

8 How does light allow us to see a tree outside on a sunny day?

Applying

9 Josie stands 50 cm in front of a full-length mirror in her bedroom (Figure 5.4.19). A pot plant sits 30 cm in front of the mirror and her soccer ball is 20 cm in front. Identify how far inside the mirror Josie, her pot plant and her soccer ball will each appear to an observer.

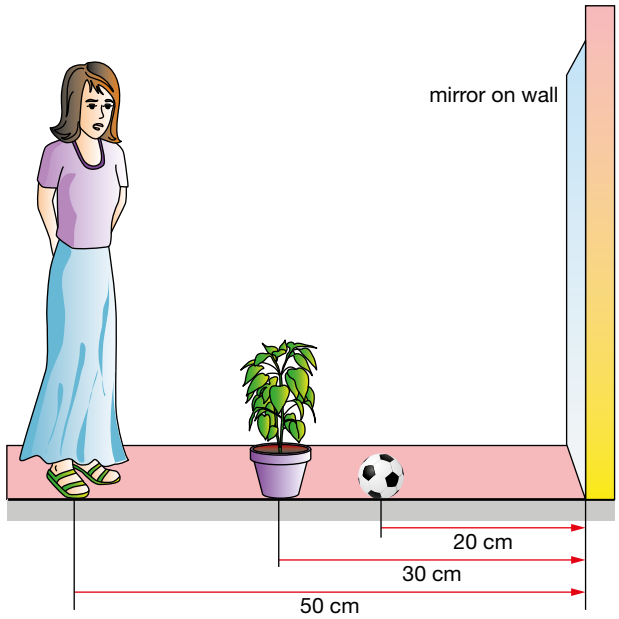


FIGURE 5.4.19

10 Use Figure 5.4.2 on page 229 to identify the type of electromagnetic radiation that has waves closest in size to:
- **a** an onion cell
- **b** an aircraft
- **c** a 5-cent coin
- **d** a silicon atom.

11 Identify whether a convex or concave mirror would be useful in each situation listed below.
- **a** a security mirror at a train station
- **b** a mirror by the side of a road to show what is around a bend
- **c** a make-up mirror in an actor's dressing room.

MODULE
5.4 Review questions

Analysing

12 **a** Does light need a medium in which to travel?
b Justify your answer.

13 Classify the following materials as transparent, translucent or opaque.
a ceramic mug
b frosted bathroom window
c muddy car window
d clean car windscreen.

14 Compare:
a reflection with refraction
b lenses and mirrors
c convex, concave and plane mirrors.

15 List three situations that you have seen where you think refraction caused some sort of optical illusion.

Evaluating

16 Fernando is tidying up. In one hand he carries a polished metal tray, and in the other a woollen sock. Fernando can see his image in the tray but not in the sock. Why do you think this occurs?

17 **a** Which type of curved mirror is shown in Figure 5.4.20?
b Justify your answer.

FIGURE 5.4.20

18 A curved mirror similar to the one in Figure 5.4.21 can be used in astronomical telescopes.
a Identify this type of curved mirror.
b How do you think this mirror is used in a telescope?

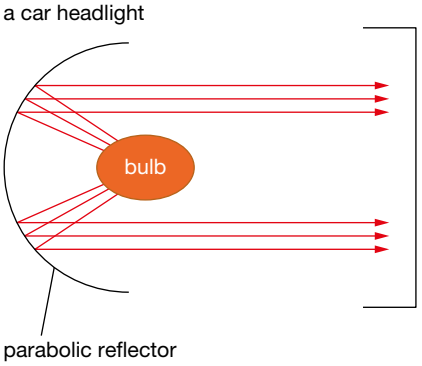


FIGURE 5.4.21

19 When you see a movie at the cinema, an image is projected onto a screen.
a Discuss whether you think an image seen in a plane mirror could be captured on a screen.
b Justify your response.

20 In the science4fun on page 228, an image is formed using a magnifying glass.
a Identify the type of lens used in this activity.
b Why do you think the image formed cannot be magnified?

MODULE
5.4 Practical investigations

1 • Looking at images from a mirror

Planning & Conducting | Processing & Analysing

Purpose

To compare the images created using plane and curved mirrors.

Timing 30 minutes

Materials

- concave mirror
- convex mirror
- plane mirror
- globe and battery, or power pack, or a candle
- piece of white cardboard to use as a screen

Procedure

1. Copy the table found in the results section below. Give your table a title. Record your observations in the table as you work through this experiment.
2. Slightly darken the room you are in for the experiment.
3. Connect a globe to a battery or power pack, or use a lit candle as a source of light.
4. Place the light source in front of a plane mirror.
5. Investigate the type of image that is seen in the mirror. Examine how the image changes when the light source is positioned very close to the mirror (5 cm away) and when positioned further away (50 cm) from the mirror.
6. Try to produce an image of the light source on the white cardboard screen.
7. Exchange the plane mirror for the convex mirror. Repeat steps 5 and 6 using the convex mirror.
8. Replace the convex mirror with the concave mirror. Repeat steps 5 and 6 (Figure 5.4.22).

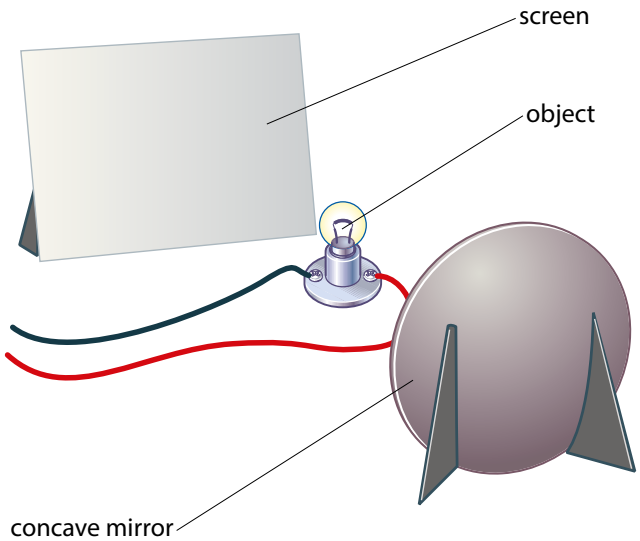


FIGURE 5.4.22

Review

1. Were you able to capture any images on a screen from the three types of mirrors tested?
2. Describe a situation which captures an image on a screen like you did here in this experiment.
3. Which type of mirror would be best used to give a wide view of an area?
4. Which type of mirror and which position of the light source produced the image with the greatest magnification?

Results

Type of mirror	Description of image of light (e.g. upright, upside-down, larger, smaller)		Could the image be captured on a screen?
	Positioned 5 cm from mirror	Positioned 50 cm from mirror	
plane			
convex			
concave			

MODULE 5.4

Practical investigations

2 • Multiple images

Questioning & Predicting | Processing & Analysing

Purpose

To investigate the relationship between the number of images formed and the angle separating two plane mirrors.

Timing 30 minutes

Materials

- two plane mirrors taped together along a vertical edge so they can stand upright and the angle between them be altered
- protractor
- pencil or birthday candle
- Blu-Tack®

Procedure

1 Copy the table shown in the Results section. Give your table a title. Record your observations in the table as you work through this experiment.

2 Position the pencil or unlit birthday candle upright on some Blu-Tack and place the hinged mirrors in front of this, as shown in Figure 5.4.23.

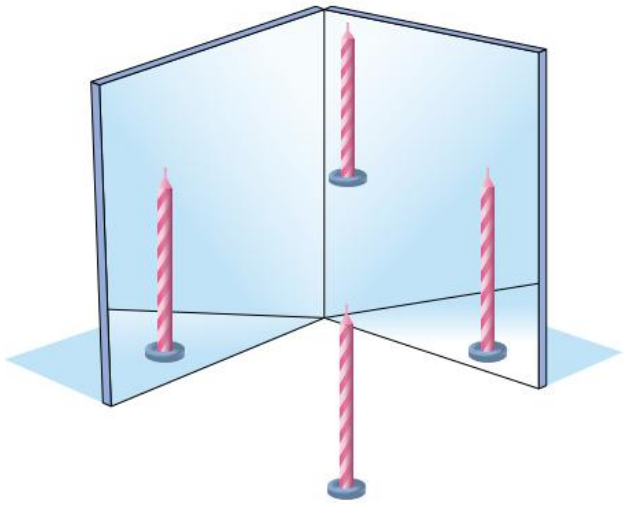


FIGURE 5.4.23

3 Using the protractor, open the mirrors so that the angle between them is 180°. Count the number of whole images you see in the mirrors and record in your table.

4 Repeat this process for all the angles in the table.

Results

Angle between mirrors (°)	Number of whole images	
	Observed	Predicted
180		
150		
120		
90		
60		
30		

Review

1 a State whether more images were observed for a larger or a smaller angle between the mirrors.

b Propose why this is the case.

2 The number of images observed should be equal to:

$$\frac{360}{\text{angle between mirrors}}$$

Using this equation, calculate the expected number of images that are predicted to be seen for each angle tested above.

Enter your results in the table.

3 Discuss whether your observations closely matched the predicted results.

4 Propose reasons for any differences between the observed results and those predicted by calculations.

MODULE
5.4 Practical investigations

• STUDENT DESIGN •

3 • Colours of the rainbow

Questioning & Predicting

In this activity, your task is to disperse light into its colours and see who can capture the best images of this in photos. Two methods have been suggested here: one if conditions are sunny, and the other if not.

Purpose

To disperse white light into colours of the rainbow and to capture the best image possible.

Materials

- plane mirror, torch, beaker or range of glasses; or
- white paper, beaker or range of glasses; or
- a CD or DVD

SAFETY

A Risk Assessment is required for this investigation.

Procedure

1 Design an investigation to obtain images of rainbows of colour produced by the dispersion of white light. The hints given below and Figure 5.4.24 will help you to do this.

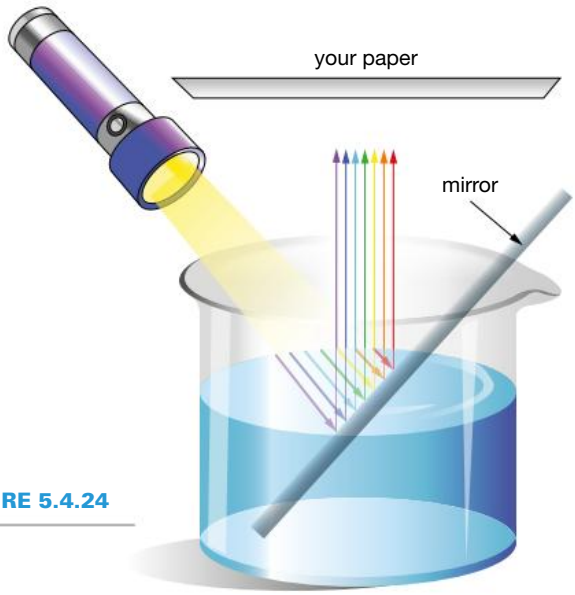


FIGURE 5.4.24

2 Write your procedure in your workbook. Consider variables that you can change to try to improve the image captured. For example, if doing the task outside: the type of glass or beaker used, the angle it is tilted, the amount of water used. If doing the task inside: the angle of the mirror, the depth of water, the brightness of the torch and the darkness of the room.

3 Before you start any practical work, assess your procedure. List any risks that your procedure might involve and what you might do to minimise those risks. Show your teacher your procedure and your assessment of its risks. If your teacher approves, collect all the required materials and start work.

Hints

If the day is sunny:

- Take a half-filled glass of water outside.
- Direct sunlight through the glass and hold a white piece of paper underneath the glass.
- See if you can see a rainbow of colours on the paper.

  Alternatively, use a CD or DVD instead of the glass of water.

If the day is overcast:

- Darken the room.
- Place the plane mirror on an angle inside a beaker that is half-filled with water.
- Direct a beam of light from the torch onto the mirror in the water and hold a piece of white paper or card above, as shown in Figure 5.4.24. Vary the angle and hopefully you will see some rainbow colours appear.
- Use the STEM and SDI template in your eBook to help you plan and carry out your investigation.

Results

Take photos to record your results. Select your best photo to enter on a class display page. Perhaps conduct a vote for the best piece of science art!

Review

1 Name the process that you investigated in this activity.

2 Propose the role of the water if you used it in this investigation. If you used a CD, propose how the CD could split the light.

3 Propose reasons why the image you think is the best was successful.

4 Evaluate your procedure and identify ways it could be improved if you were to repeat the experiment.

CHAPTER 5

Chapter review

Remembering

1 What is another name for stored energy?

2 List four types of stored energy.

3 Name the process in which green plants use light from the Sun to produce chemical energy.

4 Name a device that can directly convert the Sun's light into another form of energy.

Understanding

5 Visible light lies between which two forms of electromagnetic radiation in the electromagnetic spectrum?

6 Describe three examples of an object with kinetic energy.

7 Describe two examples in which heat is transferred by conduction.

8 a Predict whether sound travels faster on a warm day or a cool day.
b Explain your response.

9 Give an example in which sound energy is transformed into another form of energy.

10 Explain why light refracts as it enters and leaves different substances.

Applying

11 Identify an example to match each form of energy in the following table.

Form of energy	Example of something it can make happen
sound	makes windows vibrate
kinetic	
light	
heat	
electrical	

12 A particular electric hot water system is 60% efficient. This means that, for every 100 J of energy supplied, 60 J of heat energy is produced. If the system needs 60 000 J of heat energy to heat a body of water, calculate how many joules of electrical energy must be supplied.

13 Identify three similarities and three differences between light energy and sound energy.

Analysing

14 Appliances are independently tested under Australian standards to produce the energy rating label of each device. Discuss what could happen if there were not strict rules about testing these products.

Evaluating

15 A Washwell washing machine has 5 stars and a SudZ washing machine has 7½ stars.
a Assess which washing machine is more energy efficient.
b Which machine will require fewer joules of electrical energy to complete a load of washing?
c Evaluate whether this would make a difference over the lifetime of the washing machine.

16 a Which type of lens is shown in Figure 5.5.1?
b Justify your answer.

FIGURE 5.5.1

17 Light slows down when it enters glass from air. Propose a reason why this happens.

18 a Assess whether you can or cannot answer the questions on page 192 at the start of this chapter.
b Use this assessment to evaluate how well you understand the material presented in this chapter.

Creating

19 Use the following ten key terms to construct a visual summary of the information presented in this chapter.

kinetic energy
chemical energy
sound energy
energy efficiency
electrical energy
light energy
potential energy
gravitational potential energy
elastic potential energy
heat energy

AB 5.10

CHAPTER 5

Inquiry skills

Research

1 Processing & Analysing

Find the website of one of your favourite fast-food chains.

a Select a typical meal and drink from the restaurant. State the energy content of each of the foods you have listed.

b Calculate a total kilojoule count for this meal.

c Name a sport or leisure activity that you enjoy. Search the internet to state an estimate of the number of kilojoules per hour your body burns up while conducting this exercise.

d Use the figure you calculated in task c to estimate how many hours of this exercise it would take to burn off the kilojoules in the meal that you have selected.

e Propose why fast food is recommended as an occasional treat in a balanced diet.

Present your findings as a set of answers to the above tasks.

2 Processing & Analysing Communicating

Find a website that compares the energy rating labels found on household appliances.

a Select one type of appliance, such as an air conditioner, television or refrigerator. Choose three models of the appliance you are investigating that are similar in retail price. List the three models you have found and their energy ratings.

b Compare the cost and the energy rating labels of the three appliances you have researched.

c Recommend which appliance you would purchase if given the choice of these three models.

Present your research as an article for a consumer website.

3 Processing & Analysing Questioning & Predicting

a Research the birth date and place of the scientist, Ernst Chladni.

b Chladni is called the 'father of acoustics'. Describe the techniques he outlines in his 1787 paper, *Discoveries in the theory of sound*.

c Chladni's figures show incredible patterns caused by the interaction of sound waves. These figures (Figure 5.5.2) can be made visible by using salt or fine particles light enough to be moved by the sound waves. Use the internet to find video footage of Chladni's figures.

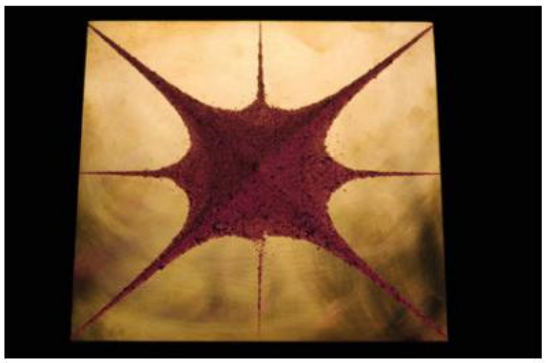


FIGURE 5.5.2

d Explore how these patterns are created by sound waves. Propose any ways that this knowledge could be used in applications in the future.

4 Planning & Conducting Processing & Analysing

a Explore 'infinity mirror' using a search engine and describe what you find.

b Gather a collection of images of infinity mirrors like that shown in Figure 5.5.3.

FIGURE 5.5.3

c Explain how an infinity mirror can be built. Use the concept of an infinity mirror as the starting point for a science fiction short story in which a portal is opened through successive reflections.

CHAPTER 5

Inquiry skills

Thinking scientifically

1 The temperature of particles is a measure of their average kinetic energy. Particles at a higher temperature have more kinetic energy than particles at a lower temperature. Sarah adds one drop of food colouring to each of four water samples. Study the spread of the dye through the samples (Figure 5.5.4).

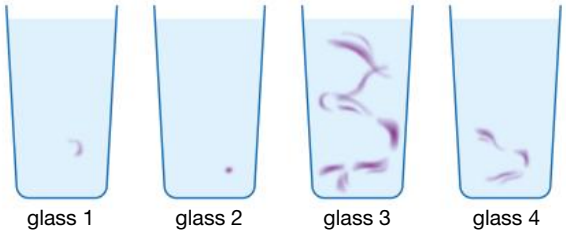


FIGURE 5.5.4

Which of the following correctly ranks the water in the glasses in order of increasing temperature?

A glasses 3, 4, 1, 2
B glasses 2, 1, 4, 3
C glasses 4, 3, 1, 2
D glasses 1, 2, 4, 3

2 Angelo is about to start washing the dishes when he is called to answer the front door. He leaves half a mug of coffee and half a glass of lemonade floating in the sink. At the moment he leaves, these have the temperatures shown in Figure 5.5.5. Angelo is gone for 15 minutes. When he returns, the coffee in the mug, the lemonade in the glass and the washing-up water in the sink are most likely to be which temperatures?

	Coffee in mug	Lemonade in glass	Washing-up water
A	90°	11°	20°
B	80°	5°	19°
C	20°	25°	25°
D	75°	10°	18°

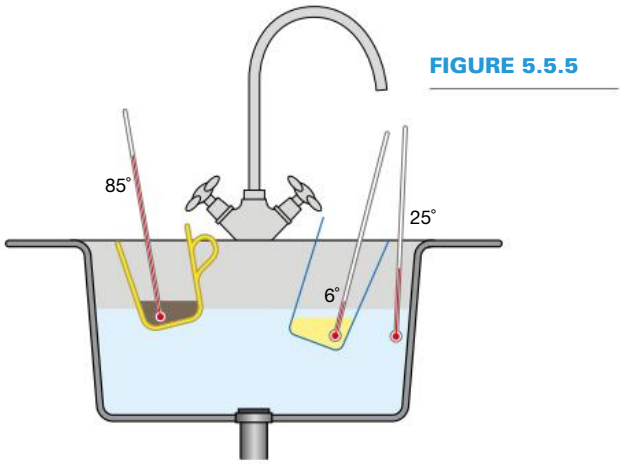


FIGURE 5.5.5

3 You find an unusual machine in an abandoned warehouse. It has a set of operating instructions lying in the dust next to the machine. You read in the instructions that the machine converts sound energy into kinetic energy, light energy, gravitational potential energy and heat energy. The efficiency of the machine is listed as 65% as some energy is used as heat within the machine itself. Feeling adventurous, you turn the machine on and scream into its large funnel, which is facing you. Amazingly, three small pebbles shoot out from the other end of the machine. You observe that in total, the pebbles rise to a height equivalent to 120 J of gravitational energy. The digital display shown in Figure 5.5.6 flashes that your incredibly loud scream had sound energy of 1300 J and that each pebble was released with 90 J of kinetic energy. Using the handy light detector you have in your pocket, you measure the light energy of the display as 230 J.

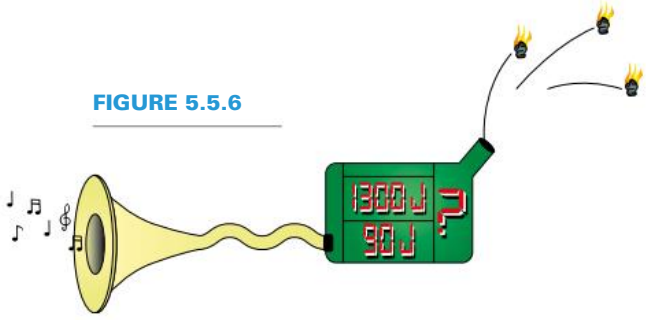


FIGURE 5.5.6

Given that the efficiency rating on the machine is accurate, calculate how many joules of heat energy were possessed by each pebble when fired from the machine. Show all your steps and describe your thinking at each stage.

CHAPTER 5

Glossary

acoustics: the science of sound

chemical energy: energy stored within a substance, such as fuel or food, that may be released when the substance is burnt or digested

concave lens: a lens that curves inwards

concave lens

concave mirror: a mirror that curves inwards

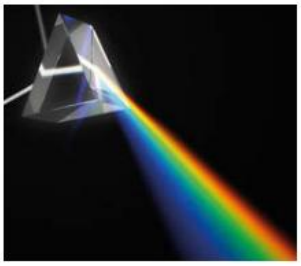
conduction: heat transfer between two objects in contact

convection: the transfer of heat in a liquid or gas

convex lens: a lens that curves outwards

convex mirror: a mirror that curves outwards

dispersion: the splitting of white light into colours of the rainbow



dispersion

echo: a reflected sound

elastic potential energy: energy stored within a stretched or compressed object, such as a spring or elastic material

electrical energy: energy that causes charged particles to move

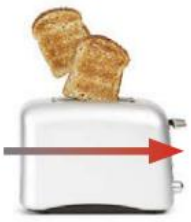
electromagnetic radiation: radiant energy released by stars, which includes vibrating electric and magnetic fields

electromagnetic spectrum: the range of all forms of electromagnetic radiation, including visible light

energy: the ability to make a change happen; different forms include heat energy, light energy and sound energy

energy efficiency: the proportion of useful energy output from a device compared to the amount of energy that is input; usually expressed as a percentage

energy flow diagram: a diagram using arrows that shows the way energy is passed on or changed into other forms



energy flow diagram

energy rating label: a label showing a number of stars (usually from 1 to 10), which can be used to compare the energy efficiency of different appliances

energy rating label

energy transfer: the flow of energy from one object into another object; examples are the flow of heat from a metal spoon to your hand, and the flow of kinetic energy from a bat to a ball that it hits

energy transformation: the conversion of one type of energy into another type of energy; for example, the conversion of electrical energy used in an MP3 player into sound, light and heat energy

frequency: the number of waves that travel past a given point per second, measured in hertz (Hz)

gravitational potential energy: the stored energy of an object that is held above the Earth's surface

heat energy: a measure of the total kinetic energy possessed by particles in a substance

heat energy

image: the figure of an object produced by reflected or refracted rays of light

insulation: material placed inside ceilings and between the walls of a house to reduce heat transfer

joule (J): a unit of measurement for energy

kinetic energy: energy possessed by a moving object

kinetic energy

law of conservation of energy: the 'law' that energy cannot be created or destroyed, but can only be transferred from one object to another or transformed into another form of energy

light energy

CHAPTER 5

Glossary

light energy: a form of energy that is visible, such as that produced by the Sun

loudness: a measure of the intensity of a sound as heard by a listener; measured in decibels (dB)

National House Energy Rating Scheme: a scheme that uses computer simulations to provide a star rating (maximum of 10 stars) to houses based on the effectiveness of the external walls against heat loss

nuclear energy: energy stored inside an atom

photosynthesis: the process in which green plants convert light energy into chemical energy

pitch: how low or high a sound is; the faster particles producing the sound vibrate, the higher the pitch

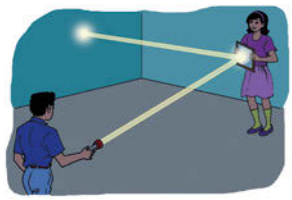
plane mirror: a flat mirror

potential energy: stored energy possessed by an object such as elastic potential energy of a squashed spring

potential energy

radiation: heat transfer as a wave, which can even travel through the vacuum of space

reflection: the change in direction of a wave as it bounces off a surface



reflection

refraction: the bending of light as it enters or leaves a material

regenerative braking: a vehicle braking system that stores some of the kinetic energy of a car as it slows down

sound energy: energy that travels as vibrating waves and can be heard by our ears as sound

visible spectrum: the band of colours produced from the splitting of white light

wavelength: the length of one complete wave, measured in metres

AB 5.9

CHAPTER

6 Substances

Have you ever wondered ...

- why you can feel a breeze even though it's invisible?
- why diamond is the hardest natural substance on Earth?
- why water is sometimes called H_2O?
- what rocks are made from?

LS

After completing this chapter you should be able to:

- model the arrangement of particles in elements and compounds
- describe elements and simple compounds by symbols and formulas
- locate elements on the periodic table
- *contrast pure substances and mixtures and identify examples of each*
- *explain why elements and compounds can be represented by chemical formulas while mixtures cannot*
- investigate how scientists have created new materials such as synthetic fibres
- describe how rocks are a collection of different minerals
- outline how rocks, minerals and ores provide valuable resources
- investigate how the location of mineral resources relies on knowledge from different branches of science.

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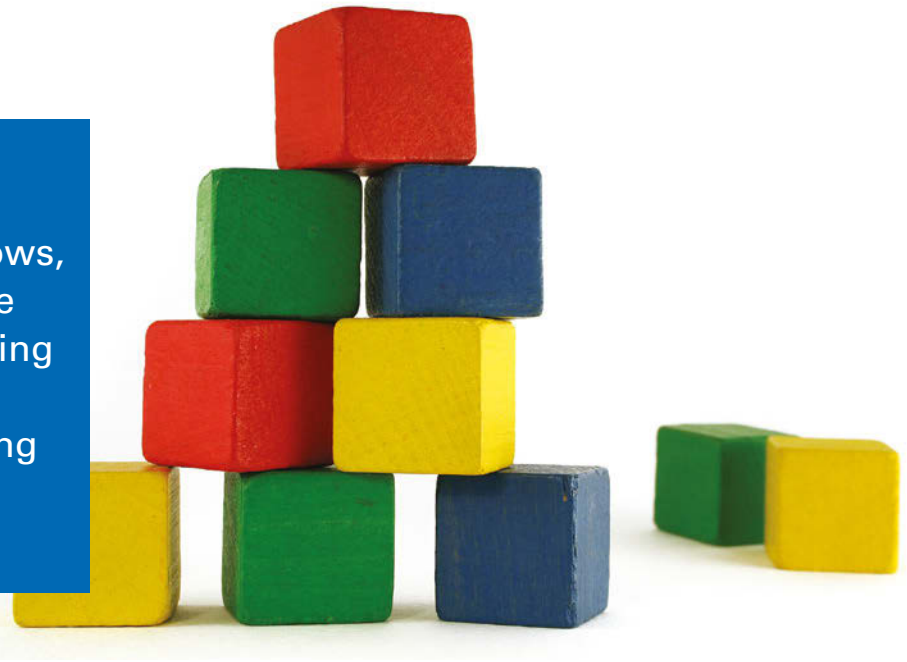
AB 6.1

MODULE
6.1 Elements

Elements are the most basic materials for building the world around you—chairs, desks, windows, your skin, the trees, the ocean, the Sun and the stars. By understanding elements, scientists can use them to create new materials for building bridges, powering cars, making clothes and curing disease.



Atomic Lego®

Every substance in the universe is made up of building blocks known as **atoms**. There are only about 100 types of atoms. However, these 100 types of atoms can be arranged in different combinations to create a countless number of different substances. In this way, atoms are like tiny pieces of Lego. Imagine you just have red, blue and green blocks of Lego. With just these three types you can construct many different Lego combinations. Figure 6.1.1 shows just a few. In a similar way, the 100 or so different types of atoms can be used to create the millions of substances that make up the world around you.

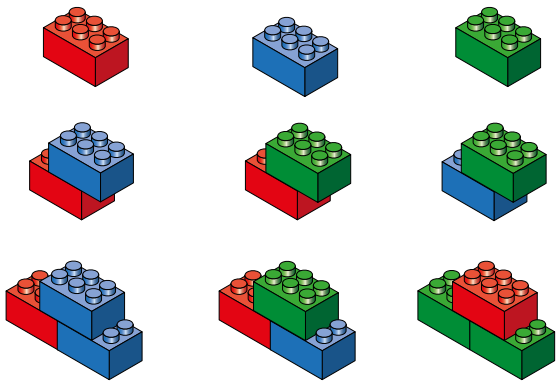


FIGURE 6.1.1 With just a few types of Lego, you can create many different combinations. Similarly, it takes just 100 or so different types of atoms to make up every substance in the universe.

Unlike blocks of Lego, atoms are round, like tiny balls. They are so small that they cannot be seen with even the most powerful optical microscope. Instead, scientists must use a **scanning tunnelling microscope (STM)** to obtain images of atoms such as the copper atoms, shown in Figure 6.1.2.

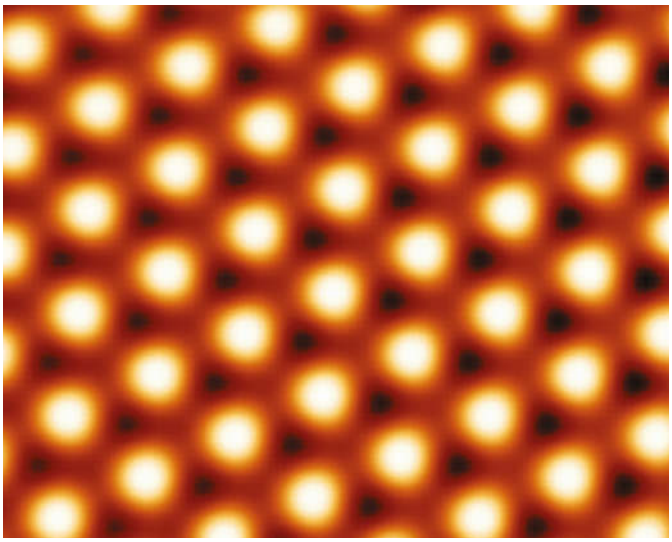


FIGURE 6.1.2 An STM is the only type of microscope powerful enough to get an image of these copper atoms.

Elements

Elements are substances that are made up of just one type of atom. For example, copper is an element because it is made up of only copper atoms. Likewise, oxygen is an element because it is made up of only oxygen atoms. Other examples of elements include iron, hydrogen and gold. In each case, these substances are made up of just one type of atom.

Each element has a unique set of characteristics that scientists refer to as its **properties**. These properties determine whether an element is classified as metallic or non-metallic. The properties also determine how the elements can be used.

Metallic elements

Aluminium, iron, mercury, gold and silver are all examples of metallic elements that are used every day in construction, electronics and jewellery. Your body needs metals too—iron, calcium, sodium and potassium are metallic elements needed for your body to function properly. Metallic elements all share some characteristic properties. Some of these properties are shown in Figure 6.1.3. **Metals**:

- tend to be shiny or can be polished to make them shiny. This is referred to as being **lustrous**.
- are solid at room temperature (except mercury, which is a liquid)
- are good conductors of heat and electricity. This means that they allow heat and electricity to flow easily through them.
- can be bent and hammered into sheets. This is referred to as being **malleable**.
- can be stretched into wires. This is referred to as being **ductile**.

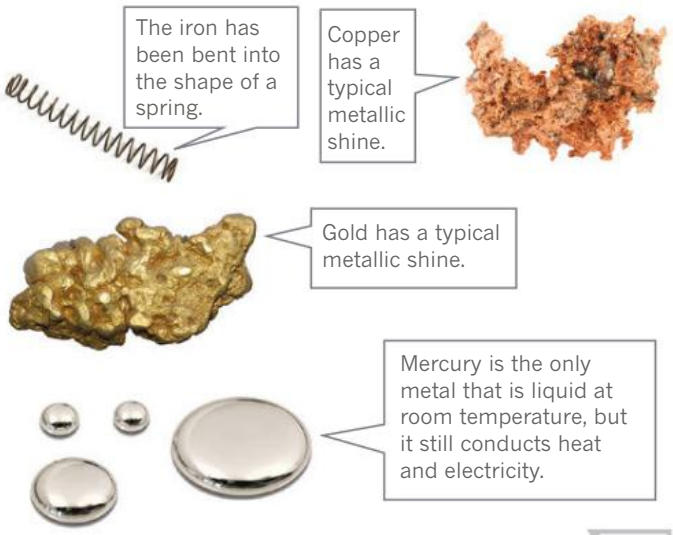


FIGURE 6.1.3 Common metallic elements

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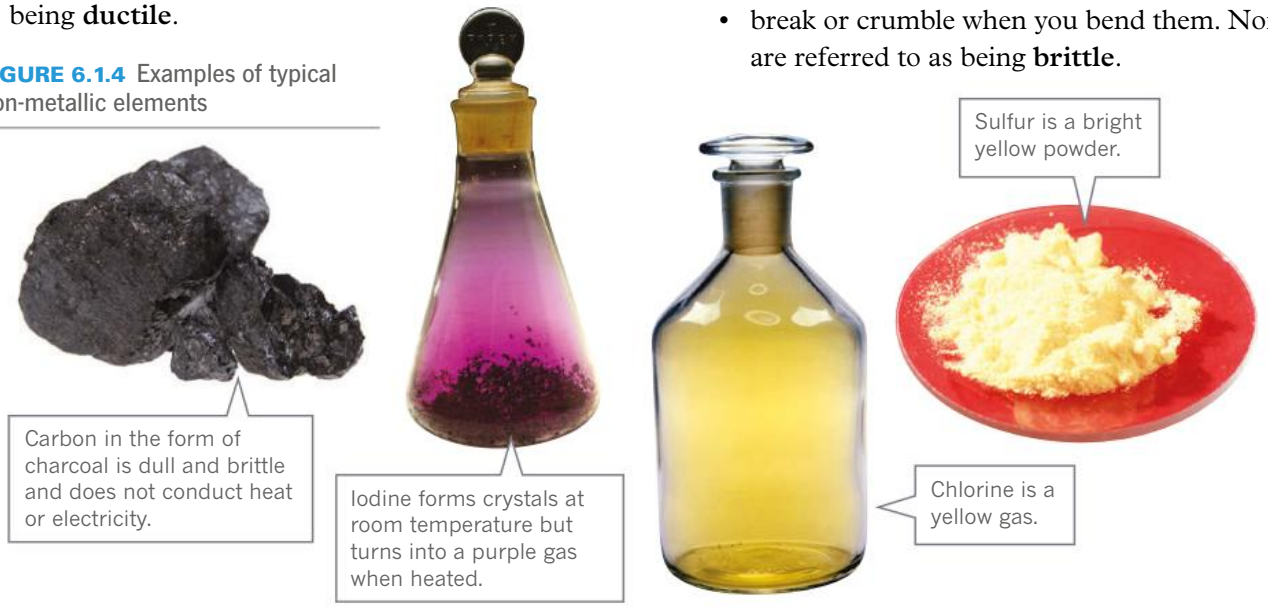
These properties make metals useful in many situations. For example, the facts that metals conduct electricity and are ductile make them ideal for electrical wiring. Metals are good conductors of heat, which makes them ideal for making pots and pans. Likewise, because metals are malleable they can be used for roofing sheets, to make thin foils to insulate roofs or to wrap food in for cooking.

Non-metallic elements

In general, non-metallic elements have lower melting and boiling points than metals and tend to be solids or gases at room temperature. Bromine is the only non-metal that is liquid at room temperature. Some non-metallic elements are shown in Figure 6.1.4. **Non-metals**:

- tend to be dull (not shiny).
- do not conduct heat or electricity. Non-metals are insulators for electricity and heat.
- break or crumble when you bend them. Non-metals are referred to as being **brittle**.

FIGURE 6.1.4 Examples of typical non-metallic elements



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In comparison to metals, the properties of non-metals can be very different. The black ash or charcoal formed when you burn paper or wood is made of the element carbon. The element hydrogen is a non-metallic gas. It is colourless, odourless and lighter than air. However, it is so flammable that it reacts violently with oxygen. For this reason, it used as a fuel in rocket engines such as those powering the *Ariane 5* shown in Figure 6.1.5.

FIGURE 6.1.5 Hydrogen is highly flammable, making it an ideal fuel for rockets, such as *Ariane 5* shown here.

SciFile

The elements of war

The non-metallic element chlorine was used in World War I (1914–1918) as one of the first 'weapons of mass destruction'. Chlorine is extremely toxic when breathed in, causing a burning feeling in the chest and painful suffocation. It is much heavier than air, so it filled the trenches where the soldiers fought. The first use of chlorine received worldwide criticism but started a trend in chemical warfare. For this reason, World War I is sometimes referred to as 'the chemists' war' (Figure 6.1.6).

FIGURE 6.1.6 Chlorine gas floating over the trenches in France during World War I

The periodic table

There are 118 known **elements** but only 98 of these occur naturally—the rest must be made in a laboratory. Each element has a name and a chemical symbol.

The same set of chemical symbols is used by scientists all around the world. This makes communicating new scientific research between scientists much clearer and more accurate.

Scientists display all the known elements and their symbols in a table called the **periodic table**, shown in Figure 6.1.7. The periodic table lists the elements from lightest to heaviest and helps scientists to understand some of their properties.

Chemical symbols

Often the chemical symbol of an element comes directly from its name. For example, the element calcium is given the symbol Ca, carbon has the symbol C and magnesium has the symbol Mg. However, sometimes the symbol of an element does not appear to relate to the name at all. For example, potassium has the symbol K and sodium has the symbol Na. This is because the symbols for potassium and sodium come from the names for the elements in other languages. The Latin names may be different from those used in English. For example, the Latin name for potassium is *kalium*, while sodium is *natrium*. That is why the symbol for potassium is K and the symbol for sodium is Na. Likewise, tungsten has the symbol W because its name is *wolfram* in German.

AB 6.2 AB 6.3 AB 6.4

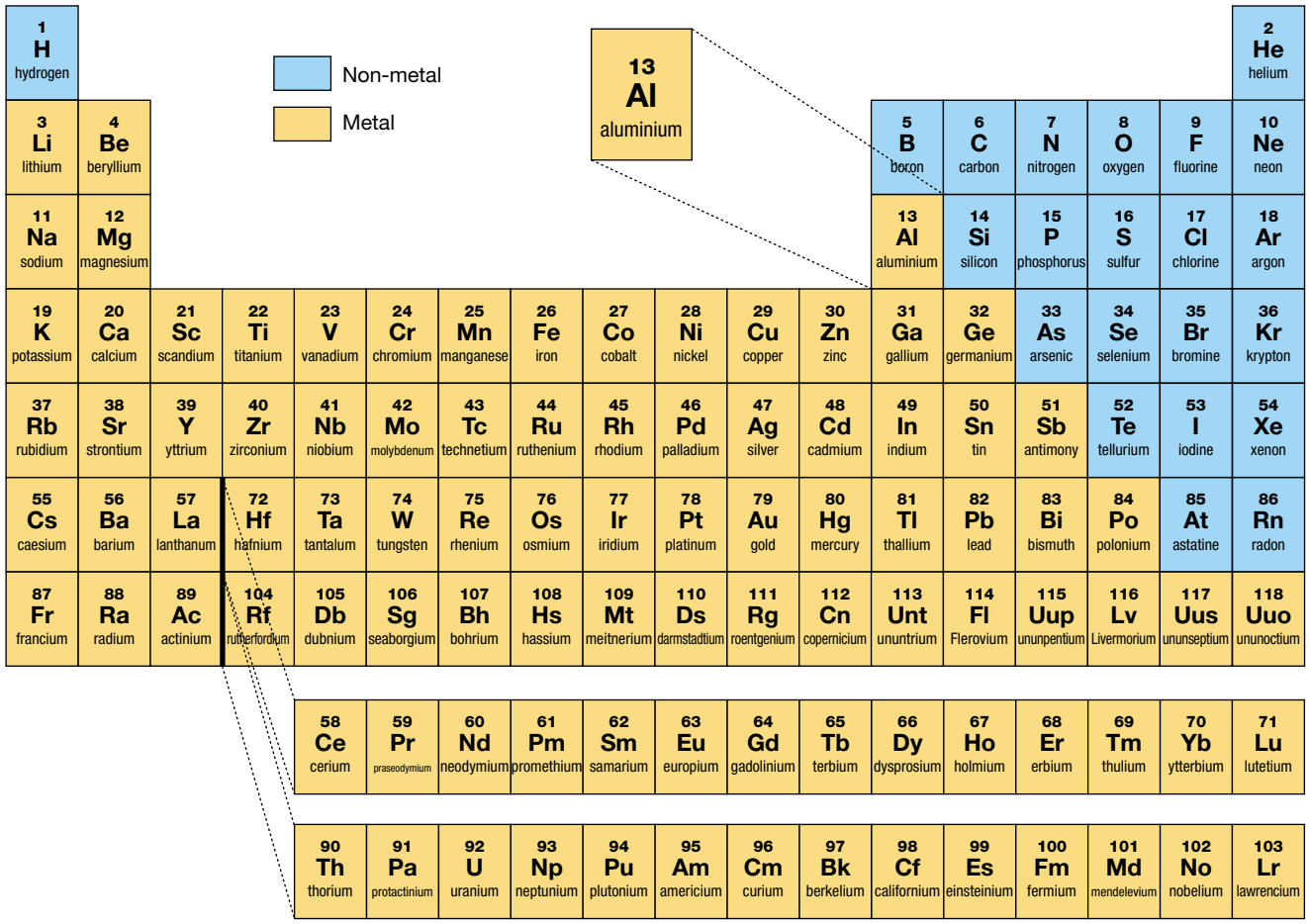

FIGURE 6.1.7 The periodic table is a list of the known elements from the lightest to the heaviest.

SkillBuilder

Writing chemical symbols

The chemical symbol of an element is usually made of one or two letters.

- The first letter is always in upper case.
- The second letter is always in lower case.

So the chemical symbol for chlorine is always written as Cl and never CL or cl. Likewise, sodium is Na and not NA or na.

The last four elements of the periodic table are so radioactive that they only recently been proved to exist, by synthesising them in the laboratory. They still have temporary symbols of three letters. An example is Uup. Now that its existence has been confirmed, it will be given a 'normal' chemical symbol of one or two letters.

science 4 fun

Scientific message

What scientific message can you 'write' using the symbols of the periodic table?

Collect this ...

- periodic table

Do this ...

1. Join the symbols together in different combinations to create words and sentences.
2. Write your creation out and share it with your class.

Atoms in elements

Elements are made up of just one type of atom. However, the atoms in elements can be arranged in different ways. The atoms can exist:

- as single atoms
- in clusters of atoms called molecules
- in large grid-like structures called crystal lattices.

The way the atoms are arranged in an element determines many of the physical properties of the element. Physical properties include whether the element is solid, liquid or gas, its melting and boiling points, how well it conducts heat or electricity, and if it bends or breaks when a force is applied.

Monatomic elements

An element that is made up of many individual atoms is known as **monatomic**. Monatomic elements are rare, with only six of the 98 naturally occurring elements being monatomic. These are helium (He), neon (Ne), argon (Ar), krypton (Kr), xenon (Xe) and radon (Rn). These elements are all non-metallic gases.

The element helium is monatomic and has such low density that it is lighter than air, allowing it to float. It is also non-toxic, making it safe to use in party balloons and weather balloons. Weather balloons carry into the sky instruments that can measure information about the atmosphere.

Neon (Ne) is used in neon lights for creating signs of different colours, like those shown in Figure 6.1.8. Old-fashioned light globes contained the monatomic element argon (Ar) to stop the filament from burning.

FIGURE 6.1.8 Hong Kong is well known for the neon signs hanging above its roadways.

Molecular elements

Most non-metallic elements are made up of molecules. **Molecules** are clusters of two or more atoms bonded (joined) together. In a molecular element, all the molecules are identical, with the same size, shape, number and type of atoms. Molecules of some common elements are shown in Figure 6.1.9.

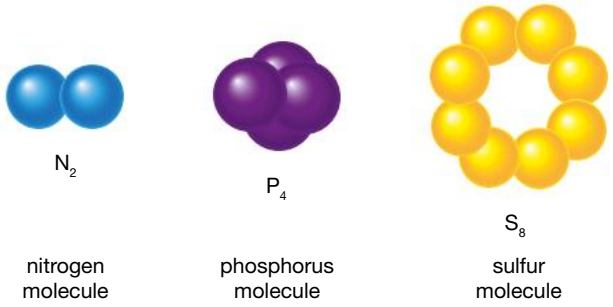

FIGURE 6.1.9 Non-metallic elements tend to form molecules like these, where every molecule contains just one type of atom.

The oxygen you are breathing right now is made up of billions of oxygen molecules like those shown in Figure 6.1.10. Each oxygen molecule contains two oxygen atoms.

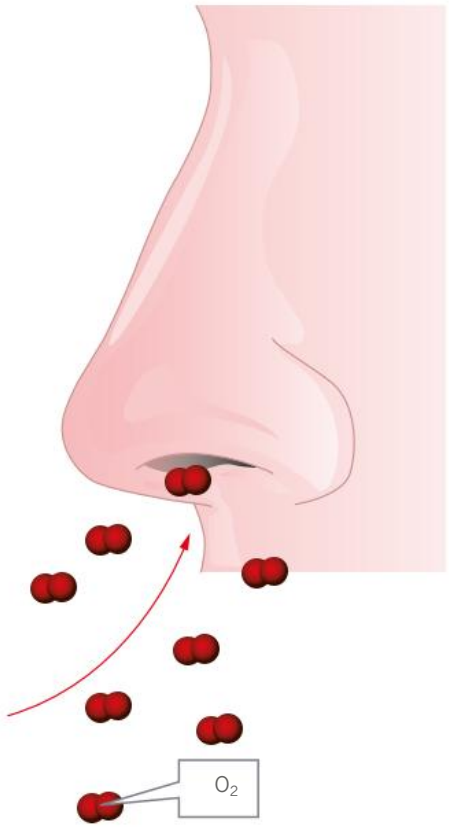

FIGURE 6.1.10 When you inhale, oxygen molecules made up of two oxygen atoms enter your nose and then move to your lungs.

AB 6.5

For this reason, scientists represent oxygen gas by the molecular formula O_2. The molecular formula shows what atoms are in a molecule and how many there are of each. The molecular formula O_2 shows that each oxygen molecule has two oxygen atoms. Some other elements that are made up of molecules with just two atoms are nitrogen (N_2), hydrogen (H_2) and chlorine (Cl_2).

Some elements are made up of molecules with more than two atoms. For example, phosphorus molecules commonly have four atoms, giving it the molecular formula P_4. Sulfur forms ring-shaped molecules of different sizes. One ring has just six sulfur atoms (with a molecular formula S_6) while other rings contain eight sulfur atoms (S_8) or 20 sulfur atoms (S_{20}).

