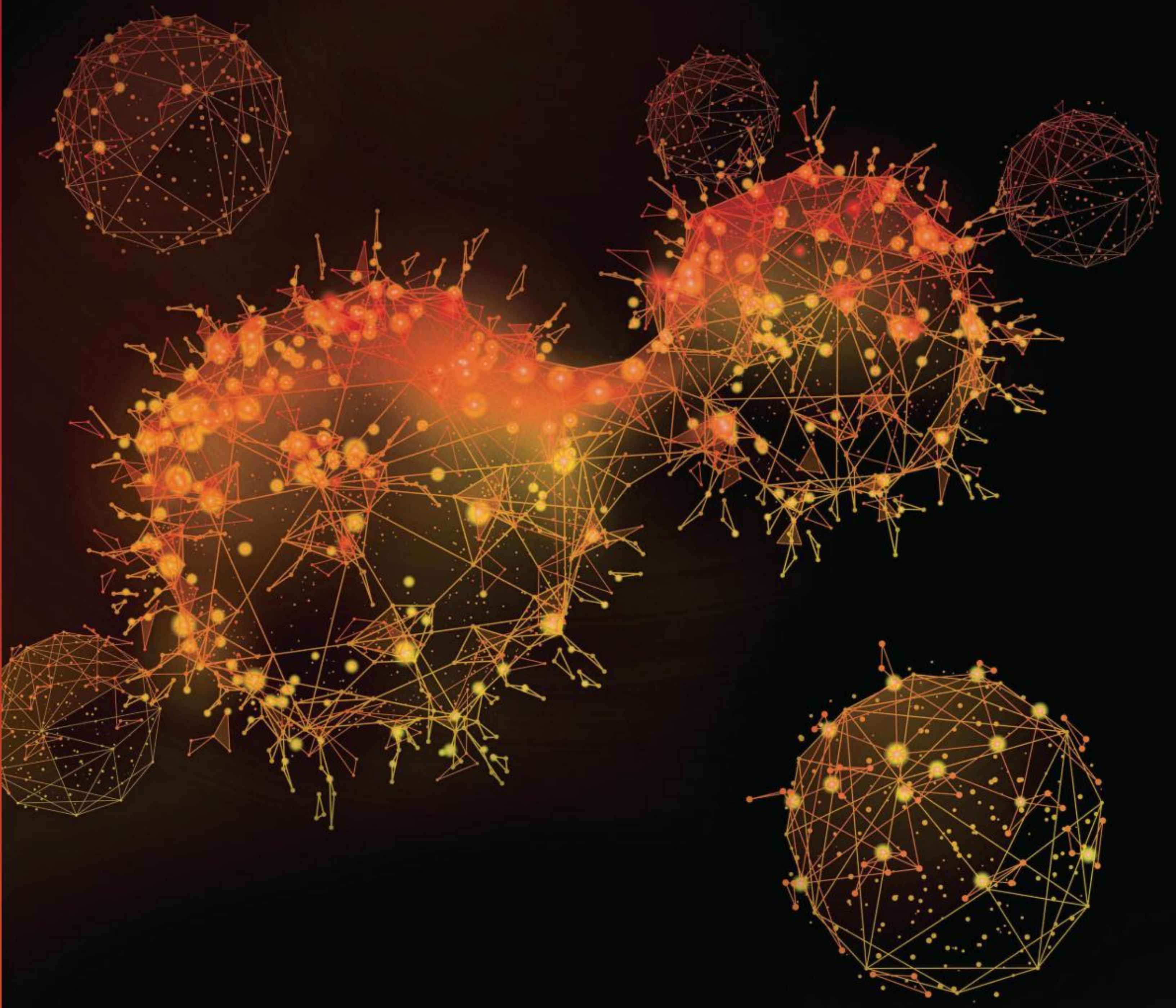
GRAEME LOFTS | MERRIN J. EVERGREEN

JACARANDA SCIENCE QUEST 8

VICTORIAN CURRICULUM | SECOND EDITION



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JACARANDA

SCIENCE QUEST 8

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CONTRIBUTING AUTHORS

Sarah Beamish | Nicole Cox | Stacey Gwilym
Angela Stubbs | Neale Taylor | Dayna Wilkie

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PREFACE

To the science student

Science is much more than a body of knowledge. It is a way of thinking and learning, which we refer to as Science Inquiry. Science helps you understand the world around you: why the sun rises and sets every day, why it rains, how you see and hear, why you need a skeleton and how to treat water to make it safe to drink. You can't escape the benefits of science. Whenever you turn on a light, eat food, watch television or flush the toilet, you are using the products of scientific knowledge and inquiry.

Global pandemics, climate change, overpopulation, famine, pollution, resource shortages, the potential use of biological and nuclear weapons, and issues associated with genetic engineering currently challenge the world as we know it. Possible solutions to some of these challenges may be found by applying scientific knowledge to develop new technologies and creative ways of rethinking the problems. It's not just scientists who solve these problems; people with an understanding of science, like you, can influence the future. It can be as simple as using a recycling bin or saving energy and water in your home.

Science inquiry involves both identifying problems that need to be solved, and planning and conducting investigations. It involves collecting, processing and interpreting evidence so that useful conclusions can be reached. Science inquiry could involve, for example, investigating whether life is possible on other planets, discovering how to make food crops grow with less water, finding out how to swim faster, developing a vaccine for COVID-19 and even finding a cure for cancer. Science inquiry usually involves working with a team. The outcomes of science inquiry should be shared with other scientists and the community at large.

You live in a time in which the growth of scientific knowledge and technological development is occurring faster than ever before. A consequence of this is that learning how to learn has become just as important as learning itself. *Science Quest* has been designed with this in mind, taking you on a quest for both scientific knowledge and inquiry.

To the science teacher

This edition of the *Science Quest* series has been developed to enhance the already comprehensive suite of engaging and innovative resources tailored to the Victorian Curriculum of the previous edition. It provides both activities that focus on seven **general capabilities** (literacy, numeracy, ICT competence, critical and creative thinking, ethical behaviour, personal and social competence, and intercultural understanding) and **differentiated learning**. The history and culture of Aboriginal and Torres Strait Islanders, Australia's engagement with Asia, and sustainability have been embedded with the general capabilities where relevant and appropriate.

Science Quest interweaves **Science understanding** with **Science as a human endeavour** and **Science inquiry skills** under the umbrella of six **Overarching ideas** that 'represent key aspects of a scientific view of the world and bridge knowledge and understanding across the disciplines of science'.