Carbon is unique among the non-metallic elements in that it can form very large molecules of almost any size. The most famous is called the buckyball. This is a molecule that has 60 carbon atoms arranged in the shape of a soccer ball and has the molecular formula C_{60}. The bucky ball is shown in Figure 6.1.11.

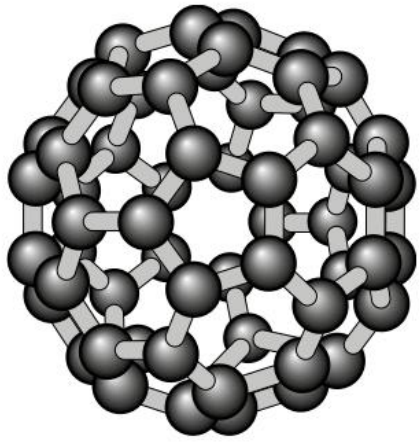

FIGURE 6.1.11 The buckyball

Crystal lattices

Crystal **lattices** are large grid-like structures that repeat the same arrangement of atoms over and over. All metallic elements form crystal lattices. Only a few non-metallic elements form crystal lattices.

Metallic lattices

Eighty per cent of elements are metals. The atoms in metals form lattices, rather than molecules. An example is shown in Figure 6.1.12. The lattice structure makes metals dense, strong and solid at room temperature. The only exception is mercury, which is a liquid at room temperature. As a result, metals are important materials for the construction and manufacture of a large variety of objects—from buildings and bridges through to trains, planes, cars, tools and jewellery.

The atoms in metallic lattices can slide and move over each other without breaking the lattice. This means that metals can be bent, drawn into thin wires or hammered into thin sheets. Metal sheets can be thick, like the ones used to build a corrugated iron shed. Or the sheets can be very thin, like aluminium foil. In addition, metals are very good at conducting heat and electricity, making them perfect for pots, pans, heating elements and electrical wiring.

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p. 258

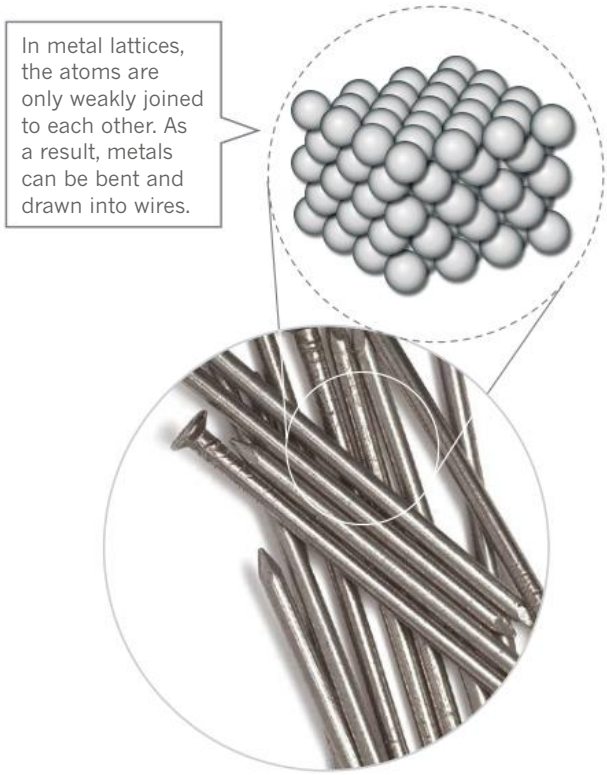


FIGURE 6.1.12 The atoms in metal lattices can move across one another, allowing metals to bend, be drawn into wires and hammered into thin sheets.

Non-metallic lattices

Only a few non-metallic elements form lattices. An example is silicon. You can see its lattice in Figure 6.1.13. Another example is carbon, which forms crystal lattices to make graphite and diamond.

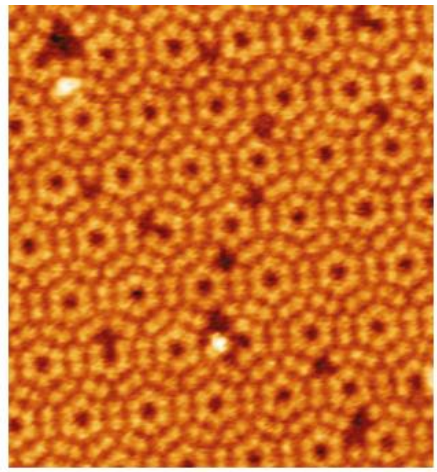


FIGURE 6.1.13 An image of a lattice of silicon atoms taken with a scanning tunnelling microscope (STM)

In graphite, the carbon atoms form sheets that are stacked on top of each other as shown in Figure 6.1.14. These sheets can slide across each other. This makes graphite a good lubricant for industrial machinery. The lead in grey-lead pencils is also made of graphite mixed with clay. As you write, the thin layers of graphite are slowly rubbed off onto the page. Graphite can also withstand very high temperatures and conduct electricity, and so it can be used to replace electrical wiring in very hot situations such as industrial kilns for firing clay tiles.

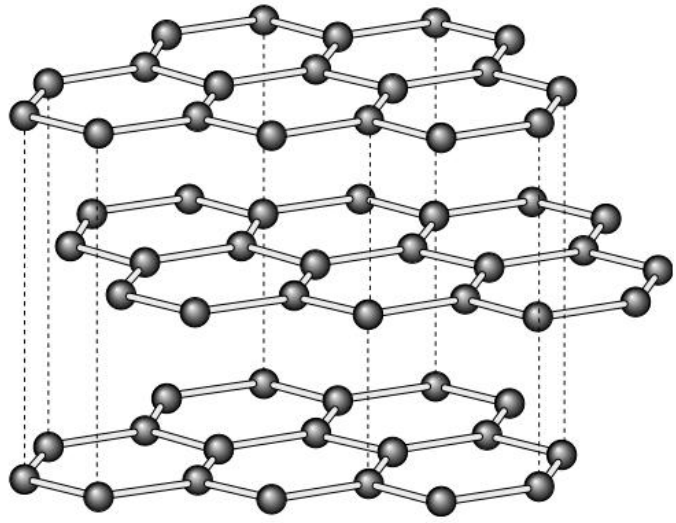


FIGURE 6.1.14 The carbon atoms in graphite form layers. The layers can slide over each other easily, making graphite an excellent lubricant.

AB
6.6

The many faces of carbon

Carbon is an incredibly useful element as it can be found in many different forms. Different forms of the same element are called allotropes and almost every allotrope of carbon is useful to humans.

Charcoal

When most people think of carbon, they think of the black powdery ash or charcoal left over after paper, wood or toast has been burnt (Figure 6.1.15). Charcoal is used by artists for sketching (Figure 6.1.16) but it is also used in industry for processes such as the smelting of iron. Charcoal can also absorb certain gases so is used as odour-eaters in shoes and as poisonous gas filters in gas masks.

Graphite

Graphite is a dark grey and brittle form of carbon that is commonly found in lead pencils. Like other forms of carbon, graphite has a high melting point. Unlike most non-metals, graphite is able to conduct electricity.

Diamond

Diamond is another form of carbon. In diamond, all the carbon atoms are tightly bonded (joined) to each other in a rigid crystal lattice.

FIGURE 6.1.15 Diamonds don't look like burnt toast but are made from the same substance.

As a result, diamond is extremely hard and does not conduct electricity. Most people know diamonds as sparkling and very expensive jewels, like the one shown in Figure 6.1.17. However, only 20% of diamonds mined are used in jewellery. The rest are used by industry to make long-lasting tools for cutting and drilling.

FIGURE 6.1.16 Carbon in the form of charcoal is used for drawing because it is black and soft and crumbles easily.

FIGURE 6.1.17 Carbon in the form of diamond is the hardest natural substance on Earth because the bonds between the carbon atoms are extremely strong.

SciFile

Wear the ones you love

It is now possible to keep your loved ones wrapped around your little finger—quite literally. A company called Life Gem in the USA creates synthetic diamonds from the carbon ashes of your dead loved ones. The diamonds can then be made into jewellery such as rings, bracelets and necklaces.

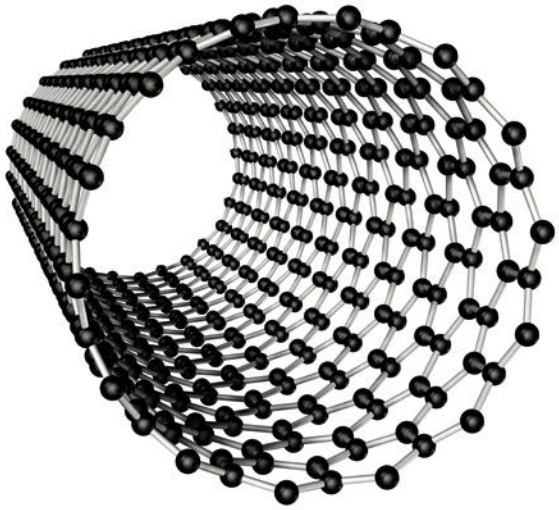
Carbon fibre

Carbon fibres are very thin strands of compressed crystals of carbon. These fibres can be woven together to form new types of material that are very strong but also very lightweight. As a result, carbon fibre materials are ideal for things such as tennis racquets, bike frames (like the one in Figure 6.1.18) and aircraft, which require maximum strength yet minimum weight.

FIGURE 6.1.18 Carbon fibre is very light, very strong and flexible and so is often used in sporting equipment such as this mountain bike.

Buckyballs and nanotubes

In 1985, Americans Robert Curl and Richard Smalley and Briton Harold Kroto discovered yet another allotrope of carbon that they called buckyballs. These are balls of 60 carbon atoms that have the same geometric shape as a soccer ball. This discovery led to a whole new area of chemistry and the development of another allotrope of carbon called nanotubes. Nanotubes are sheets of carbon rolled into hollow tubes like the one shown in Figure 6.1.19.



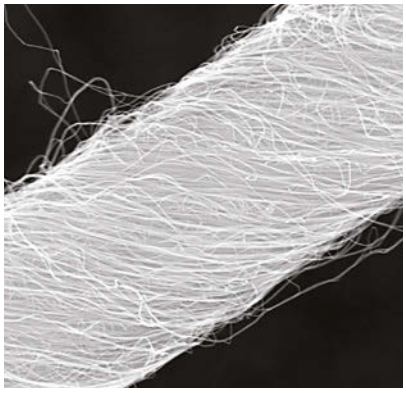


FIGURE 6.1.19 A carbon nanotube (above) can be thought of as a sheet of carbon rolled into a tube. These tubes are very tough, so scientists at CSIRO are researching how to spin them into yarn to create advanced materials (left).

Like graphite, carbon nanotubes conduct electricity. This means they can be used to construct nanowires for miniature electrical circuits. Nanotubes are also very strong. For this reason, the CSIRO is currently studying ways to mass–produce carbon nanotubes. This would allow creation of a new generation of materials that are strong, lightweight and heat–resistant.

REVIEW

1. Define the term *allotrope*.
2. List four allotropes of carbon.
3. What properties of graphite make it good for electrical wiring in industrial kilns?
4. Construct a table that compares the following physical properties of charcoal, graphite and diamond:
   - appearance
   - hardness
   - electrical conductivity.
5. Explain how synthetic materials made from different allotropes of carbon are useful to society.

MODULE
6.1 Review questions LS

Remembering

1 Define the terms:
- a ductile
- b malleable
- c brittle.

2 What term best describes each of the following?
- a a substance made of one type of atom
- b clusters of two or more atoms bonded together
- c the building blocks of the universe.

3 List four properties of metallic elements.

4 Name three monatomic elements and give their chemical symbols.

5 What is the correct way to write the chemical symbol for iron?
- A Ir
- B FE
- C Fe
- D fe

6 What are chemical symbols of the following elements?
- a hydrogen
- b helium
- c carbon
- d oxygen
- e nitrogen.

Understanding

7 Explain why metallic elements bend, while solid and non-metallic elements break or crumble.

8 Why is graphite used instead of gold or copper wires to conduct electricity in very hot situations such as an industrial kiln?

Applying

9 Group the following elements into metals and non-metals: *carbon, iron, copper, chlorine, helium, gold, oxygen, sulfur, nickel.*

10 Use the periodic table to identify an example of a metal and a non-metal.

11 Use the periodic table to identify an element named after a:
- a famous scientist
- b continent
- c USA state.

12 Determine what type of atoms are in each of the following molecules, and how many of each are there.
- a nitrogen (N_2)
- b oxygen (O_2)
- c ozone (O_3)
- d phosphorus (P_4)
- e sulfur (S_{20}).

Analysing

13 An allotrope is a different form of the same element. Analyse the molecular formulas given on page 251 and identify three allotropes.

14 Classify the following elements as monatomic, molecular or lattice: *helium, oxygen, copper, chlorine, neon, iron, nitrogen, argon, gold.*

Evaluating

15 a Imagine you have four Lego blocks. One is red, one blue, one green and one yellow. How many different combinations of blocks can you construct from these four blocks?
- b Assess how the Lego blocks in part a help you understand how millions of different compounds can be constructed from just 118 elements.

16 Iron and calcium are metallic elements that are important in everyone's diet. Both are sometimes added to breakfast cereals.
- a Iron helps with the transport of oxygen in the blood. Propose a reason why people with anaemia (a lack of iron) are often pale and have little energy.
- b What do you think calcium is used for in the body?

17 a Would you use a metal or a non-metal for the following applications?
- i the element in a heater
- ii a fishing rod
- iii a lightning rod
- iv an oven mitt.

b Justify each of your choices above.

Creating

18 Use the periodic table to construct a table of elements including only those elements with chemical symbols that do not match their English names.

MODULE 6.1

Practical investigations

1 • Obtaining copper, a metallic element

Planning & Conducting

Purpose

To form crystals of metallic copper.

Timing 30 minutes

Materials

- zinc metal strip
- 0.1 M copper sulfate solution
- beaker
- filter paper
- magnifying glass or microscope

SAFETY

Copper sulfate is toxic, so wear gloves and safety glasses and avoid contact with eyes, skin and mouth.

Procedure

1. Add copper sulfate solution until it reaches the 50 mL mark on your beaker (Figure 6.1.20a).
2. Place the zinc metal strip so that it is partly immersed in the copper sulfate solution (Figure 6.1.20b).
3. Observe the copper crystals as they deposit on the zinc strip (Figure 6.1.20c).
4. Once you have seen a noticeable change, remove the zinc strip and place it on the filter paper (Figure 6.1.20d).

Results

1. Record your observations as the copper crystals form.
2. Record what happens to the colour of the copper sulfate solution as the experiment proceeds.
3. Once you have removed the zinc strip, observe the copper crystals more closely and record what you see. Use a magnifying glass or microscope if possible.

Review

1. Use the periodic table to find the following information for copper:
   - **a** chemical symbol
   - **b** atomic number
   - **c** whether it is a metal or a non-metal.
2. **a** Would copper exist in a monatomic form, as a lattice or as molecules?
   b Justify your answer.

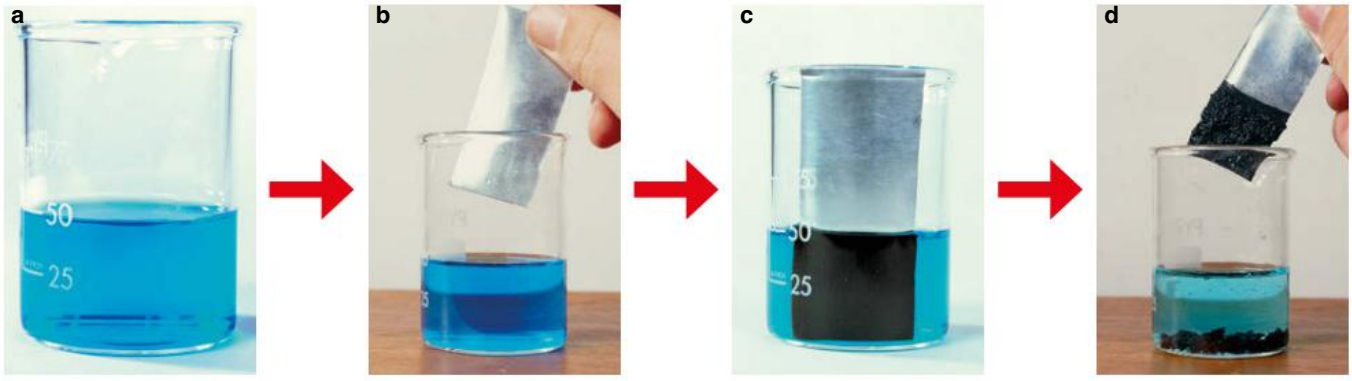


FIGURE 6.1.20

MODULE 6.1

Practical investigations

2 • Obtaining hydrogen, a non-metallic element

Planning & Conducting

Purpose

To form the element hydrogen.

Timing 15 minutes

Materials

- 2 M hydrochloric acid
- magnesium metal strip
- test-tube
- scissors
- eye-dropper

SAFETY

Hydrochloric acid is very corrosive. Take care to ensure none touches your skin or clothing. Be aware of first aid procedures. Report any spills to your teacher immediately.

Procedure

1. Use scissors to cut the magnesium ribbon into small pieces (2 cm) and place them into the test-tube.
2. Using the eye-dropper, add enough hydrochloric acid to cover the pieces of magnesium metal (Figure 6.1.21).
3. Watch what happens.

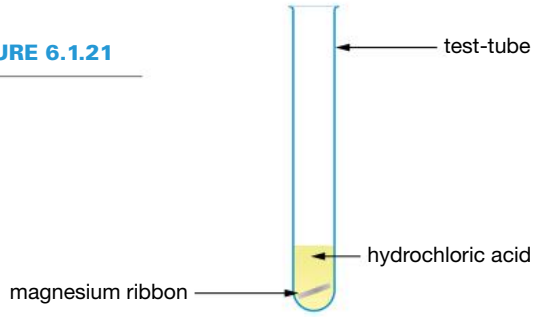
Results

Record your observations.

Review

1. The bubbles you see in this experiment are hydrogen. What evidence is there that a new substance is being produced?
2. State:
   a. whether hydrogen is a solid, liquid or gas at room temperature
   b. the colour of hydrogen.
3. Use the periodic table to find the following information for hydrogen:
   a. chemical symbol
   b. atomic number
   c. whether it is a metal or a non-metal.
4. a. Would hydrogen exist in a monatomic form, as a lattice or as molecules?
   b. Justify your answer.

FIGURE 6.1.21



MODULE 6.1

Practical investigations

3 • Measuring density, a physical property

Planning & Conducting | Evaluating

Density is a physical property that measures the amount of matter (mass) packed into a certain space (volume). It is calculated using the formula:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

Purpose

To measure the density of metals.

Timing 45 minutes

Materials

- blocks of metallic elements such as iron, copper and aluminium
- access to electronic balance
- ruler
- calculator

Procedure

1. In your workbook, construct a table like the one below. Alternatively, construct a spreadsheet with similar columns. Give your table or spreadsheet a title.
2. Use the electronic balance to measure the mass of each metallic cube and record your measurements in the table.
3. Use the ruler to measure the length, width and height of the blocks. Once again, record your measurements.

Results

1. Enter all the masses and sizes you measured in your table or spreadsheet. When calculating density, mass is usually measured in grams (g) and volume is measured in cubic centimetres (cm^3). So the units for density are g/cm^3.
2. Calculate the volume of each cube by multiplying length × width × height. Enter these values in the table. Alternatively, program your spreadsheet to do this calculation for you. A sample calculation has been done for you in the table.
3. Calculate the density of each cube by dividing the mass by the volume.

Review

1. Look at your table. Which element is most dense and which is least dense?
2. The official densities for these metals are:
   - iron 7.88 g/cm^3
   - aluminium 2.70 g/cm^3
   - copper 8.93 g/cm^3.

   Compare your calculated densities with these values.
3. Propose reasons why the values above might be a little different from the ones you calculated.

Metal	Mass (g)	Length (cm)	Width (cm)	Height (cm)	Volume ($l \times w \times h$) (cm^3)	Density (mass/volume) (g/cm^3)
strontium	20	2	2	2	2 x 2 x 2 = 8	2.5/8 = 2.5
iron						
aluminium						
copper						

MODULE
6.2 Compounds and mixtures

The billions of substances in the universe are all made up of just 100 or so elements. By understanding how the elements combine to form new substances, scientists can develop new, useful materials such as plastics, perfumes and medicines. Scientists can also make natural materials such as vitamins, flavours and even blood in the laboratory.

Compounds

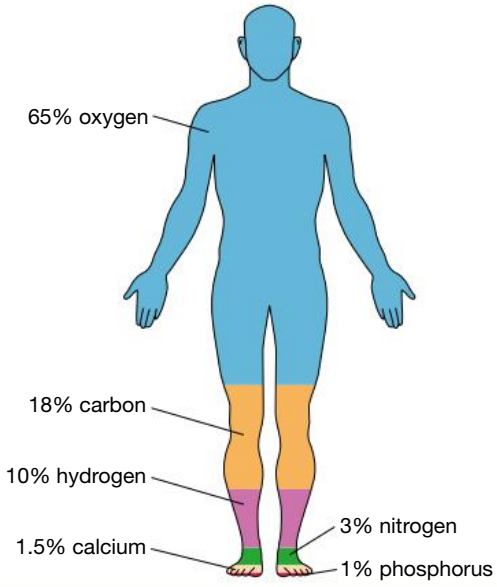
Most substances you encounter every day are made up of more than one type of atom. These forms of matter are known as **compounds**. Every compound has a unique set of characteristic properties. The properties of compounds are usually very different from the properties of the elements that make them up. Some compounds found around your home are shown in Figure 6.2.1.

FIGURE 6.2.1 Different compounds have different properties.

SciFile

What are you made of?

The human body is made up of just 16 elements arranged into a huge variety of compounds. However, 98.5% of the body is made up of just six elements! These are oxygen (65%), carbon (18%), hydrogen (10%), nitrogen (3%), calcium (1.5%) and phosphorus (1%). This is shown in the human-shaped graphic below.



Some compounds are made up of molecules—such as water, wax and vegetable oil. In these compounds, each molecule contains two or more different types of elements. Other compounds form crystal lattices. For example, table salt is made of a lattice of sodium and chlorine atoms, while beach sand is a lattice of silicon and oxygen.

Molecular compounds

All the molecules in a compound are identical in size and shape, and have the same number of atoms. Scientists represent the molecules of a compound using a chemical formula. The chemical formula for a molecular compound is also known as a molecular formula, because it describes how many of each atom make up the molecule. The number of each type of atom in the compound is written in subscript (written below the line).

Figure 6.2.2 shows three examples of compounds made from different combinations of the same elements:

- Carbon monoxide has the molecular formula CO, which means it contains one carbon atom and one oxygen atom.
- Water is a molecular compound with the molecular formula H_2O. This molecular formula indicates that there are two hydrogen (H) atoms and one oxygen (O) atom in each molecule of water (H_2O).
- Glucose has the molecular formula $C_6H_{12}O_6$, which means it contains six carbon atoms, twelve hydrogen atoms and six oxygen atoms.

These three compounds are all are relatively small molecules, made up of just a few atoms. However, the molecules of other compounds, such as some plastics, contain thousands of atoms and can stretch several metres long.

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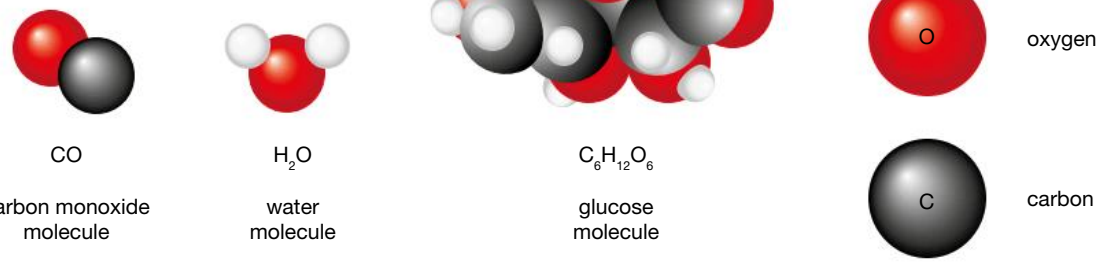
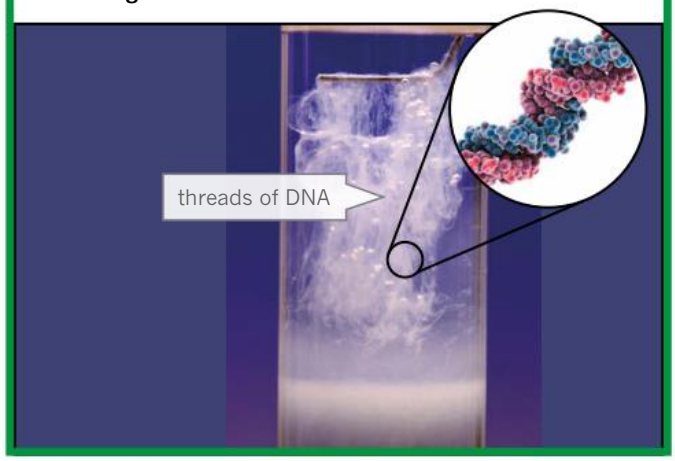
FIGURE 6.2.2 Molecules of three common compounds. All of these compounds are made from just three elements—oxygen, hydrogen and carbon.



SciFile

DNA

DNA (deoxyribonucleic acid) is a molecule found in the nucleus of a cell. DNA contains all the genetic information that makes you who you are. DNA is a very, very long molecule. The fine threads of DNA shown below would each be 2–3 metres long if stretched to their full length.



SkillBuilder

Making sense of molecular formulas

The molecular formula of a compound indicates exactly what is in the compound's molecules.

The chemical symbols tell you what types of atoms are in the molecule.

H_2O

The subscript numbers tell you how many atoms of each type are in the molecule.

If there is no number, then it means there is only one atom.

Worked example

Making sense of molecular formulas

Problem 1

Identify the types and numbers of atoms in a molecule of nitric acid, HNO_3. The molecule is shown in Figure 6.2.3.

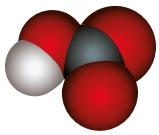


FIGURE 6.2.3

Solution

Thinking: Identify the elements in the molecule by looking at the chemical symbols.

Working: The molecule contains hydrogen (H), nitrogen (N) and oxygen (O).

Thinking: Identify the number of atoms for each element by looking at the subscripts.

Working: H and N have no subscripts, so there is one H atom and one N atom in each molecule.

O has 3 as its subscript, so there are three O atoms in each molecule.

Problem 2

Identify the types and numbers of atoms in a molecule of ethanol, C_2H_5OH. The molecule is shown in Figure 6.2.4.

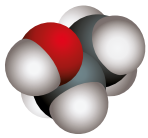


FIGURE 6.2.4

Solution

Thinking: Identify the elements in the molecule by looking at the chemical symbols.

Working: The molecule contains carbon (C), hydrogen (H) and oxygen (O).

Thinking: Identify the number of atoms for each element by looking at the subscripts.

Working: C has the subscript 2, so there are two C atoms.

O has no subscript so there is one O atom.

H appears in two places, so add the subscripts together: 5 + 1 = 6. So there are six H atoms in each molecule.

Problem 3

Construct a molecular formula for the sulfuric acid molecule shown in Figure 6.2.5.

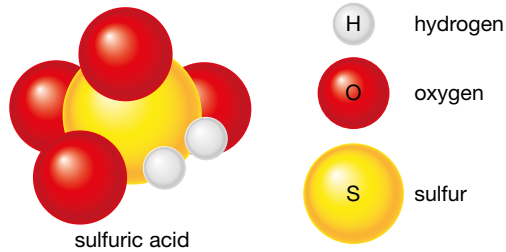


FIGURE 6.2.5

Solution

Thinking: Identify the elements in the molecule by looking at the key.

Working: The molecule contains hydrogen (H), sulfur (S) and oxygen (O) atoms.

Thinking: Identify the number of atoms for each element by counting how many of each type there are.

Working: There are 2 white balls (H), 1 yellow ball (S) and 4 red balls (O) so the molecular formula for sulfuric acid is H_2SO_4.

Try yourself

1. Identify the types and numbers of atoms in molecules of:
   - **a** benzene C_6H_6
   - **b** acetone CH_3COCH_3
2. Construct a molecular formula for the methanol molecule shown in Figure 6.2.6.

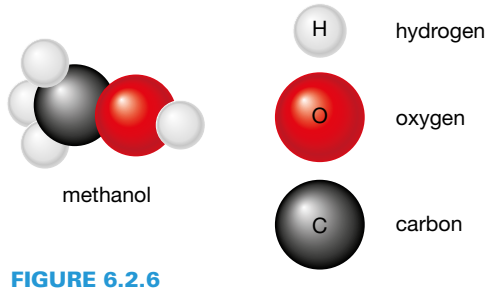


FIGURE 6.2.6

Lattice compounds

Compounds can also form crystal lattices. In these lattices, the atoms are bonded very strongly to each other, so these compounds tend to be hard solids at room temperature. Two common examples of lattice compounds are table salt and beach sand.

The chemical formulas for lattice compounds are different from the molecular formulas used for molecules. For example, the lattice for table salt is shown in Figure 6.2.7. The scientific name for table salt is sodium chloride and its chemical formula is NaCl.

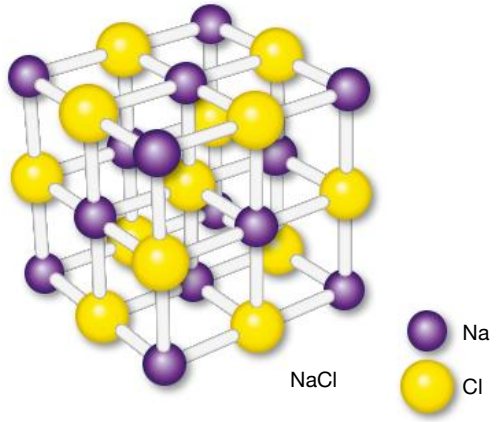


FIGURE 6.2.7 In a lattice of sodium chloride, sodium and chlorine atoms form a grid-like structure with one sodium atom for every chlorine atom.

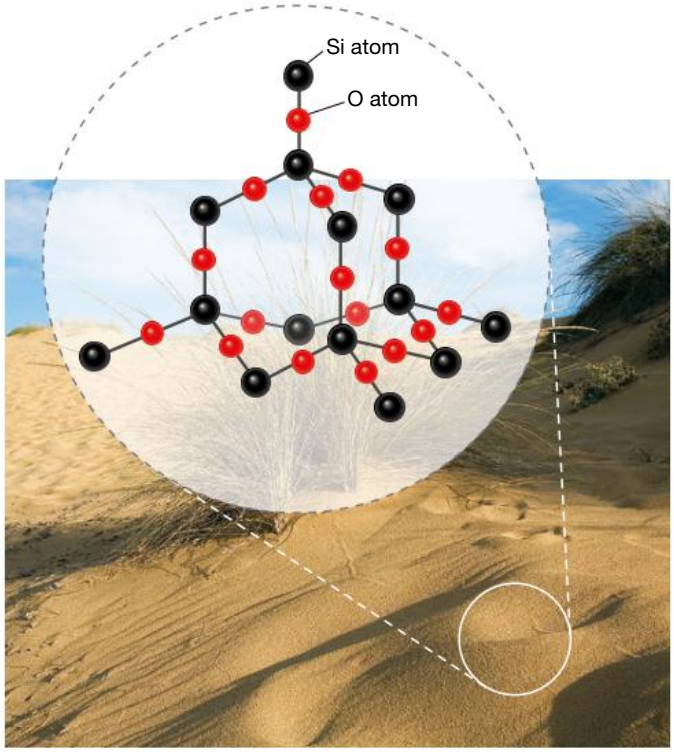


FIGURE 6.2.8 Silicon dioxide is a compound lattice. Its formula indicates that there are two oxygen atoms for every silicon atom in the lattice.

From the chemical formula, you can see that table salt is made from sodium (Na) and chlorine (Cl). The formula also shows that there is one sodium for each chlorine atom in the crystal lattice.

Beach sand has the scientific name silica or silicon dioxide. Its chemical formula is SiO_2. This formula indicates that in a grain of beach sand, there is one silicon atom for every two oxygen atoms.

You can see the structure of silicon dioxide in Figure 6.2.8. Silicon dioxide also makes up minerals like quartz, amethyst and opal. It is the main ingredient in glass, and so it is used in optical fibres to carry information such as cable TV and broadband internet.

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Mixtures

Many of the substances used every day are not simply elements or compounds but are **mixtures** of elements and compounds. A mixture is made up of more than one substance, where the substances are not chemically bonded together.

STEM 4 fun

Models from nuts and bolts

PROBLEM

Model elements, compounds and mixtures with nuts, bolts and washers.

SUPPLIES

- bolts, nuts and washers (that fit the bolts)

PLAN AND DESIGN Design the solution. What information do you need to solve the problem? Draw a diagram. Make a list of materials you will need and steps you will take.

CREATE Follow your plan. Construct your solution to the problem.

IMPROVE What works? What doesn't? How do you know it solves the problem? What could work better? Modify your design to make it better. Test it out.

REFLECTION

1. What area of STEM did you work in today?
2. In what career do these activities connect?
3. What did you do today that worked well? What didn't work well?

This means the substances that make up the mixture can be easily separated. For example, salt water is a mixture of table salt (sodium chloride) and water. You can separate the salt from the water by heating the saltwater, which causes the water to evaporate, leaving behind salt crystals. Air is a mixture of the elements oxygen (O_2) and nitrogen (N_2) with compounds such as water vapour (H_2O), carbon dioxide (CO_2) and carbon monoxide (CO). It is billions of molecules of these elements and compounds that you feel hitting your skin when you feel a breeze. Likewise, water from the tap is not pure but a mixture of water molecules (H_2O) and elements including chlorine, fluorine and many other elements in extremely small amounts (trace elements). Anything that has a list of ingredients, such as shampoo or soft drink, is a mixture.

Everyday mixtures

There are many different types of mixtures that you use every day. One common type of mixture is a **solution**. A solution is formed when a solid dissolves in a liquid. In a solution:

- the dissolving solid is known as the **solute**
- the liquid in which the solute dissolves is known as the **solvent**.

Many common solutions have water as their solvent. These water-based mixtures are referred to as **aqueous solutions**. For example, sugar dissolves in water to form an aqueous sugar solution—sugar is the solute and water is the solvent.

However, there are everyday mixtures other than solutions. For example, smoke is a mixture of fine solid particles mixed with air.

Working with Science

COSMETIC SCIENTIST

The ingredients and mixtures that make up our personal care products, such as shampoo, sunscreen and lipstick, are carefully selected and tested by scientists who are trained in cosmetic chemistry. Cosmetic scientists are responsible for developing products that are safe to use on skin and hair and have the right consistency, scent and colour. There is a growing demand for organic products that have not been tested on animals. This demand fosters innovation and research into these products.

A cosmetic scientist is mostly based in a laboratory, where they use different combinations of ingredients to create new products, update existing products by altering the quantities of existing ingredients, and undertake testing and quality control (Figure 6.2.9). One of the challenges of a cosmetic scientist's job is formulating products that don't 'go off'. Some products, like perfume and sunscreen, will be used over months or even years, so it is important that they keep their qualities for a long period of time.

Cosmetic science can be studied through a Certificate in Advanced Cosmetic Science, a Diploma of Personal Care Formulation or a Bachelor of Science (Chemistry). These qualifications will give you skills and knowledge in the chemistry and safety requirements of cosmetics, the biochemical interactions between skin and hair and chemical mixtures, and the formulation and testing of cosmetic products.

FIGURE 6.2.9 A cosmetic scientist's job involves mixing ingredients to create personal care products, such as lipstick, moisturiser and nail polish. This cosmetic scientist is working in a perfumery in France.

With these skills, you will be qualified to work for cosmetic manufacturers, as a researcher, or as a freelance cosmetic scientist, making and selling your own formulations.

Review

1. Cosmetic scientists need to have a very good understanding of the chemical properties of each of the ingredients they work with. Why do you think this is important?
2. List five to ten products that you use that would have been formulated by a cosmetic scientist.

The shaving foam in Figure 6.2.10 is another mixture—this one is made up of tiny gas bubbles contained in a liquid. Milk is an example of an everyday mixture where solid particles are suspended in a liquid. Although the particles in milk are solid, they are very small and so will never settle to the bottom of the liquid.

FIGURE 6.2.10 Shaving foam is a mixture of gas bubbles in a liquid.

AB 6.7

Describing mixtures

In a mixture there are a variety of substances, and the amount of each substance can vary. Therefore you cannot write chemical formulas for mixtures in the same way as you do for elements and compounds. Instead, mixtures can be often only be described as a list of ingredients, like the one shown in Figure 6.2.11.

FIGURE 6.2.11 Any substance made up of two or more ingredients is a mixture.

Solutions of substances dissolved in water are commonly used in chemistry and so these mixtures have been given more formal scientific names. For example, when copper(II) sulfate is dissolved in water, the solution is written as $CuSO_4(aq)$. In this formula, the (aq) stands for aqueous, which means dissolved in water. However, even this formula does not say exactly how much copper(II) sulfate is dissolved. For this reason, scientists must also say how concentrated a solution is. The concentration of a solution measures how much of a substance is in the solution. Concentration can be given in a number of ways. In the laboratory, concentration is usually expressed using a unit called molar (M). Hence, a 10 M solution of hydrochloric acid is much more concentrated (and dangerous) than a 0.1 M solution of hydrochloric acid.

Alloys

Alloys are a mixture of a metal with other metals or non-metals. Alloys are particularly important because they often have very different and useful properties compared to the pure metal. For example, iron is cheap to produce but is soft and rusts easily, making it less useful. The properties of steel alloys vary greatly depending on what the iron is mixed with. This makes iron useful in a wide variety of applications. However, it is not possible to write a chemical formula for steel, because steel is a mixture of iron and other substances. Therefore, steel can only described by listing the substances in the alloy and how much there is of each substance, for example 3% carbon steel.

Adding small amounts of carbon to iron produces the alloy steel, which is strong and useful for building skyscrapers, bridges, machinery and cars. Adding chromium and nickel produces stainless steel, which stops it rusting. Some other common alloys are shown in Figure 6.2.12.

FIGURE 6.2.12 Different mixtures of metals make different alloys with very different properties and a wide range of uses.

MODULE 6.2

Review questions LS

Remembering

1 Define the terms:
- a compound
- b mixture
- c solution.

2 What term best describes each of the following?
- a a solid that dissolves in a liquid to form a solution
- b a large network of atoms strongly bonded to each other
- c a mixture of two metals.

3 What are two examples of molecular compounds and two examples of lattice compounds?

4 a List three alloys.
- b State a use for each of the three alloys.

5 What are the chemical formulas for the following compounds?
- a carbon monoxide
- b glucose
- c water
- d silica (silicon dioxide).

6 List the elements and compounds that make up air.

Understanding

7 Explain what the chemical formula tells you about:
- a a molecular compound
- b a crystal lattice compound.

8 Explain why a chemical formula cannot be written for a mixture.

9 Why is iron rarely used in its pure form?

10 a What is the chemical name for salt?
- b What is its chemical formula?
- c Is salt an example of a molecule or a crystal lattice?
- d Classify salt as an element or a compound.
- e Justify your classification.

11 The molecular formula for sulfuric acid is H_2SO_4. In this formula, what does the number 4 tell you?

12 Sodium oxide is a compound formed when sodium metal reacts with oxygen. It has the chemical formula Na_2O. In this formula, what does the number 2 tell you about the sodium oxide crystal lattice?

Applying

13 What types of atoms are in the molecules below, and how many of each are there?
- a carbon dioxide, CO_2
- b nitrous oxide, N_2O
- c sucrose (sugar), $C_{12}H_{22}O_{11}$
- d trinitrotoluene (TNT), $C_7H_5N_3O_6$
- e acetic acid (vinegar), CH_3COOH
- f urea, NH_2CONH_2

Analysing

14 Classify the following as element, compound or mixture.
- a pool water
- b helium
- c air
- d nitrogen
- e gold
- f sugar
- g cordial
- h carbon dioxide.

15 Classify the following compounds as either molecular or lattice.
- a water
- b carbon monoxide
- c silicon dioxide
- d carbon dioxide.

16 Determine the chemical formula for the molecule of methane shown in Figure 6.2.13.

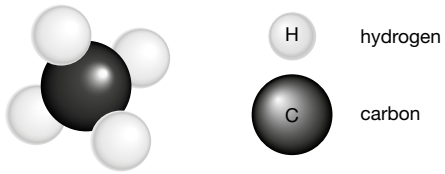
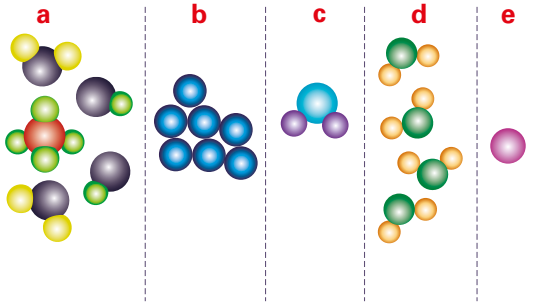


FIGURE 6.2.13

17 Match the following terms to the pictures below: *atom, molecule, element, compound, mixture.*



Evaluating

18 Contrast:
- a elements and compounds
- b mixtures and compounds.

MODULE 6.2

Practical investigations

1 • Forming carbon dioxide, a molecular compound

Planning & Conducting | Evaluating

Purpose

To form the molecular compound carbon dioxide, CO_2.

Timing 30 minutes

Materials

- 1 M hydrochloric acid
- sodium carbonate
- test-tube
- spatula
- dropper
- wooden splint
- matches

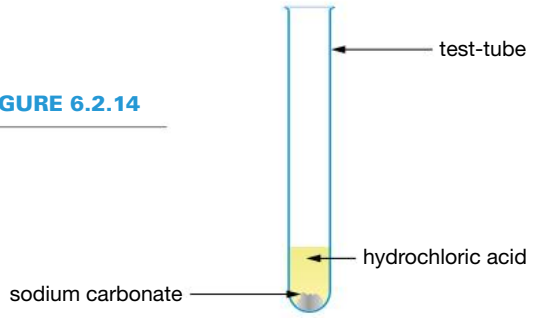
SAFETY

Hydrochloric acid is corrosive, so wear safety glasses at all times.

Procedure

1. Use the spatula to deposit a small amount of sodium carbonate in the test-tube.
2. Use the dropper to add enough hydrochloric acid to the sodium carbonate to cover it (Figure 6.2.14).

FIGURE 6.2.14



3. Light the end of the wooden splint with a match, and then blow out the splint so that the end is glowing red.
4. Place the glowing splint in the test-tube.

Review

1. What evidence is there that a new substance is being formed?
2. Is carbon dioxide a solid, liquid or gas at room temperature?
3. What colour is carbon dioxide?
4. Explain why you think the splint glows in air but not in carbon dioxide.

2 • Forming alum, a lattice compound

Planning & Conducting | Evaluating

Purpose

To grow crystals of potassium aluminium sulfate, also known as alum.

Timing

30 minutes
+ 7 days observation

Materials

- alum
- water
- 250 mL beaker
- glass rod
- measuring cylinder
- string
- filter paper
- spatula
- electronic scales
- hotplate or Bunsen burner, bench mat, tripod and gauze mat
- thermometer
- camera, mobile phone or tablet with camera function (optional)

SAFETY

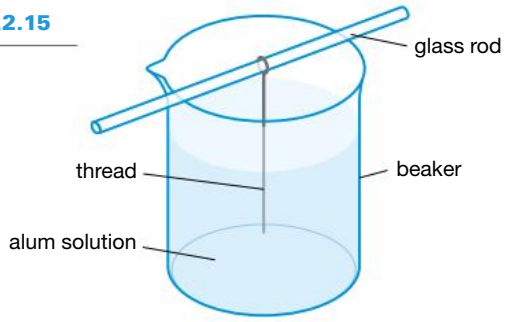
Take care when using Bunsen burners and boiling liquids. Tie long hair back when using a Bunsen burner.

Procedure

1. Use the electronic balance to measure out 17 g of alum onto the filter paper.
2. Pour the alum into the 250 mL beaker.
3. Add approximately 70 mL of water.
4. Heat the mixture to 60°C and stir with the glass rod until all the alum is dissolved or no more alum will dissolve. Then carefully remove it from the heat.
5. Wash the glass rod and tie a string around the middle as shown in Figure 6.2.15.
6. Lie the glass rod across the top of the beaker so that approximately 3 cm of string is immersed in the solution.
7. Place the beaker in a sunny spot and observe each day for 7 days.

Practical investigations

FIGURE 6.2.15



Results

Use diagrams or photos to record your observations every day.

Review

1. List three physical properties of the alum crystals.
2. Describe where the crystals initially began to grow and explain why you think they grew there first.
3. Describe where the biggest crystals were.
4. Predict what might happen if you prepared a new solution of potassium aluminium sulfate and deposited these crystals in it.
5. The diagram in Figure 6.2.15 is a 3D diagram of the experimental setup. Construct a 2D scientific diagram of the apparatus.

3 • Making models

Evaluating Communicating

Purpose

To construct models of different compounds.

Timing 45 minutes

Materials

- different-coloured sticks of modelling clay

Procedure

Use modelling clay to construct models of the following compounds:

a carbon monoxide molecule (CO)
b sulfuric acid (H_2SO_4)
c water molecule (H_2O)
d glucose ($C_6H_{12}O_6$)
e sodium chloride lattice (NaCl).

Results

1. Copy the table below into your workbook. Give your table a title.
2. Complete the table of compounds.

Review

1. Explain why you cannot give a number of atoms per molecule for sodium chloride.
2. What does the chemical formula for a lattice compound tell you about the number and type of atoms in the compound?
3. Explain what a molecular formula tells you about the atoms in the molecules of a compound.
4. How do chemical formulas help scientists to communicate scientifically?

Compound name	Chemical formula	Molecule or lattice	Number and type of atoms in each molecule
carbon monoxide			
sulfuric acid			
water			
glucose			
sodium chloride			

MODULE
6.3 Minerals

Rocks are made of minerals. Minerals such as this gold nugget are very important to Australia as the minerals industry employs people and helps drive Australia's economy.

science 4 fun

Stalactites and stalagmites

Stalactites are structures that hang from the ceilings of caves. Stalagmites are structures that build up from the cave floor. Can you grow these structures at home?

Collect this …

- bicarb soda (sodium bicarbonate)
- large plate or tray
- 2 large ceramic or plastic cups
- small saucepan
- 30 cm long thin strip of material (such as cotton, linen)
- 1 tablespoon
- 20 cm plastic cling wrap
- access to electric kettle

SAFETY

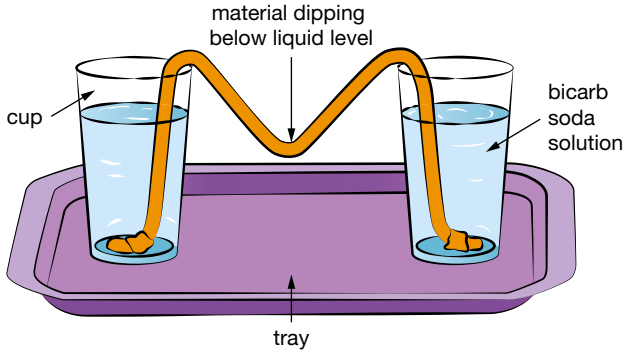
Most of this activity needs to be done over a sink.