Science Quest provides the basis for the development of a course of study based on the Victorian Curriculum. This new edition incorporates practical activities and resources that provide tools for science inquiry in remote learning settings as well as in the classroom.

We have attempted to make the *Science Quest* VC series a valuable asset for teachers, and interesting and relevant to the students who are using it. *Science Quest* comes complete with online support for students, including answers to questions, interactivities to help students investigate concepts, and video eLessons featuring real scientists and real-world science.

Exclusively for teachers, the online *Science Quest* teacher resources provide teaching advice and suggested additional resources, testmaker questions with assessment rubrics, and worksheets and answers.

Graeme Lofts and *Merrin J. Evergreen*

ABOUT THE AUTHORS

AUTHORS

Dr Merrin J. Evergreen

Merrin J Evergreen has been awarded academic qualifications from five different Australian universities, and was awarded Monash University's Jeff Northfield Memorial Award for Excellence in Teacher Research.

Merrin loves the excitement and fun of learning, and with thirty years of experience as a science and biology teacher (both Victorian Certificate of Education and International Baccalaureate), Merrin endeavours to share and transfer both her passion and understanding of teaching and learning into each new and evolving edition. Her quest continues to be that of inspiring others with the excitement of learning and understanding more about ourselves, our world, and our place within it.

Graeme Lofts

Graeme Lofts has taught physics, science and mathematics at both government and independent schools in Victoria for more than twenty-three years. He has also lectured in Science Education at the University of Melbourne and RMIT University. During his teaching career Graeme was awarded an International Teaching Fellowship, the BHP Science Teacher Award and an STAV Fellowship "for major contributions to the Science Teachers' Association of Victoria".

Graeme remains passionate about science education and is keen to see *Science Quest* continue to improve and adapt to rapidly advancing teaching and learning technology. He is determined that it must remain relevant and address important issues of concern for the students and teachers using it.

CONTRIBUTING AUTHORS

Sarah Beamish

Sarah Beamish has a Bachelor of Science (Plant Physiology and Honours in Meteorology), and a Diploma of Education. Formerly a research scientist, Sarah's rich passion for education and communicating complex scientific concepts led her to become a teacher. Having taught for over 13 years, Sarah is currently the Assistant Head of Science at St Kevin's College in Toorak where she is a teacher of VCE Biology, Science and Geography. Sarah has also been a VCAA assessor for VCE Biology.

Nicole Cox

Nicole Cox has a Master of Science in Geology. Her passion for exploring landscapes and learning how the Earth works has led her on many global adventures, which in turn have inspired her to share that passion with others through teaching. Nicole taught geological and environmental subjects at a university level for 11 years and is currently an independent consultant for both geoscience education and the resource industry.

Stacey Gwilym

Stacey Gwilym has a Bachelor of Science (Biology with Honours), Postgraduate Diploma in Clinical Embryology and Master of Teaching (Secondary). Stacey was a clinical embryologist in London and Melbourne and has extensive experience in cell culture and laboratory management as well as clinical embryology research. Stacey moved into teaching in 2016 to help engage and inspire the next generation of scientists and creative thinkers. Stacey teaches VCE Biology and junior science, where she brings the excitement and discipline of the science industry into the classroom.

Angela Stubbs

Angela Stubbs has a Bachelor of Science Education and a Bachelor of Education. While Head of Science, she encouraged the development of innovative programs to bring the relevance of science to students in Years 7 to 10. A long-term author for both junior and VCE Chemistry texts, she delights in creating original resources for teachers and students, with a particular focus on developing critical thinking skills. Her knowledge and skills have been shared through regular presentations at Science and Chemistry Teachers' Conferences. Angela has also been a VCAA assessor for VCE Chemistry for many years.

Neale Taylor

Neale Taylor has a Bachelor of Science (Chemistry and Pure Mathematics) and a Diploma of Education, with over 20 years of 'teaching experience in secondary schools'? (Or just 'teaching experience') Currently sounds like he has inferior experience…experience, including two years teaching the Diploma of Education, Chemistry at RMIT. Neale has authored both junior and senior Chemistry texts and has written and coordinated the VCE Chemistry Trial exams for The Centre for Strategic Education. Having previously enjoyed 14 years as Science publisher at Jacaranda, Neale has returned to authoring to share his enthusiasm and experience of science with the next generation of students.

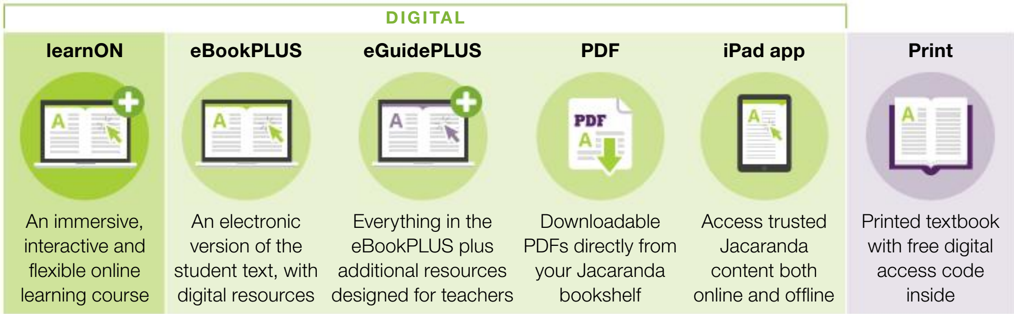
Dayna Wilkie

Dayna Wilkie has a Bachelor of Science (Physics and Applied Mathematics) from the University of Melbourne, a Diploma of Education, and is currently working towards her Master of Applied Science (Statistics). Dayna has been a teacher of mathematics and physics for 10 years at Star of the Sea College, has teaching experience in the UK and has been a VCAA assessor for VCE Further Mathematics.

ABOUT THIS TITLE

New features!

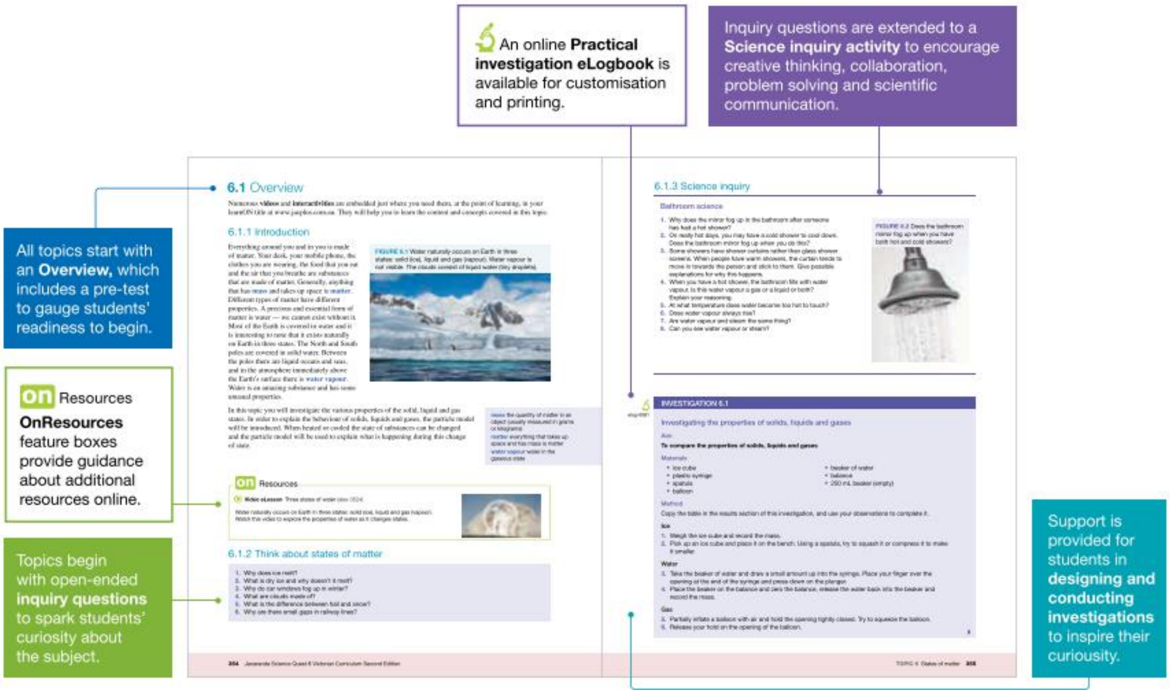
Jacaranda Science Quest Victorian Curriculum Second Edition has been completely revised and updated to help teachers and students navigate the Victorian Curriculum syllabus. The *Jacaranda Science Quest* series is designed to enrich the learning experience and improve learning outcomes for all students. The series is available across a number of digital formats: learnON, eBookPLUS, eGuidePLUS, PDF and iPad app.



Teaching Science inquiry skills, sparking curiosity

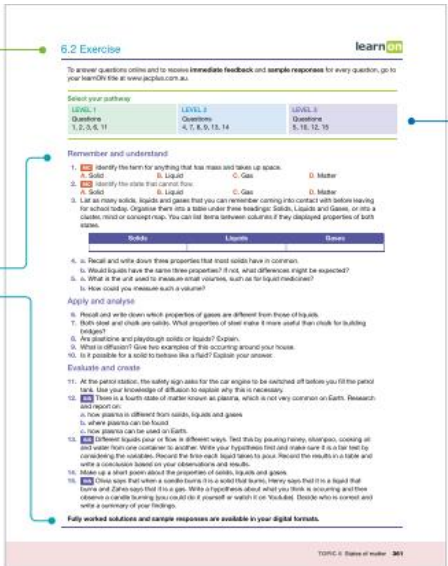
Science is an engaging, dynamic, inquiry-based subject that provides students with the opportunity to understand the world around them. The understanding of science involves more than understanding concepts; it also involves learning how to inquire, communicate and investigate scientifically. Science inquiry skills (SIS) are integrated throughout, through explicitly targeted SkillBuilders and a dedicated, stand-alone science inquiry topic that introduces students to the key components of predicting, conducting, designing, communicating and evaluating scientific investigations. This topic has been specifically tailored for each year level in content and complexity, to show the progression of inquiry skills throughout students' studies of science. Throughout the topics, students will find links to SIS alongside exercises and activities.

This suite of resources is designed to allow for differentiation, flexible teaching and multiple entry and exit points so teachers can teach their class their way.



Exercise sets at the end of each subtopic allow students to check and apply their understanding.

Corrective feedback and sample responses are available online for every question.



Questions at 3 levels of difficulty provide differentiation while allowing all students to work on the same subtopic.

Level 1 Try these for initial understanding.

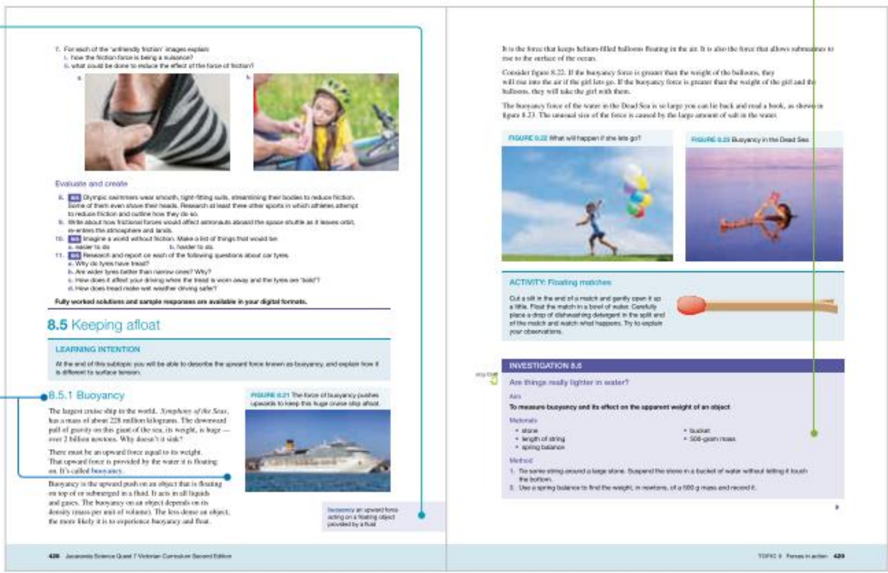
Level 2 Try these when you're feeling more confident.

Level 3 Try these when you're ready to try something harder.

Practical investigations throughout each topic provide students with opportunities to engage with science and develop an understanding of content and science skills.

Definitions are provided within the content to help students understand key terms; online, definitions are included as clickable pop-up notes.

Content is presented using **age-appropriate language** and a wide range of engaging interactivities, diagrams and images to support concept learning.