Do this …

1. Heat two cups of water in an electric kettle until almost boiling. Pour the hot water into the saucepan.
2. Place ½ cup of bicarb soda in the hot water. Stir the water until as much bicarb as possible is dissolved. Add more bicarb, a tablespoon at a time, until no more bicarb will dissolve in the water. You should now have a saturated solution.
3. Leave the saucepan to cool for about ten minutes, then pour half the solution into each cup.
4. Put the two cups on the large plate or tray about 10 cm apart.
5. Tie a knot at each end of the strip of material and then wet it by dipping it into one of the cups.
6. Put one end of the strip into each cup. Move the cups until the material droops down to a bit below the level of the liquid in the two cups. Cover the top of each cup with plastic cling wrap.
7. Leave overnight and observe it the next morning. Leave the set-up for another day or two until some large stalactites and stalagmites have grown.

Record this …

1. Describe what happened.
2. Explain why you think it happened.



Minerals

A **mineral** is a chemical substance which is a naturally occurring solid that has not been made by animal, plant or any other type of organism. The atoms in a mineral are arranged in an orderly way in a crystal lattice.

Rocks are made up of minerals. Because soil is mostly broken-down rock, it too contains minerals. Many minerals can dissolve in water and so these minerals may also be found as aqueous solutions in groundwater, lakes and the ocean.

Some minerals are pure elements. Examples are the elements gold and silver. However, most minerals are compounds made up of different elements. Examples of mineral compounds are shown in Table 6.3.1.

Many precious gemstones, or gems, are also mineral compounds. Examples include rubies and emeralds.

Not all solids found in the Earth are minerals. Solids formed by organisms (living things) are not classified as minerals. This means that fossil fuels like coal and oil are not minerals—they were formed by the decay of long-dead organisms, not by natural processes of the Earth itself.

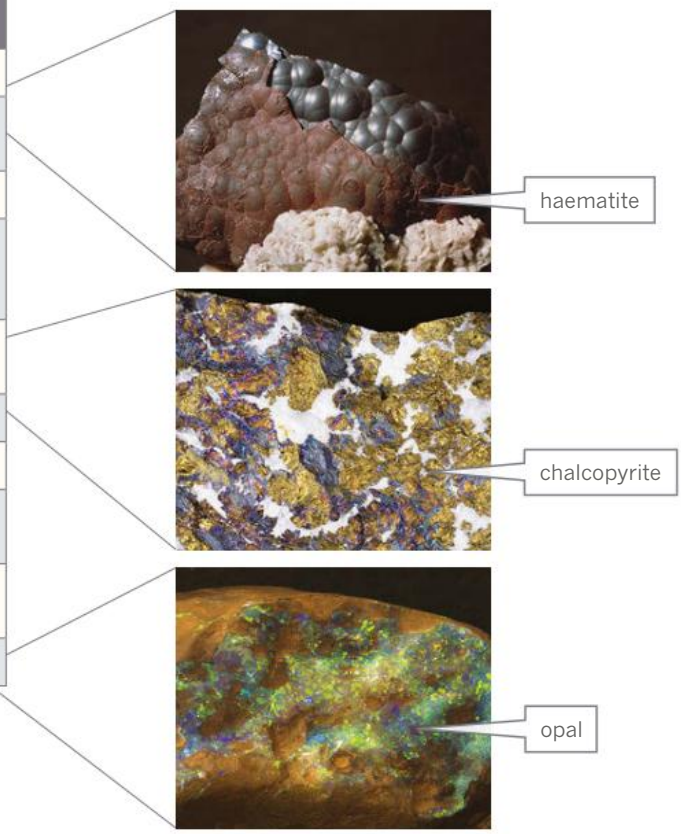
TABLE 6.3.1 Common minerals

Mineral	Compound in mineral	Element, compound or material used
haematite	iron oxide Fe_2O_3	iron Fe
bauxite	aluminium hydroxide $Al(OH)_3$	aluminium Al
galena	lead sulfide PbS	lead Pb
malachite	copper carbonate hydroxide $Cu_2CO_3(OH)_2$	copper Cu gemstones
chalcopyrite	copper iron sulfide $CuFeS_2$	copper Cu
rutile	titanium dioxide TiO_2	titanium Ti
cassiterite	tin dioxide SnO_2	tin Sn
chromite	iron chromium oxide $FeCr_2O_4$	chromium Cr
pentlandite	iron nickel sulfide $(FeNi)_9S_8$	nickel Ni
opal	silicon dioxide SiO_2	gemstones

Ores

Ores are rocks that contain valuable minerals like iron and copper. For example, iron ore contains iron. Copper can be found as pure native copper or in a variety of copper ores, three of which are shown in Figure 6.3.1. Native copper is found as an element, while the other ores are found as compounds of copper bonded to other elements.

FIGURE 6.3.1 Native copper is found as pure copper. More commonly, copper is found as an ore. Three copper ores are bornite, azurite and malachite.



SciFile

Beauty in the rocks

Some people collect minerals because of their beautiful crystal shapes and colours. A good sample of some rare minerals can be worth tens of thousands of dollars, and gem shows are held regularly around the world for enthusiasts. Some geologists chose their career because they were attracted by the beauty in the rocks.

FIGURE 6.3.2 This rhodochrosite (manganese carbonate) sample is called 'The Alma Queen'.

Sometimes the whole mineral is extracted from the ore and used. At other times, the metallic element needs to be extracted from its compound within the ore. For example, the mineral titanium oxide, TiO_2, can be:

- used as a whole mineral to colour paints white
- separated into the elements titanium metal, Ti, and oxygen, O_2. The titanium can then be used to make steel alloys.

Properties of minerals

Minerals can be identified by their physical properties. The main properties are their:

- hardness
- lustre
- colour
- streak colour
- flame colour.

Hardness

Hardness is assessed by comparing minerals using Mohs scale. The scale is given in Table 6.3.2. This set of minerals is used to find:

- what can scratch an unknown mineral
- which minerals can be scratched by the unknown mineral.

TABLE 6.3.2 Mohs hardness scale

Hardness	Mineral	Description	Image
1	talc	very soft, like chalk	
2	gypsum	about as hard as a fingernail	
3	calcite	about as hard as copper and some gold	
4	fluorite	about as hard as an iron nail	
5	apatite	about as hard as teeth	
6	feldspar	about as hard as a steel knife blade	
7	quartz	scratches glass	
8	topaz	harder than quartz	
9	corundum	harder than topaz	
10	diamond	hardest mineral known	

Another way of testing for hardness is shown in Table 6.3.3. It uses a range of commonly available materials to compare hardness. This is useful as a rough guide if a geologist is outdoors and does not have a set of minerals to perform a Mohs test.

TABLE 6.3.3 An alternative test for hardness

Test object	Will scratch materials of hardness less than
fingernail	2.5
copper washer	4
cast iron	4.5
window glass	5.5
steel knife or nail	6

SkillBuilder

Using Mohs scale

To determine the hardness of an unknown mineral, you need to try to scratch it with the different minerals or objects listed in Tables 6.3.2 and 6.3.3. An example is shown in Figure 6.3.3.

- If the unknown mineral can be scratched, then it must be softer than whatever you scratched it with.
- If you can scratch something with the unknown mineral, then the unknown mineral is harder.

FIGURE 6.3.3 Mohs hardness test showing quartz scratching calcite, which shows quartz is harder than calcite.

Worked example

Problem

On testing, topaz scratched an unknown mineral, but feldspar did not. State the hardness of the unknown mineral and identify what the mineral could be.

Solution

Thinking: Determine what scratches the unknown mineral.

Working: Topaz scratched the unknown mineral.

Thinking: Determine its maximum hardness on Mohs scale.

Working: The mineral is not as hard as topaz, so its maximum hardness is 8.

Thinking: Determine what the unknown mineral scratches.

Working: The unknown mineral scratches feldspar.

Thinking: Determine its minimum hardness.

Working: The mineral is harder than feldspar, so its minimum hardness is 6.

Thinking: Express its hardness as a range.

Working: The unknown mineral has a hardness of 6–8.

Thinking: Identify the likely mineral.

Working: The mineral may be quartz or something with a similar hardness.

Try yourself

An unknown mineral was tested by a geologist. Window glass scratched the unknown mineral but the mineral scratched a lump of cast iron.

a Determine the approximate hardness of the unknown mineral.

b Identify what the mineral could be.

Lustre, colour and streak tests

The appearance of a mineral can give a good idea of what it might be. The way a mineral looks can be analysed in three ways.

- Colour is very useful when prospecting (searching) for minerals. For example, gold shows up as a yellowish colour in rock and soil.
- **Lustre** is how shiny a mineral is. Lustre can be useful when you are out prospecting for minerals. For example, gold has a bright shiny surface when clean or wet. Lustre is divided into many categories. Examples are glassy, waxy, metallic and dull. These are shown in Figure 6.3.4. Some other common lustres are adamantine (sparkles like diamonds), pearly (glows like pearl), greasy (looks like oil or grease) and silky (like silk).

FIGURE 6.3.4 Glassy, waxy, metallic and dull are all words used to describe the lustre of a mineral.

- **Streak** is the colour left behind when you try to scratch an unglazed white tile with the mineral. The streak is often different from the colour of the mineral itself. For example, iron pyrites (commonly known as 'fool's gold') looks very similar to real gold. They both have a similar golden colour. However, fool's gold has a greenish-black streak, while real gold has a gold streak. This is shown in Figure 6.3.5.

FIGURE 6.3.5 The greenish-black streak of iron pyrites at top right, and the gold streak of real gold, bottom left.

Flame colour

Flame tests are chemical tests that provide another way of identifying a mineral. In these tests, minerals are first ground into powders or dissolved. Some of the powdered or dissolved mineral is then put into a hot flame. The mineral glows and gives the flame a characteristic colour that may then be used to identify the mineral (Figure 6.3.7).

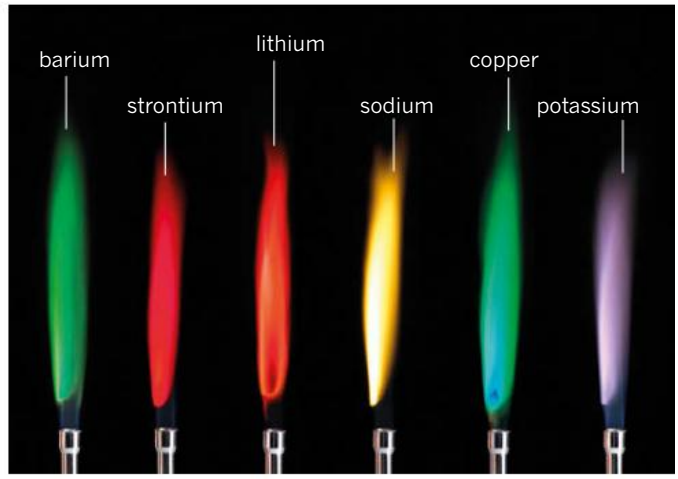


FIGURE 6.3.7 Minerals glow in a flame, giving out a distinctive colour. Note the slight variation in green between barium (yellow/green) and copper (blue/green) flame.

Prac 3
p. 278

A streak test of black and red haematite is shown in Figure 6.3.6.

FIGURE 6.3.6 Black and red haematite look different but both show a rust-red streak. This is evidence that that they are the same mineral, iron oxide.

Prac 1
p. 276
Prac 2
p. 277

Mineral exploration

Minerals need to be found before they can be mined and used. Mineral exploration is complex and requires the skills and knowledge of people from a variety of science disciplines. Geologists, geophysicists and geochemists all have vital roles in the three common exploration methods—aerial, on-site and satellite surveys.

Aerial methods of exploration

A quick way of exploring vast areas of land for **mineral resources** fairly quickly is to survey it from the air using aircraft or helicopters (Figure 6.3.8). There are three common ways this is done.

FIGURE 6.3.8 This aircraft is fitted with a magnetic system to detect magnetic anomalies in Earth's north–south field.

Magnetic surveys

Minerals containing iron, nickel or cobalt change Earth's magnetic field in their vicinity. Sensitive instruments called **magnetometers** detect this change and show the effect as a disruption to the normal field or 'magnetic anomaly'. An example is shown in Figure 6.3.9.

The magnetic data from the magnetometer is fed into a computer and a coloured map can then be constructed. Colours are used to indicate areas likely to contain iron, nickel or cobalt.

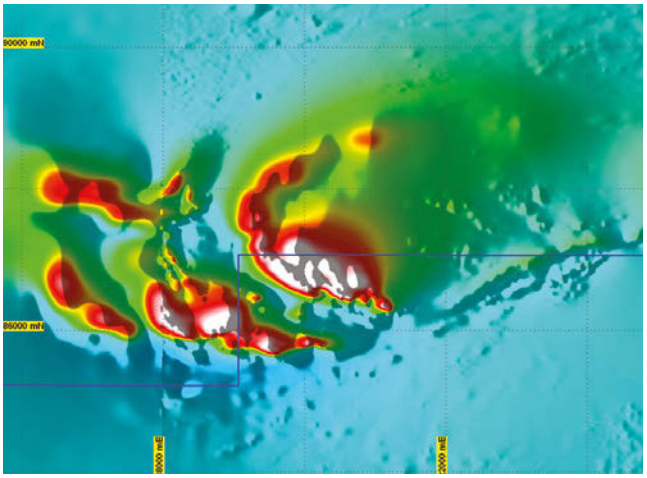


FIGURE 6.3.9 This map of magnetic anomalies near Mt Oscar in the Pilbara region of Western Australia helped in discovering a mountain made of magnetite iron ore. White and red areas are more magnetic than the other colours.

Gravity surveys

Small differences in the gravitational pull of the Earth can be detected by very sensitive instruments called **gravimeters**. Dense rocks and minerals affect the gravitational pull on the aircraft, and gravimeters on board can detect this. Variations in gravitational pull can give geologists clues about where particular minerals may be found.

Electromagnetic surveys

Electromagnetic (EM) surveys detect ore bodies that are good electrical conductors. A magnetic field is sent from a transmitter on an aircraft or helicopter. The magnetic field creates tiny electrical currents in minerals in the ground below.

These currents are called eddy currents and they create their own magnetic field, called the secondary field. This field is then detected by a receiver. You can see how this works in Figure 6.3.10.

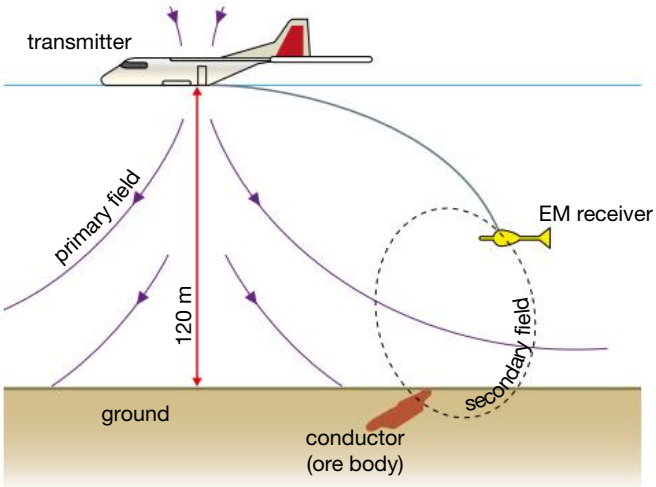


FIGURE 6.3.10 Airborne electromagnetic methods apply a magnetic field to the ground below. The secondary field created by the eddy currents in the ore body is then detected.

Prac 4
p. 279

On-site methods

Aerial methods give a quick overview of large areas. More specific data can come from on-site methods.

Seismic surveys

A **seismic survey** involves sending a shock wave into the ground surface, and recording the reflected sound waves. Different rocks layers reflect the sound waves in different ways and a 3D image can be created from the reflections. Explosives can be used to create the shockwave, but mechanical vibrators give a better picture and can go deeper. Detectors called geophones detect the reflected sound waves. The data obtained helps geologists predict likely areas where minerals can be found.

Geochemical surveys

Geochemistry uses chemistry to show what minerals are present. Rock and soil samples from the surface may be used, but generally holes are drilled into the rocks. The rock that is removed is called a **core sample**. Some core samples are shown in Figure 6.3.11.

FIGURE 6.3.11 Core samples of rock from holes drilled into a potential ore body. These will be tested chemically for minerals of interest.

Water from the surface or below ground can also be used as an indicator of minerals in the rocks or soil. Groundwater dissolves minerals in buried rocks and is especially useful in detecting metals.

Satellite images

Humans can see visible light but not other forms of light, such as infrared. Satellites can take images of the Earth using visible light and these other frequencies. The **satellite images** produced often help geologists see features in the landscape that cannot normally be seen. These features often contain particular minerals. Typical satellite images can be seen in Figure 6.3.12.

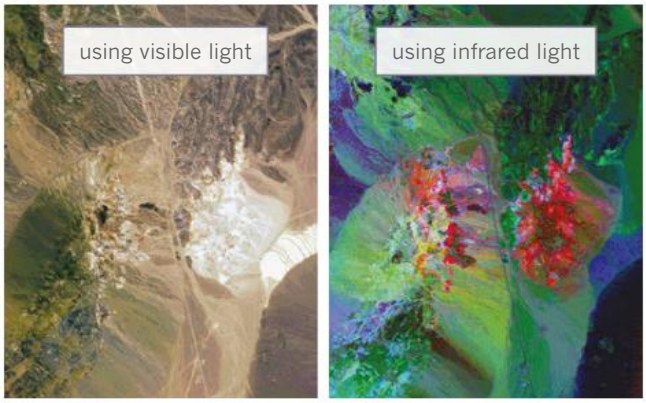


FIGURE 6.3.12 These two satellite images show the same area, using different frequencies of light. The red parts indicate deposits of azurite (an ore of copper).

REVIEW

1. Describe how a magnetometer and gravimeter are useful to a geologist or a geophysicist.
2. Aerial surveys don't just use the skills of scientists. Describe some jobs of other people likely to be involved in aerial surveys.
3. Describe two exploration methods used by geochemists.
4. Explain how a geologist could use data from a satellite.

AB
6.8

MODULE 6.3

Review questions LS

Remembering

1 Define the terms:
   a mineral b hardness c streak.

2 What term best describes each of the following?
   a a mineral glowing with a characteristic colour when placed in a hot flame
   b how shiny a mineral is
   c rocks that contain valuable minerals.

3 a List five minerals.
   b Name the chemical compound in each of them.
   c Name the element extracted from the compound.

4 Group the following substances into those that are minerals and those that are not:
gold, coal, iron ore, bauxite, oil.

5 List four physical properties used to identify minerals.

Understanding

6 How are lustre and colour used to identify a mineral?

7 a How would you use a streak test to decide whether two minerals were the same or different?
   b Explain whether any other tests would be necessary to help you decide.

8 a Explain what a flame test is and what it shows.
   b Below are the results of three flame tests. Refer to Figure 6.3.6 on page 272 and name the metallic element in each mineral sample.
      i bright red ii blue/green iii violet

9 Refer to Figure 6.2.8 on page 262, showing silicon dioxide and sand. Discuss whether sand can be called a mineral based on this information.

10 In the science4fun on page 268, crystals of sodium carbonate formed as stalactites and stalagmites. This activity works for sodium carbonate but not for some other minerals. Explain why.

Applying

11 Use Mohs scale to identify minerals that could:
   a be scratched by a fingernail
   b scratch a fingernail.

12 An unknown mineral was scratched by fluorite, but not by calcite. Use Mohs scale to state the likely value of its hardness.

13 One of the minerals in Table 6.3.2 on page 270 was scratched by topaz but not by an iron nail. Identify what mineral it probably was.

Analysing

14 Compare a rock, a mineral and an ore.

15 Use the properties of the following substances to classify them as mineral or non-mineral.
   a Sugar comes from the sugar cane plant. It forms a crystal structure when it solidifies.
   b Oxygen is a gas at all temperatures above –183°C.

Evaluating

16 Two unknown white, lustrous minerals were tested for hardness and streak. Both had a hardness of 4, and had a white streak. What can you conclude from these tests?

17 Some gold nuggets that were rounded like sand grains were found by a prospector in dry soil nowhere near a stream. The prospector insisted that the gold was carried there by an ancient stream that had disappeared long ago. The land was fairly flat but there were some hills about 1 km away. Assess the prospector's argument.

Creating

18 Water can exist as a liquid and as solid ice. In both forms this compound has the chemical formula H_2O. Ice fits the definition of a mineral but liquid water does not.
   a Use Figure 6.3.13 to determine the property of ice that makes it fit the definition of a mineral.
   b What property of liquid water makes it fail the definition of a mineral?
   c Write a letter to a science magazine explaining why it makes no sense to classify water as a mineral.

FIGURE 6.3.13

MODULE 6.3

Practical investigations

1 • Comparing minerals

Processing & Analysing | Communicating

Purpose

To compare the physical properties of different minerals.

Timing 45 minutes

Materials

- selection of minerals
- steel nail
- copper washer or nail
- cast iron
- white unglazed tile
- stereo microscope or hand lens

Procedure

1. In your workbook, copy the table shown in the Results section. Include enough rows for all the minerals you are about to test. Give your table a title.
2. Choose one mineral sample. Record its name from the label or identify it using Figure 6.3.14. Describe its colour and lustre.
3. Use the stereo microscope or a hand lens to observe the shape of any crystals. Describe or draw them in your table.
4. Do a streak test and record the colour in your table.
5. Determine the hardness using Tables 6.3.2 and 6.3.3 on page 270 and enter the result in your table.
6. Repeat for all other mineral samples.

Results

Record all observations in your Results table.

Mineral name	Colour and lustre	Crystal shape	Streak colour	Approximate hardness

Review

1. Describe any difficulties you had in conducting these tests.
2. What difficulties might geologists have if they rely only on these tests to identify a mineral?
3. Propose reasons why minerals look different and have different properties.

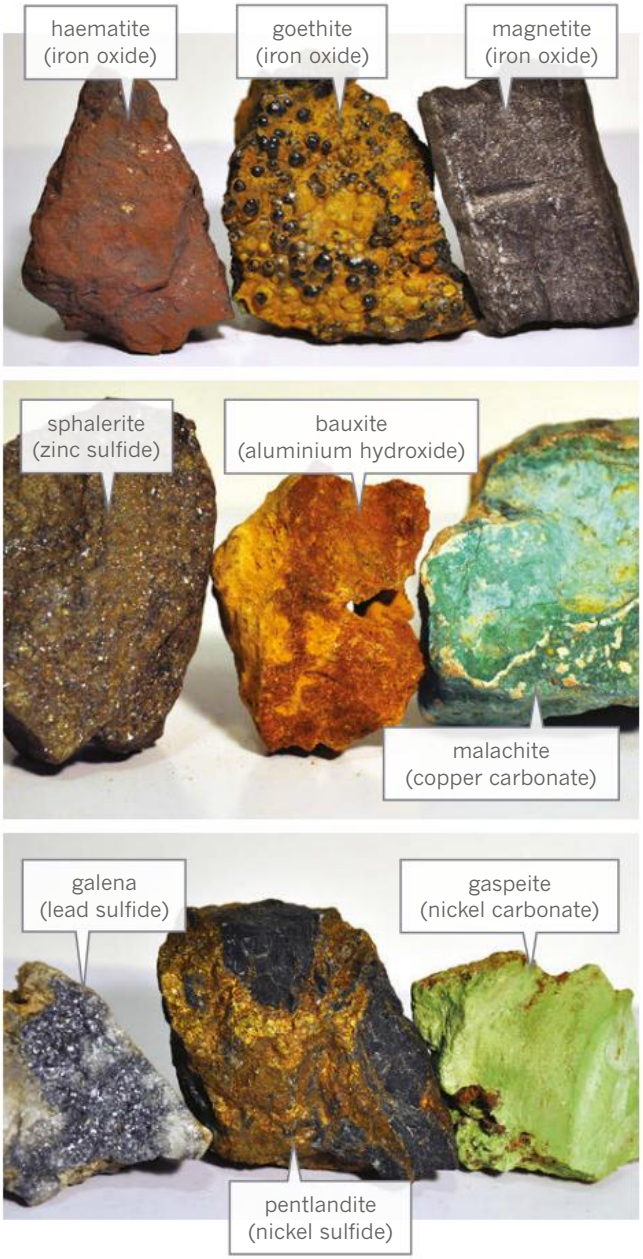


FIGURE 6.3.14

MODULE 6.3

Practical investigations

2 • Chemical properties of a mineral

Planning & Conducting | Processing & Analysing

Purpose

To investigate the composition of malachite, a green-coloured copper carbonate mineral found in rock.

Timing 60 minutes

Materials

- 2 g copper carbonate powder (powdered malachite)
- 20 mL 0.5 M sulfuric acid
- limewater
- steel wool

SAFETY

0.5 M sulfuric acid is corrosive.

Wear safety glasses at all times.

Wear rubber gloves at all times.

- 125 mL conical flask with one-hole stopper and delivery tube
- test-tube and test-tube rack
- video camera or mobile phone (optional)

Procedure

1. Place about 2 g of the powdered copper carbonate in the conical flask with the stopper and delivery tube.
2. Pour about 3 cm of limewater into the test-tube and place it in the rack.
3. Add about 20 mL of sulfuric acid to the conical flask containing copper carbonate. Replace the stopper and delivery tube, and bubble the gas through a limewater solution for no more than 30 seconds (Figure 6.3.15). Remove the end of the delivery tube from the limewater.
4. Let the conical flask stand for a few minutes until a definite colour can be seen in the conical flask containing the copper carbonate. Record your observations of the conical flask and the test-tube.
5. Wait until the copper carbonate has stopped producing gas (fizzing). Place some steel wool (about as much as a ball of cotton wool) into the liquid in the conical flask with the copper carbonate and leave it for 2 minutes.

Results

1. Record or video your observations.
2. Leave the conical flask until the end of the class and again record your observations.

Review

1. What changes did you observe in the conical flask as the acid was added?
2. Limewater turning milky white is a chemical test for carbon dioxide gas. What do you conclude that the acid did to the copper carbonate?
3. In the conical flask containing the copper carbonate, there were two changes that were evidence of a chemical change. Identify these changes.
4. What changes did you observe in the conical flask several minutes after the steel wool was added to the flask?
5. What do you conclude happened to the steel wool and the solution?

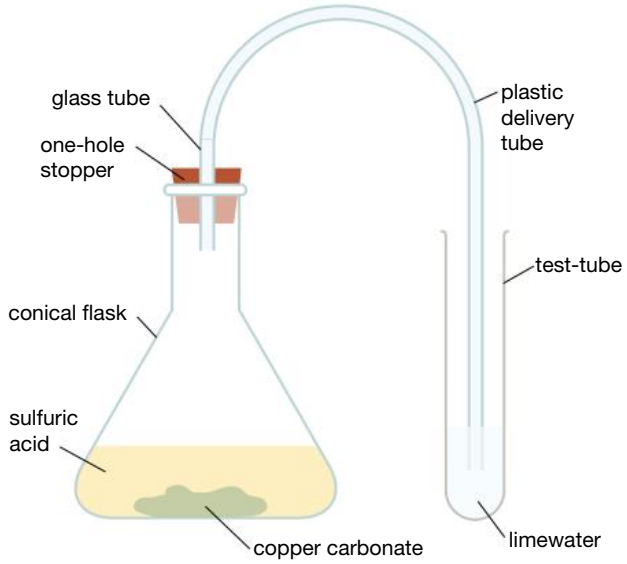


FIGURE 6.3.15

MODULE 6.3

Practical investigations

3 • Flaming minerals

Processing & Analysing | Evaluating

Purpose

To use flame tests to identify the element in different minerals.

Timing 30 minutes

Materials

- at each station, small vial with a few grams of one of the following solid chlorides: copper, barium, strontium, lithium, sodium, potassium, zinc
- 50 mL 0.1 M hydrochloric acid
- 100 mL beaker
- opened paper clips
- test-tube holder
- Bunsen burner and bench mat
- matches
- safety glasses

SAFETY

Do not breathe in any of the fumes from the flames.

Do not get any of the minerals or acid on your skin or eyes.

Keep the test-tube holder away from the flame.

Wear safety glasses.

Procedure

1. Copy the table in the Results section into your workbook. Include enough rows for all the different mineral samples to be tested. Give your table a title.
2. Stations have been set up around the laboratory. At each station there is a small amount of a solid mineral containing a different metallic element.
3. At each station, set the Bunsen burner to a blue flame.
4. Go to a station, grip the unopened end of the paper clip in the test-tube holder. Hold the opened end (the point) of the paper clip in the blue flame for a few seconds. Remove the paper clip from the flame.
5. Dip the end of the paper clip into the acid in the beaker. Now dip the paper clip into the sample of the mineral so that some of the crystals stick to the paper clip. Then carefully place the tip of the paper clip with the mineral sample stuck to it into the Bunsen burner flame for one or two seconds, observing the flame colour (Figure 6.3.16).

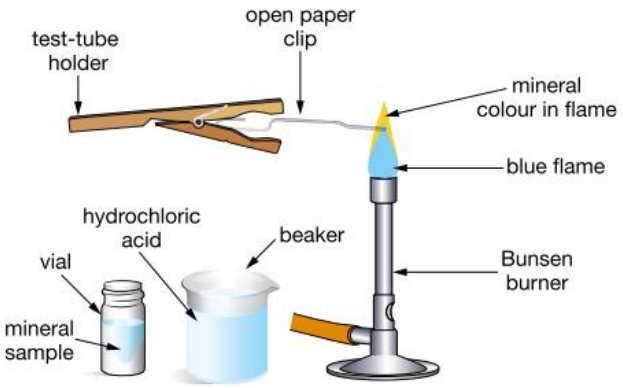


FIGURE 6.3.16

6. Dip the paper clip back into the acid for a few seconds to wash it and then place it on the bench mat. Record the flame colour you saw.
7. Repeat steps 5 and 6 for the other stations around the room.

Results

1. Record your results in the table.
2. Use Figure 6.3.7 on page 272 to identify the most likely metal in each mineral sample. Record its name and symbol in the table.

Sample #	Flame colour	Probable metal in the sample
1		
2		
3		

Review

1. Propose a reason why a blue Bunsen burner flame was used for this test and not a yellow flame.
2. Did the flame stay a distinctive colour or did it 'die out'?
3. Did you have any problems in assessing the colour of the flame? If so, which colours caused problems?
4. Discuss whether this test is enough to definitely identify the metal in a mineral sample.

MODULE 6.3

Practical investigations

4 • Electromagnetic surveys

Processing & Analysing | Communicating

Purpose

To model an electromagnetic survey to detect minerals.

Timing 45 minutes

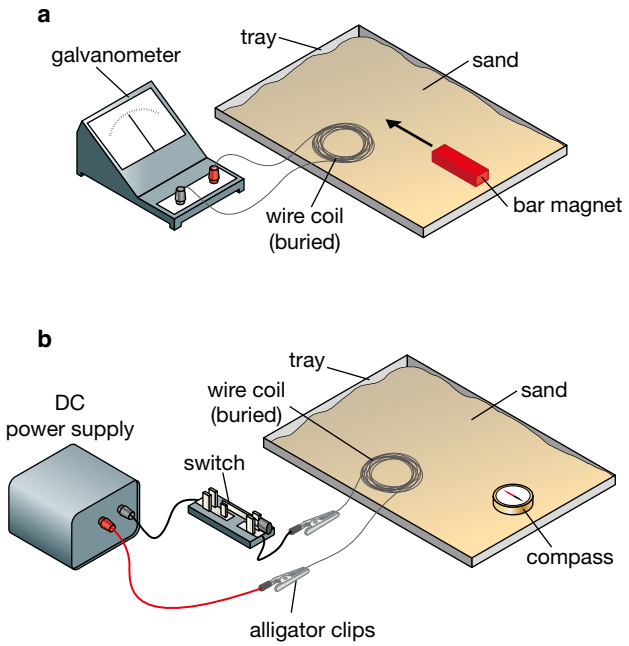
Materials

- varnished copper coil (representing the ore body)
- clean sand
- laboratory tray
- good-quality magnetic compass
- strong bar magnet
- galvanometer
- 4V power supply (or battery)
- 3 electrical leads with alligator clips
- switch

Procedure

1. Fill the tray with sand and bury the coil just below the surface, with the ends of the coil over the edge of the tray.
2. Connect the two wires from the coil to the galvanometer. A galvanometer is an instrument that detects very small electric currents. Your set-up should look like Figure 6.3.17(a).
3. Pick up the magnet and imagine it to be on an aircraft with an electromagnetic (EM) survey system. 'Fly' the magnet a few centimetres above the sand and towards the coil (your 'ore body') and watch the galvanometer. Try it a few times to be sure.
4. Try 'flying' faster or slower, and higher or lower. Record the readings on the galvanometer each time. Record your observations in a table.
5. Disconnect the galvanometer from the coil and connect the coil to DC terminals of the power supply (or battery) with a switch. The power supply represents the eddy currents created in the ore body. Turn the knob on the power supply to 4V. Your set-up should look like Figure 6.3.17(b).
6. Pick up the compass and imagine it to be on an aircraft with an EM system. The compass is modelling the detector on the aircraft. Hold the compass flat and start at the end away from the coil.

FIGURE 6.3.17



7. 'Fly' the compass just above the sand and towards the coil. Close the switch a few seconds before the compass 'flies' over the coil. Watch the response of the compass. Turn off the switch as soon as the compass passes the coil. Try 'flying' faster or slower, and higher or lower.

Results

1. Record your observations of the effect on the compass.
2. Predict what would happen to the compass direction if you turned the coil over in the sand and repeated step 7. Try this and record any observations.

Review

1. When a magnetic field was passed through the coil, what happened to the galvanometer?
2. Explain what the changing magnetic field must have done to the coil.
3. Describe what the electric current in the coil did to the compass.
4. Explain why the electric current in the coil affected the compass.
5. Compare this model with a real electromagnetic survey.

CHAPTER 6

Chapter review

Remembering

1 Define the terms:
- a malleable
- b ductile
- c monatomic
- d molecule.

2 What are the two broad categories that elements can be divided into?

3 List the names of two elements and three compounds found in air.

4 Name the following substances:
- a O_2
- b CO
- c P_4
- d $C_6H_{12}O_6$
- e S_6
- f NaCl
- g SiO_2

5 List five characteristics of a mineral.

6 What is a flame test and why is it used?

Understanding

7 Explain what an alloy is and why alloys are useful.

8 Modify the following statements to make them correct.
- a A chemical substance is classified as a mineral if it is naturally occurring and not made by humans.
- b The lustre of a mineral is the colour that you see when it is cleaned.
- c The hardness of a mineral is determined by using Ohm's scale.
- d The streak of a mineral is unique; only that mineral has that streak colour.
- e An ore is a mineral that is very valuable.

9 Some minerals can be found in lakes, rivers and seas, while other minerals are never found in those places. Explain why.

Applying

10 An unknown mineral was scratched by apatite, but not by fluorite. Use Mohs scale to calculate the likely value for its hardness.

11 One of the minerals in Table 6.3.2 on page 270 was scratched by quartz but not by a copper washer. Identify what mineral it could be.

AB 6.10

12 a What types of atoms make up each of the following molecules?
- b How many of each type of atom are there in each molecule?
  - i ozone, O_3
  - ii hydrofluoric acid, HF
  - iii water, H_2O
  - iv natural gas, CH_4
  - v petrol, C_8H_{18}
  - vi deadly nightshade poison, $C_{45}H_{73}NO_{15}$

Analysing

13 Compare elements, compounds, mixtures and minerals by listing their similarities and differences.

14 Classify the following as elements, compounds or mixtures.
- a lemonade
- b carbon (C)
- c zinc (Zn)
- d bronze
- e air
- f tap water
- g pure water (H_2O)
- h carbon dioxide (CO_2)
- i chlorine gas (Cl_2)
- j sodium chloride (NaCl)
- k shampoo
- l iron (Fe).

15 Classify the following as monatomic, molecular or crystal lattice.
- a gold
- b helium
- c pure water
- d sodium chloride
- e carbon dioxide
- f copper.
- g neon
- h nitrogen

Evaluating

16 a Do you think that a monatomic compound would be possible?
- b Justify your answer.

17 a Assess whether you can or cannot answer the questions on page 245 at the start of this chapter.
- b Use this assessment to evaluate how well you understand the material presented in this chapter.

Creating

18 Use the following twelve key words to construct a visual summary of the information presented in this chapter.

atom	molecule	crystal lattice	element
compound	mixture	metal	brittle
malleable	mineral	Mohs scale	non-metal

CHAPTER 6

Inquiry skills

Research

1 Processing & Analysing · Evaluating

Three-part inquiry question

Select your entry point and complete the relevant parts of this inquiry.

Iron is the framework upon which our modern society is built. Iron and alloys of iron are used to build the structures of modern skyscrapers, the bodies and engines of cars, railway tracks, and many other things from frypans to spacecraft.

Human use of iron began around 4000 years ago, when we first learned how to extract iron from the rocks in which it is found. Before that, the metal of choice for weapons and farm implements was bronze. Bronze is a mixture of copper and tin, sometimes with trace amounts of other metals.

a **i** Investigate bronze and iron. Explain why the use of iron became more popular 4000 years ago.

ii If iron is better than bronze, why didn't people use it earlier? Explain.

b Iron was perceived to be better than bronze, but it was not perfect for applications where strength was needed, like swords. Explain the limitations of iron for use in weapons.

c Modern applications do not use iron. Instead we use steel.

i How is steel different from iron?

ii Draw a diagram showing the structure of steel at a molecular level. Explain how this structure is different from the structure of iron. Use the diagram to explain why steel is better than plain iron for building construction.

2 Questioning & Predicting · Communicating

Research one element in detail. Find:

- when the element was discovered
- who discovered the element
- whether it is a metal or a non-metal
- some of its properties
- some of its uses.

Present your research as a poster or digital slide show.

3 Evaluating · Communicating

Investigate the relationship between elements and the periodic table by:

- listing the monotomic elements
- finding these monotomic elements on the periodic table
- finding their main physical and chemical properties
- listing features common to them (for example, whether they are solids, liquids or gases, and where they can be found on the periodic table).

Present your findings as periodic table with labels that meet the above requirements.

4 Evaluating · Communicating

Research an alloy to find:

- what elements the alloy is a mixture of
- the alloy's properties
- how those properties contrast with the properties of the elements that make up the alloy
- where and how the alloy is used.

Present your findings as a poster.

5 Questioning & Predicting · Communicating

The Australian telephone network is largely based on copper wires, which makes our internet slower than many other Western countries around the world. Research how the Australian government plans to improve Australia's internet speeds. Find:

- the name of the plan
- how it will work
- how much it is expected to cost
- how long it will take to complete
- how it will compare to our current network
- what some of the benefits to society will be.

Present your findings as a billboard or TV advertisement for or against the plan.

CHAPTER 6

Inquiry skills

6 Processing & Analysing

Research the recent discovery that several types of bacteria can form gold.

- **a** Describe the observations in Australia by Frank Reith that led him to investigate the link between bacteria (called *Cupriavidus*) and gold.
- **b** Outline the discoveries that Reith's team made.
- **c** Outline the research done in Canada on bacteria called *Delftia* that precipitate gold.
- **d** Discuss some future benefits of the research into bacteria that form gold.
- **e** Find images relevant to these discoveries.

Present your findings in digital form.

7 Processing & Analysing Evaluating

Research mineral crystals to:

- **a** find images of different crystal shapes
- **b** explain why crystals take different shapes
- **c** explain why crystals can grow to any size, whereas molecules have a fixed size.

Present your research as a digital slide show.

FIGURE 6.4.1

8 Processing & Analysing Communicating

Mining mobile phones

There are nearly as many mobile phones in use in the world as there are people. That amounts to nearly 7 billion mobile phones. The average lifespan of a mobile phone has been estimated at about 3 years. So that's approximately 2 billion mobile phones thrown away every year (Figure 6.4.1).

Estimates vary, but the gold in the phones thrown away every year is worth over a billion dollars. But that's not all. Along with the gold, a mobile phone contains many other rare and valuable materials.

Many people keep their old mobile phones and store them in cupboards and drawers, concerned about the data contained in them, rather than the use of their recycled components.

There is controversy about the disposal of old mobile phones as well as other electronic waste, which is often called 'e-waste'. Mobile phones are not biodegradable and contain substances that can potentially harm the environment if not handled correctly at the end of the phone's useful life.

Dumping phones into landfill leads to chemicals leaching into the soil and groundwater, to say nothing of the waste of the valuable materials they contain. However, extracting those valuable materials is not an easy process, and because of this much of this e-waste has been shipped to developing countries.

You are concerned about the waste and see the recycling of the elements in mobile phones as a worthwhile project. You want to encourage people in your neighbourhood, town or city to recycle their mobile phones.

Task

- Develop a list and a description of the valuable elements used in mobile phones that might be extracted in the recycling process.
- Encourage people to recycle their phones.

Hints

- What is the Mobile Muster?
- Find out why people don't bother to recycle their mobile phones.
- Gold is one component of mobile phones. Why is gold used instead of copper?

CHAPTER 6

Inquiry skills

Thinking scientifically

1 Percy wants to create an experiment to determine whether sugar, salt or bicarbonate of soda is the most soluble. In his experiment, which of these could be considered the dependent variable?

- **A** the type of solvent
- **B** the type of solute
- **C** the amount of solvent
- **D** the amount of solute

2 Alberto measures the electrical resistance of 1 metre wires made from different metals and plots the resistance in the graph shown in Figure 6.4.2.

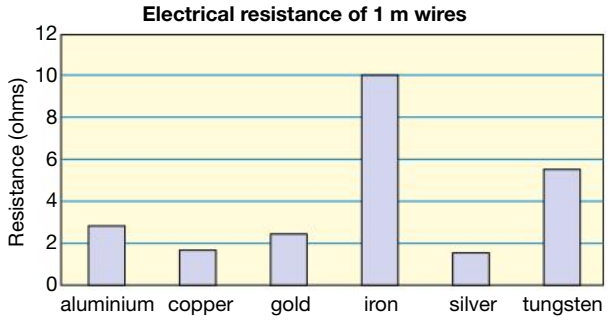


FIGURE 6.4.2

Which of the following are the three wires with the highest resistance?

- **A** silver, copper, gold
- **B** iron, tungsten, aluminium
- **C** iron, tungsten, gold
- **D** aluminium, tungsten, iron

3 Harriet places a pure substance in a test-tube and heats it up. She notices that a gas is given off and that another solid has formed in the bottom of the test-tube. What can Harriet deduce from her experiment?

- **A** The initial substance is definitely an element.
- **B** The initial substance is definitely a compound.
- **C** The gas given off is definitely an element.
- **D** The solid that forms in the test-tube is definitely a compound.

4 Fool's gold (iron pyrites) and gold are a similar colour, and people are often fooled by this similarity. However, when a streak test is done, fool's gold has a greenish black streak and gold has the same colour streak as the lump of gold. What can be concluded from this example?

- **A** Gold and fool's gold are the same mineral but with a different structure.
- **B** The streak test does not prove that these two minerals are the same.
- **C** Streak tests are very unreliable as a means of deciding whether two minerals are different.
- **D** The streak test can show that two minerals are different, but not that they are the same.

5 Consider the key in Figure 6.4.3, which shows how to distinguish between four black minerals. Which of the following is correct?

- **A** Cassiterite can only be distinguished from tourmaline by checking the streak.
- **B** Haematite and tourmaline do not react with hydrochloric acid when in contact with zinc.
- **C** Tourmaline cannot be distinguished from cassiterite by the streak test.
- **D** Magnetite and tourmaline are magnetic.

Key:

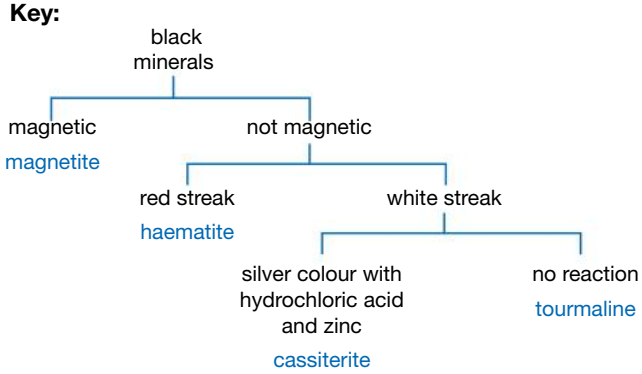


FIGURE 6.4.3

CHAPTER 6

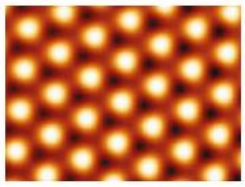
Glossary

alloy: a mixture of a metal with other metals or non-metals

alloy

aqueous solution: a solution in which a substance is dissolved in water

atoms: the smallest building blocks of matter



atoms

brittle: easily crumbled or shattered

compounds: substances made of lattices or identical molecules with two or more types of atoms

core sample: a drilled sample of rock

ductile: able to be stretched to form a wire

electromagnetic survey

electromagnetic (EM) survey: a survey that measures the effects of applying a magnetic field to the Earth

elements: substances made up of only one type of atom

flame test: a test where a mineral glows with a characteristic colour when heated to a high temperature in a flame

flame test

geochemistry: the use of chemistry to show what minerals are present in an area

gravimeter: a very sensitive instrument that measures small differences in the gravitational pull of the Earth

hardness: a measure of the ability to scratch or be scratched by other minerals

lattice: grid-like structure of atoms

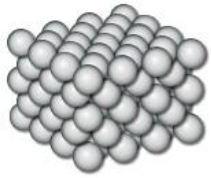
lustre: how shiny a mineral is

lustrous: shiny

magnetometer: a device that measures the strength of a magnetic field

malleable: able to be hammered or bent into new shapes

metals: substances that have a metallic shine, conduct heat and electricity, and can be hammered into sheets and drawn into wires



metal

mineral: a naturally occurring chemical substance that has not been made by an organism and that has atoms arranged into crystal lattices

mineral resources: minerals that are dug up and used

miscible: describes liquids that can be mixed

non-metal

mixture: any combination of two or more elements or compounds

molecule: a cluster of atoms

monatomic: describes elements that consist of single atoms

non-metals: substances that are usually dull (not shiny), do not conduct heat and electricity, and break or crumble

ore: rocks containing valuable minerals

periodic table: a table that shows all the known elements

properties: the characteristics of a substance

satellite images: images created using data from satellites that detect electromagnetic radiation from Earth

satellite image

scanning tunnelling microscope (STM): a microscope that can show atoms by scanning a tip across the surface of crystals and sensing the atoms as bumps on the surface

seismic survey: when a shock wave is sent into the ground surface, and the reflected sound waves are recorded

solute: a substance being dissolved

solution: a mixture in which one substance is dissolved in another

solvent: a substance that dissolves another substance

streak

streak: the colour of the mark left by scraping a mineral on a white unglazed tile

AB 6.9

CHAPTER

7 Physical and chemical change

Have you ever wondered ...

- where sugar goes when it dissolves?
- how a thermometer works?
- how you can smell something from across the room?
- why exercise makes you hungry? LS

After completing this chapter you should be able to:

- explain why a model for the structure of matter is needed
- model the arrangement of particles in solids, liquids and gases
- use the particle model to explain changes of state
- identify the differences between chemical and physical changes
- identify evidence that a chemical change has taken place
- investigate simple reactions such as combining elements to make a compound
- describe how the chemical properties of a substance will affect its use
- outline how our understanding of the nature of matter has changed over time as scientific developments have provided new evidence for particle theory
- outline how the idea of elements has developed as knowledge of the nature of matter has improved
- outline the process of recycling of household waste
- *use the particle model to distinguish between the properties of liquid water, ice and steam.*

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AB 7.1

MODULE 7.1

When substances change

The world around you is constantly changing. Whether it is the passing of the seasons, a cool breeze or ice blocks melting in a drink, changes are occurring. Most of these changes can be classified as physical or chemical changes, depending on if any new substances are produced.

science 4 fun

Invisible ink

Can you use a chemical change to write a secret message?