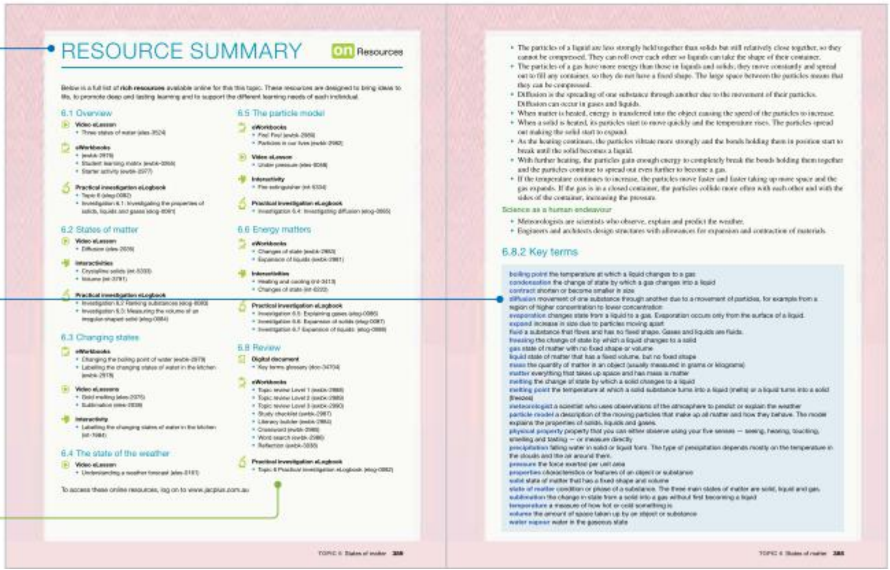


Resource summaries for each topic help teachers and students to find online resources easily and quickly.

A **range of questions** and a post-test are available online and in print to test students' understanding of the topic.

Summaries and key terms are available in every topic review.

An online **eWorkbook** is available for customisation and printing. It contains numerous worksheets including a literacy builder, a student learning matrix and opportunities for reflection to encourage students to take ownership of their learning.



ACCESS ALL OF YOUR ONLINE RESOURCES

Using learnON

The *Jacaranda Science Quest Victorian Curriculum* series learnON resources provide an immersive digital learning platform that provides teachers with valuable insights into their students' learning and engagement. Hundreds of engaging videos and interactivities are embedded just where you need them — at the point of learning. learnON provides a deeper, richer and more meaningful teaching and learning experience for educators and their students in today's digital world, with important additional features that allow you to assign, mark and track student work. The platform can monitor and report progress in real time to give you immediate insights into student achievement. This helps you to easily isolate areas in which students (or groups of students) need additional support or extension.

The learnON platform gives you the control over your students' learning pathways.

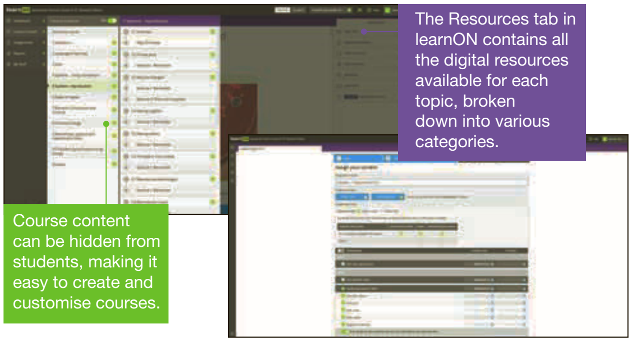
Some of the many benefits of the learnON platform include:

- online questions with a 1 : 1 correspondence to questions in print
- real-time immediate corrective feedback and fully worked solutions for every question to help students get unstuck
- a new side-by-side lesson view, enabling access to reading content and question sets on one screen
- hundreds of videos and interactivities to bring concepts to life
- customisable course content, giving teachers more flexibility to create their own course
- the ability to connect students and teachers in a class group
- the ability to separate a class into subgroups, making differentiation simpler
- dashboards to track progress
- immediate insight into student progress and performance using the Results page
- the ability to send important documents to the class
- formative and summative assessments.

Customise student learning

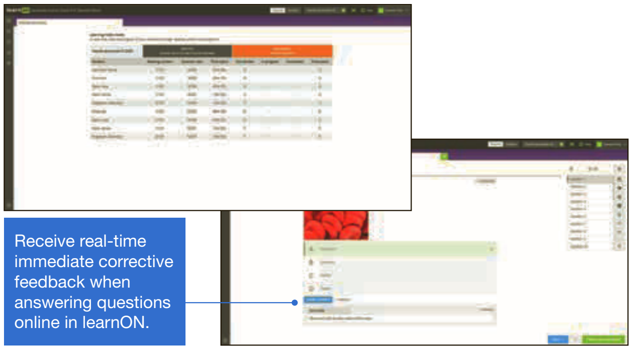
At Jacaranda, we understand that no-one knows your students' learning needs better than you. With learnON, you can tailor each task and assign it to individual students, create your own groups or assign to the whole class. You have complete control over assigning questions or tasks for each student, whether they are for practice or assessment, due dates and when students have access to results.

You also have the ability to hide specific parts of the reading content from student view, to allow for closed-book tests or to create your own pathway through the material for your class.



Track activity

The learnON platform provides real-time summaries of student activity. At a glance, you can see how long a student spends reading content pages, how many question-sets they have attempted and their progress with assessment tasks.

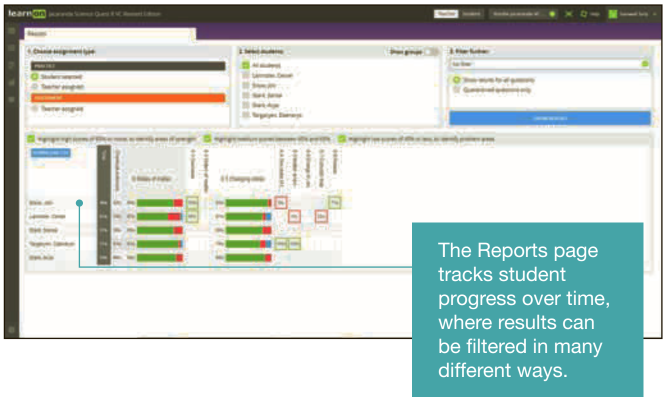


Provide meaningful feedback — quickly and easily

The learnON platform also provides an easy-to-navigate marking interface that allows you to see student responses, comment on and mark their work.

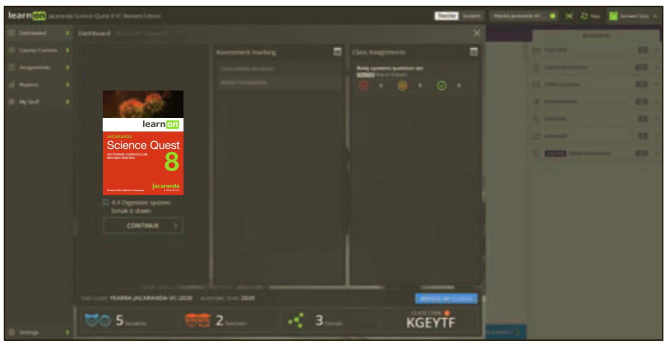
Gain deep insights into student performance

You also have access to detailed reports on student progress that allow you to filter results for specific skills or question types. With learnON, you can show students (or their parents or carers) their own assessment data in fine detail. You can filter their results to show their development with each proficiency strand, skill, topic or subtopic. Results are also colour-coded to help students understand their strengths and weaknesses at a glance.



Keep track of your 'to do' list

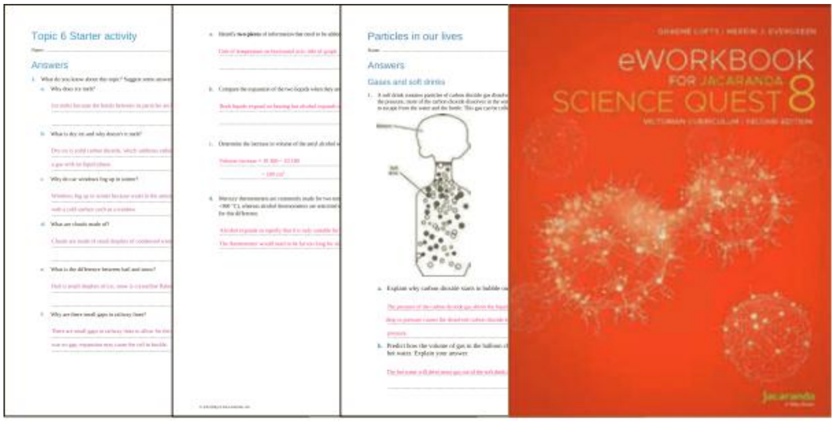
The learnON dashboard gives students and teachers a clear picture of their progress throughout the year. For teachers, it provides a visual summary of upcoming assessment deadlines, student submissions waiting to be marked and overdue tasks. For students, it providers reminders of due dates and notifications about the availability of feedback and marked tasks.



NEW in the *Jacaranda Science Quest* VC series

eWorkbook for Science Quest

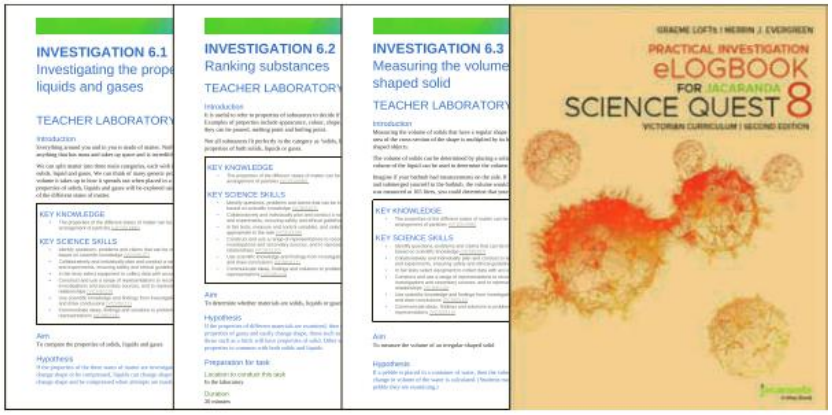
The **eWorkbook** is the perfect companion to the series, adding another layer of individualised learning opportunities for students, and catering for multiple entry and exit points in student learning. The eWorkbook also features fun and engaging activities for students of all abilities and offers a space for students to reflect on their own learning.



The new eWorkbook and eWorkbook solutions are available as a downloadable PDF or a customisable Word document in learnON.

Practical Investigation eLogbook for Science Quest

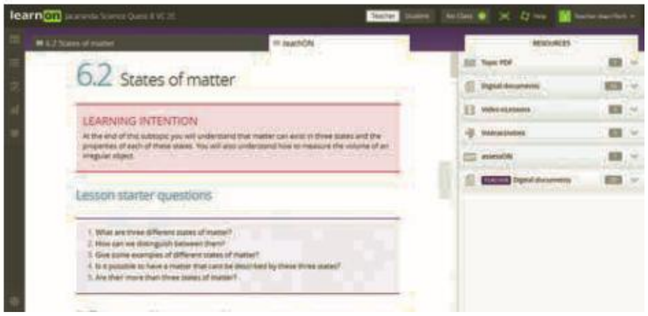
The **practical investigation eLogbook** ignites curiosity through science investigation work, with an extensive range of exciting and meaningful practical investigations. Aligned with the scientific method, students can develop rich science inquiry skills in conducting scientific investigations and communicating their findings, allowing them to truly think and act like scientists!



The practical investigation eLogbook is supported with an unrivalled teacher and laboratory guide, which provides suggestions for differentiation and alteration, risk assessments, expected practical results and exemplary responses.

teachON

teachON offers teachers time-saving support and inspiration, with ready-made lesson plans, practical teaching advice, differentiated work programs, extensive practical and lab support and customisable assessment. With access to the learnON platform, teachers also receive immediate insights into their students' performance and engagement.



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1 Investigating science

LEARNING SEQUENCE

1.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

1.1.1 Introduction

Although science is a body of knowledge, it is also a way of solving problems and finding the answers to questions. Scientific knowledge is always growing and changing because scientists design and perform new investigations.

Observing, measuring, constructing tables, drawing graphs and forming conclusions are just some of the skills used in conducting scientific investigations.

FIGURE 1.1 Scientific investigation drives scientific progress.

1.1.2 Think about science

1. What is the connection between a pendulum, a playground swing and a metronome?
2. Why are graphs useful to scientists?
3. How do you start your own scientific investigation?
4. What do the letters CSIRO stand for?

1.1.3 Science inquiry

Researching the CSIRO

1. What is the CSIRO?
2. The CSIRO's website describes some of the research done by CSIRO scientists. Australia has a significant role in scientific research; we are world leaders in many different research areas. Read the information provided for one area of research that the CSIRO is involved with and summarise this research in point form.
3. Form groups of three. Explain to the other two students the area of research you have just read about. Try doing this without referring to your notes.

on Resources

Weblink CSIRO

elog-0588

INVESTIGATION 1.1

Milk now or later?