Collect this ...

- lemon juice
- paper
- fine paintbrush
- warm light globe or hairdryer

Do this ...

1. Use the paintbrush to write a secret message on the paper in lemon juice.
2. Let the paper dry and then give the secret message to a friend.
3. To read the message, tell your friend to hold the message up to a warm light globe or use a hairdryer to heat the paper.

Record this ...

1. Describe what happened.
2. Explain why you think this happened.

Identifying physical change

The key feature of a **physical change** is that no new substance is produced during the change. A substance undergoes a physical change if it changes shape or form, if it expands (gets bigger) or contracts (gets smaller), if it changes state (into a solid, liquid or gas), or if it mixes with another substance. Figure 7.1.1 shows some examples of physical changes. The **physical properties** of the substance may change but the substance before and after the change is exactly the same. For this reason, physical changes can often be reversed.

Changing shape or form

The simplest example of a physical change is a change in the shape or form of a substance. In this case, a force is applied to break, bend, stretch, crush, twist or compress the object. These changes do not produce new substances. For example, when you squash an aluminium can, its shape changes but the can is still made of aluminium. Similarly, if you crush an aspirin tablet into a powder, it is still aspirin but in a different form. These changes can be reversed relatively easily.

FIGURE 7.1.1 During these physical changes, no new substances are produced.

If you bend a metal rod in one direction then you can easily bend the rod back to its original shape. Even the crushed aspirin powder can be compacted back into the form of an aspirin tablet.

Expansion and contraction

Physical changes also occur when the temperature of a substance increases or decreases. When solids, liquids and gases are heated, they expand and take up more space. When **expansion** occurs, the volume of the object increases and its density decreases, but no new substances are formed. The reverse of expansion is **contraction**. When a solid, liquid or gas is cooled, it contracts—the volume of the substance decreases and its density increases.

Thermometers use expansion and contraction of liquids such as ethanol and mercury to measure temperature. When the temperature increases, the liquid in the thermometer expands and moves up the thermometer. When the temperature decreases, the liquid contracts and moves down.

Prac 1
p. 295

Hot-air balloons use the expansion of heated air to lift off the ground. Figure 7.1.2 shows how hot-air balloons use a burner to heat the air inside. As the air heats, it expands to fill the balloon. The hot air inside is much less dense than the cooler air outside, and so the balloon floats and lifts off the ground. The hot air in the balloon takes up more space but is still the same substance as it was before it was heated. Therefore, expansion is a physical change.

FIGURE 7.1.2 Heating the air inside the balloon causes it to expand and become less dense than the air outside. As a result, the balloon floats.

Changes of state

If enough heat is applied to a substance, then it will change state from a solid to a liquid (**melting**) or from a liquid to a gas (**evaporation**). These changes are known as changes of state. When a substance is cooled, the change of state is reversed from a gas to a liquid (**condensation**) or from a liquid to a solid (**freezing** or **solidification**). A few substances change directly from a solid to a gas (**sublimation**) or from a gas to a solid (**deposition**).

Melting

When a solid is heated enough, it will melt and change into a liquid. For example, when you place an ice cube in your mouth, the heat from your mouth melts it into liquid water. Likewise, when butter is spread on hot toast, the butter melts and soaks into the bread. The physical properties of the solid and the liquid may be very different, but they are both made from the same substance. Therefore melting is a physical change.

Freezing

When a liquid is cooled enough, it will form a solid. This is what happens when liquid water is put in the freezer to form ice cubes. Freezing can also be seen when drops of liquid candle wax cool and become solid again. Freezing converts liquids into solids, so is the reverse of melting.

Evaporation

Evaporation occurs when a liquid is warmed and becomes a gas. Evaporation occurs at the surface of a liquid at all temperatures, but it becomes faster as the temperature of the liquid increases. This is the reason that puddles of water dry faster on a hot day. It is also why tumble-driers heat clothes to dry them more quickly. If the liquid is heated above a certain temperature, known as the boiling point, then bubbles of gas will form within the liquid and the liquid boils.

Condensation

The opposite of evaporation is condensation. Condensation is when a gas cools and becomes a liquid. When you leave a cold can of soft drink out of the fridge, it develops moisture on the outside, as shown in Figure 7.1.3. This is because water vapour in the air condenses on the cold outside of the can to form liquid water. Similarly, when you breathe out on a cold day, 'fog' may come out of your mouth. This 'fog' is water vapour in your breath condensing to form a mist of tiny liquid water droplets.

FIGURE 7.1.3 Water vapour in the air condenses as liquid water on the outside of a can taken straight from the fridge.

SciFile

Water out of thin air

Engineers at the University of Engineering and Technology (UTEC) in Lima, Peru, have created a billboard that supplies pure drinking water. The area has rainfall of less than 1.3 cm per year, so locals rarely have enough clean water to drink. However, humidity is very high. The billboard uses special filters to condense the water vapour out of the air. In this way, it can produce more than 3000 litres of water per month. This is enough to supply hundreds of families with fresh water.

FIGURE 7.1.4 A local Peruvian boy drinks fresh water collected from the UTEC billboard.

Mixing

The mixing of two substances is another type of physical change. Figure 7.1.5 shows a bucket of different-coloured balls. It is an example of a mixture that can be seen by eye. The different-coloured balls mix but no new balls are formed.

FIGURE 7.1.5 The balls do not change or form new colours despite being spread evenly through this mixture.

Dissolving

When a solid is dissolved in a liquid, they form a mixture. The solid is known as the **solute**, the liquid is the **solvent**, and the mixture formed is referred to as a **solution**. The smallest particles of the solute mix and spread evenly throughout the smallest particles of the solvent—just like a mixture of balls but invisible to the naked eye. Although the solution looks and acts differently to the solute and solvent, no new substance is formed. For this reason, the process of dissolving is a physical change.

In a solution, the solute seems to disappear. In reality, the solute is broken down into such small particles that they are invisible. If the solvent is removed by boiling or evaporation, then the solute particles can join together again to form crystals. This process is known as **crystallisation**.

For example, when sugar is dissolved in water, the sugar particles spread evenly throughout the water to form a sugar solution (Figure 7.1.6). This is a physical change because the sugar particles remain sugar particles and the water particles remain water particles—a physical change has occurred. If the water is boiled off or left to evaporate, then the dissolving process is reversed and sugar is left behind.

FIGURE 7.1.6 When two substances mix, one substance is spread evenly through the other but no new substances are formed.

Identifying chemical change

To distinguish between a **chemical change** and a physical change, you need to determine whether a new substance has formed as a result of the change. If a new substance has been produced, then a chemical change has occurred.

The new substance formed in a chemical change could be a solid, liquid or gas. You can detect the presence of a new substance by:

- seeing a change in colour
- smelling a gas or seeing bubbles
- seeing a new solid forming in a clear solution. The solid that appears is known as a precipitate
- seeing light or feeling a change in temperature.

These signs of chemical changes are shown in Figure 7.1.7. However, these are just guidelines. Identifying chemical change also requires a good understanding of physical changes because there can be exceptions to these rules.

FIGURE 7.1.7 Some indications of a chemical change

Sometimes both types of change can happen at roughly the same time. For example, toasting bread starts as a physical change—heat evaporates water from the bread, drying it out. The drying bread then starts to burn, changing colour to brown then black. This is a chemical change.

A colour change occurs

If you see something changing colour, then it is very likely that a chemical change has occurred. This happens because the new substance produced by the chemical change has a different colour to what you started with. Burning a match, paper or wood produces a black powder, which is carbon. When iron is left in the rain, it turns orange-brown because iron oxide (rust) is produced.

Other examples include green apples ripening to turn red, the changing colour of leaves in autumn, a bruised leg turning purple, bleaching or dyeing clothes or hair (Figure 7.1.8).

FIGURE 7.1.8 Dyeing hair is an example of a permanent colour change caused by a chemical reaction.

Sometimes a physical change can also cause a colour change. For example, when snow melts to form liquid water it turns from white to colourless. This is not a chemical change because snow and liquid water are both made of water (molecular formula H_2O).

Mixing paint is another example of a physical change that causes a colour change. Figure 7.1.9 shows yellow and blue paint being mixed together. They produce green paint. However, no new substances are formed. The yellow and blue particles are mixed so closely together that they give the illusion of green paint.

FIGURE 7.1.9 Despite changing colour, mixing paint is still a physical change because no new substance has been formed.

A gas is produced

The production of a gas usually indicates a chemical change. A gas produced during a chemical change may be observed as bubbles, a new smell or perhaps smoke. When vinegar is added to bicarbonate of soda, many bubbles of carbon dioxide (molecular formula CO_2) are formed. Carbon dioxide is also formed by chemical changes in soft drink to create fizz or when antacid tablets are dissolved in water.

Rotten eggs are well known for their pungent smell. This smell is the gas hydrogen sulfide (molecular formula H_2S), which is produced when eggs rot. Rotting things often produce gas. Therefore, rotting is another example of a chemical change. Often when something is burning, the first thing you notice is the smell. This is because burning causes a chemical change that produces smelly gases.

However, not all gases indicate a chemical change. Sometimes physical changes give off gases too. For example, **boiling** is a physical change in which bubbles of vapour are released from a liquid.

SciFile

Life-saving gases

A chemical reaction that has already saved many lives is the one used to inflate car airbags. In a car accident, an electrical current ignites a small pellet of sodium azide. The sodium azide burns very rapidly, producing enough nitrogen gas to fill the airbag in just 0.03 second.

A precipitate forms

Occasionally, a new solid is produced when two solutions are mixed. This indicates that a chemical change has occurred. The solid precipitates (falls) out of the solution. The new solid is known as the **precipitate**. Precipitation occurs in pipes and drains when scale or lime deposits inside, as shown in Figure 7.1.10. Crystals can also precipitate inside the body. Some collect in the kidneys and can cause very painful kidney stones.

A precipitate can also form when a gas is bubbled through a liquid. This type of precipitation is the basis of a simple test for carbon dioxide gas. When carbon dioxide gas is bubbled through a solution of calcium hydroxide (limewater), it precipitates solid calcium carbonate, which turns the clear solution milky white.

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FIGURE 7.1.10 Scale or lime can precipitate from water, causing blockages in pipes.

Energy is produced or absorbed

Energy plays an important role in chemical changes. Some chemical changes release energy in the form of heat, light or both. As a result, a change in temperature or a flash or glow of light can be a sign that a chemical change has occurred. Some chemical changes release huge amounts of energy. For example, the explosion in Figure 7.1.11 released so much energy as light, heat and sound that it would have been observed from far away. Likewise, the light, heat and sound from bushfires, fireworks and sparklers are easily observed. In contrast, some chemical changes give out light but with little or no heat. Examples are the chemical changes that happen in glow sticks and glow worms.

FIGURE 7.1.11 Fires and explosions are examples of extreme exothermic reactions—they release large amounts of heat and light energy.

Other chemical changes absorb heat, causing their surroundings to cool. For example, the chemical ice pack shown in Figure 7.1.12 uses a chemical change that absorbs a lot of heat energy and so feels icy cold. Photosynthesis in plant leaves is another example of a chemical change that absorbs energy, this time from sunlight.

However, some physical changes can also cause a change in temperature. When you sweat, you feel cooler because the moisture evaporates and absorbs some heat from your skin. In contrast, steam can cause serious burns as it condenses on your skin and releases its heat energy.

FIGURE 7.1.12 The reaction in a chemical ice pack causes a dramatic drop in temperature as it absorbs heat from the surroundings.

AB
7.2

Recycling

Recycling substances such as paper, glass, plastics and aluminium conserves these resources, helps reduce waste and saves money (Figure 7.1.13).

In most cases when a substance is recycled, the form of the substance may change but the substance itself stays the same. Therefore, the recycling process is simply a series of physical changes as outlined in the following steps.

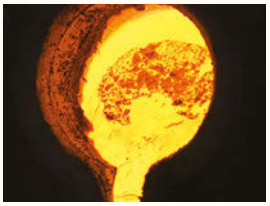
FIGURE 7.1.13 Aluminium is recycled because recycling is cheaper than making it from new material.

Crushing: When you finish a can of soft drink you might crush the can before throwing it away.

Mixing: When you throw the can in the rubbish bin it is mixed with all the other materials, creating a mixture of garbage.

Separation: Before the aluminium cans can be recycled, they must be separated out of the garbage and cleaned.

Shredding: Once cleaned, the aluminium cans are shredded into tiny pieces.



Melting: The aluminium pieces are melted into liquid aluminium, which is then poured into moulds.

Solidification: The liquid aluminium is allowed to cool and solidify, forming blocks of pure aluminium, known as ingots.

Processing: The ingots can then be processed into any aluminium product, including more aluminium cans to start the process all over again.

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AB 7.3

REVIEW

1. List the steps involved in recycling aluminium.
2. Explain how you know that recycling is a series of physical changes and not chemical changes.
3. Identify two physical changes in the recycling of aluminium that involve changes of state.

MODULE 7.1

Review questions

Remembering

1 Define the terms:
- **a** change of state
- **b** physical change
- **c** chemical change
- **d** precipitate.

2 What term best describes each of the following?
- **a** A solid is heated to form a liquid.
- **b** A gas cools to form a liquid.
- **c** A solute mixes with a solvent and seems to disappear.

3 List four examples of physical changes.

4 List four signs of a chemical change.

5 State which type of change:
- **a** is easily reversible
- **b** produces new substances.

6 What is the reverse process for each of the following changes of state?
- **a** condensation
- **b** freezing.

7 What are the two components of a solution?

Understanding

8 Mix red and yellow paints and you get orange paint. Explain why this is a physical change even though there is a colour change.

9 Explain how perspiring helps to keep you cool on a hot day.

Applying

10 Identify three examples of both physical and chemical changes you might observe in the home.

11 When a solute is dissolved in a solvent, the solute particles are distributed evenly through the solvent. Identify which of the following diagrams in Figure 7.1.14 best represents what happens when the particles of the blue solute are dissolved in a beaker of water.

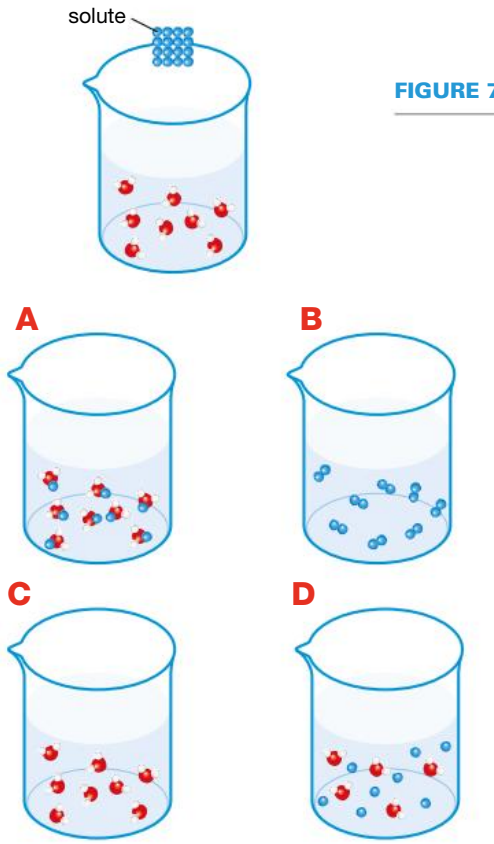


FIGURE 7.1.14

Analysing

12 Classify the following as a physical or chemical change.
- **a** A banana goes black after a few days.
- **b** Strawberries are blended with milk to make a smoothie.
- **c** Wet clothes dry on the clothesline.
- **d** Spilt petrol explodes.
- **e** Steel roofing expands on a hot day.
- **f** Water boils on the stove.
- **g** A sausage is cooked on the barbeque.

13 A recipe for a banana cake instructs you to carry out the following steps. Classify each step as a physical or chemical change.
- **a** mash a banana
- **b** melt butter
- **c** mix sugar and eggs into butter
- **d** bake for 40 minutes
- **e** whip cream for topping.

MODULE 7.1

Review questions

Evaluating

14 You are performing a chemical reaction and notice condensation on the outside of the test-tube.

- **a** Do you think the reaction absorbed or released heat?
- **b** Justify your answer.

15 Terry spilt some lemon juice on his homework. When he tried to dry it with a hair dryer, the pages quickly turned brown.

- **a** Classify the change that Terry observed as a physical or chemical change.
- **b** Justify your answer.

16 Jo says that an aspirin fizzing and dissolving in water is a physical change (Figure 7.1.15). Joe says that it is a chemical change. Discuss whether Jo or Joe is right, or whether they might both be right.

FIGURE 7.1.15

17 How could you reverse the following physical changes?

- **a** Sand is mixed with water.
- **b** Salt is dissolved in water.
- **c** Iron filings are mixed with sand.

18 Draw a table with the following words and define each of the words. Then give an example of materials that can be affected by each of these words.

- **a** rot
- **b** crush
- **c** burn
- **d** freeze
- **e** stretch
- **f** decompose
- **g** mix
- **h** rust
- **i** explode
- **j** compress.

MODULE 7.1

Practical investigations

1 • Expansion and heat

Questioning & Predicting | Evaluating

Purpose

To observe how changing temperature affects the air inside a balloon.

Hypothesis

What do you think will happen to a balloon as the air inside it cools—will it expand or contract? Before you go any further with this investigation, write a hypothesis in your workbook.

Timing 15 minutes

Materials

- hot tap water
- tray of cold water

- glass bottle
- balloon

Procedure

1. Fill the glass bottle with hot tap water.
2. Pour out the hot water and quickly stretch a balloon over the mouth of the bottle (Figure 7.1.16).
3. Place the bottle in a tray of cool water and observe what happens.

Results

Construct a series of diagrams showing what happened.

Review

1 a Is this a chemical or physical change?
b Justify your answer.

2 Use the terms *expand* and *contract* to describe your observations.

3 Use the particle model to describe what is happening inside the balloon.

4 a Construct a conclusion for your investigation.
b Assess whether your hypothesis was supported or not.

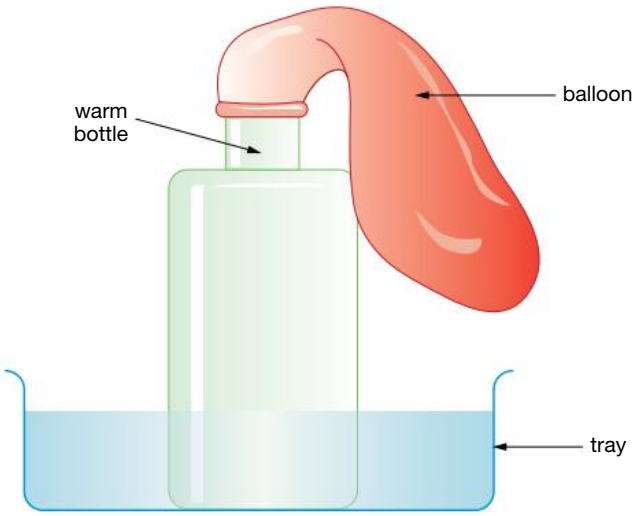


FIGURE 7.1.16

2 • A precipitation reaction

Planning & Conducting

Purpose

To observe the precipitation of barium sulfate.

SAFETY

All chemicals should be treated as toxic, so wear gloves and safety glasses at all times and avoid contact with skin, eyes and mouth.

Timing 15 minutes

Materials

- barium hydroxide ($Ba(OH)_2$) solution
- magnesium sulfate ($MgSO_4$) solution

- large test-tube
- 2 droppers

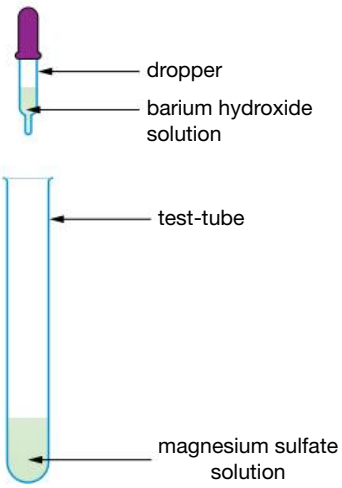


FIGURE 7.1.17

continued over page

Procedure

1. Using a dropper, add about 2 cm of barium hydroxide to the test-tube.
2. Using the second dropper, add about 2 cm of magnesium sulfate solution.
3. Dispose of residues as directed by teacher.

Results

Record your observations.

Review

1. Define the term *precipitate*.
2. What does the formation of a precipitate indicate?
3. What indicated that a chemical reaction took place in this experiment?

3 • Making recycled paper

Planning & Conducting

Purpose

To see how physical changes can be used to process materials into different shapes and different purposes.

Timing 45 minutes

Materials

- 4 sheets of newspaper
- warm water
- large bowl or bucket
- absorbent paper towels
- frame with fine mesh stretch across it and stapled in place
- deep tray larger than the frame
- blender (optional)

Procedure

FIGURE 7.1.18

1. Cut or shred the newspaper into small pieces.
2. Create a paper pulp either by placing the shredded paper and warm water in a blender and blending until finely chopped or by allowing the paper to soak in the large bowl overnight and mashing it by hand.

FIGURE 7.1.19

3. Place the frame and mesh in the tray with the mesh at the bottom.
4. Pour the paper pulp into the tray.
5. Gently lift out the frame and allow the water to drain. Ensure that the mesh is covered evenly by the paper pulp.

FIGURE 7.1.20

6. Place the frame on some paper towel to absorb excess water.
7. Leave in a warm sunny place to dry.

FIGURE 7.1.21

8. Remove the paper from the frame.

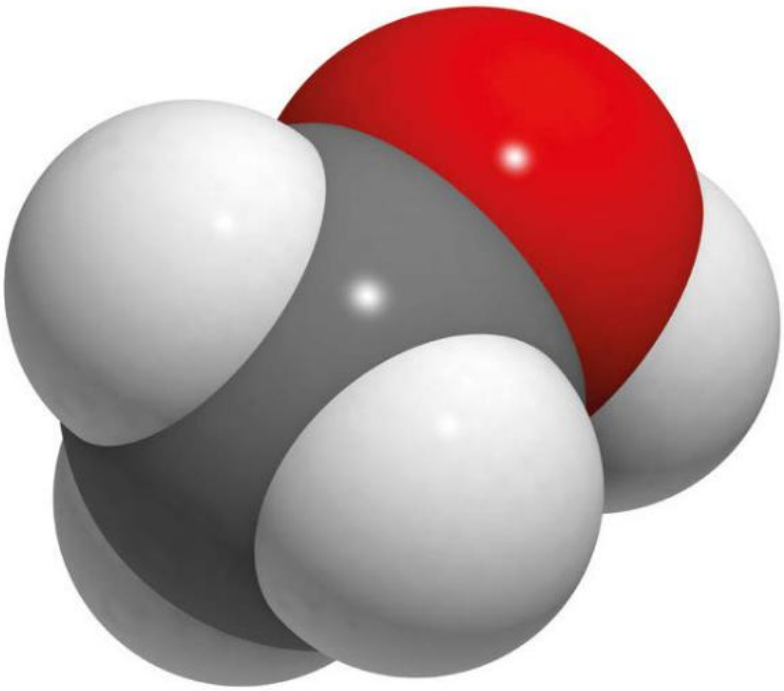
Review

1. List all the physical changes that occurred during the recycling process.
2. Describe how the paper you made was different from the paper you started with.
3. a. Assess whether this is an efficient method for recycling paper.
   b. Justify your answer.

MODULE 7.2

Understanding physical change

Physical changes occur when something happens to the particles making up a substance. These particles are invisible to the eye and cannot even be seen through the most powerful optical microscopes. Therefore, to understand physical change, scientists use models to help explain and understand their observations.



science 4 fun

Magic finger

Can you observe detergent molecules by indirect observation?

Collect this ...

- dinner plate
- ground pepper
- washing detergent
- water

Do this ...

1. Fill the dinner plate with water.
2. Cover the surface of the water evenly with ground pepper.
3. Place a small amount of detergent on the end of your finger and dip your finger in the plate of water.

Record this ...

1. Describe what happened to the pepper.
2. Explain what you think is happening to the detergent particles on your finger.

The particle model

Most physical changes can be understood by using the **particle model**. The particle model is a simplified representation of solids, liquids and gases. It can explain some but not all of their properties (Figure 7.2.1).

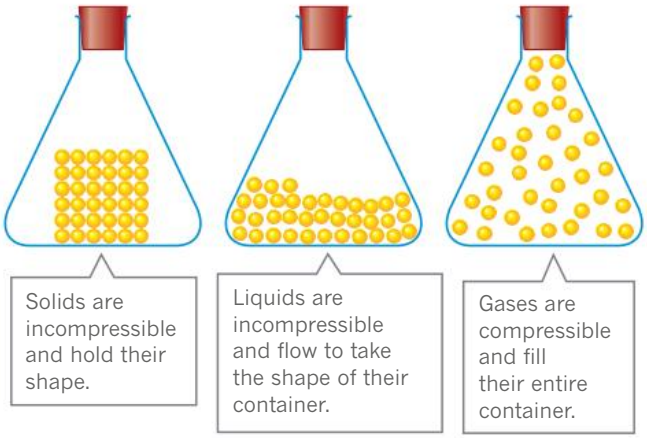


FIGURE 7.2.1 The physical properties of solids, liquids and gases can be explained by the particle model. In the particle model, we show particles as small spheres, even though they do not look like this.

Having a model of the structure of matter helps scientist to predict and explain the properties of matter. When matter behaves differently to what the model predicts, it provides clues about how the model can be improved.

The particles that make up solids, liquids and gases are too small to see with the naked eye, or with most microscopes, and so scientists have developed the particle model through indirect observation. This means that scientists use their observations about the behaviour of solids, liquids and gases to work out information about the particles that make up each state.

The particle model assumes that all matter is made up of invisible, ball-like particles that are:

- hard, incompressible (not able to be squashed) and indivisible (unable to be split)
- attracted to each other
- constantly moving.

Solids

In solids, the attraction between particles binds them tightly together. For this reason, solids are incompressible and hold their shape. Although the particles in solids are fixed in position, they vibrate on the spot. These vibrations increase when the temperature increases.

Liquids

In liquids, the particles are packed tightly together, which makes liquids incompressible. However, the particles in a liquid are not stuck to each other as much as they are in solids. This gives liquids the ability to flow and take on the shape of their container. Particles in a liquid vibrate but can also move freely through the liquid.

Gases

In gases, the particles are not stuck to each other at all and there are large spaces between gas particles. For this reason, gases are highly compressible (able to be squashed). The particles are free to move anywhere within their container. The particles move in straight lines until they collide with another gas particle or the side of the container. This is why gases always fill their container.

Expansion and contraction

Expansion and contraction change the size of a substance. When a substance expands, its volume increases and the atoms are spread further apart. This means that the density of the object decreases. When a substance contracts, its volume decreases, the atoms become packed more closely together and the substance becomes more dense.

The physical changes of expansion and contraction can be understood by looking at how the motion of particles changes with temperature. In solids, the particles vibrate in fixed positions. As the temperature increases, the particles vibrate more. The vibrations push the particles further apart and cause the solid to expand (get larger). This expansion is shown in Figure 7.2.2. When the solid is cooled, the reverse happens. The particles vibrate less, allowing them to be packed more tightly and the solid contracts (shrinks).

When a liquid is heated, the particles vibrate more energetically, so the liquid expands. When a liquid is cooled, the particles reduce their vibrations and the liquid contracts. However, in liquids the particles are free to move, so liquids tend to expand and contract more than solids.

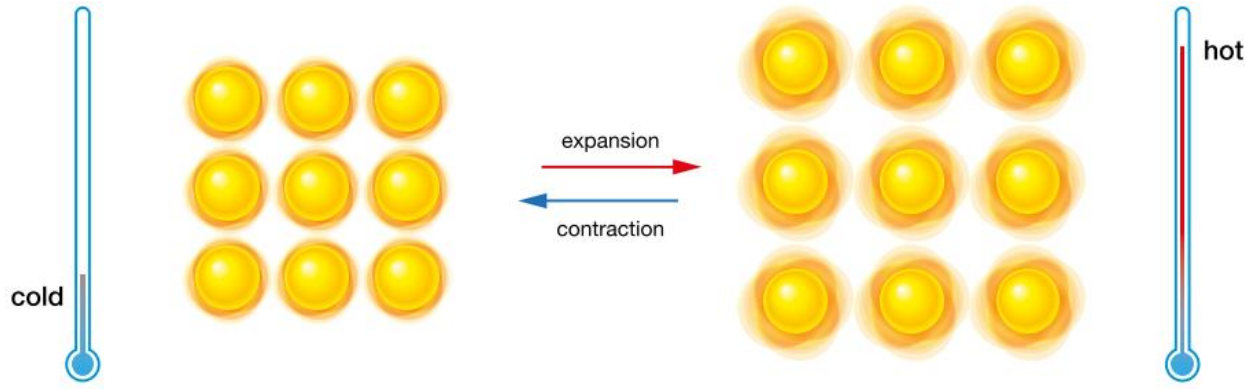


FIGURE 7.2.2 Increasing temperature causes the particles in solids and liquids to vibrate more. As a result, solids and liquids expand with increasing temperature.

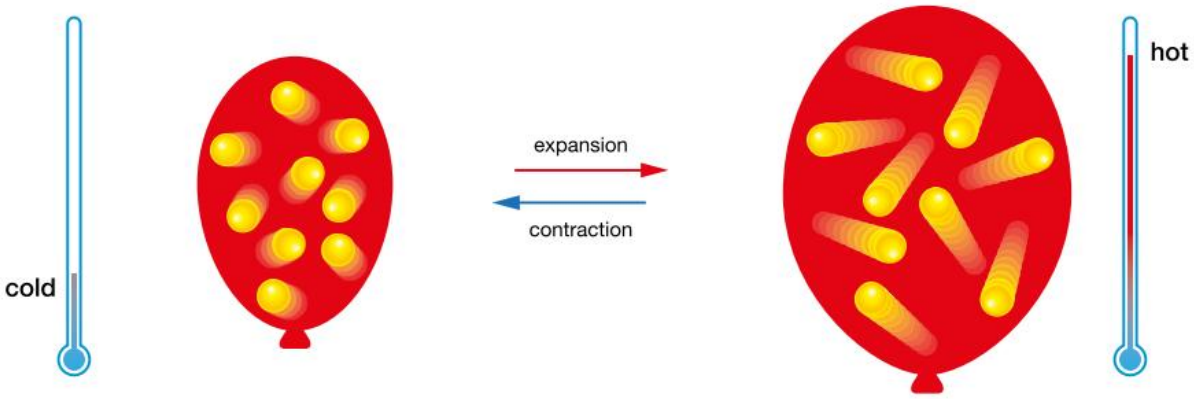


FIGURE 7.2.3 When the temperature of a gas is increased, the particles travel faster, hitting the sides of their container more frequently and with more force. This causes a balloon to expand.

Gases will always expand or contract to fill their container. However, as the temperature of a gas is increased, the particles travel faster. This means they hit the sides of their container more frequently and with more force. If the container is flexible, then increasing the temperature of the gas will cause the balloon to expand. This is what is keeping the balloon in Figure 7.2.3 inflated.

The reverse is also true. If a gas is cooled, then the particles travel more slowly and hit the sides of their container less frequently and with less force. If the gas is cooled in a flexible container, then the container will contract.

AB 7.4
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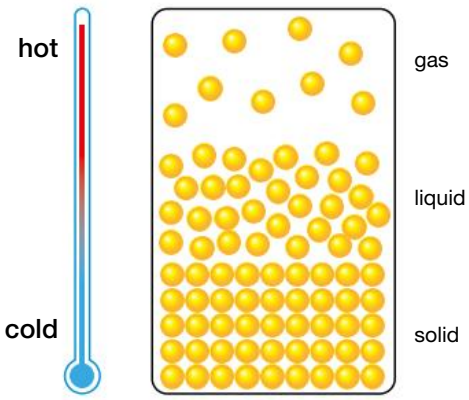

FIGURE 7.2.4 When a solid is heated to a high enough temperature, the particles break apart to form a liquid. When a liquid is heated, the particles fly off to form a gas.

Changes of state and the particle model

The particle model explains changes of state by looking at the relationship between how the particles move and the attraction between the particles (Figure 7.2.4).

Melting

In a solid, the particles vibrate but are held in position by the forces of attraction between them. As the temperature increases, the vibrations increase and the solid expands. As the temperature increases further, the solid melts. This is because the vibrations become so energetic that the attraction between the particles can no longer hold the particles in fixed positions. At this point, the particles become unstuck and start moving freely. However, there is still a small amount of attraction between the particles that holds them together as a liquid.

Freezing

Freezing is the opposite of melting. As the free-moving particles in the liquid are cooled, they slow and become less energetic. Eventually, the particles are moving so slowly that the attraction between the particles is able to hold them in position and a solid is formed.

Evaporation

Evaporation occurs when particles in a liquid escape from the surface of the liquid to form a gas. The particles in a liquid are stuck together but only weakly. As the liquid particles are heated, they move faster until some are able to break free from the other particles at the surface of the liquid. The escaped particles have formed a gas. They have evaporated. At the boiling point, the particles within the liquid are moving so fast that they fly apart and form bubbles within the liquid.

Condensation

Condensation occurs when a gas is cooled. As the temperature falls, the particles of gas move more slowly, until the forces of attraction between the particles stick them together. When the particles stick together, they form a liquid. Condensation converts gases into liquids and is therefore the reverse of evaporation.

Mixing

A mixture is formed when two or more substances are mixed together. A mixture of sand and iron filings is an example of a mixture that you can see. However, substances can also mix on the particle level to form solutions and alloys. Mixing can also be understood through the particle model.

Solutions and the particle model

Solutions are an example of a mixture. When a solute dissolves, the solvent particles surround the solute particles and carry them away. You can see this in Figure 7.2.5. As a result, the solute seems to disappear. However, the solute particles are not destroyed. They are simply spread so thinly throughout the solvent that they seem invisible. The individual solute particles are so small that they cannot be seen, with even the most powerful optical microscope.

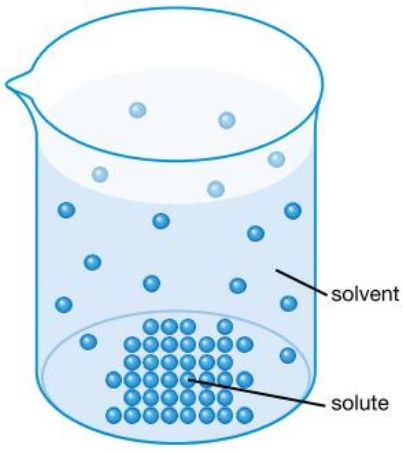

FIGURE 7.2.5
When a solute dissolves, its particles are spread evenly through the solvent. The particles are so small that they are invisible, even with the most powerful optical microscope.

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p. 306

Diffusion and the particle model

When two liquids are mixed together, their particles will diffuse and mix evenly without stirring. The same thing happens if two gases are mixed together. This process is known as **diffusion**. For example, when a bottle of perfume is opened on one side of a room, the perfume particles will diffuse through the air particles. That is why you soon smell the perfume on the other side of the room.

During diffusion, gas particles travel in a zig-zag fashion. This is shown in Figure 7.2.6. Each particle moves in a straight line until it collides with another particle and then changes direction. However, eventually the particles will be distributed evenly throughout the space as diffusion is the movement of particles from an area of high concentration, to an area of low concentration. Increasing the temperature speeds up diffusion because the particles will travel faster.

FIGURE 7.2.6
The perfume particle makes its way across the room in a zig-zag fashion, travelling in straight lines but changing direction whenever it collides with a particle in air.

Diffusion is even faster if there is a gust of wind or movements in the air caused by differences in temperature. Even when you move or exhale, you can send air particles flying across the room, making them diffuse faster through it.

Diffusion in liquids occurs less rapidly because the liquid particles are packed closer together. However, the liquids will ultimately spread evenly through one another.

AB 7.5
AB 7.6
Prac 2
p. 305

Discovering the particle nature of matter

Substances haven't always been studied in scientific laboratories. Before the 1700s, the study of substances was known as alchemy and was surrounded by magic and mystery.

However, as people developed scientific methods and new technologies, their understanding of the particles that make up matter improved. This understanding has led to new scientific models and the ability to control matter at the particle level.

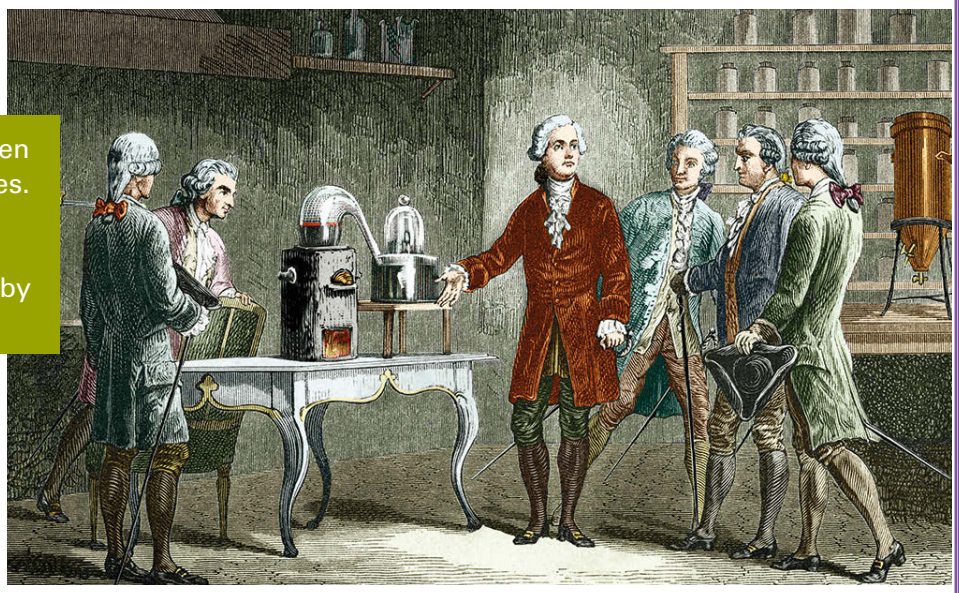


FIGURE 7.2.7 Lavoisier shows his experiments using oxygen to other members of the scientific community.

Scientific method

Modern chemistry began in the 1700s. During this century, much of the magic associated with the study of substances was replaced by scientific method and analysis. This led to a deeper understanding of the particle nature of matter and the discovery of all known elements.

For example, in the late 1700s, people believed that burning something such as wood or paper released a substance called *phlogiston*. However, chemists Joseph Priestley (1733–1804) and Carl Wilhelm Scheele (1742–1786) used the scientific method to show that when substances burn, they combine with a substance in air. Through their research, Priestly and Scheele independently discovered the element oxygen in 1772. Their work was also confirmed through experiments by Antoine Laurent Lavoisier (1743–1794), who is considered a father of modern chemistry. Lavoisier and his experiment are shown in Figure 7.2.7.

The particle nature of elements

It wasn't until 1803 that chemist John Dalton (1766–1844) first proposed his atomic theory of matter. Dalton's theory correctly predicted that:

- elements are made up of tiny particles (atoms)
- each element is made up of a different type of particle
- the particles that make up an element are identical.

In 1827, botanist Robert Brown (1773–1858) observed direct evidence of the particle nature of matter using the microscope. Brown noticed that small grains of pollen sitting on the surface of water are constantly moving randomly on the surface. He concluded that the movement of the pollen was due to the motion of invisible water particles.

Dalton's atomic theory of matter also predicted that compounds are made up of combinations of the same particles that make up elements. This meant that scientists could discover new elements by breaking down compounds into their simplest parts. For example, by heating some metal ores, scientists could extract the pure metal, as shown in Figure 7.2.8 on page 302. As a result, most of the naturally occurring elements had been discovered by the 1800s and early 1900s.

FIGURE 7.2.8 Heating the black copper(II) oxide compound in this test-tube breaks it into the elements that make it up: copper metal and oxygen gas.

Synthetic elements

Francium was the last element to be discovered in natural compounds, in 1939. However, by this time scientists were able to create new elements in the laboratory. These elements are known as synthetic elements.

To create synthetic elements, scientists used a cyclotron, like the one in Figure 7.2.9. A cyclotron bombards particles of one element with particles of another element travelling at extremely high speeds. If the particles fuse together, then a new element may be formed. In 2016, scientists reached a new milestone by creating the last four elements on the periodic table. These four elements had been predicted to exist but until then, no-one knew if they could be created.

REVIEW

1. State the two models that have helped scientists understand the particle nature of matter.
2. Name the last element to be discovered in nature, and the year it was discovered.
3. What technology was used by Robert Brown to confirm the particle nature of matter?
4. Create a timeline of the important discoveries that have helped scientists develop their understanding of the particle nature of matter.

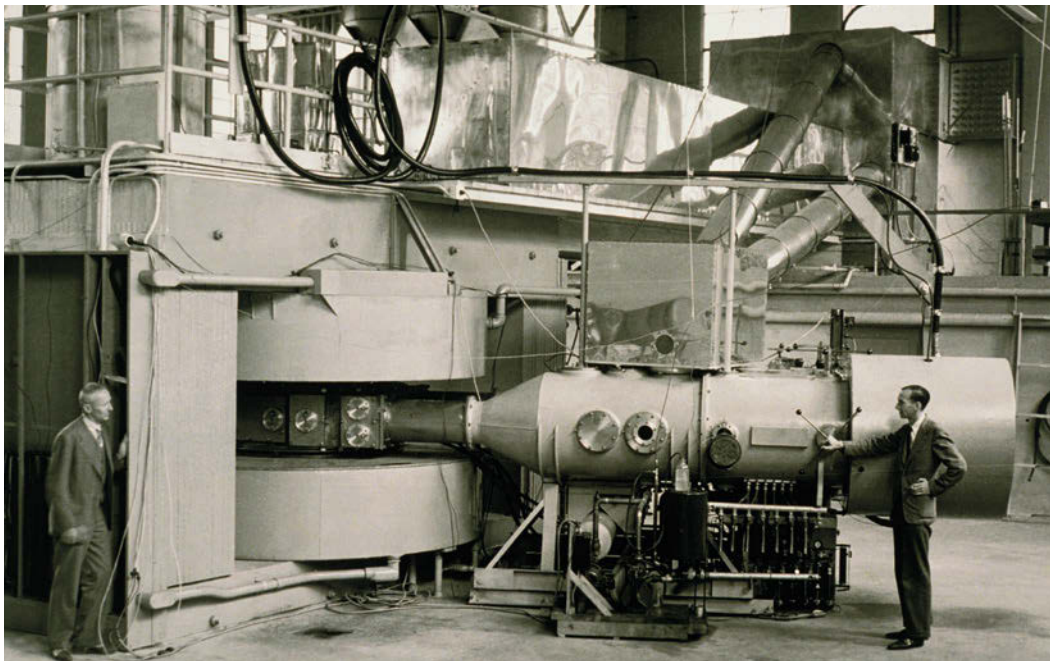


FIGURE 7.2.9 Ernest Lawrence, nuclear scientist and winner of the Nobel Prize in Physics in 1939 for his invention, the cyclotron.

MODULE 7.2

Review questions

Remembering

1 Define the following terms:
- **a** solution
- **b** diffusion
- **c** compressible
- **d** incompressible.

2 What term best describes each of the following?
- **a** when a substance increases in size
- **b** a substance in which the particles are closely packed but free to move
- **c** gas particles moving through air due to random motion.

3 List the changes that occur when the temperature of a gas inside a balloon is increased.

4 What is the reverse process for each of the following physical changes?
- **a** expansion
- **b** melting
- **c** evaporation.

5 List the assumptions made by the particle model.

Understanding

6 Describe the arrangements of particles in solids, liquids and gases.

7 Outline how the particle model explains expansion and contraction.

8 Explain why you can smell something that is burning on the other side of the room.

9 Describe what happens to the particles in a solid as it is heated up to its melting point.

10 Why does a solid seems to disappear when dissolved into a liquid?

Applying

11 The liquid in a thermometer rises as the temperature increases. Use the particle model to explain why.

12 Use the particle model to explain why your bike tyres may seem deflated on a cold day.

Analysing

13 Compare:
- **a** solute and solvent
- **b** dissolving and diffusion.

14 Compare the properties of solids, liquids and gases by copying and completing the following table.

	Solid	Liquid	Gas
shape	fixed		
compressibility	very low		
strength of attraction between particles		weak	
movement of particles		medium	
space between particles			a large amount

Evaluating

15 Propose reasons why the smell of a scented candle spreads quickly through a room while the candle is burning but not when the candle is unlit.

16 When pepper is sprinkled over a pool of water, it spreads across the surface evenly. However, when a drop of detergent is put into the middle of the pool, the pepper is pushed to the edges of the pool. Use the particle model to propose a reason why.

17 Terry puts a glass of water on a scale and finds that it has a mass of 345 g. He then dissolves two teaspoons of sugar so that the sugar seems to completely disappear.
- **a** Predict whether the mass of the glass of water will increase, decrease or stay the same.
- **b** Justify your answer.

FIGURE 7.2.10

Creating

18 Construct a short story from the perspective of a particle in a solid that is being heated. Describe what happens to you as the solid changes to a liquid and then to a gas.

MODULE 7.2

Practical investigations

1 • A model thermometer

Planning & Conducting | Evaluating

Purpose

To construct a model thermometer that uses the expansion of gases to measure temperature.

Timing 45 minutes

Materials

- water
- food dye
- ice cube
- conical flask
- rubber stopper with single hole
- glass tubing
- retort stand
- 2 bossheads and 2 clamps
- clear plastic tubing
- rubber gloves

SAFETY

Food dye can stain your clothing or skin, so wear rubber gloves.

Procedure

1. Build the model thermometer shown in Figure 7.2.11.
2. When you have built your thermometer, wrap your hands gently around the flask to warm it. Observe what happens to the water in the plastic tubing.
3. Place an ice cube on top of the flask to cool it. Again, observe what happens.

Results

Record what happened to the liquid in the tube in both cases.

Review

1. Define the terms *expansion* and *contraction*.
2. Explain why liquid rises in a thermometer when the temperature goes up, and why the liquid drops when the temperature drops.
3. Explain how this model thermometer could be used to measure temperature.

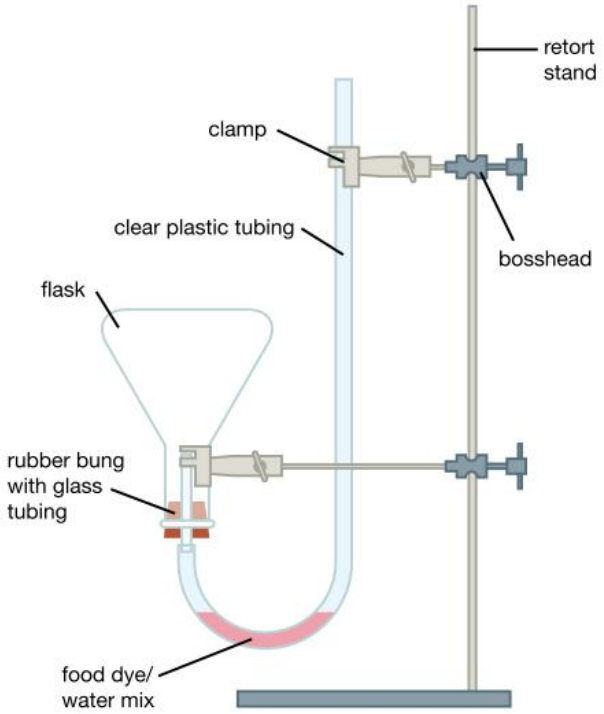


FIGURE 7.2.11

FIGURE 7.2.12 Medical thermometers like this one depend on the expansion and contraction of liquid mercury or red-coloured alcohol to measure temperature.