You have just finished making yourself a cup of coffee when the phone rings. For your coffee to stay as warm as possible, should you add the milk now or after you have finished talking on the phone? Does your answer depend on the length of the phone call?

Aim

To compare the rate of cooling of hot coffee with and without the addition of milk

Materials

- kettle
- 2 identical cups
- instant coffee
- milk
- 2 thermometers or a data logger with 2 temperature probes
- 2 measuring cylinders

A data logger can be used for this investigation.

Method

1. Your teacher will assign a particular length of 'phone call' time to each group of students.
2. Make a hypothesis about this investigation.
3. Heat some water in a kettle and use it to make two cups of instant coffee. Use the same type of cup and the same amount of hot water and coffee powder.
4. Place a thermometer or temperature probe in each cup of coffee. If you are using a data logger, set it to collect results for at least 10 minutes.
5. Add 40 mL of milk to one of the cups.
6. If you are using thermometers, record the temperature of the coffee in both cups every 30 seconds.
7. After your phone call time has passed, add 40 mL milk to the second cup.
8. Continue measuring the temperature in both cups every 30 seconds until 10 minutes has passed since you added the milk to the second cup.

Results

1. If you used thermometers, record your results in a table.

TABLE Results of investigation 1.1

	Temperature (°C)	
Time (minutes)	**Milk added at time 0**	**Milk added after 'phone call'**
0.0		
0.5		
1.0		
1.5		

2. Plot line graphs of your results on the same set of axes. Put time on the horizontal axis and temperature on the vertical axis.
3. If you used a data logger, a graph is plotted automatically. If necessary, adjust the settings so that the graph shows the temperatures measured by both probes on the same set of axes. Put the graph into the results section of your experiment report.
4. Was you hypothesis correct? Explain you results.

Discussion

1. Does hot coffee cool faster than warm coffee? How can you tell from your graph?
2. Did the two lines on the graph cross at any stage? What does this indicate?
3. Does the length of the 'phone call' affect the results? Compare your graphs with those of other groups.
4. Why was it important to put exactly the same amount of water in both cups and to use the same type of cup?
5. What are the advantages and disadvantages of using a data logger for this experiment?
6. Explain how this experiment could be improved.
7. How could this experiment lead to further experiments?

Conclusion

Write a conclusion for this investigation.

on Resources

eWorkbooks	Topic 1 eWorkbook (ewbk-4961) Student learning matrix (ewbk-4963) Starter activity (ewbk-4964)
Practical investigation eLogbook	Topic 1 Practical investigation eLogbook (elog-0592)
learnon	Access and answer an online Pre-test and receive **immediate corrective feedback** and **fully worked solutions** for all questions.

1.2 Investigating skills

LEARNING INTENTION

At the end of this subtopic you will understand that you need to take into consideration all aspects of fair testing, available equipment and safe investigation when planning investigations.

1.2.1 Safety rules

Conducting scientific investigations in a laboratory can be exciting, but accidents can happen if experiments are not carried out carefully. There are general rules that must be followed for your own safety and the safety of others, but there may be more for your school laboratory.

ALWAYS . . .

- follow the teacher's instructions
- wear safety glasses and a laboratory coat or apron, and tie back long hair when mixing or heating substances
- point test tubes away from your eyes and away from your fellow students
- push chairs in and keep walkways clear
- inform your teacher if you break equipment, spill chemicals, or cut or burn yourself
- wait until hot equipment has cooled before putting it away
- clean your workspace — don't leave any equipment on the bench
- dispose of waste as instructed by your teacher
- wash your hands thoroughly after handling any substances in the laboratory.

NEVER . . .

- enter the laboratory without your teacher's permission
- run or push in the laboratory
- eat or drink in the laboratory
- smell or taste chemicals unless your teacher says it's OK. When you do need to smell substances, fan the odour to your nose with your hand.
- leave an experiment unattended
- conduct your own experiments without the teacher's approval
- put solid materials down the sink
- pour hazardous chemicals down the sink (check with your teacher)
- put hot objects or broken glass in the bin.

Using equipment safely

- Use a **filter funnel** when pouring from a bottle or container without a lip.
- Never put wooden test-tube holders near a flame.
- Always turn the tap on before putting a **beaker**, **test tube** or **measuring cylinder** under the stream of water.
- Remember that most objects get very hot when exposed to heat or a naked flame.
- Do not use tongs to lift or move beakers.

filter funnel used with filter paper to separate solids from liquids

beaker container for mixing or heating substances

test tube thin glass container for holding, heating or mixing small amounts of substances

measuring cylinder used to measure volumes of liquids accurately

1.2.2 Working with dangerous chemicals

Your teacher will tell you how to handle the chemicals in each experiment. At times, you may come across warning labels on the substances you use.

- Always wear gloves and **safety glasses** when using chemicals with the 'Corrosive' symbol. Corrosive substances can cause severe damage to skin and eyes. Acid is an example of a **corrosive** substance.
- Flammable substances are easily set on fire, so keep them away from flames. Ethanol is **flammable**.
- Chemicals with the 'Toxic' label can cause death or serious injury if swallowed or inhaled. They are also dangerous when touched without gloves because they can be absorbed by the skin. Mercury is a **toxic** substance.

safety glasses plastic glasses used to protect the eyes during experiments

corrosive describes a chemical that wears away the surface of substances, especially metals

flammable describes substances such as methylated spirits that burn easily

toxic describes chemicals that are dangerous to touch, inhale or swallow

FIGURE 1.2 Examples of warning labels

1.2.3 Heating substances

Many experiments that you will conduct in the laboratory require heating. In school laboratories, heating is usually done with a Bunsen burner. A Bunsen burner provides heat when a mixture of air and gas is lit.

Bunsen burners heat objects or liquids with a naked flame. Always tie hair back, and wear safety glasses and a laboratory coat or apron when using a Bunsen burner.

eles-2360

A GUIDE TO USING THE BUNSEN BURNER

1. Place the Bunsen burner on a heatproof mat.
2. Check that the gas tap is in the 'off' position.
3. Connect the rubber hose to the gas tap.
4. Close the airhole of the Bunsen burner collar.
5. Light a match and hold it a few centimetres above the barrel.
6. Turn on the gas tap and a yellow flame will appear.
7. Adjust the flame by moving the collar until the airhole is open and a blue flame appears.
8. Remember to close the collar to return the flame to yellow when the Bunsen burner is not in use.