MODULE 7.2

Practical investigations

2 • Rate of diffusion

Questioning & Predicting | Processing & Analysing

Purpose

To test whether the rate of diffusion changes with temperature.

Hypothesis

What do you think will happen to the rate of diffusion as temperature increases—will the rate increase or decrease? Before you go any further with this investigation, write a hypothesis in your workbook.

Timing 30 minutes

Materials

- hot and cold water
- food colouring
- shallow tray
- overhead transparency with a grid of 2 cm × 2 cm squares printed on it
- dropper
- stopwatch
- rubber gloves

SAFETY

Food colouring can stain, so wear rubber gloves and avoid contact with skin and clothing.

Procedure

This prac should be performed in pairs or small groups.

1. Copy the table from the Results section into your workbook.
2. Place the gridded transparency on the bottom of the shallow tray as shown in Figure 7.2.13.
3. Fill the tray with cold water.
4. With one person measuring time on the stopwatch, place a drop of food colouring and estimate how many squares are coloured after 5, 10 and 20 seconds.
5. Repeat the experiment with hot water.

Results

Record all measurements in your Results table.

	Number of squares		
	After 5 s	After 10 s	After 20 s
cold water			
hot water			

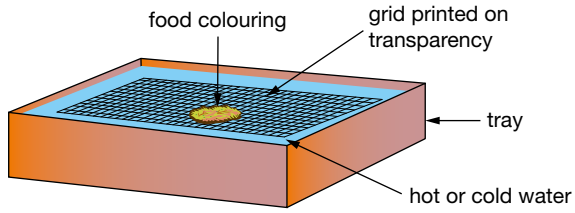


FIGURE 7.2.13

Review

1. **a** Name the process that allows the food colouring to move through the water.
   b State whether this is a physical or chemical change.
2. Compare your observations for cold and hot water.
3. Explain your results in terms of the particle model.
4. **a** Construct a conclusion for your investigation.
   b Assess whether your hypothesis was supported or not.

SciFile

Deadly diffusion

The process of liquid diffusion helps sharks track their prey. The blood from an injured animal diffuses through the water and can be detected by sharks several kilometres away due to their extremely powerful sense of smell.

MODULE 7.2

Practical investigations

3 • Temperature of water and solubility

Questioning & Predicting | Evaluating

Purpose

To investigate how water temperature influences how much solute can be dissolved.

Hypothesis

What do you think will happen as water temperature increases—will you be able to dissolve more or less solute in it? Before you go any further with this investigation, write a hypothesis in your workbook.

Timing 60 minutes

Materials

- as selected by students

SAFETY

A Risk Assessment is required for this investigation.

Procedure

1. The amount of solute that can be dissolved in a certain amount of water depends on the temperature of the water. Design an investigation to test how the temperature of water affects how much solute can be dissolved.
2. Brainstorm in your group and come up with several different ways to investigate the problem. Select the best procedure and write it in your workbook. Draw a diagram of the equipment you need.
3. Before you start any practical work, assess your procedure. List any risks that your procedure might involve and what you might do to minimise those risks. Show your teacher your procedure and your assessment of its risk. If your teacher approves, then collect all the required materials and begin your investigation.

Hints

- Choose a solute that can be obtained easily and is easy to dissolve, such as salt or sugar.
- Avoid using large amounts of solute and only use a small amount of solvent.
- Consider how you will change the temperature of the water and measure the water's temperature.
- Consider how you will measure how much solute has dissolved, and how you will determine accurately when no more solute can dissolve at a certain temperature.
- Consider how you will record and display your results.

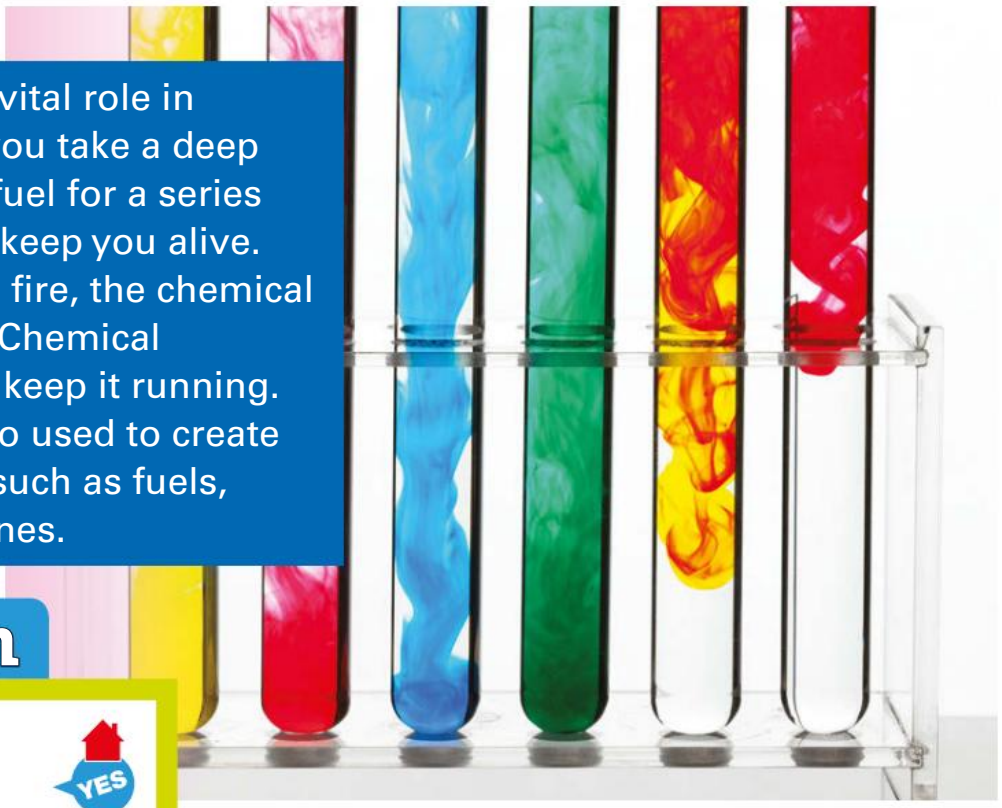
Review

1. Describe how the amount of dissolved solute changes as the temperature of water increases.
2. a. Construct a conclusion for your investigation.
   b. Assess whether your hypothesis was supported or not.
3. Discuss how your procedure could be made more accurate if you did it again, or if you had different equipment or more time.
4. Compare your results with others in the class and explain the differences and similarities.
5. Use your results to predict how much solute will dissolve at 80°C and at 10°C.

MODULE 7.3

Chemical reactions

Chemical reactions play a vital role in your everyday life. When you take a deep breath, you are providing fuel for a series of chemical reactions that keep you alive. When you place a log on a fire, the chemical reactions keep you warm. Chemical reactions in a car's engine keep it running. Chemical reactions are also used to create new and useful materials such as fuels, plastics, foods and medicines.



science 4 fun

Milk putty

YES

Can you create putty using just milk and vinegar?

Collect this ...

- 1 mug of milk
- white vinegar
- teaspoon
- sieve
- access to a microwave oven

SAFETY

Be careful with hot milk. It can cause serious burns if it comes in contact with your skin.

Do this ...

1. Warm the mug of milk in the microwave so that it is hot but does not boil (about 60–90 seconds in most microwaves).
2. Carefully remove the mug of milk from the microwave and then add about 1 tablespoon of white vinegar to the mug.
3. Stir quickly with a teaspoon.
4. Pour the contents of the mug into the sieve over a sink and let it strain and cool for 2 minutes.
5. When it is dry and cool enough to touch, take out the solid from the sieve and mould it with your hands into putty.

Record this ...

1. Describe your observations.
2. Explain what happened.

Understanding chemical change

The key difference between a physical change and a chemical change is that new substances are produced during a chemical change. You can usually determine that new substances have been produced by observing one or more of the following:

- a permanent colour change occurs
- a gas is given off
- a solid precipitates (falls) out of a solution
- a change in temperature happens or light is produced.

These observations are only indicators, because there are exceptions to all of them. In each case, there are examples of physical changes that cause the same observations. Also, some chemical changes might not show any of these effects. For these reasons, the only way to truly know if a chemical change has taken place is to understand what has happened to the particles before and after the change.

Prac 1 p. 317

Why are substances different?

There are billions of substances that make up the universe, and each substance is special in its own way. The unique set of characteristics of each substance is known as its **properties**. The properties of a substance are determined by the types of atoms it contains and how those atoms are arranged. Take graphite and diamond, for example. Both of these substances are made from carbon atoms and so both are different forms of the element carbon. However, graphite is a grey, brittle substance that conducts electricity, while diamond is a clear, very hard substance that is an electrical insulator. The reason for the different properties is that the carbon atoms in the two substances are arranged differently.

Particles can be arranged differently in compounds too. Compounds made from the same types of atoms can have very different properties if these atoms are arranged differently. For example, water and hydrogen peroxide are both made up of hydrogen and oxygen atoms. The molecules for these two compounds are shown in Figure 7.3.1.

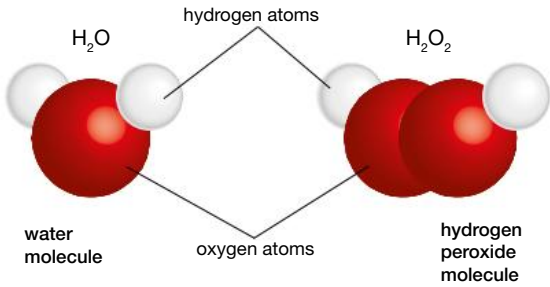


FIGURE 7.3.1 Water and hydrogen peroxide (bleach) molecules are similar—both are made of oxygen and hydrogen atoms. Despite having similar molecules, these two compounds have very different properties.

A water molecule has two hydrogen atoms and one oxygen atom, and so it has the chemical formula H_2O. A hydrogen peroxide molecule has two hydrogen atoms and two oxygen atoms, and so it has the chemical formula H_2O_2. Despite water and hydrogen peroxide having very similar molecules, water is safe for drinking, bathing and washing, whereas hydrogen peroxide is a type of bleach that will burn your eyes, skin and hair and reacts explosively with some metals.

Chemical reactions

During a chemical change, old substances disappear and new substances form. The only way this can occur is if the atoms in the old substances rearrange to form the new substances during the change.

The process of rearranging atoms to form new substances is known as a **chemical reaction**. In a chemical reaction:

- the old substances are known as the **reactants**.
- the new substances that form are referred to as the **products**.

This is shown in Figure 7.3.2.

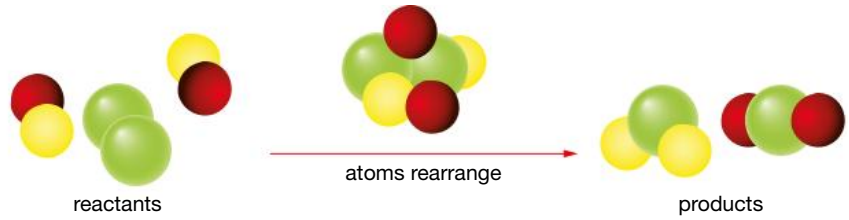


FIGURE 7.3.2 During a chemical reaction, new substances are formed because the atoms in the reactants rearrange to form the products.

Examples of chemical reactions

Every day there are thousands of chemical reactions going on around and even inside you. These chemical reactions play an important role in industry, medicine, your home, the environment and your body.

An example of a simple chemical reaction is the reaction that occurs when magnesium is burnt in air. In this reaction, magnesium metal (Mg) and oxygen gas (O_2) are the reactants (the substances reacting). Magnesium is a light and soft, silver-grey metal and when it burns in oxygen gas it produces large amounts of light and heat. At the end of the chemical reaction, the magnesium metal has gone but a light grey, non-metallic powder has formed in its place. This is a new substance called magnesium oxide (MgO). Magnesium oxide is the product of the reaction.

The word equation for this reaction is:

magnesium + oxygen → magnesium oxide

SkillBuilder

Word equations

Chemists usually don't use detailed descriptions or diagrams to describe what is happening in a chemical reaction. Instead they use a shorthand description known as a chemical equation. The simplest chemical equation is a **word equation**. A word equation lists the reactants taking part in the reaction and the products that form. All chemical equations are written in the form:

reactants → products

The arrow indicates that a chemical change has taken place.

Worked example

Word equations

Problem

Identify the reactants and products in the word equation:

sodium + water → sodium hydroxide + hydrogen

Solution

Thinking: Identify the reactants by listing the substances to the left of the arrow.

Working: Reactants: sodium, water

Thinking: Identify the products by listing the substances to the right of the arrow.

Working: sodium hydroxide, hydrogen

Try yourself

Identify the reactants and product(s) in the following word equations.

a hydrogen + chlorine → hydrogen chloride

b glucose + oxygen → carbon dioxide + water vapour

We can be sure that this reaction is a chemical change, because heat and light are produced and the resulting magnesium oxide looks very different to the original magnesium metal. However, you can also examine what happens to the atoms during this chemical reaction. Figure 7.3.3 shows how the atoms are arranged before and after the chemical reaction. Before the reaction, there is a crystal lattice of magnesium atoms surrounded by oxygen molecules. After the reaction, the oxygen atoms have been added into the magnesium lattice. A new substance has formed—magnesium oxide.

Now consider a chemical reaction between hydrogen (H_2) and chlorine (Cl_2). When hydrogen and chlorine gas are heated together, they react to produce a different substance—hydrogen chloride (HCl).

Figure 7.3.4 shows a diagram of the hydrogen and chlorine molecules before the chemical reaction and how the atoms are arranged after the chemical reaction. After the reaction, individual hydrogen and chlorine atoms have paired up to create the molecules of hydrogen chloride.

The word equation for this reaction is:

hydrogen + chlorine → hydrogen chloride

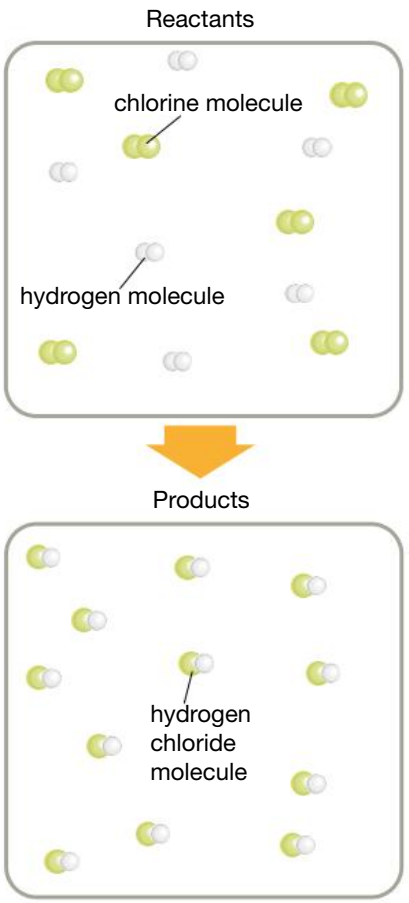


FIGURE 7.3.4 During the chemical reaction between chlorine and hydrogen, the atoms in the chlorine and hydrogen molecules rearrange to form hydrogen chloride molecules.

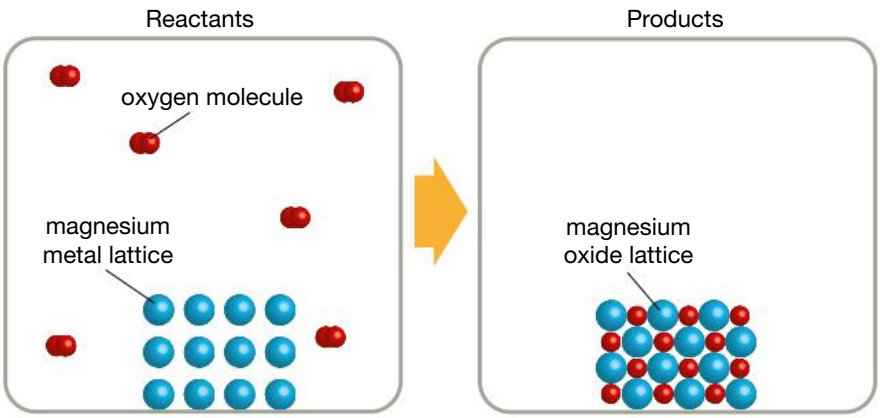


FIGURE 7.3.3 During the chemical reaction between magnesium metal and oxygen gas, the atoms on the magnesium metal lattice and the oxygen molecules rearrange to form a compound—magnesium oxide. This is a completely different substance.

In a chemical change, particles rearrange to form new substances. This is very different from what happens in a physical change. Figure 7.3.5 shows what happens to the water molecules during evaporation. Before evaporating, the water molecules stick closely together, moving over and around each other. Afterwards, the water molecules float around as gaseous water vapour. Although liquid water, ice and water vapour appear to be very different, they are made up of exactly the same particles. The atoms haven't rearranged and so no chemical change has occurred. This shows instead that evaporation is a physical change.

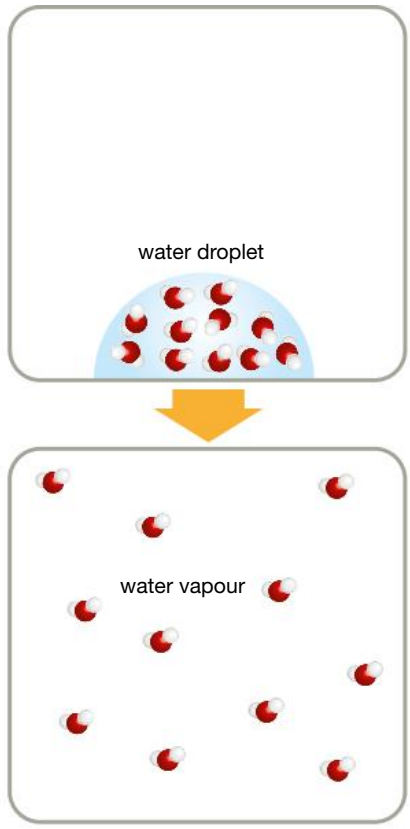


FIGURE 7.3.5 When water evaporates, the water molecules break away from the liquid to form a gas. The atoms do not rearrange to form different molecules, so evaporation is a physical change.

AB 7.7

STEM 4 fun

Steel wool in copper sulfate solution

NO

PROBLEM

What happens when steel wool and copper sulfate solution react?

SUPPLIES

- steel wool, tongs, beaker, copper sulfate solution

PLAN AND DESIGN Design the solution. What information do you need to solve the problem? Draw a diagram. Make a list of materials you will need and steps you will take.

CREATE Follow your plan. Draw your solution to the problem.

IMPROVE What works? What doesn't? How do you know it solves the problem? What could work better? Modify your design to make it better. Test it out.

REFLECTION

1. What field of science did you work in? Are there other fields where this activity applies?
2. In what career do these activities connect?
3. If another student was to do this task, what advice would you give?

Combustion

Combustion is the term given to any chemical reaction that involves burning with oxygen to release light and heat. Sometimes combustion releases so much energy so quickly that an explosion occurs. An explosion happens when petrol is ignited. Likewise, when hydrogen (H_2) is heated with oxygen (O_2), they react explosively to produce water vapour (Figure 7.3.6). The word equation for this reaction is:

hydrogen + oxygen → water vapour

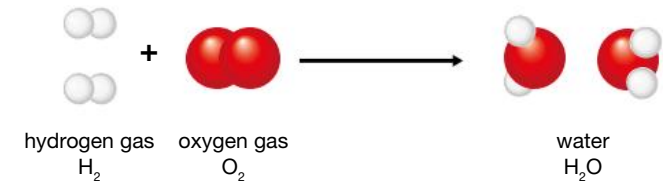


FIGURE 7.3.6 When hydrogen burns in oxygen, two hydrogen molecules react with one oxygen molecule to form two water molecules.

An example of combustion is shown in Figure 7.3.7.

FIGURE 7.3.7 Combustion happens whenever something burns in oxygen.

Even metals such as magnesium can undergo combustion. The most common examples of combustion are the burning of fuels such as petrol, natural gas, coal, wood and paper. For example, when you light a Bunsen burner, you are burning methane (CH_4). It reacts with oxygen (O_2) to form carbon dioxide (CO_2) and water vapour (H_2O). Figure 7.3.8 shows a combustion reaction.

methane + oxygen gas → carbon dioxide + water vapour

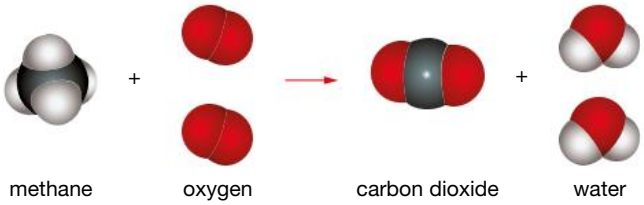


FIGURE 7.3.8 Methane and oxygen combustion reaction

Combustion allowed prehistoric humans to make light, cook, keep themselves warm and even defend themselves against predators. Combustion was a reaction that was useful and easily controlled. Throwing another log on the fire or fanning the fire added reactants to keep the reaction going. Starving the reaction of its fuel or oxygen would stop it and put the fire out. Since then, combustion has been central to the development of human civilisation, from extracting and forging metals during the Iron Age to running factories and steam engines during the Industrial Revolution. Today, we use combustion to heat and cook, run cars, buses, trains and aircraft, and to generate electricity in coal or gas power stations and diesel or petrol generators. Figure 7.3.9 shows how humans have used combustion since prehistoric times.

AB 7.8

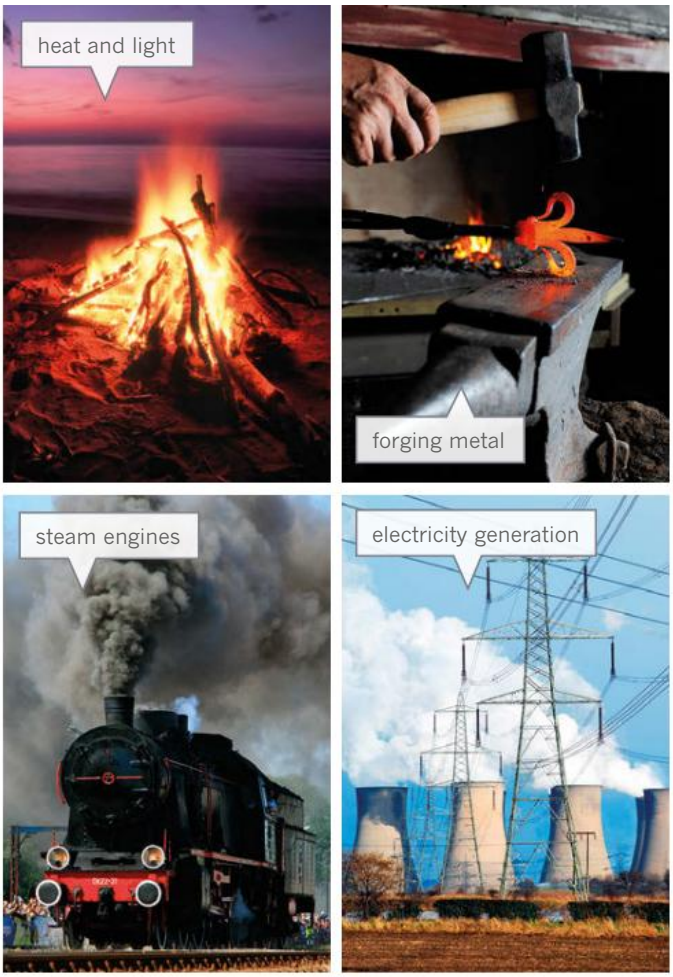


FIGURE 7.3.9 Combustion has been an important part of civilisation throughout human history.

Flammability

Flammability describes how easily a substance undergoes combustion (burns). Substances that don't burn are said to be non-flammable, while substances that burn easily are said to be flammable. Substances that ignite quickly or explosively might be considered highly flammable.

The flammability of a substance often affects how it is used. For example, fibreglass is non-flammable, and so it can be used in fire blankets and home insulation. Paraffin wax is flammable but it burns slowly. This is why it is used in candles. Petrol is highly flammable, making it perfect for motor vehicle engines. Hydrogen gas is extremely explosive and so it is used in engines that power rockets like the one in Figure 7.3.10 on page 312. Examples of flammable substances and their uses are shown in Table 7.3.1 on page 312.

Prac 2 p. 318

FIGURE 7.3.10 Hydrogen combusts so explosively that it has been used in some rockets as fuel. It has the added advantage of producing pure water when it combusts.

TABLE 7.3.1 Flammable substances and their uses

Flammable substance	Uses
hydrogen	rocket engines, some welding torches
natural gas	generation of electricity, domestic cooking and heating, fuels some cars and buses
acetylene	oxyacetylene welding torches
ethanol	motor vehicle fuel, added to petrol
butane	lighter fluid, added to petrol and liquid petroleum gas
petrol	fuel for car and bus engines
kerosene	portable stoves for camping and for cooking in some countries
diesel	heavy duty motor vehicles, truck engines, military vehicles
coal	generation of electricity
paraffin wax	candles

Photosynthesis

Millions of biological chemical reactions take place every day to help support life on Earth. One of the most important of these reactions is photosynthesis.

Photosynthesis is a series of chemical reactions that uses sunlight to convert water (H_2O) and carbon dioxide (CO_2) into oxygen (O_2) and a form of sugar called **glucose** ($C_6H_{12}O_6$). The word equation for photosynthesis can be summarised as:

carbon dioxide + water → oxygen + glucose

Photosynthesis occurs only in plants because the chemical reaction requires **chlorophyll**—the chemical that makes leaves green, like the leaves in Figure 7.3.11. Chlorophyll captures the sunlight that is required to start the chemical reaction. Plants obtain the carbon dioxide they need from the air and the water they need from the soil.

FIGURE 7.3.11 Green leaves contain chlorophyll, a chemical that collects energy from sunlight. This energy drives the chemical reaction of photosynthesis.

Plants use the glucose produced by photosynthesis as food, to provide them with energy to live and grow. Animals eat the plants, and this provides the animals with the energy they need to live and grow. Animals also eat each other as an energy source. However, in all cases, the energy can be traced back to the glucose produced in plants by photosynthesis.

SciFile

Taking a leaf out of nature's book

Scientists are researching ways of using solar energy to produce fuels using a process called artificial photosynthesis. This process takes water (H_2O) and carbon dioxide (CO_2) and converts them into fuels such as methane (CH_4). These fuels are known as solar fuels and could supplement or even replace fossil fuels in the future.

Respiration

The process of obtaining energy from food is known as **respiration**. Respiration involves a chemical reaction that converts oxygen and glucose into carbon dioxide and water vapour, while releasing energy. The word equation for respiration is:

glucose + oxygen → carbon dioxide + water vapour

If you compare this equation with the equation for photosynthesis on page 312, you will notice that the reactants of respiration are the products from photosynthesis; respiration is the reverse of photosynthesis. Respiration is a crucial chemical reaction that occurs in all living things because it provides the energy for them to live, grow, move and even think. When you take in a breath of air, you provide your body with the oxygen it needs for respiration. When you eat, you provide your body with the glucose it needs for respiration. The oxygen and glucose travel through your bloodstream to each cell, where respiration is going on constantly. The carbon dioxide that is produced is removed from your body when you breathe out, while the water is excreted through your breath, sweat and urine. When you exercise, you need more energy and so respiration has to take place more quickly. This is why you have to breathe more heavily, like the athletes in Figure 7.3.12. It is also why you might feel especially hungry after a lot of physical activity.

FIGURE 7.3.12 After a long race, athletes are exhausted because their bodies are starved of oxygen and glucose, so respiration becomes more and more difficult.

Corrosion

Corrosion is a chemical reaction that can cause damage to metals. For example, iron (Fe) and steel (an alloy of iron) have **chemical properties** that cause them to react slowly with water and the oxygen gas in air. The product is iron oxide (Fe_2O_3), commonly known as rust. The word equation for this reaction is:

iron + water + oxygen gas → iron oxide

Iron and steel are strong and relatively cheap, so they are commonly used to build cars and ships, nails and pins. They are also used for reinforcing concrete for everything from bridges to skyscrapers. Rust weakens and eventually destroys anything made of iron or steel. For this reason, iron and steel objects must be protected by a coating of paint or even oil. Galvanised iron is protected by a layer of the element zinc (Zn). The chemical properties of zinc cause the zinc to corrode faster than the iron and steel. Zinc corrodes before the iron does, even when the iron is exposed to the weather because of a scratch or dent. In this way zinc is sacrificed to save the iron. It is only after the zinc has all gone that the iron begins to rust. You can see this in Figure 7.3.13.

FIGURE 7.3.13 Galvanised iron is common in Australia. It starts to rust when its protective layer of zinc has corrode away.

AB 7.9

SciFile

Painting the bridge

The Sydney Harbour Bridge is a steel structure. Without its protective layer of paint, the bridge would have rusted badly since it was opened in 1932, making it unsafe. To stop this happening, the bridge was first painted with three coats of paint, totalling an amazing 270 000 litres! Since then, a permanent workforce of painters continually recoats the bridge with new paint!

Working with Science

FORENSIC SCIENTIST

Shari Forbes

Forensic scientists use scientific evidence to piece together events around crimes. This enables police to identify victims, understand the circumstances of the crime, identify suspects and present evidence in court. Scientists analyse and gather information from blood, other body fluids, bones, hair, clothing fibre and insects. The physical and chemical changes that corpses undergo also give scientists important clues about the time and place of death. The study of the decay and decomposition of human remains is called forensic taphonomy. This is the specialty of forensic chemist, Shari Forbes (Figure 7.3.14).

Professor Forbes is a researcher at the University of Technology Sydney, and through her research she works with police and fire and rescue organisations. Her research investigates the changes in odour that occur during decomposition, and she is working to identify the chemical profile of decomposition odour that will help train sniffer dogs to quickly locate crime scenes. She studied a Bachelor of Science in Applied Chemistry and Forensic Science and then completed a PhD in Forensic Chemistry.

FIGURE 7.3.14 Professor Shari Forbes studies the chemical decomposition of human remains. She is the lead researcher of Australia's first body farm, a facility that will improve forensic research and investigations in Australia.

Professor Forbes is also the lead researcher of a team that has recently set up Australia's first body farm (the Australian Facility for Taphonomic Experimental Research), just outside Sydney. Body farms are research sites where the decomposition process of human remains can be studied. The Australian facility will accommodate approximately 20 corpses per year that will be monitored by different forensic specialists from all over Australia. Before the Sydney body farm opened, forensic scientists in Australia used data from body farms in the USA. Because the climate, ecology and geology of Australia are very different, it is important to conduct this research in Australia, so that the data collected is relevant to the conditions of local crime scenes. This facility will be valuable to forensic investigations, giving police more accurate information to help them solve crimes quickly, and to help the families of victims of crime to find closure.

Review

1. Why do you think forensic research is important?
2. There are many specialisations within forensic science. These specialists often work together on investigations. Using the following table, can you match the type of forensic scientist to the type of evidence they use to solve crimes?

Type of forensic scientist	Forensic evidence
forensic archaeologist	plant material (e.g. leaves, pollen, seeds)
forensic botanist	digital media (e.g. website history, text messages)
forensic computer scientist	human remains and objects (e.g. jewellery)
forensic dentist	DNA and RNA
forensic entomologist	teeth, dental records and bite marks
forensic geneticist	mental health profiles, victim impact statements and criminal behaviour
forensic microbiologist	insects, arthropods and larvae
forensic psychologist	fur, feathers, tusks and leather
forensic toxicologist	microorganisms
forensic zoologist	drugs, gases and poisons

Turning the fashion industry green

The current trend for low-cost, ever-changing fashion is coming at an extremely high cost to the environment and the people working in the supply chain.

FIGURE 7.3.15 Waste water from textile factories is often heavily polluted with excess dyes and toxic chemicals used in treating and dyeing fabric.

After oil, the clothing industry is the second biggest polluter in the world, after oil. Cotton is grown using pesticides and herbicides, and synthetic fabrics like polyester and viscose are made from oil. The industry also uses toxic dyes and enormous amounts of water. Packaging and shipping of clothes also uses lots of resources. In addition to the environmental impacts, the people who make our clothes often do so in poor conditions, with minimal pay.

The process of dyeing fabric can be particularly bad for the environment, as it requires heavy use of water, energy and toxic synthetic dyes. Chemicals are needed to fix the dye to cotton fibres and the excess dye is then rinsed out, with 10–50% of the dye ending up in waterways, like the river in Figure 7.3.15. The waste water makes textile factories some of the most polluting of all industries, causing heavy pollution of nearby rivers with chemicals such as mercury, lead and formaldehyde (Figure 7.3.16).

Inspired to clean up the textile industry, companies are beginning to turn to more environmentally friendly and energy-efficient ways of colouring clothes. Three companies are leading the way with dye technology that minimises the use of water, toxic chemicals and energy: ColorZen, DyeCoo and AirDye.

- ColorZen uses special technology to pre-treat cotton so that it is more receptive to dyes at the molecular level. Because the dye is chemically bonded to the cotton fibre, no toxic chemicals are required and there is almost no dye excess, halving the amount of dye used.
- DyeCoo uses a dyeing process that replaces water with high-pressure CO_2. The CO_2 helps the dye to dissolve and bond easily to the fibres. Over 98% of the dye is taken up by the cotton, meaning there is almost no excess. No added chemicals are required, no water is used and the CO_2 is re-used.
- AirDye transfers dye on paper to textiles using heat to bond the dye to the fibres. This process also uses no water or added chemicals. AirDye also recycles the paper and any excess dye.

Some big brands, such as Nike and Adidas, are already moving to environmentally friendly dyes for their products. With further support from other fashion brands and consumers, environmentally friendly dyes could transform the fashion industry for the better.

REVIEW

1. List the problems traditional clothing industries cause.
2. Using environmentally friendly dyes is one way to reduce the environmental impact of the clothes we wear. In what other ways can the clothing supply chain be improved?

FIGURE 7.3.16 Using toxic dyes to colour fabrics impacts the environment.

MODULE 7.3

Review questions LS

Remembering

1 Define the terms:
- a reactant
- b combustion
- c corrosion
- d flammable.

2 What term best describes each of the following?
- a the substance(s) formed in a chemical reaction
- b the process plants use to convert carbon dioxide and water into food
- c the process our cells use to convert food into energy
- d the green substance needed for photosynthesis.

3 What is the key difference between a chemical change and a physical change?

4 Name the particles that make up all substances.

5 What is the chemical formula for:
- a water?
- b hydrogen peroxide?

6 List three substances that undergo combustion.

7 Name the substance that is produced when magnesium metal reacts with oxygen.

Understanding

8 Explain why a gas being produced is not always a sign that a chemical change has taken place.

9 Describe how you get the reactants you need to carry out respiration into your body.

10 Describe how coating an iron nail with zinc stops it from rusting.

Applying

11 Use word equations to explain why photosynthesis and respiration might be considered the reverse of each other.

12 Look at the STEM4fun activity on page 310 and consider what evidence you look for when suspecting a chemical change has occurred.

13 For each of the following indicators of a chemical change, identify an example of a physical change that might produce the same observation.
- a There is a permanent colour change.
- b A gas is produced.
- c A solid is formed out of a solution.
- d The temperature increases or decreases.

14 Identify the reactants and products in the following word equation.

methane + oxygen → carbon dioxide + water vapour

Analysing

15 Compare a molecule of water with a molecule of hydrogen peroxide, listing their similarities and differences.

Evaluating

16 a Analyse the particle diagram in Figure 7.3.17 to determine whether it shows a chemical or physical change.
- b Justify your response.

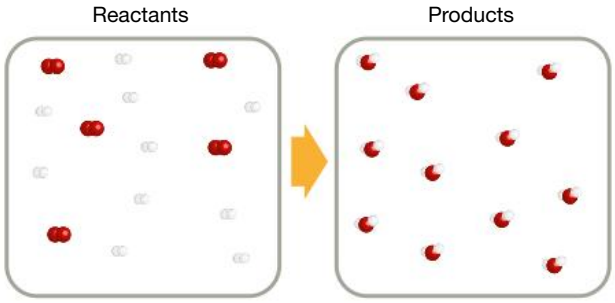


FIGURE 7.3.17

17 In Figure 7.3.17, the red atoms represent oxygen atoms and the white atoms represent hydrogen atoms. Use this information to:
- a determine the chemical formulas for the red and white molecules in the reactants box
- b determine the chemical formula for the molecules in the products box
- c name the compound in the products box.

Creating

18 When solid carbon (C) is heated with oxygen gas (O_2), they undergo a chemical reaction to produce carbon dioxide gas (CO_2). Construct a particle diagram to show the arrangement of atoms before and after the chemical reaction.

19 When a water (H_2O) droplet freezes, it undergoes a physical change that turns the liquid into a solid. Construct a particle diagram that shows the arrangement of atoms before and after the chemical change.

MODULE 7.3

Practical investigations

1 • Observing chemical reactions

Planning & Conducting | Communicating

Purpose

To observe examples of chemical change.

Timing 60 minutes

Materials

- dilute hydrochloric acid
- blue litmus paper
- piece of magnesium metal
- silver nitrate
- sodium hydroxide solution

SAFETY

Silver nitrate stains the skin.

Hydrochloric acid and sodium hydroxide are corrosive and burn, so wear gloves and safety glasses.

- 4 large test-tubes and rack
- 3 droppers
- thermometer

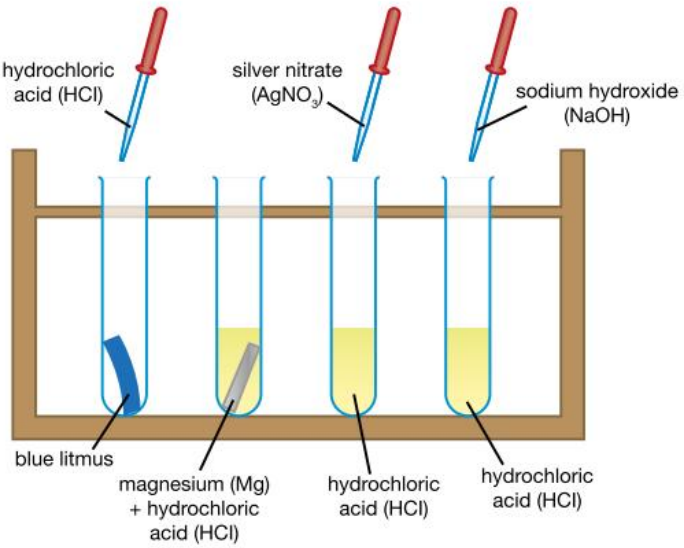


FIGURE 7.3.18

Procedure

1 Copy the table from the Results section into your workbook.

Test-tube 1

2 Place a strip of blue litmus paper into the test-tube.

3 Add two drops of dilute hydrochloric acid using a clean dropper.

4 Record your results in the table.

Test-tube 2

5 Add 2 cm of dilute hydrochloric acid to the test-tube.

6 Add a small strip of magnesium ribbon.

7 Record your results in the table.

Test-tube 3

8 Add 2 cm of dilute hydrochloric acid to the test-tube.

9 Add 10 drops of silver nitrate using a clean dropper.

10 Record your results in the table.

Test-tube 4

11 Add 2 cm of dilute hydrochloric acid to the test-tube.

12 Use a thermometer to record the temperature of the hydrochloric acid, then rinse the thermometer.

13 Add 2 cm of sodium hydroxide solution.

14 Use a thermometer to record the temperature of the solution, then rinse the thermometer.

15 Dispose of all residues as directed by the teacher.

Results

Record all observations in your Results table.

Reaction number	Reaction	Observation
1	blue litmus and dilute hydrochloric acid	
2	magnesium metal and hydrochloric acid	
3	silver nitrate and hydrochloric acid	
4	sodium hydroxide solution and hydrochloric acid	

Review

In each case, identify the clue(s) that suggests that a chemical change has taken place.

MODULE 7.3

Practical investigations

2 • Combustion of hydrogen and helium

Questioning & Predicting | Evaluating

Purpose

To compare the combustion of hydrogen and helium gases.

Hypothesis

Hydrogen and helium have similar physical properties, both being light, colourless gases. Which do you think will be more flammable—hydrogen or helium? Before you go any further with this investigation, write a hypothesis in your workbook.

SAFETY

This experiment requires at least two people.

Acid is corrosive, so keep the acid away from skin and eyes. Wear safety glasses and rubber gloves at all times.

Keep open flames away from things that burn easily such as notebooks, paper and hair.

Timing 60 minutes

Materials

- 2 cm of magnesium ribbon
- 1 M hydrochloric acid
- helium gas in a helium balloon
- 2 medium-sized Pyrex test-tubes
- eye dropper
- wooden splint
- gas lighter
- rubber gloves

Procedure

1. Put on rubber gloves. Place the magnesium ribbon in one large test-tube.
2. Use the eye dropper to put enough hydrochloric acid into the test-tube so that it completely covers the magnesium ribbon.
3. One person should cover the top of the test-tube with their hand to trap the hydrogen gas that is produced by the reaction.
4. Wait until the magnesium stops reacting or is dissolved completely.
5. Have another person light the end of the wooden splint so that it produces its own flame.
6. Quickly uncover the top of the test-tube and put the burning splint near the mouth of the test-tube.
7. Blow out the burning splint and record your observations.
8. Take the second test-tube and hold it upside down.

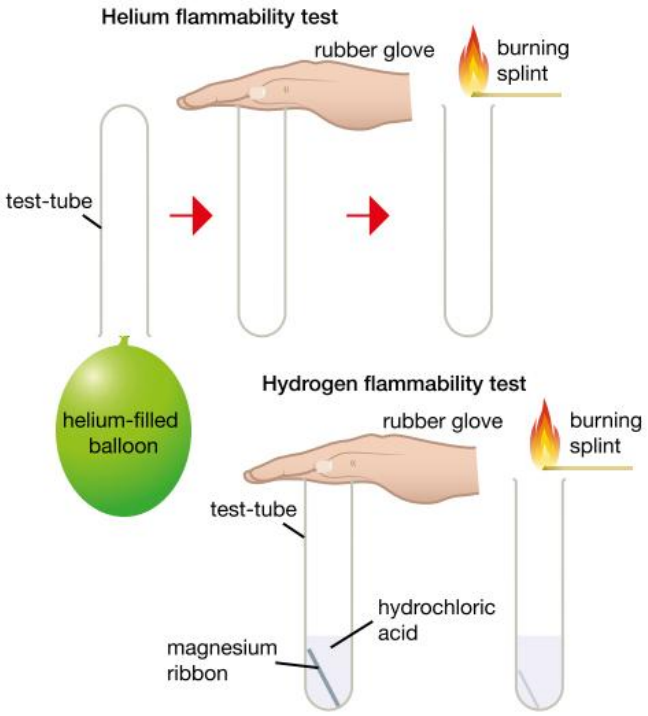


FIGURE 7.3.19

9. Release helium into the test-tube from the balloon. Hint: Because helium is very light, it will flow up into the test-tube and push the air out.
10. Cover the test-tube with your hand and turn it back up the right way.
11. Light the wooden splint once again.
12. Quickly uncover the top of the test-tube and put the burning splint near the mouth of the test-tube.
13. Blow out the burning splint and record your observations.

Results

Record your observations from each test.

Review

1. Identify some of the physical properties that hydrogen and helium have in common.
2. a Construct a conclusion for your investigation.
   b Assess whether your hypothesis was supported or not.

MODULE 7.3

Practical investigations

STEM INQUIRY

Biodegradable plastic

Processing & Analysing | Communicating

Background

The local supermarket of an Australian country town is keen to introduce biodegradable plastic bags for its shoppers.

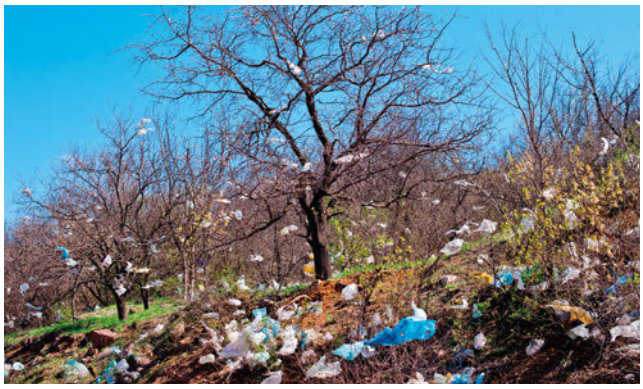


FIGURE 7.3.20 The local landfill site. Where do non-biodegradable plastics go?

The supermarket has agreed to supply (free) all the necessary ingredients for anyone who wishes to experiment with making suitably strong sheets of biodegradable plastic for the bags. A combination of glycerine (vegetable oil), vinegar, plant starch (corn, potato or tapioca) when heated is known to make a plastic-like material.

Problem

Your task is to develop a formula and instructions for a production process to make suitable biodegradable plastic for the supermarket bags. In addition, you need to justify the formula and the process you are proposing, using evidence from the testing and data you have collected.

Timing 120 minutes + 60 minutes to trial the plastics

Procedure

Use variations of the following recipe to make biodegradable plastic of suitable strength and flexibility for the manufacture of supermarket bags.

Basic steps in the procedure for making a plastic from starch:

1 Mix ingredients and stir over heat. Keep stirring after the mixture has thickened, and continue to stir until it starts to become translucent.
2 Pour the hot mixture onto a tray covered with foil or baking paper. Dusting surfaces with the powdered starch prevents sticking.
3 Taking great care, consider and try safe, effective ways of spreading the warm 'plastic' into a thin layer.
4 Dry overnight, preferably in a warm place.

Materials

You will have access to these and perhaps other materials:

- 5 tablespoons of water
- 1 tablespoon corn starch, tapioca starch, potato starch
- 3 drops food colouring (optional)
- 1 teaspoon glycerine
- 1 teaspoon white vinegar

Equipment

You will have access to these and perhaps other equipment:

- measuring cylinders
- jugs
- saucepan
- 500 mL beakers
- plastic spoons
- stirring rods
- baking paper
- patty pans
- scales
- water

Scientific inquiry process

1 Identify the purpose.
2 Identify the independent, dependent and controlled variables, and only change one variable at a time.
3 Based on your purpose, and the controls and variables, write a hypothesis for this experiment.
4 Before you commence your investigation you must conduct a risk assessment and write down safety measures that you will follow to keep yourself and other students safe. (See the activity book for a template.)
5 Summarise your experiment in a scientific report. Include Purpose, Hypothesis, Materials, Procedure, Risk Assessment, Results (including data presented in tables and/or graphs), Discussion and Conclusion.

CHAPTER 7

Chapter review

Remembering

1 Define the following terms:
- a expansion
- b evaporate
- c combustion
- d chemical reaction
- e word equation.

2 What term best describes each of the following?
- a a change where no new substance is produced
- b a mixture where a solute is dissolved in a solvent
- c the chemical process involving chlorophyll that plants use to create food
- d any reaction where a substance burns in oxygen.

3 List four examples of physical changes and four examples of chemical changes.

4 List four things that indicate a chemical change has occurred.

5 List the changes of state that occur as you heat a solid to a gas and cool a gas to a solid.

6 What chemical is needed for combustion to occur?

7 What are the word equations for the following reactions?
- a the combustion of magnesium in oxygen
- b respiration
- c the formation of rust.