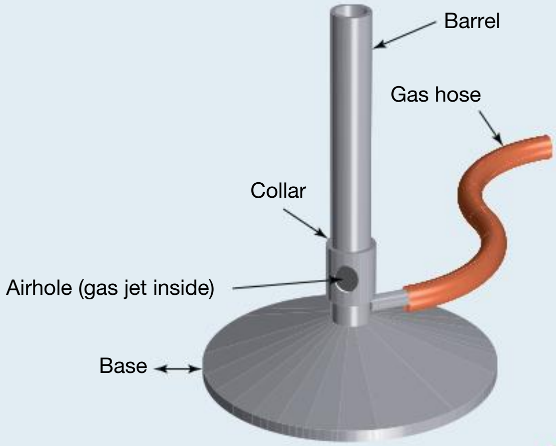


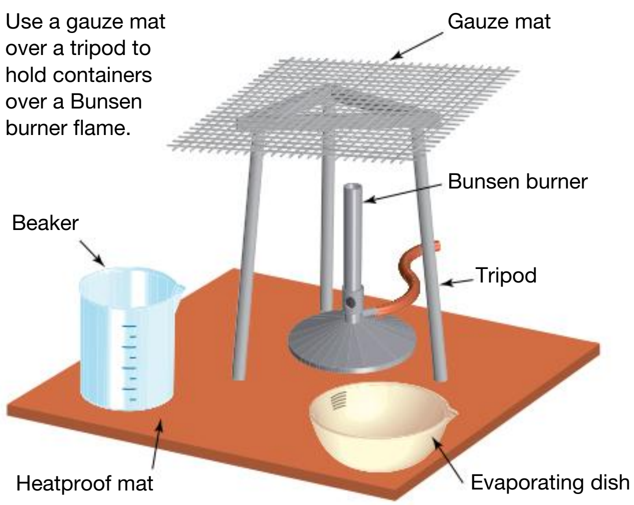
FIGURE 1.3 A brief flowchart showing the main steps of using a Bunsen burner

Connect host to gas tap → Close air hole → Hold lighted match above burner → Turn gas tap on → Once lit open air hole

Heating containers

There are a number of pieces of equipment you will need in the laboratory when using a Bunsen burner for heating; these are shown in figure 1.4. Beakers and evaporating dishes can be placed straight onto a gauze mat for heating. Never look directly into a container while it is being heated. Wait until the equipment has cooled properly before handling it. Never heat an empty container as it is likely to shatter or melt.

FIGURE 1.4 How to heat containers and test tubes over a Bunsen burner



Heating a test tube

Tripods and gauze mats are not used when heating test tubes. Hold the test tube with a test-tube holder. Keep the base of the test tube above the flame. Make sure that the test tube points away from you and other students.

on Resources

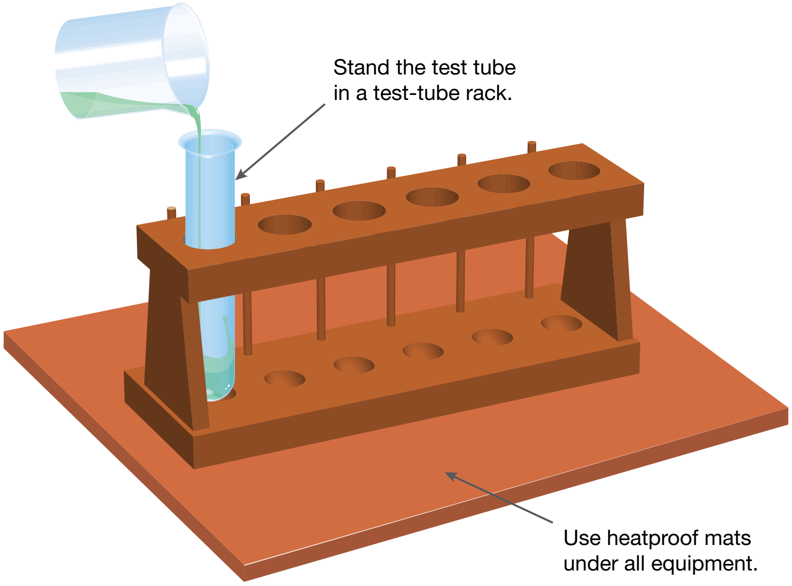
Weblink Robert Bunsen

1.2.4 Glassware

Pouring a liquid into a test tube

Pour liquids carefully into the test tube from a beaker or measuring cylinder. Use a filter funnel when pouring from bottles or containers without a lip.

FIGURE 1.5 Pouring a liquid into a test tube



Shaking a test tube

There are two ways to shake substances in a test tube (figure 1.6).

Method 1

Hold the top of the test tube and gently move its base in a sideways direction. This method is good to use with non-hazardous substances that do not need to be shaken vigorously. This is the method you will use most of the time.

Method 2

Use a stopper when a substance needs to be mixed by shaking vigorously. Place an appropriately sized stopper into the mouth of the test tube. With your thumb over the stopper and your hand securely around the test tube, shake the test tube with an up and down motion. Shake a test tube in this way only if instructed to do so by the teacher.

FIGURE 1.6 Two correct ways to shake a test tube

1.2.5 Using electricity safely

Electrical equipment in the science laboratory should be used with great care, just as it should be in the home or workplace.

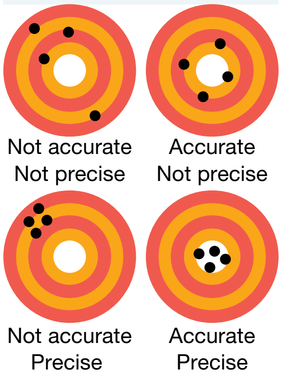
Never:

- place heavy electrical appliances near the edge of a bench or table
- allow water near electrical cords, plugs or power points
- place objects other than the correct electrical plug into a power point
- use appliances with damaged cords or exposed wires.

1.2.6 Precise measurements

Precision is the degree to which repeated measurements produce the same result. It tells us how close a series of measurements are to each other, as can be seen in figure 1.7. The degree of precision of the measurements taken in an experiment depends on the instruments that have been used. If you want to measure the length of your classroom, you could use a trundle wheel with marks every 10 cm, or you could use a tape measure marked in millimetres. The tape measure would provide the most precise measurement. Similarly, to measure 100 mL water, you could use a measuring cylinder that is graduated in millilitres or you could use a measuring cup that is marked every 100 mL. The measuring cylinder would provide a more precise measurement than the cup. A set of scales that measures mass to two decimal places is more precise than one that measures mass to one decimal place.