Understanding

8 Explain why gases are compressible while solids and liquids are incompressible, in terms of the particle model.

9 Outline the physical changes that aluminium undergoes when it is recycled.

10 Describe the chemical and physical changes you would observe while watching a candle burn.

Applying

11 Use the particle model to describe what happens to the particles of:
- a a solid as it is heated to form a liquid
- b the liquid formed is heated further to form a gas.

12 Use the particle model to explain why a solute seems to disappear when dissolved by a solvent.

13 When methane gas is burnt in oxygen, carbon dioxide and water are produced. Use a word equation to describe this reaction.

Analysing

14 Classify the following as physical or chemical changes: *apples rotting, breaking a plate, dissolving copper sulfate, baking bread, making popcorn, melting butter, boiling oil, bending a paperclip, mixing paint, fermenting wine.*

15 Compare photosynthesis with respiration.

Evaluating

16 Janet heats a mixture of two liquids in a test-tube and observes bubbles forming. What are two possible explanations for her observation?

17 Samuel ties a balloon over the mouth of an empty 2-litre soft-drink bottle, then places the bottle in very hot water.
- a Predict what will happen to the balloon.
- b Use the particle model to justify your prediction.

18 a Assess whether you can or cannot answer the questions on page 285 at the start of this chapter.
- b Use this assessment to evaluate how well you understand the material presented in this chapter.

Creating

19 Use the following ten key terms to construct a visual summary of the information presented in this chapter.

matter	atoms
mixing	change of form
physical change	molecules
chemical reaction	change of state
chemical change	chemical equation

AB 7.11

CHAPTER 7

Inquiry skills

Research

1 Processing & Analysing

Use the internet or magazines to find ten images that show examples of physical change, and another ten showing chemical change. Present your images as a collage.

2 Processing & Analysing Communicating

Research how water is recycled. Find out how the water is:

- collected
- stored
- treated to remove solid waste
- treated to remove dissolved waste.

Present your findings as a list of the different water treatment processes, with each step classified as a physical or chemical change.

3 Processing & Analysing

Research different places in industry and at home where combustion is used. Collect images that represent the different ways combustion is used. Present your findings as a digital slide show.

4 Processing & Analysing

Choose an element or a compound mentioned in this module and research its physical and chemical properties. Whatever element you choose, find:

- its state (solid, liquid or gas) at room temperature
- its colour
- its melting point and boiling point
- whether it is flammable
- whether it corrodes
- whether it is toxic
- how its properties affect its use.

Present your research as a set of answers to the above questions.

5 Processing & Analysing Evaluating

Iron is the framework upon which our modern society is built. Iron and alloys of iron are used to build the structures of modern skyscrapers, the bodies and engines of cars, railway tracks along with any other things from frypans to spacecraft.

Human interaction with iron began around 4000 years ago when we first learned how to extract iron from the rocks in which it is found; prior to that the metal of choice for weapons and farm implements was bronze. Bronze is a mixture of copper and tin with occasionally trace amounts of other metals.

a **i** Consider bronze and iron; investigate both substances. Explain why the use of iron became more popular 4000 years ago.

ii If iron is better than bronze, why didn't people use it earlier? Justify your answer.

b Iron was perceived to be better than bronze but it was not perfect for applications where strength was needed, like swords. Explain the limitations of iron for its use in weapons.

c Modern applications do not use iron—instead we use steel.

i How is steel different to iron?

ii Draw a diagram showing the structure of steel at a molecular level. Explain how this structure is different to the structure of iron. Use the diagram to explain why steel is better for building construction than plain iron.

CHAPTER 7

Inquiry skills

Thinking scientifically

1 During a physical change, no new substances are produced. Which of these processes is *not* an example of a physical change?

A

B

C

D

2 When a chemical change occurs, new substances are produced. This may result in:

- a permanent colour change
- a gas being produced
- a solid precipitate being produced
- energy being produced or absorbed in the form of heat or light.

Identify which of these processes is *not* an example of a chemical change.

A

B

C

D

3 Amanda needs to know how much sugar will dissolve at 100°C in 1 litre of water. She has found the following data in a textbook, but the data is only for 100 mL and only goes up to 80°C.

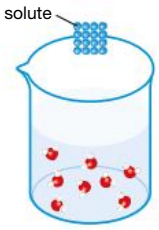
Temperature (°C)	0	10	20	30	40	50	60	70	80
Grams of sugar dissolved in 100 mL	179.2	190.5	203.9	219.5	238.1	260.4	287.3	320.5	362.1

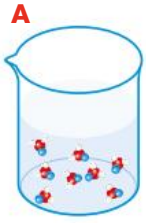
a Identify which of the following models best represents what happens when Amanda dissolves the sugar (solute) in water (solvent).

b Use plotting software to plot Amanda's data in the table as a line graph.

c Use the graph to predict how much sugar will dissolve at 100°C in 100 mL of water.

d Calculate how much sugar Amanda can dissolve in 1 litre of water at 100°C.



A 

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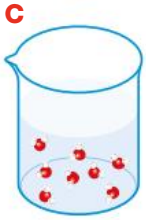
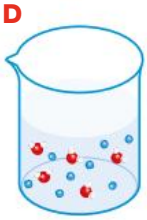
C 

D 

CHAPTER 7

Glossary

boiling: a change of state where a liquid is heated and changes to a gas within the liquid

boiling

chemical change: a change that results in a new substance being formed

chemical properties: the characteristics of substances that determine how they react chemically with other substances

chemical reaction: the process of rearranging atoms in substances to form different substances

chlorophyll: the substance found in plant leaves that make leaves green and collects energy from the Sun for photosynthesis

combustion: any chemical reaction where a substance burns in oxygen to produce light and heat

condensation: a change of state where a gas is cooled and forms a liquid

condensation

contraction: a decrease in size

corrosion: when a metal reacts with the chemicals in its environment

crystallisation: evaporation of a solvent from a solution, leaving solute behind as crystals

deposition: a change of state from gas to solid

diffusion: a process where two liquids or two gases mix due to the motion of their particles

evaporation: the change of state where a liquid changes to a gas at the surface of the liquid

expansion: an increase in size

flammability: the chemical property of a substance that describes how easily the substance undergoes combustion

freezing: the change of state from liquid to solid

glucose: a form of sugar that is produced during photosynthesis and used in respiration to produce energy

melting: the change of state when a solid is heated and forms a liquid

particle model: a simplified representation of solids, liquids and gases

photosynthesis: the chemical reaction in plants that converts carbon dioxide and water into oxygen and glucose using energy from the Sun

physical change: a change that does not result in a new substance being produced

physical properties: the characteristics of a substance that describe how it looks, feels, smells and responds to external forces

precipitate: a solid formed during a chemical change

precipitate

products: the substances formed in chemical reactions

properties: the characteristics of a substance; they can be either physical or chemical

reactants: the starting substances in chemical reactions

respiration: a chemical reaction that occurs in all living cells. In this reaction, oxygen and glucose are converted into water and carbon dioxide while releasing energy. The energy released can be used by living things to live, grow and move.

solidification (freezing): the change of state from liquid to solid

solute: a substance dissolved in a solvent to form a solution

solution: a mixture where the substances are mixed on the atomic level

solvent: the substance (usually a liquid) that dissolves a solute to form a solution

sublimation: a change of state from solid to gas

word equation: a simple chemical equation where chemicals are represented by their names

AB 7.10

CHAPTER

8 Rocks and mining

Have you ever wondered...

- why there are different types of rocks?
- what types of rocks are in your area?
- why rocks and minerals are important?

LS

After completing this chapter you should be able to:

- outline how igneous, metamorphic and sedimentary rocks form
- compare how long these rock types take to form
- identify a range of common rock types using a key that describes physical and chemical properties
- recall that rocks are a collection of different minerals
- explain the role of forces and energy in the formation of different types of rocks and minerals
- recall that some rocks, minerals and ores provide valuable resources
- investigate how minerals are extracted, and how different branches of science assist in this process
- investigate strategies that can be used to maintain part of an environment.

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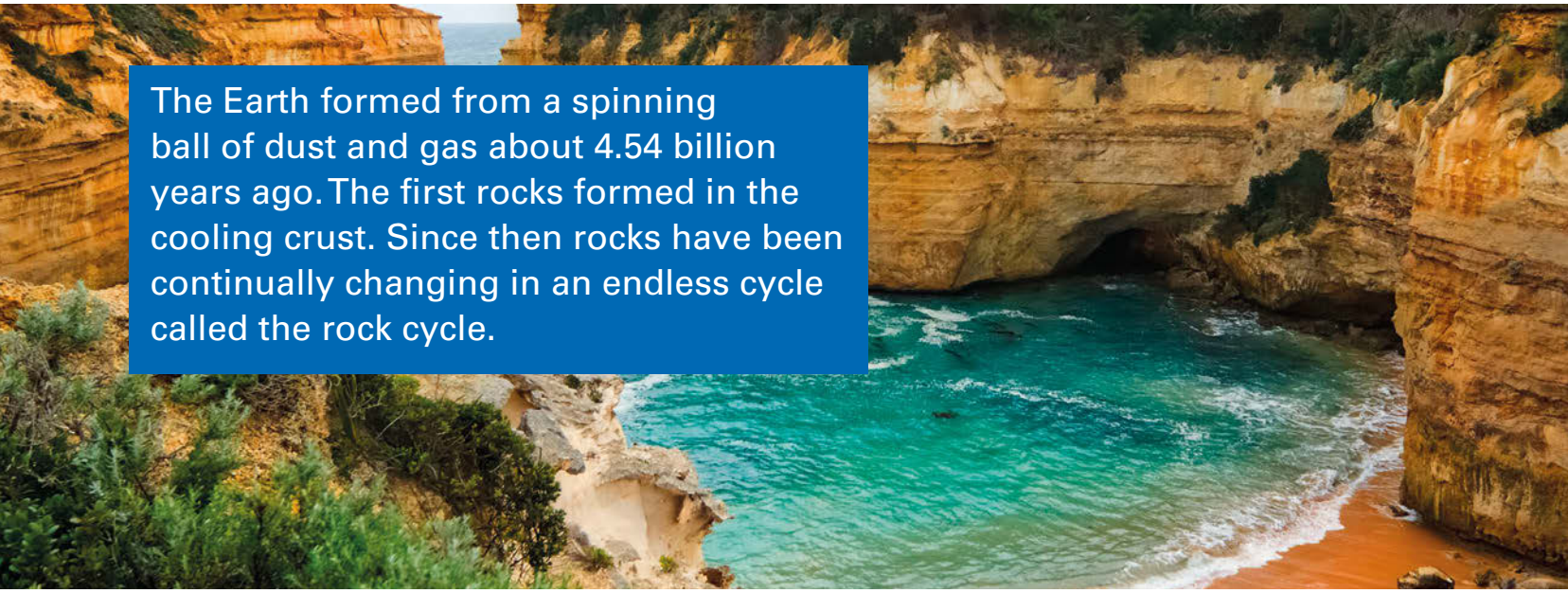
AB 8.1

MODULE

8.1 The Earth and its rocks



The Earth formed from a spinning ball of dust and gas about 4.54 billion years ago. The first rocks formed in the cooling crust. Since then rocks have been continually changing in an endless cycle called the rock cycle.

Structure of the Earth

Geology is the study of rocks, and the scientists who study them are geologists. Although scientists cannot actually see what is inside the Earth, information from earthquakes, meteors and volcanic eruptions provides data that helps geologists understand the structure of the Earth. This structure is shown in Figure 8.1.1.

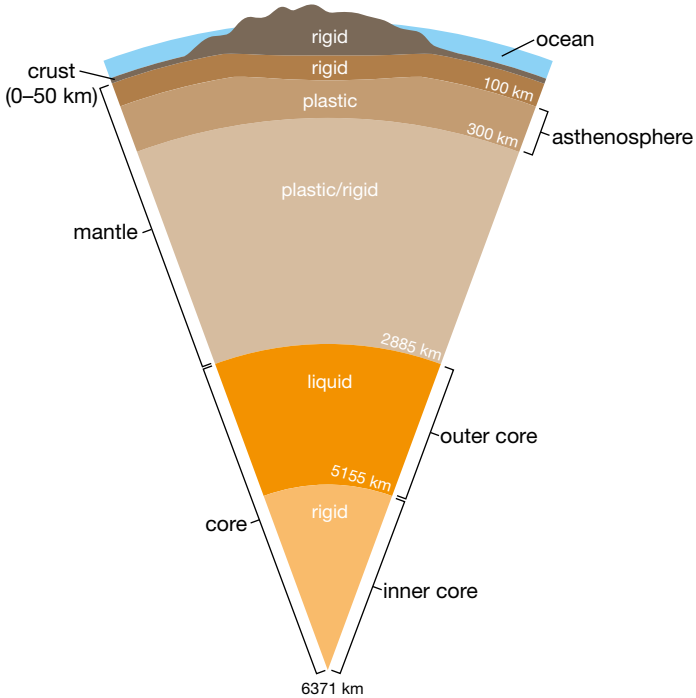


FIGURE 8.1.1 A slice or cross-section of Earth, showing the different layers that make it up

The **crust** is the outermost solid layer of the Earth. The crust varies in thickness from about 7 kilometres under the oceans to about 30–50 kilometres under the continents. The crust is the layer we live on, the layer we build our cities on, and the layer we dig up when we mine for minerals.

Beneath the crust is a layer called the **mantle**. The mantle is much hotter than the crust and is chemically different from it.

Within the uppermost portion of the mantle is a layer called the **asthenosphere**. The rock here behaves plastically. This means the rock can move slowly, like plasticine. The deepest part of the mantle is very hot. The rock flows much more slowly than in the asthenosphere, so slowly that the rock here can be considered rigid.

The **core** of the Earth is very dense, and scientists think that it is composed mostly of iron and nickel. The inner core is solid, but the outer core is liquid.

The rock cycle

Figure 8.1.2 shows the rock cycle. The **rock cycle** is a model used by scientists to explain the endless cycling of materials that make up rocks by processes within Earth and on its surface. There are three main types of rocks: igneous rocks, sedimentary rocks and metamorphic rocks.

Igneous rocks form from red hot melted rock from inside the Earth. Volcanoes are a good place to see them.

Sedimentary rocks form when small pieces worn off other rocks (sediments) become stuck together, or when minerals in solution solidify. They are commonly seen in river valleys and canyons.

SciFile

Deep but not too deep

The deepest mines in the world are two gold mines in South Africa, called TauTona and Mponeng. Both mines are 3.9 km deep. Temperatures at the bottom of these mines range from 55 to 66°C!

The third type of rock is metamorphic. These rocks have been changed by heat and pressure within the Earth. Common places to see them are around volcanoes and in mountain ranges.

The rock cycle shows how each of the three types of rock can be changed into the other types by a variety of processes that occur naturally on the Earth. Some of these processes are:

- weathering—rock is broken down into smaller pieces
- erosion—the broken rock material is transported from one place to another
- deposition—the broken rock material settles, forming sediment
- compaction and cementation—the sediment becomes packed together, and then chemically bound
- melting—the solid rock is heated, forming magma
- crystallisation—the magma becomes solid
- metamorphosis—the rock is changed by intense heat and/or pressure.

You will find the rock cycle is a very useful model if you refer back to it over the next few modules. This should help you understand the different kinds of rocks and how they form.

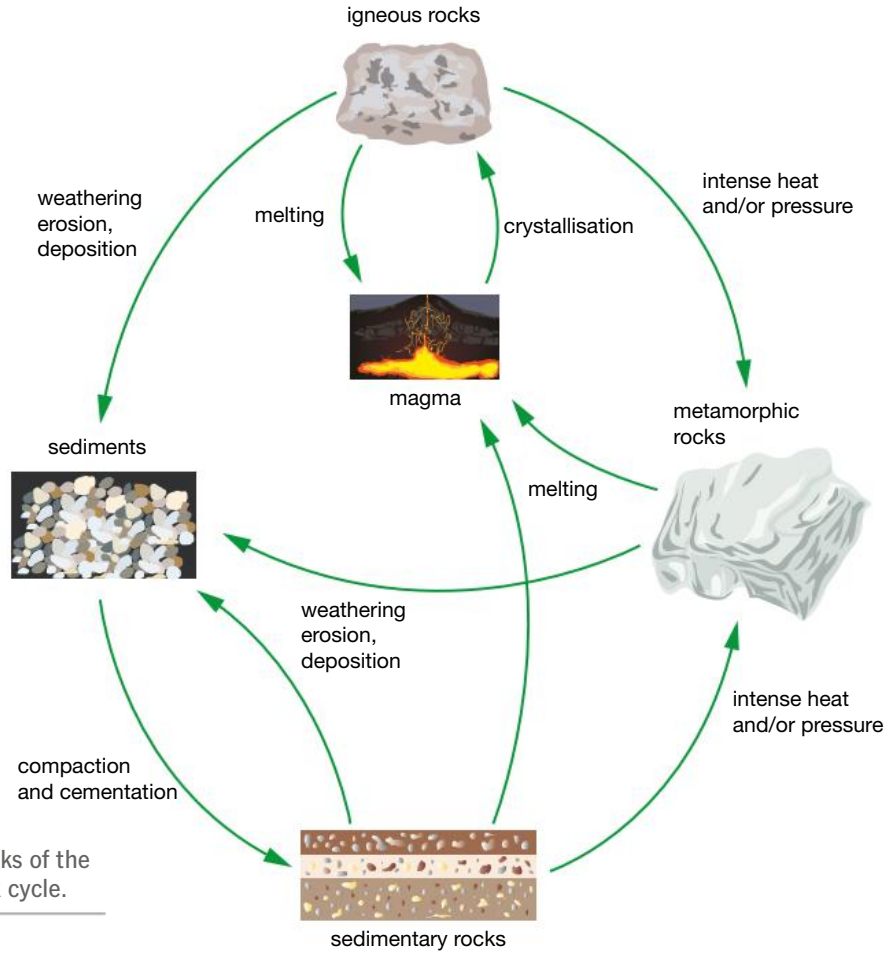


FIGURE 8.1.2 All the rocks of the Earth are part of the rock cycle.

AB 8.5

Weathering

In geology, the term **weathering** covers all the physical, chemical and biological processes that break rocks down into smaller pieces.

Physical weathering

Physical weathering can happen because of the action of:

- wind
- temperature change
- water and ice
- crystallisation of salts.

Wind

Anyone who has been on a beach on a windy day will know the feeling of sand blasting against your skin. Fine particles of rock carried by wind can also blast away at a rock surface, wearing pieces away.

Temperature change

Solids expand (get larger) when they are heated, and contract (get smaller) when they are cooled. If the day is very hot but the night is very cold, the temperature change between night and day can cause the rock to expand and contract too quickly, causing it to crack. For example, in a desert area the temperature might rise to over 40°C during the day, and drop at night to below 0°C. Figure 8.1.3 shows where some of the outer surface of the rock has broken away to expose a lighter grey, fresh surface.

FIGURE 8.1.3 This large granite rock has been split by temperature changes. The grey section shows where a piece has broken away.

The action of water and ice

Water can enter cracks in a rock. If the water freezes and becomes ice, the ice expands and makes the crack wider. This is common in colder climates and on the cold tops of mountains.

Glaciers are like frozen rivers that very slowly carve the rocks they pass over. As a glacier moves, the ice wears and knocks pieces off the surrounding rocks, forming valleys that are U-shaped, rather than the V-shape carved by a river. The sides of the valley are worn away by rocks frozen in the ice. Where glaciers merge together, there are often dark lines that show the tracks of the dark rock particles being carried by the glacier. You can see this in Figure 8.1.4.

FIGURE 8.1.4 These dark tracks are made of rock particles broken off by the two glaciers that are merging here.

Figure 8.1.5 shows how a U-shaped valley forms. Glaciers are only found in extremely cold places. Today this means places such as Greenland and on high mountains such as in the Himalayas, the Andes and in New Zealand. Glaciers scraped across Australia too, long, long ago when the climate was much, much colder.

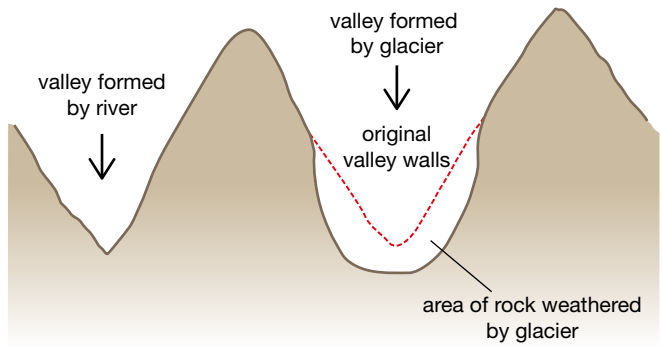


FIGURE 8.1.5 The characteristic U-shaped valley is caused by rocks within the glacier scraping the base of the valley.

Water running or washing over rock can also gradually wear away the rock. The rate of weathering depends on the type of rock the water flows over, the speed and power of the water, and what materials the water is carrying in it. Rivers can cut deep through rock, forming gorges. Pounding waves at the beach can wear away cliffs (Figure 8.1.6).

FIGURE 8.1.6 Waves weather rocks along the coast, sometimes forming spectacular shapes.

Crystallisation of salts

Water in the soil often contains dissolved chemicals, called salts. One example is sodium chloride (table salt). Salts such as sodium chloride and gypsum form crystals as the water evaporates.

If the crystals form inside spaces in a rock, then their growth can exert tremendous force on the rock, causing pieces to break off. A similar effect can occur in the mortar that is used to cement brick and limestone walls.

Chemical weathering

Water dissolving chemicals from the soil and air will react with rock, changing it or breaking it down. This is known as **chemical weathering**. Air contains oxygen and carbon dioxide. When these gases are dissolved in water, they can react with minerals in the rock, changing them. This may cause the rock to crumble or change colour. For example, you often see red colours wherever dolerite rock weathers. This is because the iron reacts with oxygen to produce iron oxide, otherwise known as rust. Its colour is clearly seen in the soil in Figure 8.1.7.

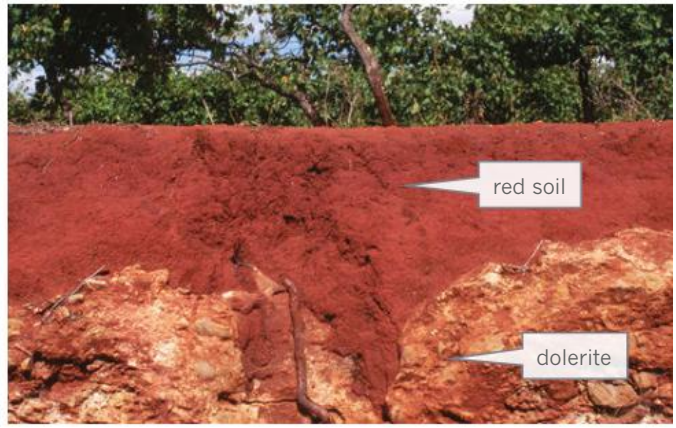


FIGURE 8.1.7 This red soil lies above chemically weathered dolerite rock.

AB 8.2

science 4 fun

Comparing crystals

NO

Are all crystals the same?

Collect this ...

- super-saturated solutions of magnesium sulfate, sodium chloride, aluminium potassium sulfate and copper sulfate
- methylated spirits
- 4 test-tubes in a test-tube rack
- 4 eye-droppers or Pasteur pipettes
- Petri dish
- stereo microscope or monocular microscope (×40)
- 4 glass slides
- access to marking pen

SAFETY

Treat all chemicals as if they are toxic.

Wear safety glasses at all times.

Methylated spirit is flammable, so keep it away from naked flames.

Wash your hands after completing this activity.

Do not touch the crystals or take them home.

Do this ...

1. Label each test-tube and glass slide with the name of one of the solutions using the marking pen.
2. Put a drop of each solution on its labelled slide and observe it under the microscope. Look first at the edge of the drop of solution.
3. If the crystals are slow to form, then add a drop of methylated spirits. Try it both with and without methylated spirits.

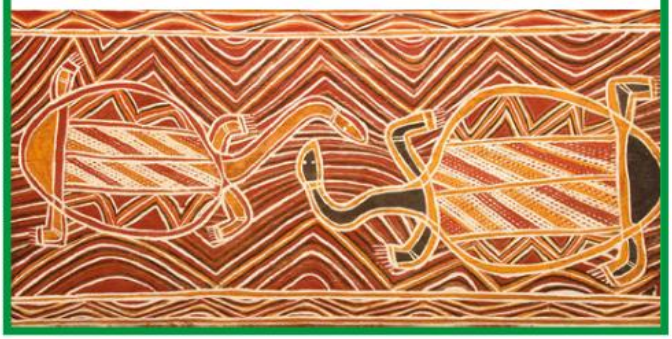
Record this ...

1. Describe what happened.
2. Explain why you think this happened.

SciFile

Red ochre

Australian Aborigines discovered that some rocks break down into coloured clays called ochres. Red and yellow ochres come from weathering of iron-rich rocks. If the clay is well-drained and relatively dry, then the colour of the ochre will be red. If the clay is wet, then the ochre will be yellow. Ochres can be mixed with other materials to change their colours. They are then used to paint bodies and caves and to make bark paintings.



Biological weathering

Living things and their products can also break down rock. This is known as **biological weathering**. As Figure 8.1.8 shows, plant roots can grow through fine cracks, or even create their own cracks. As the root grows and thickens, it splits the rock. Tree roots can be strong enough to seriously damage homes, paving and driveways. Some Australian plants release enzymes that soften rocks so their roots can travel through.

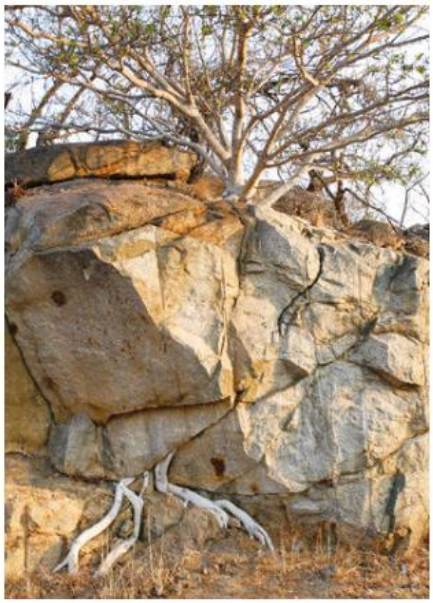


FIGURE 8.1.8 Tree roots can split rocks and walls.

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p. 332

Erosion

The small rock particles formed by weathering rarely stay near the rock they came from. Instead they are moved elsewhere. This is called **erosion**. The small rock particles are moved elsewhere by water, wind, gravity or ice, known as **agents of erosion**. You can see erosion where rivers have cut away banks, where stormwater pipes have created gullies and where large boulders have rolled downhill. The power of erosion is strongest near the source of weathering. As small rocks move further away from the source, the power of erosion weakens. In other words, the force of erosive power decreases with distance. This has two effects: the broken rock materials become smaller with distance, and their roundness increases (as the edges have been knocked off). For example, a river near its source can carry large and small pieces of rock, but once it reaches coastal plains it will carry only very small pieces such as sand and mud.

Deposition

The settling of broken rock material is called **deposition**. The layers of material formed are called sediments and so the process is sometimes also called sedimentation. Deposition occurs where moving water, wind or ice that is carrying broken rock material slows down. In rivers, this slowing down occurs at bends, and where rivers leave the mountains and enter plains. On flatter land, the path of the river can meander (bend and curve). You can see a river meandering in Figure 8.1.9. This pattern occurs because any slight curve in a river's flow means the river will erode the outside of the curve more than the inside.

FIGURE 8.1.9 The Murray River meanders because it is travelling slowly across a plain. Sand and other sediments are deposited on the inside of its bends because that is where the river is travelling the slowest.

The slower flow of the river on the inside of the curve means that more sediment is deposited there. Over time this causes the river to bend even more. Prospectors are people who search for precious minerals. They concentrate their efforts on the inside of river bends, where heavy materials such as gold can accumulate.

When a river meets the sea, the water slows down, causing the deposition of most of its materials. This can cause a delta to form. For example, large deltas have formed at the mouth of the Missisippi (USA) and the Nile (Egypt), shown in Figure 8.1.10.

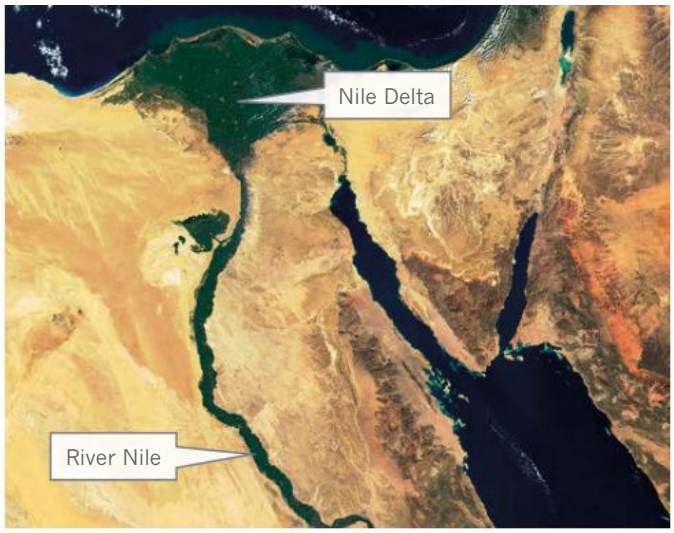

FIGURE 8.1.10 As the River Nile enters the Mediterranean Sea, it slows and deposits the soil it has been carrying. Over thousands of years, this has created the fertile farming area known as the Nile Delta.

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Prac 3 p. 333
AB 8.3

Compaction and cementation

Layer upon layer of sediment builds up over time, and most of the water held between the small rocks and sand is squeezed out by weight from above. The water is progressively squeezed out and sediment is compacted. A similar process can be observed if you stand on a pile of wet kitchen sponges!

Minerals in the remaining groundwater **cement** the compacted sediment together to form **sedimentary rock**. This is how mudstone, sandstone and limestone are made.

Melting and crystallisation

Deep in the Earth, where intense heat and pressure occur, solid rock can melt. When it cools again, new crystals form. The rock's chemical composition often remains the same but the original minerals may be rearranged into new minerals.

If the rock is completely melted and recrystallised, then an **igneous rock** is made. Its chemical composition often resembles that of the original source rock. However, it has very different physical characteristics. For example, when some sedimentary rocks melt, they form a much harder rock called granite.

If the rock is only partially melted and recrystallised, then **metamorphic rock** is made. Metamorphic rock often retains the same chemical composition of the original rock but also new minerals may form and these rocks often retain some traces of the original rock structures. For example, some fossil-rich limestone partially recrystallises to make marble.

AB 8.4

STEM 4 fun

A model for the rock cycle

PROBLEM

How can a cookie be used to model the processes of weathering, erosion and deposition?

SUPPLIES

- choc chip biscuit, ice cube, water
- straw, dropper, spray bottle

PLAN AND DESIGN Design a technique using the tools you have, to model each process. What information do you need to solve the problem? Draw a diagram. Make a list of materials you will need for each process, and the steps you will take.

CREATE Follow your plan. Produce a solution to the problem.

IMPROVE What works? What doesn't? How do you know it solves the problem? What could work better? Modify your design to make it better. Test it out.

REFLECTION

1 What area of STEM did you work in today?
2 What field of science did you work in? Are there other fields where this activity applies?
3 What did you do today that worked well? What didn't work well?

MODULE 8.1

Review questions

Remembering

1 Define the terms:
- a asthenosphere
- b weathering
- c erosion
- d deposition.

2 What term best describes each of the following?
- a the study of rocks
- b the layer on Earth that we live on
- c the endless cycling of rocks and the materials they contain through Earth's processes
- d wind, water, gravity and ice that carry particles away.

3 List the layers of the Earth in order, from the outer one on which we live to its centre.

4 List the main causes of:
- a physical weathering
- b chemical weathering
- c biological weathering.

5 List the agents of erosion.

Understanding

6 Explain what is meant by rock behaving plastically.

7 Rocks exposed at the Earth's surface are not identical to how they were just after they formed. Explain why.

8 If you put a glass bottle full of drink in the freezer, then you will probably find that the bottle has broken after a few days.
- a Explain why.
- b How does this relate to weathering?

9 Why are sediments carried by a river deposited when the river flows into a lake or a sea?

Applying

10 Figure 8.1.11 shows a satellite image of the coast of New South Wales on a very windy day. Note that there were no significant bushfires that day.
- a Identify the process occurring in this image.
- b Explain what is happening.

FIGURE 8.1.11

Analysing

11 Compare the thicknesses of the Earth's crust, mantle and core, and arrange them in order from thickest to thinnest.

12 Contrast erosion and weathering.

Evaluating

13 Crystal formation can usually be started by dropping a seed crystal into a solution that the crystal is made out of, for example, dropping a copper sulfate crystal into copper sulfate solution. However, a super-saturated solution is a solution that has so much solute dissolved in it that crystals can form very easily. You can simply put some drops of the solution onto a glass microscope slide.
In the science4fun on page 328 it is suggested that you look at the edge of the solution for crystals, and not the centre. Propose reasons why.

14 What ways can you think of to minimise soil erosion when camping, bushwalking or boating?

15 When a hilly area is excavated (dug out) to make a road, exposed banks are often left along the side. Workers sometimes cover these banks with various materials, such as a spray-on paper-like material that has plant seeds mixed with it. Propose reasons why they do this.

Creating

16 Construct a diagram showing a river flowing from mountains across a plain, where it meanders before reaching a delta at the sea. Label the places where major weathering, erosion and deposition would occur along the way.

MODULE 8.1

Practical investigations

1 • Simulating weathering

Processing & Analysing | Evaluating

Purpose

To investigate how ice and chemicals can cause weathering.

Timing 45 minutes

Materials

PART A: THE EFFECT OF ACID AND WATER

- vinegar
- 2 small samples each of granite, limestone and sandstone (to fit test-tubes)
- 6 test-tubes and a test-tube rack

PART B: THE EFFECT OF TEMPERATURE

- plaster of Paris
- 2 margarine containers or milk cartons
- small water balloon
- spoon or spatula
- rubber gloves

SAFETY

Do not mix plaster with bare hands. Mix with a spoon or spatula or use rubber gloves.

Procedure

PART A: THE EFFECT OF ACID AND WATER

1. Label your test-tubes 1 to 6. Put small samples of granite into test-tubes 1 and 2, limestone in test-tubes 3 and 4, and sandstone in test-tubes 5 and 6 as shown in Figure 8.1.12.
2. Add water to test-tubes 1, 3 and 5.
3. Add vinegar to test-tubes 2, 4 and 6.
4. Leave the test-tubes in the test-tube rack and record any observations. Leave them set up overnight or until your next science class.

PART B: THE EFFECT OF TEMPERATURE

5. Mix up enough plaster with water to half-fill two margarine containers or cut-down milk cartons.
6. Fill a small balloon with water and tie it. Push the balloon into the plaster in one container and keep it below the surface so that it remains in the plaster after the plaster sets.
7. At the end of class, put both the margarine containers or cut-down milk cartons in the freezer.

Results

Record your observations next class for the test-tubes and the containers in the freezer.

Review

1 a What happened to different rocks when placed in the acid?
   b Use this observation to explain weathering of rocks by chemicals.
2 a What happened to the plaster and the containers left in the freezer?
   b Explain what happened.
3 Justify the choice of this procedure in investigating the weathering of rocks.

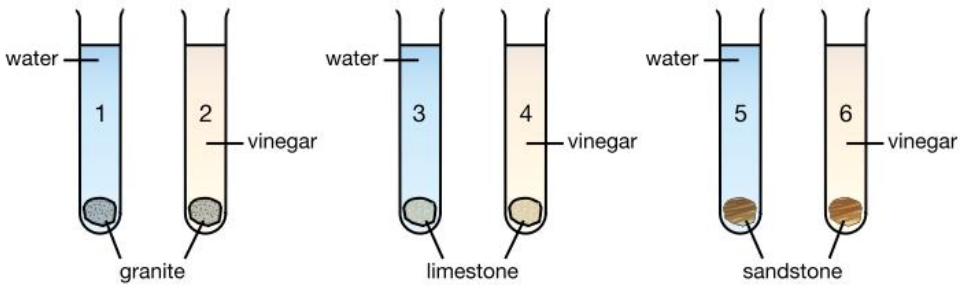

FIGURE 8.1.12

MODULE 8.1

Practical investigations

2 • Deposition of sediments

Processing & Analysing | Communicating

Purpose

To investigate how sediments settle in water.

SAFETY

Perform this investigation outside or in a tray that can catch water and soil as it overflows.

Timing 15 minutes

Materials

- about 200 mL of a mixture of different-sized soil sediment particles, such as dry gravel, sand and clay
- water
- 2 L plastic soft-drink bottle with the top 5 cm cut-off
- 2 × 200 mL beakers
- digital camera or mobile phone with camera function (optional)

Procedure

1. Pour water into the bottle to a level about 5 cm from the cut-off top.
2. Pour about 200 mL of your mixed soil into the container and let it settle to the bottom. Do not move the container around while the soil is settling.
3. Carefully observe what happens. Leave the bottle in a place where it will be undisturbed until the next science class.

Results

1. Use a labelled diagram to describe the location and layering of sediments.
2. You might also record the appearance of the sediments using a digital camera or camera function of a mobile phone.

Review

1. Explain the location and layering of the sediments in your bottle.
2. Use your results to explain:
   a. why a river meanders
   b. where you can expect different-sized particles to be deposited along the course of a river.

• STUDENT DESIGN •

3 • Erosion and deposition

Planning & Conducting | Evaluating

Purpose

To model erosion and deposition.

SAFETY

A Risk Assessment is required for this investigation.

Timing 60 minutes

Materials

To be selected by students (could include sand, roof guttering/plastic pipe, bucket, hose)

Procedure

1. Design an experiment to demonstrate one of the following things:
   - the difference between erosion by a river and erosion by a glacier
   - how slope affects erosion
   - how a river will deposit sediments as it slows down.
2. Before you start any practical work, assess your model and procedure. List any risks that it might involve and what you might do to minimise those risks. Show your teacher your planned model and your assessment of its risks. If your teacher approves, then collect all the required materials and start work.

Hints

- You could use wet sand for mountains and a small plant pot to represent glaciers carving out a valley.
- A piece of roof gutter could be used to model a river that is depositing sediment.
- Use the STEM and SDI template in your eBook to help you plan and carry out your investigation.

Results

Record all your observations, possibly using a video camera or video function on your mobile phone or tablet.

Review

How does your model show what you set out to investigate?

MODULE
8.2 Igneous rocks

Earth's crust was originally formed when molten rock cooled to form igneous rock. The word igneous means 'born of fire'. Molten magma and lava crystallise to form these spectacular rocks.

science 4 fun

Comparing lava

Are all lavas the same?

Collect this …

- 3 laboratory trays
- 3 thick rigid plastic strips (approximately 10 cm × 40 cm)
- retort stand and clamp
- 3 foods or common materials with differing viscosities (stickiness), such as tomato sauce, treacle and oil
- tablespoon
- stopwatch
- marker pen

SAFETY

Do not eat any food substances in the science laboratory.

Do this …

1. Attach a plastic strip to the retort stand using the clamp at a height of approximately 20 cm.
2. Angle the other end of the plastic strip into a laboratory tray.
3. Mark a line on the plastic strip about 5 cm from the top and another at 5 cm from the bottom.
4. Place one tablespoon of your first food for testing on the top line on the plastic strip. Using the stopwatch, time how long it takes to reach the bottom line.
5. Repeat the process with your other two foods.
6. Clean up.

Record this …

1. Describe how the different viscosities affected how the material flowed.
2. Explain how the viscosity of lava erupting from a volcano might affect how lava flows along the ground.

Magma and lava

Magma is very hot molten (melted) rock. Magma is less dense than the surrounding rock, so it rises up through any fault, crack or weak spot in the crust above. As it rises to the crust, magma melts overlying rock, changing the rock's composition. When magma reaches the surface, it is known as **lava**. Lava can be as hot as 1200°C when it erupts at the surface of the Earth. Below the surface, the magma can be even hotter.

Lava erupts from volcanoes. One type of volcano is shown in Figure 8.2.1.

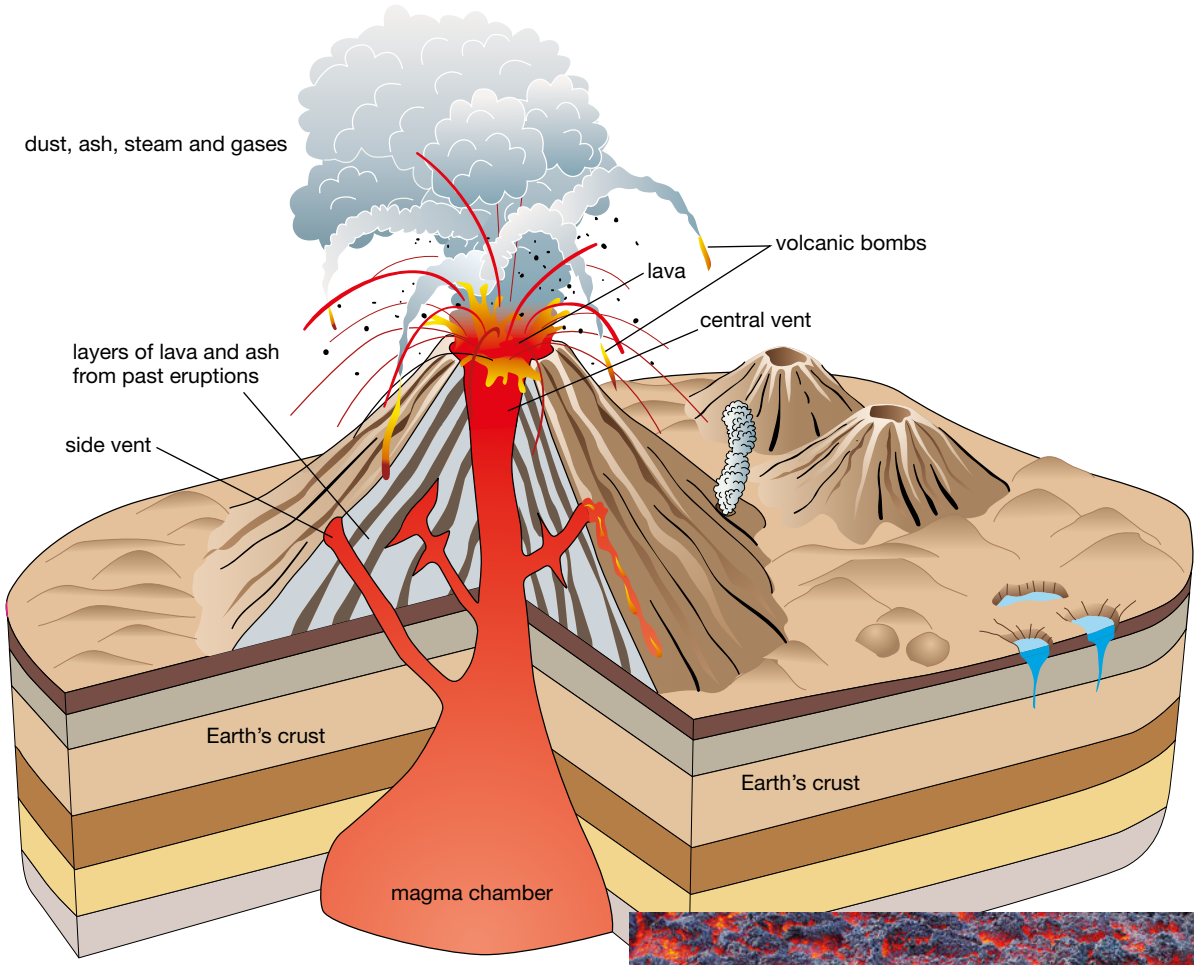

FIGURE 8.2.1 Structure of a volcano

FIGURE 8.2.2 Lava cools to form extrusive igneous rocks.

Igneous rock is formed when magma or lava cools and crystallises (forms crystals). Some igneous rocks form at the surface of the Earth. This is most obvious when a volcano spews lava across the surrounding landscape. It can also happen underwater, on the ocean floor. Some igneous rocks form when magma is trapped in cracks or between layers of rock below the surface. Other igneous rocks form deep in the crust.

If magma reaches the surface to become lava, then it cools very rapidly, especially if the eruption happens underwater. Magma that does not reach the surface cools much more slowly.

Rocks formed at or near the surface are classified as **extrusive igneous rocks**. Some are shown in Figure 8.2.2. Rocks formed from magma cooling below the surface are classified as **intrusive igneous rocks**.

When lava cools quickly, it forms rock with very small crystals or no crystals at all. Crystals have not had enough time to grow because of the rapid cooling. Rock with larger crystals forms when cooling occurs more slowly. This happens because particles within the magma can move around and keep adding to nearby crystals giving them time to grow. These crystals are usually large enough to see without a magnifying glass.

Characteristics of igneous rocks

Igneous rocks are made of **interlocking mineral crystals** that join together like pieces of a jigsaw. This can produce a hard rock. Sometimes the crystals are very difficult to see unless you use a microscope. You can see what interlocking crystals look like in Figure 8.2.3.

FIGURE 8.2.3
A jigsaw-like pattern of interlocking crystals indicates that the rock is an igneous rock. These interlocking crystals are in the igneous rock peridotite.

Classifying igneous rocks

Igneous rocks can be classified by their texture and colour. Texture is how smooth or rough the rock is and is best described by noting the size and shape of crystals and whether the rock has any air bubbles or other observable features. Colour is linked to the minerals the rock contains. Dark-coloured (**mafic**) rocks are usually made up of minerals such as olivine and pyroxene. Light-coloured (**felsic**) rocks contain high levels of silica-rich minerals such as quartz and feldspar. Figure 8.2.4 shows two examples of igneous rocks.

The current position of an igneous rock may not indicate where it was formed. Many intrusive igneous rocks have been exposed at the surface due to folding, faulting and weathering. Many extrusive igneous rocks have been buried by sediments over time. Therefore the current position of an igneous rock is not enough to classify it as intrusive or extrusive.

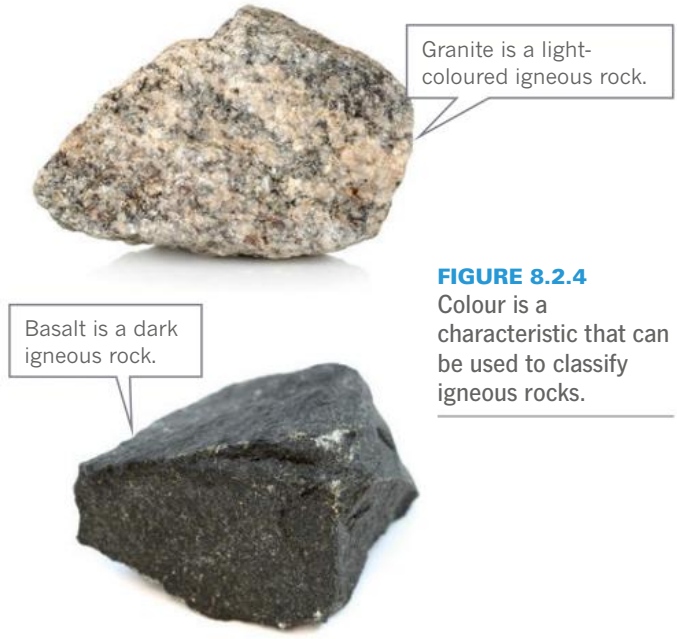

FIGURE 8.2.4
Colour is a characteristic that can be used to classify igneous rocks.

Extrusive igneous rocks

Rapid cooling of extrusive igneous rocks makes the minerals crystallise quickly, so large crystals don't have a chance to grow. The crystals may be hard to see with eyes alone, but usually can be seen with a microscope. This may require the rock to be sliced into thin sections to be able to see the crystals. Figure 8.2.5 shows a view through a microscope of the crystals in an extrusive igneous rock.

FIGURE 8.2.5
Microscopic view of an extrusive igneous rock

Basalt is an example of an extrusive rock with small, visible crystals, while obsidian has no visible crystals. Obsidian is often called volcanic glass (Figure 8.2.6).

FIGURE 8.2.6
Obsidian is an extrusive igneous rock that is characterised by its lack of crystals.

The holes or spaces in some igneous rocks are caused by gas bubbles, which were trapped when the lava cooled very quickly. This gives the rock a rough, bubbly texture. An example is pumice, which does not absorb water and has a low density. These properties allow it to float. Scoria is another type of rock that erupts out of volcanoes. Scoria has no obvious crystals, is dark in colour, and is much more dense than pumice. It sinks if placed in water. You can see samples of pumice and scoria in Figure 8.2.7.

FIGURE 8.2.7 Pumice and scoria are extrusive igneous rocks exploded out as volcanic bombs. These rocks are full of holes caused by gas bubbles.

Intrusive igneous rocks

Intrusive igneous rocks contain larger crystals, which can usually be seen without a microscope. These crystals are the result of magma cooling slowly. The crystals also interlock with each other. Two examples of intrusive igneous rocks are granite and dolerite. It is easy to see the crystals in the granite shown in Figure 8.2.4 on page 336. It is composed of three main minerals: quartz, feldspar and biotite. Figure 8.2.8 shows these three minerals as clumps of pure crystals.

FIGURE 8.2.8 The three main minerals in granite are quartz, feldspar and biotite.

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Uses of igneous rocks

Most igneous rocks are very hard and strong. These characteristics make them good for buildings and other stone structures that need to last a long time. Some common uses for igneous rocks are listed in Table 8.2.1.

TABLE 8.2.1 Uses of igneous rocks

Igneous rock	Use
basalt	buildings (e.g. Melbourne bluestone), concrete (as crushed rock), floor tiles
dolerite	road surfaces (where it is called 'blue metal'), concrete (as crushed rock)
granite	buildings, monuments, road surfaces, kitchen benchtops
scoria	landscaping, filters and concrete (all as crushed rock), barbecue rocks
pumice	cleaning dead skin off feet, emery boards for shaping nails, some soaps that feel rough on your skin
obsidian	scalpel blade for surgery in hospitals, ornaments and jewellery; ancient people used it for cutting, spear and arrow points, and pots and vases

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AB 8.6

MODULE
8.2 Review questions

Remembering

1 Define the terms:
- a magma
- b intrusive igneous rocks.

2 What term best describes each of the following?
- a molten rock that erupts from a volcano
- b igneous rock that cools and solidifies above the Earth's surface.

3 Name two igneous rocks that are:
- a extrusive
- b intrusive.

4 What are the three minerals in granite?

5 List the features that are used to classify igneous rocks.

Understanding

6 Why are some extrusive igneous rocks found buried underground, while some intrusive igneous rocks are found above ground?

7 Explain how crystal size is affected by how fast rocks cool.

8 Pumice can be formed when gassy lava erupts out of a volcano. Explain why igneous rocks such as pumice do not have any visible crystals.

Applying

9 A geologist removed some rock from the edge of an old lava flow. No crystals could be seen when the rock was studied under a microscope. The rock was a dark colour and it was hard, but very brittle. It was easily broken into pieces by hitting it, and broke into very sharp, thin strips, which were very lustrous (shiny).
- a Identify the type of igneous rock it is.
- b Explain why no crystals could be found even though the rock was obviously igneous.

Analysing

10 Contrast:
- a lava with magma
- b extrusive and intrusive igneous rocks.

11 Contrast:
- a the mineral composition of dark-coloured and light-coloured igneous rocks
- b the appearance of extrusive and intrusive igneous rocks.

12 Copy the following table into your workbook and then use it to do the activities below.

	Small crystals	Large crystals	Holes	'Glassy'
Light colour				
Dark colour				

- a Identify where each of the following rocks should be placed in the table: basalt, granite, pumice, obsidian, scoria.
- b Rhyolite is an extrusive igneous rock that is chemically like granite but has very small crystals. Analyse the data and decide where you would place rhyolite in the table.
- c Gabbro is an intrusive igneous rock that is chemically like basalt. Analyse this information and decide where you would place gabbro in the table.

Evaluating

13 Dolerite is an intrusive igneous rock. It is similar to basalt in its chemical composition, containing relatively little silica.
- a Assess whether dolerite is likely to have smaller or larger crystals than basalt.
- b Justify your decision.

14 Porphyry is an igneous rock that has a mixture of crystal sizes. It has large crystals set in a rock of finer grains. You can see an example in Figure 8.2.9. Geologists have suggested that porphyry forms in two stages.
- a How do you think this type of rock most likely formed?
- b Use your knowledge of crystallisation and cooling rates to justify your answer.

FIGURE 8.2.9 Porphyry

MODULE
8.2 Practical investigations

1 • Cooling and crystal size

Questioning & Predicting | Processing & Analysing

Purpose

To investigate how cooling rate affects the size of crystals.

Hypothesis

Which conditions do you think will grow the largest crystals—quick cooling or slow cooling? Before you go any further with this investigation, write a hypothesis in your workbook.

SAFETY

Wash your skin with soap and water immediately if you come into contact with potassium aluminium sulfate solution.

Call your teacher immediately if it contacts your face or eyes.

Be careful at all times with hot water.

Wash hands after completing this activity.

Timing 45 minutes

Materials

- a sample of about 25 g of potash alum
- ice
- rubber gloves
- oven mitt or towel
- 3 × 50 mL test-tubes and test-tube rack
- 4 × 250 mL beakers
- cotton wool
- hotplate or Bunsen burner, tripod, bench mat, gauze mat
- stirring rod
- filter funnel

Procedure

1. Collect about 100 mL of hot water in a 250 mL beaker from your teacher.
2. Wearing rubber gloves, dissolve the potash alum in the hot water by stirring it vigorously with a stirring rod until no more will dissolve.
3. Make an ice bath by half-filling another of the beakers with ice water.
4. Insulate another beaker with enough cotton wool to allow a test-tube to sit upright in the middle.
5. Place the three test-tubes in a test-tube rack. Put a filter funnel in one of the test-tubes. Hold the beaker of hot solution with an oven mitt or towel so it will not burn you. Carefully pour about 25 mL of the saturated solution into the filter funnel. The test-tube should be about half full. Repeat this process for the other two test-tubes. Place a plug of cotton wool in the mouth of each test-tube.
6. Place one test-tube in the cotton wool, one in the ice water, and one in an empty beaker as shown in Figure 8.2.10.

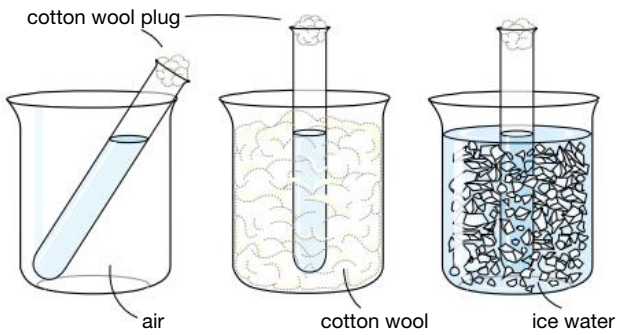

FIGURE 8.2.10

7. Leave the beakers in a safe place such as a cupboard for at least a day.

Results

Observe the contents of the test-tubes in the next science class. Record your observations.

Review

1. Which test-tube had the smallest crystals and which test-tube cooled the fastest?
2. What are the independent, dependent and controlled variables in this experiment?
3. Assess whether your hypothesis was supported or not.
4. Use the results of this experiment to explain the difference between crystal sizes in extrusive and intrusive igneous rocks.

MODULE 8.2

Practical investigations

2 • Comparing igneous rocks

Processing & Analysing | Communicating

Purpose

To compare the characteristics of different igneous rocks.

Timing 45–60 minutes

SAFETY

Wash hands after completing this activity.

Materials

- various labelled igneous rock samples: pumice or scoria, basalt, obsidian, granite, dolerite, gabbro, porphyry
- ruler
- access to stereo microscope, hand lens or magnifying glass
- margarine lid or white tile
- blunt probe or mounted needle
- graph paper

Procedure

1. Copy the table below into your workbook. Draw as many rows in as you have rock samples. Give your table a title.
2. Place each of the rock samples on a margarine lid or white tile, and record your observations in a table like the one below. Record the:
   - a. main colour of the rock
   - b. average colour and size of its minerals (if visible). For size of crystals, try to estimate the length in millimetres. Do this for each of the different types of crystal that you can see.
   - c. percentage of dark minerals. Do this by comparing your rock with a piece of graph paper on which you have coloured some squares black. Use a piece of graph paper 10 squares by 10 squares. If you colour in 20 of the squares, this will show you what 20% looks like, as in Figure 8.2.11. Create another piece for 30%, and so on. Compare these pieces of graph paper with the rock to estimate the percentage of the rock that is dark.

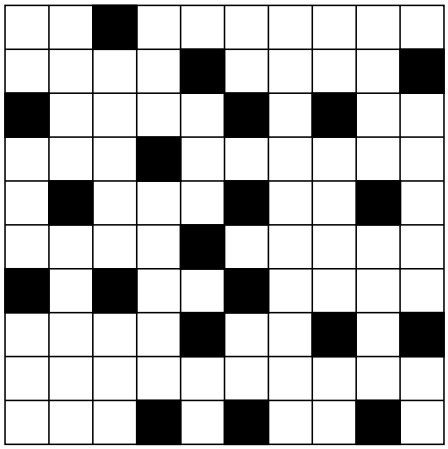

FIGURE 8.2.11

3. Use the crystal size as a guide to classify the rock as intrusive or extrusive. For other features, add anything else you notice about the rock, such as its weight, texture and lustre.

Results

Record all your observations in your Results table.

Review

1. Which rocks were mainly dark coloured?
2. Which rocks had clearly visible crystals?
3. Compare the crystal size and the rock colours for your different samples. Was there any relationship between these? For example, did all dark rocks have large crystal sizes?
4. Account for the low density of any of these rocks.

Rock name	Main colour of rock	Colour and size of minerals	Percentage of dark minerals	Extrusive or intrusive	Other features
granite					
basalt					

MODULE
8.3 Sedimentary rocks

A good place to see sedimentary rocks is the Grand Canyon in the United States. It displays some of the deepest layers of sedimentary rock on Earth.

science 4 fun

Creating 'sedimentary rocks'

NO

How do some sedimentary rocks form?

Collect this ...

- 3 margarine containers
- enough pebbles to half-fill a margarine container
- enough small (0.5–3 cm) angular pieces of rock to half-fill a margarine container
- plaster of Paris (pre-mixed just before use)
- spatula

Do this ...

1. Half-fill one margarine container with pebbles and the other with the angular pieces of rock.
2. Pour plaster of Paris into each container, while gently shaking the rocks to allow the plaster to get into the gaps.
3. Leave the containers to set.
4. Once the mixtures are set, carefully tip them out.

Record this ...

The mixture with pebbles in it represents a sedimentary rock called conglomerate. The mixture with angular rocks in it represents a sedimentary rock called breccia.

1. Describe the appearance of the two mixtures once they set.
2. Explain how you think rocks like conglomerate and breccia might form.

How sedimentary rocks form

Sedimentary rocks are rocks made from sediments. Sediments are small particles of weathered rock or crystals that have been left behind when a solution has evaporated. To form sedimentary rock, the sediments need to be compacted and cemented. This occurs during burial. Overlying layers of sediment compact the sediments and force out excess water. Groundwater naturally contains chemicals such as silica and lime, which cement (stick) the sediments together, forming a larger rock.

Classification of sedimentary rocks

There are three types of sedimentary rocks:

- clastic
- chemical
- biogenic.

All have different characteristics because they contain different sediments and were formed in slightly different ways.

Clastic sedimentary rocks

Clastic sedimentary rocks are formed when sediments are laid down by wind, water, gravity and ice, and then compacted and cemented.

Clastic sedimentary rocks have the following characteristics.

- They contain broken pieces of other rocks. These pieces are known as clasts.
- They may have layers like a stack of pages in a book, because the sediments build up on top of one another as they are deposited.
- The grains do not interlock because they did not crystallise and grow together in the rock. Instead, they were cemented together.
- The rock may contain fossils. Fossils are the preserved remains of animals and plants that died long ago. Sometimes, dead organisms sink into the sediments and get covered by them. This preserves parts of the organism or leaves a trace of their existence behind in the rock.

These characteristics are summarised in Figure 8.3.1.

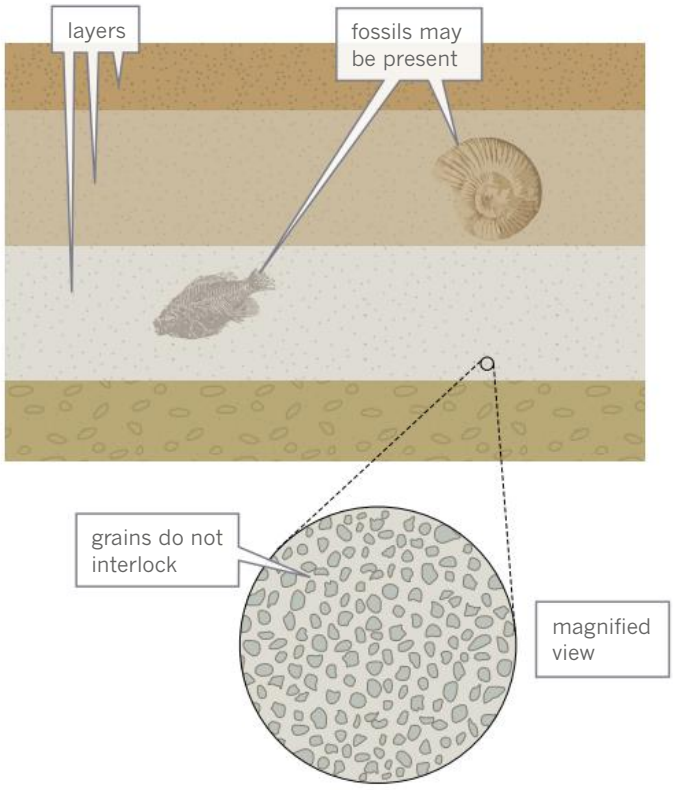

FIGURE 8.3.1 Characteristics of clastic sedimentary rocks

Clastic sedimentary rocks are classified mainly according to the size and nature of the rock grains and the chemical composition of the cement. You can see some in Figure 8.3.2.

FIGURE 8.3.2 Four different clastic sedimentary rocks

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SciFile

Sydney sandstone

Many of Sydney's early buildings such as the art gallery and museum were built from sandstone, a type of sedimentary rock that surrounds the city. The sand that settled to form the sandstone over 20 million years ago came from weathering of rocks in Antarctica. The sand was deposited in Australia when the two continents were connected as part of the ancient continent Gondwana.

FIGURE 8.3.3 The old Colonial Secretary's Building in Sydney was built from sandstone in 1880.

Chemical sedimentary rocks

Chemical sedimentary rocks form when minerals dissolved in groundwater crystallise within the sediments or when water evaporates, leaving behind crystals.

Chemical sedimentary rocks are quite soft, and this helps to distinguish them from the much harder igneous rocks. Figure 8.3.4 shows examples of chemical sedimentary rocks.

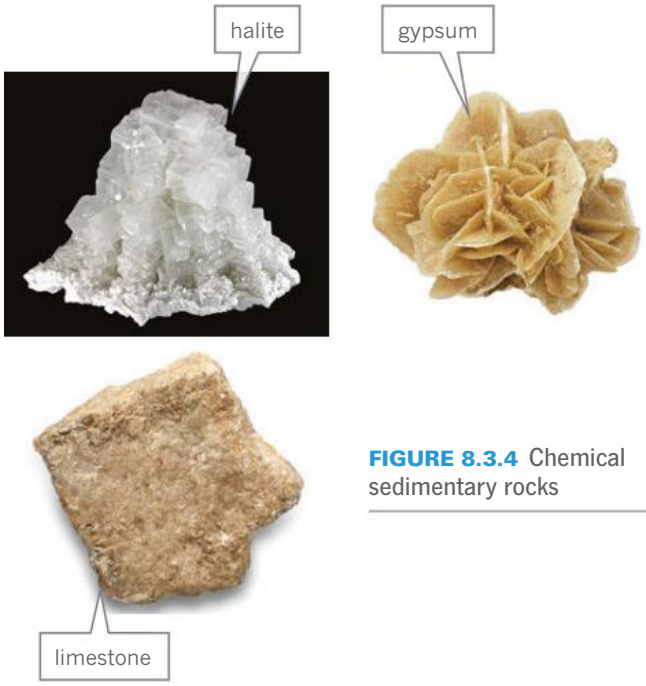

FIGURE 8.3.4 Chemical sedimentary rocks

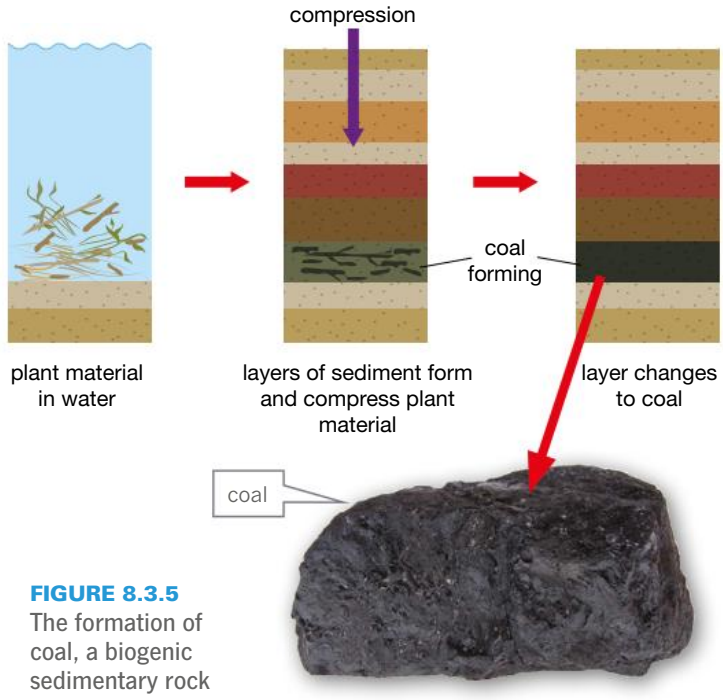

FIGURE 8.3.5 The formation of coal, a biogenic sedimentary rock

Biogenic sedimentary rocks

Biogenic sedimentary rocks form when dead plant matter or animal remains accumulate (build up) and are then cemented together. The sediments are mostly from organisms but there may be small amounts of sediment from weathered rock. Coal is a type of biogenic sedimentary rock. Its formation is shown in Figure 8.3.5.

Biogenic sedimentary rocks can be layered and are usually soft, although a few such as chert and flint can be fairly hard.

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Sedimentary rocks and geological history

Sedimentary rocks form in layers known as **strata**. Sediment is originally laid down horizontally, with younger sediment deposited on top of the older sediment. This means that, in an undisturbed sequence, the oldest layers are at the bottom (Figure 8.3.6). This gives us a way of determining which layers are older and which organisms lived earlier than others at that particular site.

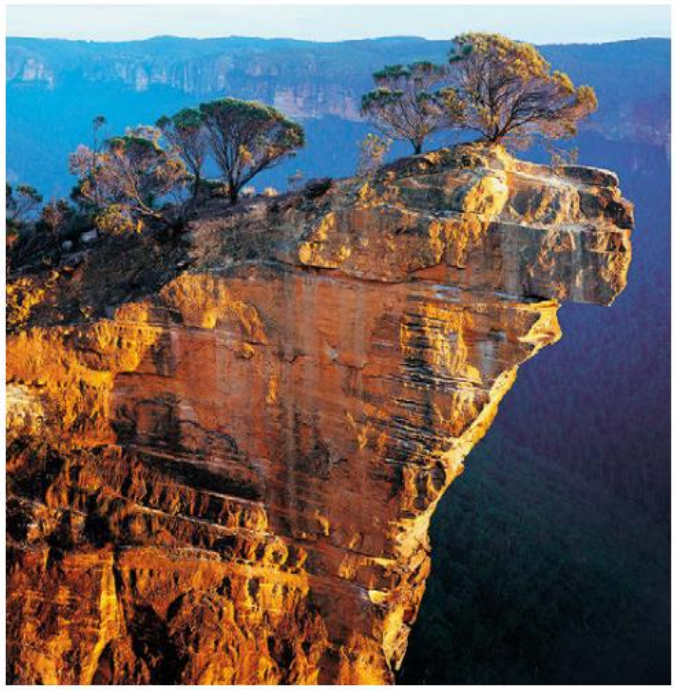


FIGURE 8.3.6 Rock strata are clearly visible as horizontal layers of sandstone in the Blue Mountains, NSW.

Formation of fossils

Fossils are the preserved evidence of organisms that once existed on Earth. A fossil may be the whole body of the organism or just a part of it. A fossil can also be traces of an organism's activities, such as its burrows or tracks. A fossil can even be an organism's dung, turned into rock (known as a coprolite). Some examples of fossils are shown in Figure 8.3.7.

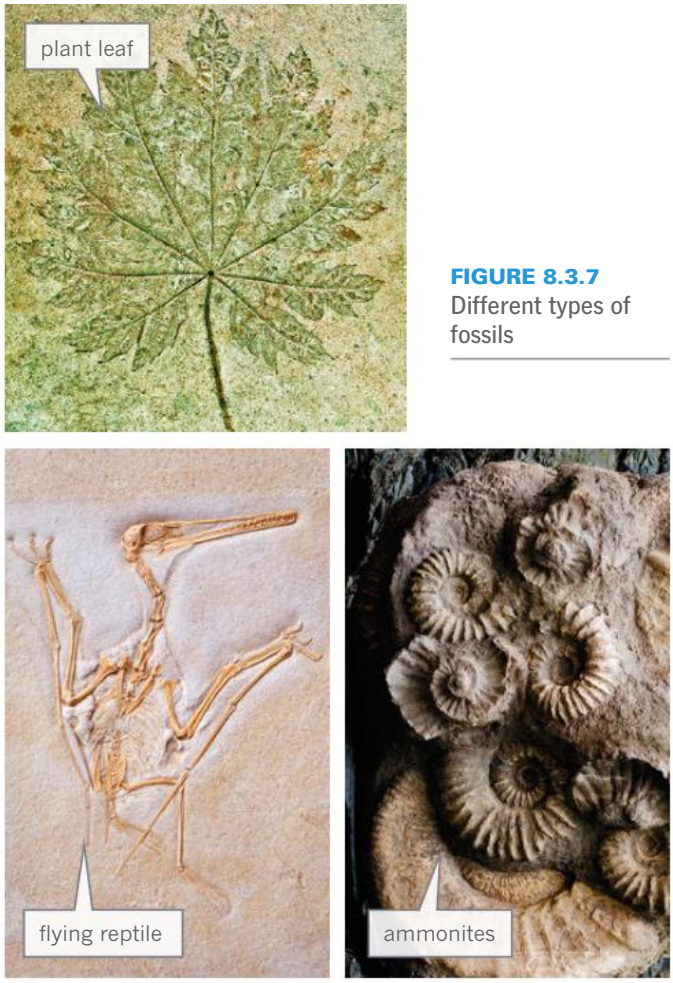


FIGURE 8.3.7 Different types of fossils

Soft parts of organisms decay much faster than hard parts. For this reason, it is extremely rare for soft parts to be preserved. Jellyfish, slugs, algae and mosses are organisms that are composed of soft parts only. These types of organisms are rarely found as fossils. Hard parts such as skeletons, shells, teeth or wood are most commonly found as fossils. The hard parts of organisms such as dinosaurs, giant kangaroos, crabs, shellfish and trees can be fossilised.

When an organism dies, its remains can be eaten, weathered away, or left to decay. If the remains are quickly covered by sediment, they are not likely to be eaten, and weathering and decay will be slowed.

If there is no oxygen in the sediment, the remains can be preserved. These conditions most often occur at the bottom of an ocean, lake or river. Sediments cover the organism, then slowly build up, compact and cement, turning it into rock. If an organism is turned into rock, it has been petrified and becomes a fossil. A similar process can also happen on land if wind-blown sediment covers the body.

Earth movements and weathering can then expose the rock layers containing the fossil or bring the layers to the surface (Figure 8.3.8).

FIGURE 8.3.8 These scientists are preparing to remove a large fossilised bone that has been exposed by weathering.

Relative age of rock strata

Relative age is not the actual age of a rock, but only indicates that it is older or younger than another rock.

If two rock layers are in one particular location, then their relative ages can be determined from their position in the rock strata—layers lower down should be older.

The relative ages of rocks from different locations can be compared using index fossils. An index fossil must:

- be found over a widespread area (for example, on different continents)
- have lived in a narrow period of time in the past
- have been abundant with lots of the organism living at that time.

If a particular index fossil is found in rock layers in two different locations, then you can be sure that the rocks in the layers are the same age.

MODULE 8.3

Review questions LS

Remembering

1 Define the terms:
   a fossil
   b clast.

2 What term best describes each of the following?
   a layers of sedimentary rock
   b rock made from cemented sand grains.

3 a Name the three main types of sedimentary rock.
   b What are two examples of each type?

4 What are the general characteristics of clastic sedimentary rocks?

5 What body parts are most likely to be fossilised?

6 State which layer in sedimentary strata is most likely to be:
   a oldest
   b youngest.

Understanding

7 How does the weight of overlying sediments contribute to the formation of clastic sedimentary rocks?

8 Outline the conditions needed for fossilisation.

9 Why are there far more fossil remains of dinosaurs than there are of jellyfish?

Applying

10 The layers in a sedimentary rock do not necessarily indicate which layer is oldest and which is youngest. Use a diagram to demonstrate how rock layers might change order.

Analysing

11 Compare a breccia and a conglomerate.

12 Igneous rocks and chemical sedimentary rocks often have crystals in them. What can you use to distinguish between them?

13 Classify each of the following sedimentary rocks as clastic, chemical or biogenic.
   a mudstone
   b coal
   c chalk
   d gypsum
   e sandstone.

14 Consider the following two facts about sedimentary rocks.
   - Oil, gas and coal are found only in sedimentary rocks.
   - Rock sediments contain fossil pollen grains from ancient plants that are now long extinct but were common in the time that oil began forming.

   Analyse these statements and explain how they may be used by geologists searching for oil, gas or coal.

Evaluating

15 Why do you think chemical sedimentary rocks can be found in salt lakes?

16 Propose reasons why:
   a animals that die in a desert are unlikely to be fossilised
   b plants living in swamps have a good chance of being fossilised
   c single-celled organisms are unlikely to be fossilised.

Creating

17 In your workbook, draw the Venn diagram in Figure 8.3.9, and use it to show the similarities and differences between the three different types of sedimentary rocks.

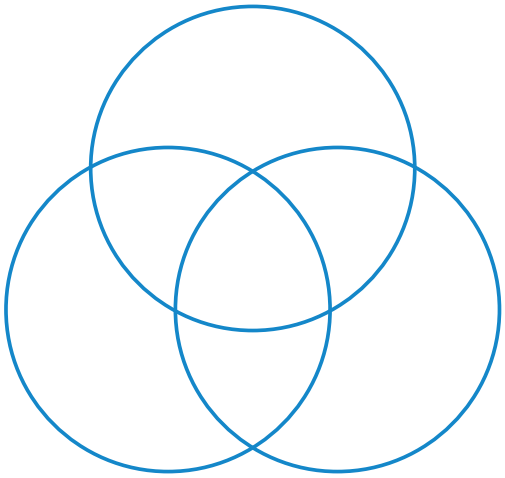


FIGURE 8.3.9

MODULE 8.3

Practical investigations

1 • Making sedimentary rocks

Questioning & Predicting | Processing & Analysing

Purpose

To investigate what factors affect the strength of an artificial sedimentary rock.

Hypothesis

Which do you think will make an artificial rock stronger:

- using rock such as blue metal or gravel, or just sand?
- using Portland cement or plaster of Paris?

Before you go any further with this investigation, write two hypotheses (one for each question) in your workbook.

Timing

45 minutes day 1, then 30 minutes two days later

Materials

- plaster of Paris
- Portland cement
- gravel (about 5 mm diameter) and bricklayers' sand mix
- blue metal (similar size to gravel) and bricklayers' sand mix
- bricklayers' sand

SAFETY

Do not mix cement or plaster of Paris with your hands. They can damage your skin.

Wear rubber gloves and safety glasses at all times.

Wash your hands after completing the activity.

Dispose of plaster of Paris in the rubbish bin, not the sink.

- ice-cream container
- 4 margarine containers
- spoon or spatula
- setting box (Figure 8.3.10)
- water
- 250 mL plastic beaker with volume scale
- G-clamp
- 6 × 500 g mass sets
- wire 15 cm long by 1.5 mm thick
- old towels or foam rubber
- slops bucket at front of class

Procedure

1 Copy the team results table from the Results section into your workbook.

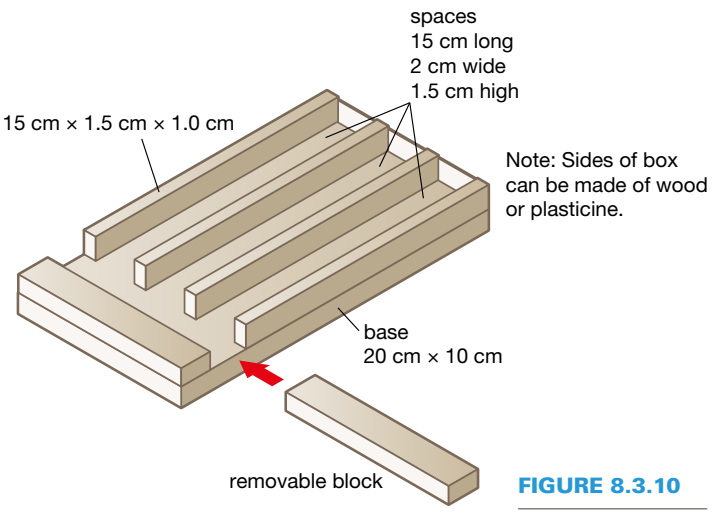


FIGURE 8.3.10

2 Each prac team will be given one cement type (either Portland cement or plaster of Paris). Collect about 150 mL of your cement. Collect about 100 mL of each of gravel/sand and blue metal/sand mixes and sand only. Place each sample in a different margarine container.

3 To each margarine container, add 50 mL of your cement type. Mix with the spatula or spoon while dry. Slowly add water a little at a time while mixing, until the particles are wet and stick together well. The mix should be like whipped cream rather than 'runny' like milk.

4 Transfer each cement–particle mix to a different section of the setting box. Label which is which. Leave the mixtures aside to dry for two days.

5 When your sedimentary 'rocks' are dry, remove them from the setting box.

6 Clamp one end of one rock to the edge of the bench, allowing about 8 cm to project over the edge. Loop the wire over the centre of the rock and attach the mass holder. Place the towels underneath to catch any masses that fall.

7 Add masses 100 g at a time until the 'rock' breaks. Make sure the rocks don't fall onto your feet. Enter your results in your Team results table.

MODULE 8.3

Practical investigations

Results

1 Record your team's results in the class results table on the board.

2 Copy the class results into your workbook when all teams have entered their results.

Team results

Particle size	Mass added to 'rock' to just break it (g)
gravel/sand	
blue metal/sand	
sand	

Class results: Average mass held before breaking (g)

Cement type	Particle size		
	Gravel/ sand	Blue metal/ sand	Sand
plaster of Paris			
Portland cement			

Review

1 a Considering only your team results, assess which rock was strongest and which was weakest.

b Justify your decision.

2 a Considering the class results, assess which rock was strongest and which was weakest.

b Justify your decision.

3 Assess whether your hypothesis was supported or not.

4 Portland cement and plaster of Paris both come from natural cements found in sedimentary rocks. Portland cement is used in making concrete and mortar for brick walls in buildings. Plaster is used to cover walls, to fix decorative edges on ceilings, and to make lightweight panels for inside walls on houses. Explain how this experiment relates to these building uses.

2 • Classifying sedimentary rocks

Questioning & Predicting | Processing & Analysing

Purpose

To use a key to classify sedimentary rocks.

Timing 45 minutes

Materials

- numbered set of unnamed sedimentary rocks
- stereo microscope and/or hand lens

Procedure

1 In your workbook, construct a table like the one shown in the Results section. Give your table a title.

2 Choose a rock and write down its number. In your table, write a brief description of what it looks like. Note features such as colour, texture, layering and fossils. What you have just recorded is the macroscopic view of the rock.

3 Now take a microscopic view of the rock by viewing it with the microscope or hand lens. Try to determine whether any grains are present. Note any grain colours, size and shape. Draw some grains.

4 Classify your rock into one of the three types of sedimentary rocks.

5 Repeat with the next rock until you have examined them all.

Results

Record all your observations in a table like the one shown below.

Rock number	Macroscopic view	Microscopic view	Classification

Review

Justify your classification of each rock.

MODULE 8.3

Practical investigations

• STUDENT DESIGN •

3 • Testing mortar mixes

Questioning & Predicting | Evaluating

Mortar is a mixture of Portland cement, bricklayer's sand and water. It dries quickly to form a solid that holds bricks or stones together in a building (Figure 8.3.11).

Purpose

To design an investigation to determine the strongest mortar mix.

SAFETY

A Risk Assessment is required for this investigation.

Wash your hands after completing the activity.

Timing

60 minutes plus 1 day to dry plus 30 minutes

Materials

As selected by students (probably similar to the materials used in Prac 1)

Procedure

1. Design an experiment that will test the strength of different mixes of Portland cement and bricklayer's sand.
2. Brainstorm in your group and come up with several different ways to investigate the problem. Select the best procedure and write it in your workbook. Draw a diagram of the equipment you need.
3. Before you start any practical work, assess your procedure. List any risks that your procedure might involve and what you might do to minimise those risks. Show your teacher your procedure and your assessment of its risks. If your teacher approves, then collect all the required materials and start work.

Use the STEM and SDI template in your eBook to help you plan and carry out your investigation.

Results

1. Construct a table showing your results.
2. Collect results from other groups and express the class results as an average.

Review

1. Compare the strongest mix obtained here with the recommended mix on the bag.
2. Construct a report on the experiment.
3. Evaluate your procedure. Pick two other prac groups and evaluate their procedures too, identifying their strengths and weaknesses.
4. Propose how the results of this investigation could be of use in the building trade.

FIGURE 8.3.11

MODULE
8.4 Metamorphic rocks

All rocks can be altered by heat and/or pressure to form metamorphic rock. Even metamorphic rocks can be metamorphosed. This process turns ordinary limestone into beautiful marble, and soft sandstone into hard quartzite.

Formation of metamorphic rock

Metamorphic rocks form when intense heat and/or pressure alter existing rocks. This may cause physical changes, folding the rocks or sliding different parts of the rock sideways in a process called shearing.

science 4 fun

Fire a rock

What happens to clay if you heat it?

Collect this ...

- modelling clay
- ice-cream container
- spatula

Do this ...

1. Make two identical models with your clay. Put one in a sunny place and take the other to the Art department to be fired in a kiln.
2. When the fired clay model is ready, compare it with the one that you left in the sunshine by trying to break a piece off each. See how strong the two pieces of clay are.

Record this ...

1. Describe what happened.
2. Explain why you think this happened.

Heat and pressure can also cause chemical changes, such as recrystallisation of minerals. New minerals such as the semiprecious gemstone garnet may form during this process (Figure 8.4.1).

As rocks get buried deeper, the temperature and pressure increase. Heat and pressure can also be increased by movements within Earth's crust. The crust is broken into massive plates, called **tectonic plates**. Australia lies within the Australian plate. These plates moving around on the mantle can collide, pull apart or scrape past each other.

The forming of metamorphic rocks is called metamorphism. Metamorphism occurs across a range of temperatures and pressure resulting in a variety of rocks with different features. For example, shale can turn into slate, schist or gneiss, depending on the temperature and the size of the force it has been exposed to.

FIGURE 8.4.1 Garnets are semiprecious stones that can form in metamorphic rocks.

Types of metamorphism

There are three major types of metamorphism (Figure 8.4.2).

- **Regional metamorphism**—this is where rock is altered by both heat and pressure. This kind of metamorphic change often occurs across large areas as a result of colliding plates or rocks being buried.
- **Contact metamorphism**—this is where rock is altered mostly by heat. It often occurs over smaller areas as a result of hot magma intruding into rock.
- **Dynamic metamorphism**–this is where rock is altered mostly by pressure. It often occurs in a small area where the crustal rocks are scraping past each other.

Metamorphic changes

The texture of a rock can be changed by metamorphism. One common change for a rock placed under heat and pressure is that it becomes foliated. **Foliation** is the movement of minerals into layers or bands. Pressure can also squash and crumple layers or bands, making them wavy. The rocks in Figure 8.4.3 all show foliation.

Not all metamorphic rocks are foliated. Examples of non-foliated metamorphic rocks can be seen in Figure 8.4.4. Diamonds are gemstones that can be formed in metamorphic rock when parts of the crust become pushed into the mantle. The crust sinks to depths of about 150 kilometres, where high temperatures and pressure cause the change.

At temperatures of over 1000°C , the carbon can crystallise into diamond. Diamonds can be transported to the surface millions of years later by fast-moving magma.

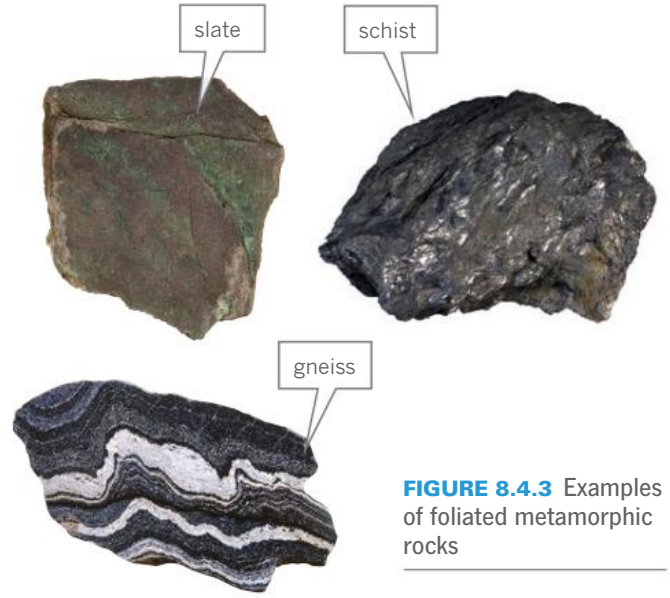
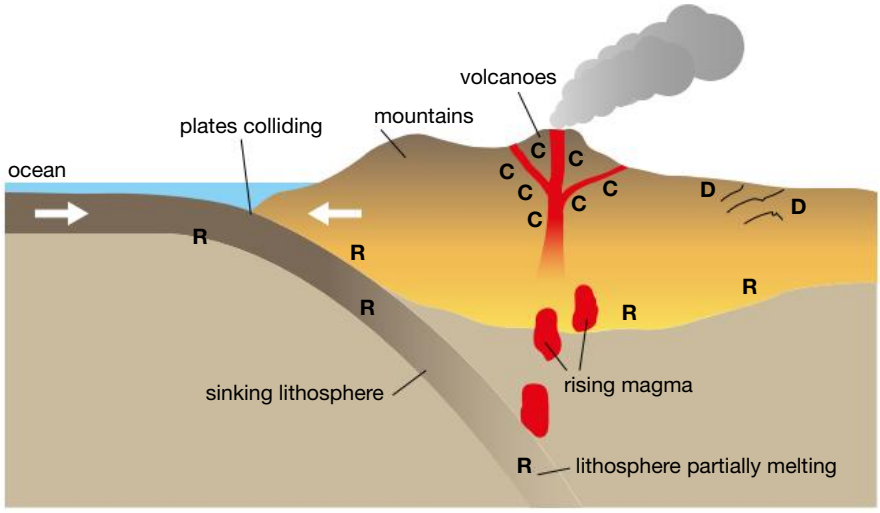


FIGURE 8.4.3 Examples of foliated metamorphic rocks

FIGURE 8.4.4 Unbanded (non-foliated) metamorphic rocks



R regional metamorphism
C contact metamorphism
D dynamic metamorphism

AB 8.7

FIGURE 8.4.2 Metamorphic rocks form in three main ways.

SkillBuilder

Classifying rocks

Scientists use dichotomous keys to classify things based on properties that can be observed. Dichotomous keys offer just two choices at each stage of the classification process.

First, a rock is sprayed with water to enhance and contrast colours. It is then viewed using a hand lens or magnifier. A ruler can be used to estimate the size of crystals or clasts. Rocks that are very fine grained are difficult to classify unless you can take thin sections and examine them under a microscope.

1	Rocks have crystals—go to 2 Rocks do not have crystals—go to 6
2	Rocks are made entirely of interlocking crystals *Igneous*—go to 3 Rocks are not made entirely of interlocking crystals *Metamorphic*—go to 10
3	Rocks have crystals large enough to see using a hand lens *Igneous intrusive*—go to 4 Rocks are crystalline but their crystals are difficult to see using a hand lens *Igneous extrusive*—go to 5
4	Rocks are dark and dense *Igneous, intrusive & mafic* e.g. *gabbro* Rocks are neither dark nor dense *Igneous, intrusive & felsic* e.g. *granite, pegmatite*
5	Rocks are dark and dense *Igneous, extrusive & mafic* e.g. *basalt* Rocks are neither dark nor dense *Igneous, extrusive & felsic* e.g. *rhyolite*
6	Rocks are non-crystalline and are made of clasts *Sedimentary, clastic*—go to 7 Rock are non-crystalline but are not made of clasts *Sedimentary, biogenic* e.g. *limestone, chalk, coal*
7	Rocks have large clasts—go to 8 Rocks do not have large clasts—go to 9
8	Rocks have large clasts that are rounded *Sedimentary, clastic e.g. conglomerate* Rocks have large clasts that are not rounded *Sedimentary, clastic e.g. breccia*
9	Rocks have medium rounded clasts *Sedimentary, clastic medium grained e.g. sandstone*
10	Rocks have clasts that are less than medium size *Sedimentary, clastic fine grained* e.g. *siltstone, mudstone*
11	Rocks are foliated (or banded) *Metamorphic* e.g. *slate, schist and gneiss*
12	Rocks are not foliated (or banded) *Metamorphic e.g. quartzite and marble*

Worked example

Classifying a rock

Problem

Use the dichotomous key to classify the rock in Figure 8.4.5.

FIGURE 8.4.5
Each bar on the scale is one centimetre

Solution

Thinking: Does the rock have obvious crystals?

Working: Yes, so move on to 2.

Thinking: Are the crystals interlocking?

Working: Yes, so move on to 3.

Thinking: Are the crystals large enough to be seen by the naked eye, or do they appear very large through a hand lens?

Working: The crystals are obvious without a hand lens, so move on to 4.

Thinking: Is the rock dense and dark?

Working: The rock is light in colour, so it is not dark. It must therefore be an igneous intrusive rock. It could be granite.

Try yourself

Use the dichotomous key to classify the rock in Figure 8.4.6.

FIGURE 8.4.6
Each bar on the scale is three centimetres

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Prac 2 p. 353
AB 8.8

MODULE
8.4 Review questions

Remembering

1 Define the terms:
   a tectonic plates
   b shearing
   c contact metamorphism.

2 What term best describes each of the following?
   a the process where rock is metamorphosed mainly by pressure
   b sideways movement of parts within a rock
   c the banding that is found in some metamorphic rocks.

3 What is the name of the tectonic plate that Australia sits on?

4 Name two gemstones that are sometimes found in metamorphic rocks.

5 Name two types of metamorphic rock that slate can turn into.

6 Where in the Earth do metamorphic rocks form?

7 List the two main factors involved in forming metamorphic rock.

8 What changes occur in rocks as they become metamorphic rock?

Understanding

9 Describe what occurs to turn a rock into a foliated (banded) metamorphic rock.

10 Explain how heat energy and pressure are important in the formation of metamorphic rock.

11 a Predict which clay figure will be strongest—one that is fired in a kiln or one that is left unfired.
   b Explain how this relates to the formation of metamorphic rock.

12 Outline how diamonds form.

Applying

13 Identify the feature of a sedimentary rock that would help you decide that it formed from weathering of a metamorphic rock.

Analysing

14 Consider the following description of a rock.
It is a light-coloured rock with white and grey crystals visible. The grains seem to be interlocking. It looks a bit like granite, but there are five wavy darker bands running right through the rock. The grains in the bands look like they are black or dark green. They seem to be very flat under the microscope. The flat dark crystals seem to be all lined up.
   a Classify this rock as foliated (banded) or non-foliated.
   b This rock is called a granite gneiss. Identify the feature that gives you a clue that this is a metamorphic rock.
   c Contrast this rock with granite, from which it was formed.

Evaluating

15 It is possible for metamorphic rocks to form at the Earth's surface. How do you think this might happen?

16 Sometimes shale can turn into slate. At other times it may turn into schist. On other occasions again it can become another rock type, called gneiss. How do you think the three different metamorphic rocks could all form from shale?

Creating

17 Construct a rock cycle poster. Include brief explanations of the process that formed each rock.

MODULE 8.4

Practical investigations

1 • Metamorphic rocks

Processing & Analysing | Communicating

Purpose

To compare metamorphic rocks with their parent igneous and sedimentary rocks.

Timing 30 minutes

Materials

- labelled rock samples in containers: limestone and marble, shale and slate, shale and schist, granite and gneiss, sandstone and quartzite
- stereo microscope
- hand lens

SAFETY
Wash your hands after completing the activity.

Procedure

1. Use the microscope and the hand lens to examine the rock samples.
2. Use the information in this chapter and any other information available to you to match each metamorphic rock to its parent rock.
3. For each pair of rocks, write the name of the parent rock first and describe its characteristics. Then do the same for the metamorphic rock.

Review

1. For each metamorphic rock, describe the characteristics that enable you to decide it is metamorphic.
2. What changes have occurred in each metamorphic rock as it altered from its parent rock?

2 • Revising rocks

Processing & Analysing | Planning & Conducting

Purpose

To classify unknown rock samples as igneous, sedimentary or metamorphic.

Timing 30 minutes

Materials

- numbered but unlabelled rock samples
- stereo microscope
- hand lens

SAFETY
Wash your hands after completing the activity.

Procedure

1. In your workbook, construct a table like the one shown in the Results section. Give your table a title.
2. Choose a numbered rock sample. Your first task is to describe the characteristics of the rock. Use your microscope and hand lens to take a clear look. Then decide whether it is igneous, sedimentary or metamorphic, recording your reasons in your table. You may need to check the earlier units in this chapter again to remind you. If you feel confident, try to name the rock.
3. Repeat step 2 for each rock.

Results

Record all observations in your Results table.

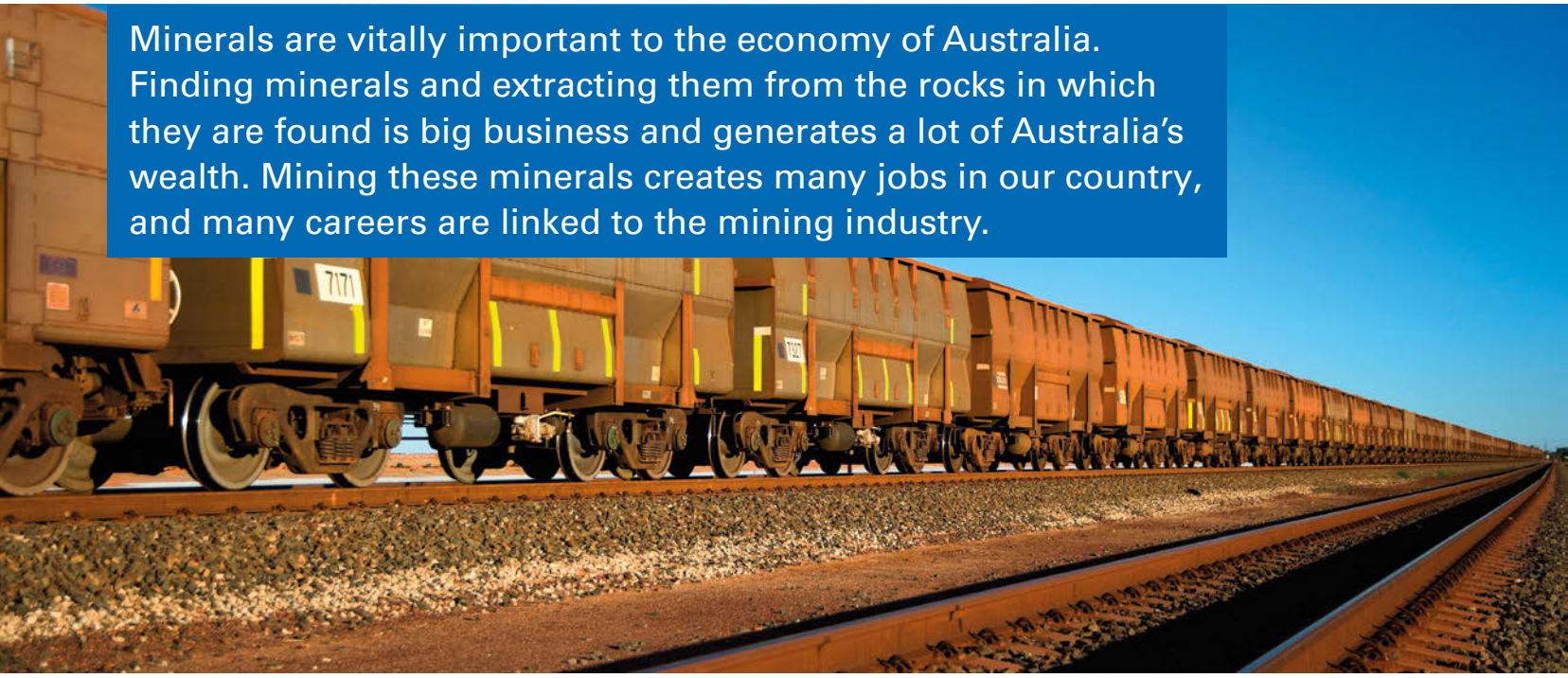
Rock number	Description	Classification	Reasons	Rock name

Review

1. What are the characteristic features of each of the main rock types: igneous, sedimentary and metamorphic?
2. How is the rock cycle is relevant to this practical activity?

MODULE
8.5 Mineral resources

Minerals are vitally important to the economy of Australia. Finding minerals and extracting them from the rocks in which they are found is big business and generates a lot of Australia's wealth. Mining these minerals creates many jobs in our country, and many careers are linked to the mining industry.



Rocks, ores and minerals

Minerals are naturally occurring chemical substances that make up igneous, sedimentary and metamorphic rocks. An **ore mineral** contains a metal or some other valuable material. Some ore minerals are pure elements. Gold is one of the few metals that can be found in nature as a pure element. A metal found as a pure element is also known as a **native metal**. Other examples of native metals are silver and copper. However, most minerals are compounds made up of different elements. For example, while copper can be found as a pure element it can also be found as a compound like copper carbonate found in the mineral malachite.

Sometimes the ore mineral is extracted from the surrounding rock and the whole mineral used. At other times, only the metallic element needs to be extracted (released) from its compound. For example, the mineral titanium oxide can be used as a whole mineral to colour paints white. The metal titanium can also be extracted from the titanium oxide. The titanium can then be used in making steel alloys.

Australia is among the world's largest exporters of iron ore, lead, zinc, gold, uranium and aluminium. We are also an important exporter of titanium, nickel, copper, tin and silver.

Australia supplies various minerals to other countries. The prices of minerals rise if there is increased demand from other countries, and prices fall if there is less demand for our minerals. Therefore, mines open if there is more demand and close if there is less demand. Mines only continue while they are profitable or until the mineral is used up.

Mineral formation

Most minerals are formed by processes that involve heat and pressure.

Magma is very hot, molten rock. As magma cools, mineral crystals can form. Therefore, many minerals are found in igneous rocks. Examples are quartz and feldspars.

The heat from magma can melt existing rocks, and forces within the Earth's crust can deform them. Both these processes can form new minerals, which can only be found in metamorphic rocks. Examples are garnets, a type of semiprecious gemstone.

Many minerals are found in sedimentary rocks. These form when solutions containing compounds rich in minerals flow through rock and the minerals slowly crystallise as the water evaporates. This may happen in a cave, forming stalagmites and stalactites of calcium carbonate. Stalagmites rise from the floor of caves, and stalactites hang from the roof of caves. Crystallisation also happens at the ground surface, such as in a salt lake where halite, gypsum and other chemical sedimentary rocks form. Crystallisation can also happen inside other rocks or cracks in the rocks (Figure 8.5.1).

FIGURE 8.5.1 This cross-section shows purple amethyst crystals inside a blue, banded rock called agate.

The amethyst crystals formed when a very hot aqueous solution seeped into the hollow space in the agate.

Copper minerals are a good example of how some minerals form. The world's major copper deposits were formed near magma that pushed into existing rocks. This is shown in Figure 8.5.2. The magma superheated nearby water. This means that the water was heated to above its boiling point. This superheated water then dissolved copper minerals in the surrounding rocks. These superheated solutions are known as **hydrothermal fluids**. The hydrothermal fluid carried its dissolved copper minerals away from the magma and into spaces in surrounding rocks. The fluids cooled and copper minerals crystallised in these spaces, forming a rich copper mineral layer.

The copper tends to be in a zone called an 'aura' that surrounds the old magma chambers. Other minerals tend to form in cracks in the rocks called 'veins'.

Hydrothermal fluids are also involved in the formation of gold. Some gold is deposited in igneous rocks but is later dissolved by hydrothermal fluids. These fluids then move through other rocks and deposit the gold in cracks, forming veins of gold.

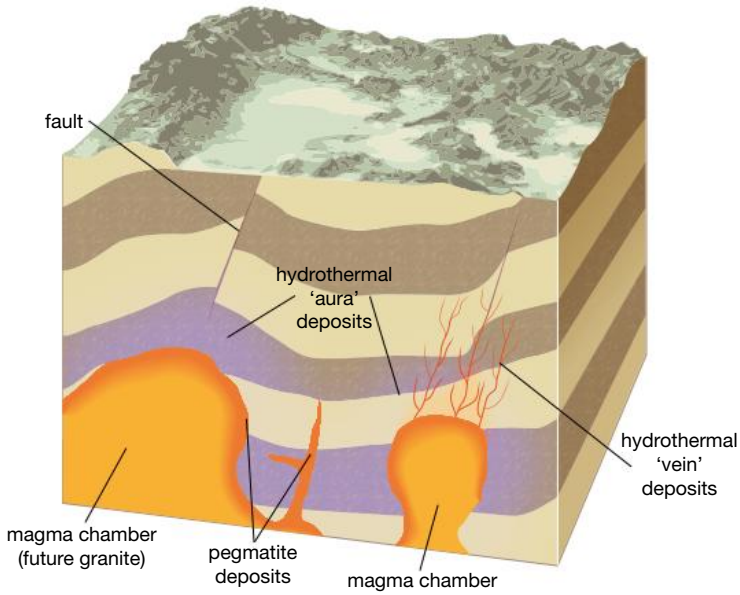


FIGURE 8.5.2 Hydrothermal fluids can form mineral deposits around magma chambers (aura) and in cracks (veins) in rocks.

From Earth to final product

Humans have been digging up minerals and using them for thousands of years. For this reason, some stages of human development are known by the metals that were mined and used. Examples are the Bronze Age and the Iron Age.

Minerals that are dug up and used are known as **mineral resources**. Some only need a little cleaning before they can be used—the gold nugget in Figure 8.5.3 is an example. Other resources are not found as pure elements but are found as compounds instead. For example, iron is commonly found as iron oxide, and aluminium as aluminium oxide. The metals iron and aluminium then need to be extracted from these compounds.

FIGURE 8.5.3 This 25.5 kg gold nugget was discovered in Western Australia in 1995. Gold is a native metal, able to be found in its pure form.

The process of obtaining minerals consists of three main steps.

1 *Mining*—the resource is removed from the ground.
2 *Processing*—the unwanted materials are removed, and the wanted material is extracted.
3 *Rehabilitation*—after all mining and processing is completed, the mining site is repaired so that it returns to something similar to the original environment.

Mining methods

Some of the more common mining methods are:

- open cut—this method is usually used when the mineral deposit is near the surface and where there are large quantities spread over a large area. It is one of the least expensive mining methods (Figure 8.5.4)
- underground mining—this method is usually used when the mineral deposit is deeper and/or concentrated into pockets or narrow veins (Figure 8.5.5)
- dredging—this method can be used when the minerals are found in sand and a large lake can be dug and filled with water (Figure 8.5.6)
- leach mining—with this method, a fluid that will dissolve the mineral is injected through drill holes into the deposit and then pumped out through recovery pipes.

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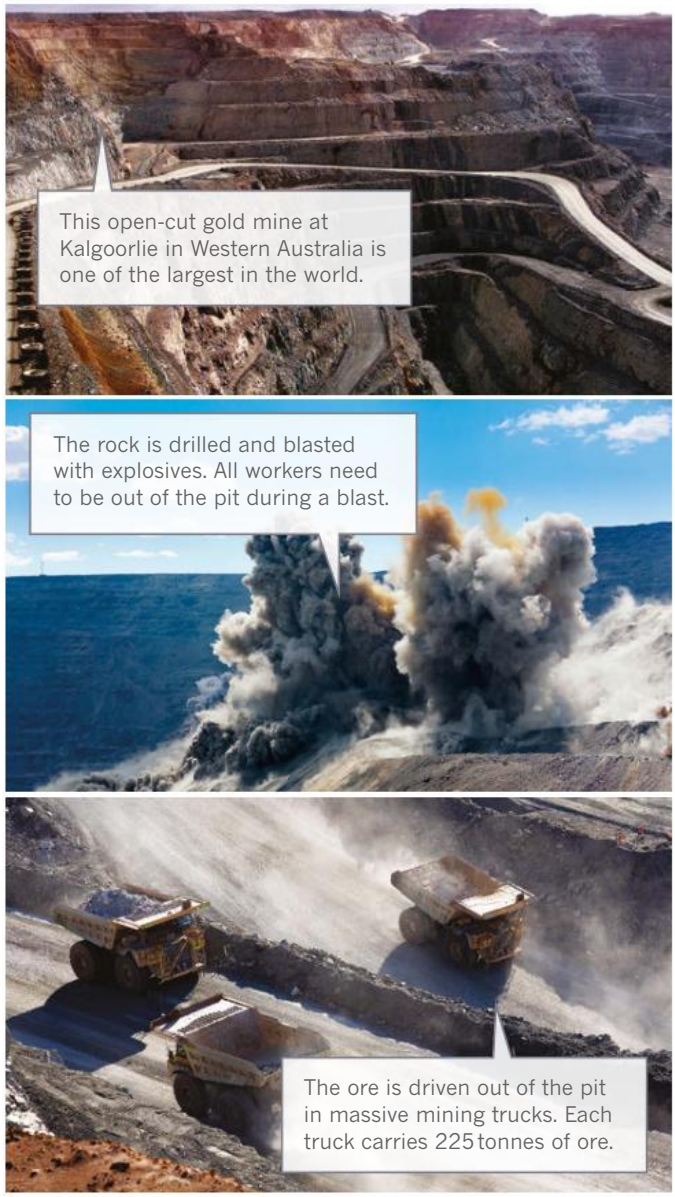

FIGURE 8.5.4 Three images of an open-cut gold mine in Kalgoorlie, Western Australia

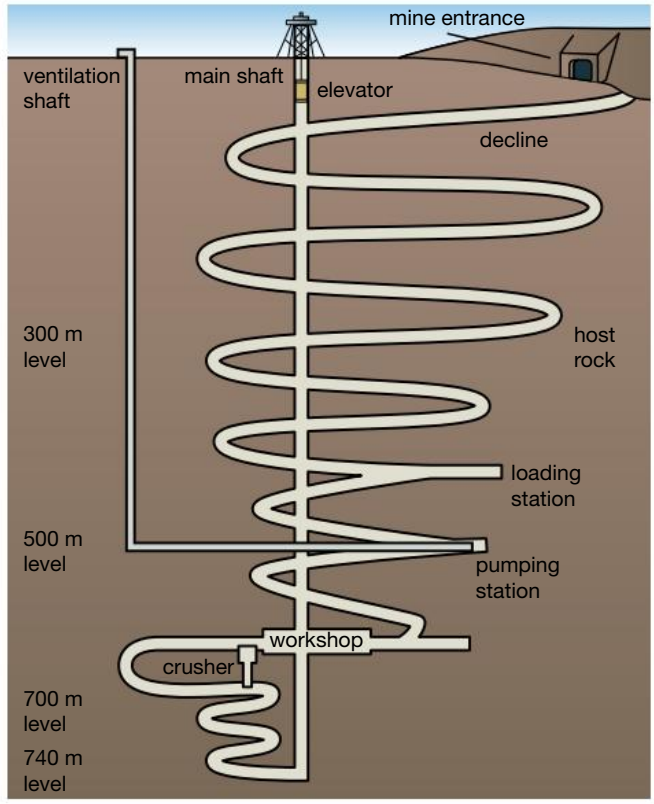

FIGURE 8.5.5 Underground mining using a decline enables trucks to drive down to pick up crushed ore and carry it to the surface.

FIGURE 8.5.6 This boat is dredging for mineral sands at the Gingko Mine, Pooncarie, 220 km south of Broken Hill in New South Wales.

Processing

The way in which a mineral ore is processed depends on its properties. Whichever method is used, some steps are common.

Step 1: Crushing is usually done over several stages to produce rocks of similar size. It also increases the surface area of the rock, making it easier to treat further.

Step 2: Minerals that are magnetic are removed by magnets, while very dense materials are allowed to drop out from the rest of the ore. The remainder of the ore continues through further processing.

Step 3: The minerals are enriched to concentrate them and improve their quality. Enrichment can be done through many different processes, depending on their chemical and physical properties. One such process is **froth flotation**, in which the desired ore is carried away on a frothy emulsion of oil and water. The unwanted remainder of the crushed rock, called gangue, is left behind. Froth flotation is shown in Figure 8.5.7.

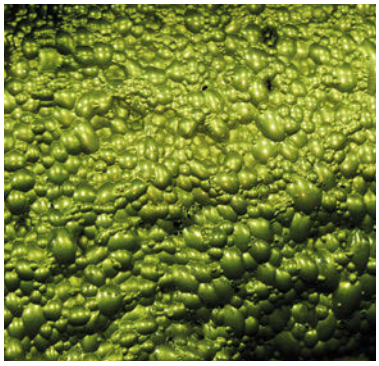

FIGURE 8.5.7 Froth flotation carries the ore away on bubbles, separating it from the gangue.

Step 4: The desired metal is extracted. **Extraction** is the chemical process of separating metals from the compounds in which they occur. For example, iron, lead and zinc are commonly extracted from their ores by heating them in a blast furnace by themselves or with limestone and carbon (Figure 8.5.8). This intense heating process is called **smelting**. Aluminium is extracted from its ore using electricity in a process called **electrolysis**.

FIGURE 8.5.8 A blast furnace is used to extract iron from iron ore.

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Rehabilitation

When a mine has ended its productive life, the site needs to be returned to the way it was before the mine was built.

Underground mines have minimal effect on the surface landscape, and so the mine area can still be used for other purposes such as farming, water reservoirs or urban development.

This is obviously not possible with open-cut mines. They have to be rehabilitated (repaired) before the area can be used for some other purpose. In general, the original top soils that were removed to create the open-cut mine are replaced. These soils are then graded to ensure the landscape drains well. The area is then fertilised and replanted with plants native to the area. Figure 8.5.9 shows the same mining site before and after rehabilitation.

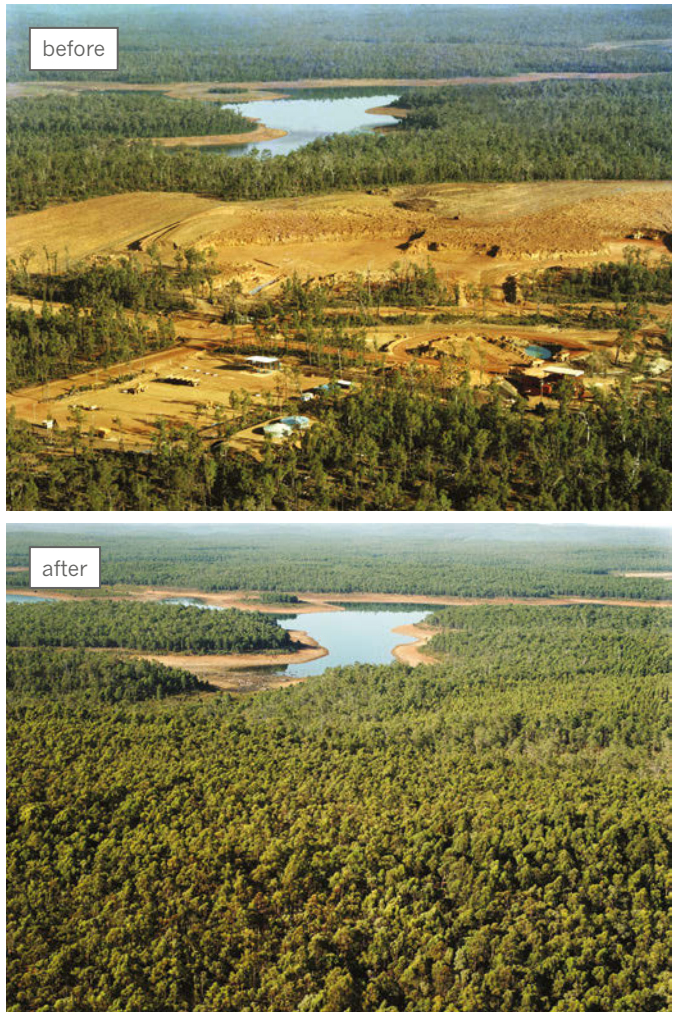


FIGURE 8.5.9 A bauxite mine site in Western Australia before and after the site was rehabilitated.

One of the biggest concerns when rehabilitating a site is tailings. **Tailings** are waste materials from the mine or mineral processing plant. Tailings are often toxic, containing acids or poisonous chemicals. For example, tailings from gold mines usually contain the poison cyanide. Tailings are usually dumped into ponds surrounded by earth walls.

In Australia, laws require mining companies to comply with strict procedures. Environmental scientists design and monitor pollution control measures. Water pollution is controlled by treating it chemically and leaving it to settle out in tailings dams. Clean run-off can then be discharged (released) into surrounding creeks and rivers.

SciFile

Deadly leaks

Up to five major spills from tailing ponds occur every year worldwide. In Hungary in 2010, a toxic sludge from a burst pond at an aluminium processing plant swept through a village, killing eight people and injuring another 150. It also polluted one of Europe's major rivers, the Danube. In Brazil in 2015, a tailing dam burst, killing 16 people and many animals, and destroying villages and crops. It badly polluted 800 km of river and eventually reached the Atlantic Ocean.

FIGURE 8.5.10 This spill at an aluminium processing plant in Hungary in 2010 killed eight people.

AB 8.9

Working with Science

ETHICAL JEWELLER

Zoe Pook

Gold mining is a billion-dollar industry worldwide, yet gold miners in developing countries are vulnerable to exploitation, unsafe working conditions and poverty. This is because of unfair trade agreements, lack of regulation, and lack of protection for the miners' working rights or basic human rights. Fairtrade gold certification ensures that the people who mined the gold are working in safe conditions, with fair pay and workers' rights, while using environmentally responsible practices. The guaranteed fair price for the miners helps them grow their business and improve their standard of living, enabling them to provide safe, clean housing, food and health care to their families, and education for their children.

Zoe Pook designs and crafts customised engagement and wedding rings in her studio in Sydney (Figure 8.5.11). What sets Zoe apart from other jewellers is her commitment to sourcing ethically and sustainably mined gold and precious gems. Zoe is one of only a few jewellers in Australia to use Fairtrade Certified Gold. Zoe sources her gold from a Fairtrade accredited mine in Peru. Her creations are not only beautiful and unique, but they are also helping miners and their families work towards a better life.

Review

1. Why do you think it is particularly important to have fair, safe working standards for people who work in mining?
2. What other Fairtrade products, aside from gold, are available in Australia?

FIGURE 8.5.11 Zoe Pook is an ethical jeweller who designs and crafts engagement and wedding rings with Fairtrade gold and precious gems.

Australian mining innovation

The mining and mineral resources industry contributes significantly to the Australian economy, making up around 50% of our exports. Mining in Australia is now faced with decreasing productivity, more competition from overseas producers and decreased demand for our products (Figure 8.5.12).

FIGURE 8.5.12 The Australian mining and mineral resources sector faces challenges after the end of the mining boom.

To help find solutions to these challenges, three Perth businessmen created Unearthed, an organisation that brings together scientists, software developers, data engineers and industry experts to create new technology for the Australian resources industry (Figure 8.5.13).

FIGURE 8.5.13 Unearthed brings together scientists, software developers, data engineers and industry experts to create innovative solutions for Australia's mining industry.

Unearthed started in 2015 with workshops, competitions and technology programs held in cities around Australia. The aim of these events was to generate and test ideas, and give business people opportunities to form start-up companies that will bring new technology to the mining and resources sector. Online competitions to create solutions for mining companies are open to developers from around the world. Prizes, training and industry connections are offered to encourage people to join in, put ideas out there, and use the brightest ideas to develop cutting-edge technology quickly and efficiently.

In 2015, Unearthed brought together over 500 people to find new solutions to some of the problems in the mining industry, and to help business people to find jobs or start their own businesses. One of the more successful start-up companies to come out of Unearthed in 2015 developed a detection system for oversized boulders. Large boulders can cause machinery to jam and stop production, costing the industry millions of dollars each year. The technology developed by the Unearthed team uses vibrations to detect the location and size of the boulder. This technology offers an effective solution that can increase production in the industry. Unearthed plans to create ten new companies every year to boost ideas and technology in the mining industry.

REVIEW

1. Unearthed is working to find solutions for Australia's mining industry by asking the community for help, usually through the internet. This process, called 'crowd-sourcing', lets people offer their ideas and also their financial support online. List two advantages and two disadvantages of crowd-sourcing for innovation and technology.
2. In 2016, Unearthed opened up its competitions to international participants. Why do you think it might be beneficial to include people from overseas?
3. With the mining boom over, what other areas do you think Australia should invest in to strengthen our economy for the future? List at least two of your ideas.

MODULE
8.5 Review questions

Remembering

1 Define the terms:
   a native metal
   b ore mineral
   c extraction.

2 What term best describes each of the following?
   a chemical substances that make up rocks
   b uses heat and a blast furnace to extract metal from its ore
   c uses electricity to extract metal from its ore.

3 Why is mining important to Australia?

4 State the three main factors that determine what type of mining method is chosen.

5 Name four methods of mining.

6 What is an example of a native metal?

7 What are hydrothermal fluids?

8 In which circumstances are the following mining methods most likely to be used?
   a open-cut mining
   b underground mining
   c dredging
   d leach mining.

9 Name two metals that are commonly extracted using:
   a smelting
   b electrolysis.

Understanding

10 How are heat energy and forces involved in the formation of copper minerals?

11 Explain how froth flotation is used to separate copper mineral ores from the other unwanted crushed rock.

12 Describe how mine sites are rehabilitated after mining.

13 What are tailings and why can they be a problem?

Applying

14 Identify the mining method you could choose if the ore body was:
   a gold at the surface
   b gold deep below the ground
   c salt deep underground
   d uranium or malachite deep underground.

Analysing

15 a Contrast stalactites with stalagmites.
   b Name the chemical that crystallises as stalagmites and stalactites.

16 Compare the impact on land use of open-cut and underground mining.

Evaluating

17 Gold miners in the past used shaft mines, whereas modern mines on the same sites are open-cut. Propose what type of gold deposit the two mines located.

18 Miners exploring for gold often search in areas where there has been a history of volcanic activity. Propose a reason why.

19 An ore body starts 20 metres below the surface and runs in narrow channels 2 kilometres into the Earth. Would open-cut or underground mining be the most appropriate method of mining this ore?

20 Propose reasons why a rehabilitated mine site is only planted with trees native to the area.

Creating

21 Construct a diagram of an ore body in the ground that would probably be recovered using:
   a solution mining
   b underground mining
   c surface mining.

MODULE 8.5

Practical investigations

1 • Leach mining

Planning & Conducting | Processing & Analysing

Purpose

To model the process of leach mining.

Timing 35 minutes

Materials

- 100 mL 0.2 M sulfuric acid
- 2 g copper carbonate
- 400 mL fine crushed rock (not soil)

SAFETY

Sulfuric acid is corrosive so wear safety glasses, rubber gloves and protective clothing.

- 250 mL beaker
- 500 mL beaker
- test-tube and test-tube rack
- 5 mL syringe and plastic tube
- 2 × 10 cm plastic tubes, each containing a pencil (for wells)
- retort stand, bosshead and clamp
- filter funnel (plastic)
- spoon
- iron nail

Procedure

1. Place 2 g of copper carbonate (your mineral) in the large beaker.
2. Fill the beaker with the fine crushed rock to a few centimetres below the top.
3. Make sure the pencil is not a tight fit in the plastic tube and can be removed easily. Drill a hole down to the copper ore using the plastic tube containing the pencil. This is the injection well. Try to reach the bottom of the beaker. Remove the pencil.
4. Place the filter funnel in a retort stand. Connect the end of the filter funnel to the plastic tube in the beaker. Make sure the lower end of the plastic tube is about half a centimetre off the bottom of the beaker as shown in Figure 8.5.14.

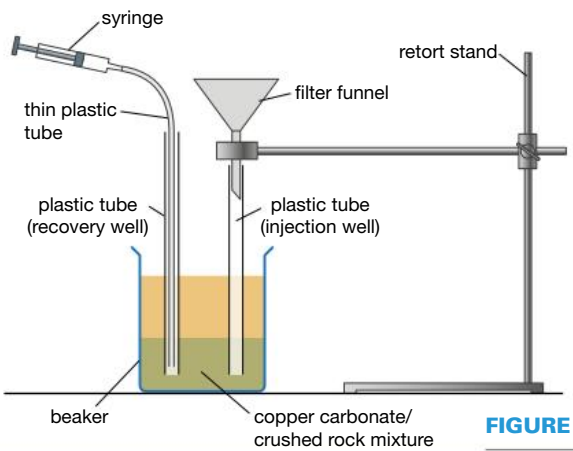


FIGURE 8.5.14

5. Carefully pour about 100 mL of sulfuric acid into the filter funnel, making sure it does not spill over the top of the funnel. Leave to stand for about 2 minutes.
6. Drill another hole down into the beaker using the other plastic tube containing the pencil. Make sure it is about half a centimetre off the bottom of the beaker. Remove the pencil. This is the recovery well.
7. Pass the other end of the plastic tube on the syringe down into the recovery well.
8. Carefully pull the plunger out on the syringe. When you recover some liquid, squirt it into the test-tube. Keep removing liquid until you have about 20 mL. (If you cannot remove any liquid, push the plastic tube of the recovery well down to the bottom of the beaker and try again with the syringe.)
9. Add an iron nail to the test-tube of recovered mineral and observe it for several minutes.

Results

Record your observations.

Review

1. Find a diagram of leach mining and use that and your experiment to answer the following questions. State the part of this model that represents the:
   - **a** ore body
   - **b** mineral
   - **c** injection well
   - **d** recovery well
   - **e** leach solution
   - **f** pump.
2. Describe how this model showed the process of solution mining using a leach solution.
3. From your observations on this simulation, propose what would need to be done to the leach solution after it is pumped out of the recovery well in a real leach mine.
4. Describe what happened when the iron nail was placed in the blue solution.
5. Propose what substance was formed on the iron nail.

MODULE 8.5

Practical investigations

2 • Extraction of copper by electrolysis

Planning & Conducting | Processing & Analysing

Purpose

To investigate the extraction of copper from copper ore by using electrolysis.

Timing 60 minutes

Materials

- 100 mL 0.2 M sulfuric acid
- copper ore (1 g copper carbonate in sand)
- sodium carbonate powder

SAFETY

Sulfuric acid is corrosive, so wear safety glasses, rubber gloves and protective clothing. Copper carbonate is poisonous if eaten.

- power pack or 2 dry cells in series (about 3 volts)
- 2 electric leads with alligator clips
- 2 graphite electrodes pushed through holes in an icy-pole stick to keep them separate
- 2 × 100 mL beakers
- spoon
- stirring rod
- filter paper
- filter funnel and stand

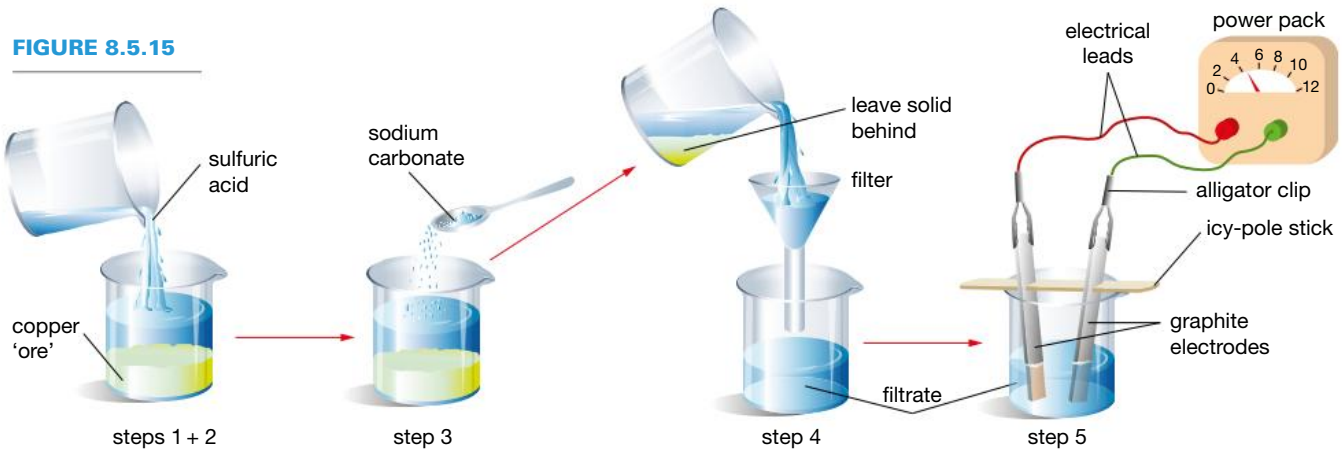
Procedure

1. Place the copper 'ore' in a 100 mL beaker.
2. Slowly add about 50 mL of sulfuric acid to the ore while stirring it. Wait until it stops 'fizzing'. Add about 5 mL more acid and stir until it stops fizzing.
3. Add sprinkles of sodium carbonate until the fizzing once again stops and the solution is neutralised. This is to ensure all the acid has been used up in the reaction.
4. Set up the filter funnel, paper, beaker and stand. Carefully decant (pour off) the liquid out of the beaker containing the acid and copper ore into the filter paper. Leave the solid behind in the beaker if possible. The filtrate in the beaker under the filter funnel is what you need. Dispose of the filter paper and the solid from the first beaker in the bin.
5. When filtering is finished, place the graphite electrodes separated with the icy-pole stick in the beaker containing the filtrate (Figure 8.5.15). Connect the electrodes to the DC terminals of a power pack (or two dry cells in series). Set the power pack on about 2 or 4 volts.
6. Observe the electrodes for a few minutes for signs of change. Record in your workbook what you observe happening at the positive and the negative carbon electrode. As soon as there is a clearly visible deposit on one electrode, switch off the power pack and disconnect the electrodes.
7. Dab the electrodes dry and observe them with your microscope or hand lens. Record your observations.

Review

1. a In the electrolysis, the main product at one electrode was oxygen gas. What do you think was produced at the other electrode?
   b Use evidence to justify your answer.
2. Malachite and azurite ore mined in Australia are mainly copper carbonate. How could this prac be relevant to the extraction of those copper ores in Australia?

FIGURE 8.5.15



MODULE 8.5 Practical investigations

STEM INQUIRY

Chocolate-chip mining

Planning & Conducting

Background

Mining companies will mine a resource if the price they receive for the mineral is greater than their costs to produce it.

Problem

Your task is to model the mining process by using a chocolate chip biscuit as the mining site. The valuable mineral the biscuit contains is chocolate. You need to design a technique to extract the most amount of mineral from the mine in 5 minutes. Extracting the minerals must be done in a way that causes the least amount of damage to the environment. You will need to balance the costs and benefits of the mine, and select tools, within your budget of $20. Each full chocolate chip you extract is worth $3.50.

Timing 60 minutes

Procedure

1. Check the available equipment, and brainstorm some solutions and ways to extract chocolate chips from a biscuit.
2. In a small group (2–3 students), plan a process to extract the chocolate chips from the biscuit.
3. Decide which tools and mine/s you are going to work with.
4. Weigh the biscuit before you start mining, and record this mass in a table like the one shown In the Results section.
5. Wait for your teacher to start the 5 minute timer, and then commence mining.
6. Carefully put each extracted chocolate chip aside.
7. Ensure the mine site is cleaned up, or risk a $4 fine.
8. Determine the average mass and volume of chocolate chips in a biscuit and the amount of 'waste' left behind.
9. Tally up your mining costs, chocolate chips extracted and any clean-up fee, to determine whether a profit has been made.

Hints

- You should test more than one biscuit, or share your results with other groups.
- You will need to develop a way of measuring or estimating the volume of the biscuit and the total amount of chocolate chips.
- Use the STEM and SDI template in your eBook to help you plan and carry out your investigation.

Materials

- play money: $20 per group
- mining site 1: $8 choc chip biscuit with lots of choc chips
- mining site 2: $4 choc chip biscuit with a few choc chips
- paperclip: $6
- toothpick: $2
- dowel or old pencil: $4
- weighing balance

Results

In your workbook, construct a table or spreadsheet like the one below.

Review

1. Compare the mass of each group's biscuit(s) and the mass of chocolate chips extracted.
2. Compare the volume of the waste material after extraction with the volume of the biscuit at the start.
3. How could you have made a better choice of mine site (biscuit) before you mined?

Mass and volume measurements

Mass biscuit (g)	Volume biscuit (mL or cm^3)	Mass chocolate chips after extraction (g)	Volume chocolate chips after extraction (mL or cm^3)	Mass waste material (g)	Volume waste material (mL or cm^3)

CHAPTER 8

Chapter review

Remembering

1 Define the term *geology*.

2 Draw a diagram showing the structure of the Earth. Label each layer.

3 Match the following types of rock with the word that describes them best.

igneous	changed
layered	metamorphic
sedimentary	volcanic.

4 Name two igneous rocks that are:
- **a** intrusive
- **b** extrusive
- **c** dark-coloured.

5 Name:
- **a** two igneous rocks in which you cannot see crystals
- **b** an igneous rock that is light enough to float in water and has holes in it.

6 Name two sedimentary rocks that are:
- **a** clastic
- **b** chemical
- **c** biogenic.

7 Name two metamorphic rocks that are:
- **a** foliated (banded)
- **b** non-foliated.

8 List ten minerals that Australia exports in large quantities.

9 Which method is used to extract the following metals from their ores—smelting or electrolysis?
- **a** zinc
- **b** sodium
- **c** iron
- **d** aluminium.

Understanding

10 **a** Draw a diagram of the rock cycle.
- **b** Explain why the rock cycle is a useful model in geology.

11 Outline the weathering processes that act on rocks.

12 Intrusive and extrusive igneous rocks have crystals of different sizes. Explain why.

13 Outline the formation of clastic sedimentary rocks.

Applying

14 **a** Choose three igneous rocks that have extreme differences in their appearance. Then use your knowledge of igneous rock formation to explain why they look the way they do.
- **b** Choose three sedimentary rocks that have extreme differences in their appearance. Use your knowledge of sedimentary rock formation to explain why they look the way they do.

Analysing

15 Compare the role of heat and forces in forming igneous, sedimentary and metamorphic rocks.

16 Contrast foliated (banded) and non-foliated metamorphic rocks.

Evaluating

17 Propose a reason why it is unwise to plant trees too close to a house.

18 Australian law requires that mines and mineral processing sites are rehabilitated.
- **a** What does this mean?
- **b** Propose reasons why mines need to be rehabilitated.

19 **a** Assess whether you can or cannot answer the questions on page 324 at the start of this chapter.
- **b** Use this assessment to evaluate how well you understand the material presented in this chapter.

Creating

20 Use the following ten key terms to construct a visual summary of the information presented in this chapter.

rock cycle	erosion
sedimentary	mining
igneous	crystals
metamorphic	mineral
weathering	magma

CHAPTER 8

Inquiry skills

Research

1 Three-part inquiry question

Processing & Analysing | Evaluating

Select your entry point and complete the relevant parts of this inquiry.

In late August, CE 79, Mt Vesuvius erupted. Its activity continued for at least two days (possibly up to three months), and it is believed that there were six separate eruptions during that period. Several towns were obliterated (including Pompeii and Herculaneum) and more than 1500 people died. The numbers of fatalities are hard to estimate. Around 1500 bodies have been found, but large areas of Pompeii and the surrounding villages have not been excavated. During the eruptions, Pompeii and Herculaneum were completely buried under around 6 metres of volcanic ash. After two days they had completely disappeared. Excavation of Pompeii began in around 1748 and has continued periodically since then.

a As well as the bodies of people, horses, cats and other animals have been discovered buried in the cities. These fossils have been preserved in excellent condition. Explain why so many well-preserved bodies have been found.

b Prior to the eruptions in CE 79, signals that Mt Vesuvius was going to erupt had been observed for nearly 20 years.

- **i** What might those signs have been? Explain their significance.
- **ii** Why do you think people didn't leave the area prior to the eruption occurring, even though there had been signs for many years?

c Most of the material excavated from Pompeii to reveal the remains of the city has been ash and a kind of rock called tuff (pronounced *toof*, which rhymes with hoof). Tuff is volcanic ash that has been compressed and cemented to form rock. There is some argument about whether tuff should be classified as a sedimentary or igneous rock. Discuss the features of both types of rock in relation to tuff. Explain whether tuff should be classified as igneous or sedimentary, giving reasons for your decision.

2

Processing & Analysing | Communicating

Research an Australian landform. It could be something local or something famous like Uluru (NT), the Glasshouse Mountains (Qld), the Warrumbungles (NSW), the Bungle Bungles (WA), the Twelve Apostles (VIC), the Flinders Ranges (SA) or Tesselated Pavement (TAS). Whichever landform you choose:

- discuss the geological history (including age) of the landform; include diagrams or photos
- identify the types of rocks in the formation
- explain how the rock cycle is relevant to the geological history of the landform.

Present your research findings in digital form.

3

Processing & Analysing | Communicating

Research how long it takes for igneous, sedimentary and metamorphic rocks to form. In your answer:

- use a rock cycle diagram
- state the times taken to form different rock types
- relate the time taken to form the rock to the processes that formed it.

Present your findings as an annotated diagram.

4

Processing & Analysing | Communicating

Research an important mining operation in your state or territory. Find:

- its location
- the likely way the minerals were formed
- the minerals mined and mining method used
- the mine's benefits to the local community and the state.

Present your research as a poster or digital poster.

5

Processing & Analysing | Communicating

Sand dune areas, bushland, lakes and deserts are often damaged by careless people who do not understand how fragile these areas are. Research how these landforms are being protected. In particular, find:

- five methods that local governments and volunteer land carers have implemented to protect such areas
- places where these methods are being tried
- how successful these methods have been.

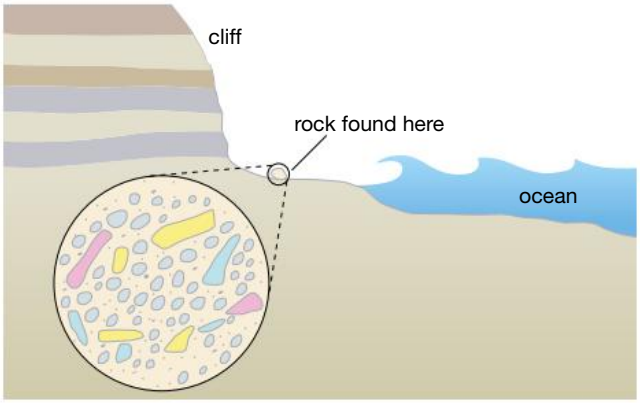
Present your findings in digital form.

CHAPTER 8

Inquiry skills

Thinking scientifically

Questions 1 and 2 refer to the following information.



1 Clastic sedimentary rocks have the following characteristics.

- They have layers.
- The grains do not interlock because they were cemented together.
- They may contain fossils.

Which of the following is a good reason to classify the rock in the diagram as a clastic sedimentary rock?

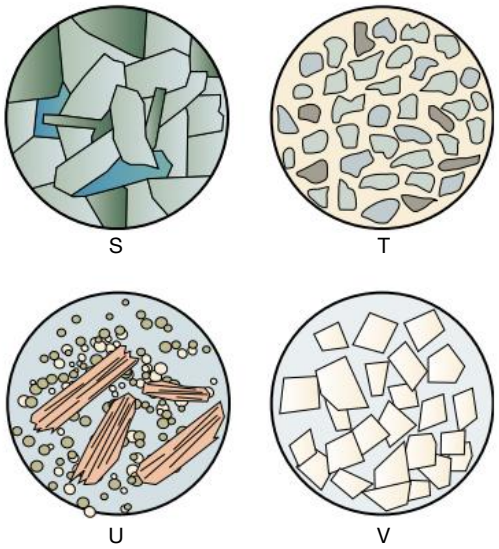
A The rock has layers in it.
B The grains are not interlocking.
C The crystals are large.
D There are no fossils in it.

2 Grains in a sedimentary rock may have travelled a long way or a short way from the parent rock before they formed the sedimentary rock. Some rocks contain all rounded grains (like little balls) that are all about the same size. These grains have travelled the furthest before being cemented into the rock. Other rocks have grains with sharp edges and grains of many different sizes. These grains have not travelled very far before being cemented into the rock.

Which of the following would probably be true for the rock found in the diagram above, based on the following information? It was shown to be identical to the rocks in the top layer of the cliff.

A The rock formed from grains that have travelled a long way from their parent rock.
B The grains are similar in size and therefore they were carried a short distance.
C The grains indicate that the rock formed from sediments in the rock cliff.
D The rock was formed from parent rocks that were fairly close to the rock cliff.

Questions 3 and 4 refer to the following diagrams of rocks.



3 Choose the correct statement from the following.

A Rock S is igneous because the grains are interlocking.
B Rock T is igneous because the grains are angular.
C Rock U is an igneous porphyry because it is a mixture of large and small crystals.
D Rock V is metamorphic because the crystals are large and all the same size.

4 In the diagram, the rocks most likely to be sedimentary are:

A S and T
B S and V
C U and V
D T and U.

CHAPTER 8

Glossary

agents of erosion: factors that cause erosion—water, wind, gravity and ice

asthenosphere: top layer of the mantle, composed of 'plastic' rock

biogenic sedimentary rock: sedimentary rock formed mainly from dead organisms

biological weathering: living things and their products breaking down rock

cement: natural chemicals found in water that can bind sediments together

chemical sedimentary rock: sedimentary rock that forms when dissolved materials precipitate from solution

chemical weathering: water, or chemicals in water or air, reacting and breaking down rock

clastic sedimentary rock: sedimentary rock formed mainly from small rock particles

contact metamorphism: a type of metamorphism where rock is altered mostly by heat

core: the innermost layer of the Earth

crust: the outermost layer of the Earth, composed of solid rock

deposition: the settling of broken rock material to form sediment

dynamic metamorphism: a type of metamorphism where rock is altered mostly by pressure

electrolysis: use of an electric current to extract minerals from solution

erosion: removal of weathered rock particles from the site of the weathering

extraction: the chemical process of separating metals from the compounds in which they occur

extrusive igneous rock: igneous rock that forms on the surface of the Earth

felsic: light-coloured rocks

foliation: a process where minerals under pressure realign and the rock develops layers or bands

force: any interaction that will change the motion of an object when unopposed. For example, a push or a pull

fossils: the preserved remains of living organisms

froth flotation: a process for extracting material from water (and chemicals) by producing air bubbles, which the material sticks to and floats

geology: the study of rocks, their history and the processes that form and change them

hydrothermal fluids: superheated fluids that circulate through the Earth's crust, picking up minerals such as gold

igneous rock: rock formed from cooling magma (or lava)

interlocking crystals

interlocking mineral crystals: crystals that lock together and grow into each other in a rock

intrusive igneous rock: igneous rock that forms below the surface of the Earth

lava: molten rock that reaches the Earth's surface

mafic: dark-coloured rocks

magma: molten rock that does not reach the Earth's surface

mantle: a layer of the Earth that is below the crust

metamorphic rock: rock formed when temperature and/or pressure alter existing rock

mineral: a naturally occurring solid substance that is inorganic, has a characteristic crystalline structure and a fairly constant chemical composition

mineral resources: minerals that are dug up and used

native metal: a metal found as a pure element

ore mineral: a valuable mineral found in rocks

physical weathering

physical weathering: the breaking down of rocks by physical processes

pressure: physical force exerted on or against a rock unit, measured as force per unit area

regional metamorphism: a type of metamorphism where rock is altered by both heat and pressure over a wide area

rock cycle: a model geologists use to explain the endless cycle of change that rocks undergo

sedimentary rock: rock made by sediments being cemented together

smelting: extracting metal from its ore by melting it, pouring it and allowing it to cool

strata: layers of sedimentary rock

tailings: waste materials from a mine or mineral processing plant

tectonic plates: massive plates that make up the Earth's crust

weathering: the physical, chemical and biological processes that break rocks down into smaller pieces

AB 8.10

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(a division of Pearson Australia Group Pty Ltd)
707 Collins Street, Melbourne, Victoria 3008
PO Box 23360, Melbourne, Victoria 8012
www.pearson.com.au

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First published 2017 by Pearson Australia

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Publisher: Alicia Brown
Project Manager: Alison Stone
Editor: Alison Stone
Rights & Permissions Editor: Samantha Russell-Tulip
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ISBN 978 1 4886 6752 7

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