FIGURE 1.7 Precision and accuracy can be visualised on a target.



1.2.7 Accurate results

Accuracy is different to precision. Accurate results are close to the actual value, as can be seen in figure 1.7. A small measuring cylinder can provide a reasonably precise measurement of a volume of water but, if it is not read at eye level, the measurement may not be accurate. A set of bathroom scales might display a reading with 2 decimal places but, if you use it on carpeted floor, it may not provide an accurate measurement of your mass if it is designed to be used on a hard floor. To ensure that your results are accurate you should use measuring instruments correctly and in some instances itmay be necessary to **calibrate** the instruments. To calibrate a set of scales, for example, you could place an object that has a mass of exactly 100.00 g on the scale and adjust the scale until it reads exactly 100.00 g.

precision how close multiple measurements of the same investigation are to each other

accuracy how close an experimental measurement is to a known value

calibrate to check or adjust a measuring instrument to ensure accurate measurements

on Resources

Interactivity	Using equipment (int-0200)
eWorkbooks	Safety in the laboratory (ewbk-4947) Safety rules (ewbk-4948)
assess on	Additional automatically marked question sets

1.2 Exercise

learn on

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 3, 5, 10	Questions 2, 6, 8	Questions 4, 7, 9

Remember and understand

1. **MC** How should a substance in a test tube be shaken if you are not instructed to shake it vigorously?
   A. Hold the top of the test tube firmly and gently move the base of the test tube in a sideways direction.
   B. Hold the test tube in the middle and move the test tube up and down.
   C. Place a stopper on the test tube so the substance does not fall out and shake hard.
   D. Place a stopper on the test tube and tip the test tube up and down.
2. **MC** Which TWO of the following are dangers in the science laboratory?
   A. Using an electronic balance to measure the mass of a substance before cleaning up some spilled water on the bench next to it
   B. Listening carefully to instructions
   C. Wearing safety glasses while entering the laboratory
   D. Not wearing safety glasses while heating a liquid in a beaker
3. Place the following steps in order to show how to heat substances in a test tube safely.
   a. Ensure safety glasses and laboratory coats are worn.
   b. Hold the test tube over the flame with the open end pointing away from people's faces.
   c. Check there is a heatproof mat below the Bunsen burner.
   d. Light the Bunsen burner correctly.
   e. Move the base of the test tube gently in and out of the blue flame to heat the substance.
4. Methylated spirits is a flammable liquid. Explain what this means.
5. You should always wear gloves when working with corrosive and/or toxic substances. True or false?

Apply and analyse

6. **MC** Which of the following is a safety precaution that must be followed in a scientific laboratory?
   A. Dispose of solid materials down the sink.
   B. Make sure the gas tap is in the 'on' position when turning on the Bunsen burner.
   C. Use tongs to lift and move beakers.
   D. Long hair should be tied back when heating or mixing substances in the laboratory.
7. **MC** Why should a test tube be standing in a test-tube rack when you are pouring a liquid into it?
   A. A test-tube rack is more stable, so spills are less likely to occur.
   B. A test-tube rack is more stable, so spills are more likely to occur.
   C. So the test tube can be labelled.
   D. So the test tube does not burn you.
8. Three students weighed a standard mass of 10.0 g using the same balance. They all returned a result of 12.4 g. Based on these results, describe the balance used in terms of its accuracy and its precision.

Evaluate and create

9. Create a six-step flowchart to illustrate the correct method for lighting a Bunsen burner.
10. Which one safety rule do you feel is the most important when you are mixing two liquids and heating them? Create a poster to illustrate the rule.

Fully worked solutions and sample responses are available in your digital formats.

1.3 SkillBuilder — Using a Bunsen burner

online only

Why use a Bunsen burner?

Many experiments in the laboratory require heating using a Bunsen burner. A Bunsen burner provides heat when a mixture of air and gas is lit. Bunsen burners heat objects or liquids with a naked flame, and therefore there are precautions that must be taken to ensure the safe usage of a Bunsen burner.

Select your learnON format to access:
- an overview of the skill and its application in science (Tell me)
- a video and a step-by-step process to explain the skill (Show me)
- an activity and interactivity for you to practise the skill (Let me do it)
- questions to consolidate your understanding of the skill.

on Resources

- **Video eLesson** Using a Bunsen burner (eles-4154)
- **Interactivity** Using a Bunsen burner (int-8088)
- **eWorkbook** SkillBuilder — Using a Bunsen burner (ewbk-4622)

1.4 Planning your own investigation

LEARNING INTENTION

At the end of this subtopic you will know why it is important to have a valid aim and hypothesis.

1.4.1 Starting your own investigation

Scientists learn new things by asking questions and then conducting investigations to find answers. You will take on the role of a scientist by planning an investigation of your own.

FIGURE 1.8 Discuss your ideas with others.

Before you define your question in detail, you need to find a topic that interests you. Selecting your topic is the first step and one of the most crucial parts in conducting your research project.

1. Start by searching for a general area of interest. List your hobbies and other interests.
2. Do you have a friend or relative who might be able to help you in a scientific investigation? Write down the topic areas in which you could get help.
3. Discuss the possible research topics you have already written down with a group of fellow students. Listen carefully to their ideas. They might help you to decide on your own topic. Write down your ideas.
4. Have a look through the list of ideas below. Even if none of the suggested topics appeals to you, they may help you to think of other ideas. For example, 'How strong is sticky tape?' could lead you to consider topics such as the strength of glass, wood, paper, plastics or some other material. Brainstorm possible topics with your friends and make your own list of suggested investigations.
5. Search online or in a library for resources about the topic areas that you have already written down. You might also find journals or magazines that include articles about these topic areas. Use reliable websites and do not rely on just one source.

ACTIVITY: Brainstorm ideas for investigation topics

- How do fertilisers affect the growth of plants?
- Can plants grow without soil?
- What makes algae grow in an aquarium?
- What is the best shape for a boomerang?
- What type of wood gives off the most heat while burning?
- What makes iron rust?
- Which paint weathers best?
- Which battery lasts longest?
- How strong is sticky tape?
- Which type of glue is best?

- How much weight can a plastic bag hold?
- Which food wrap keeps food freshest?
- How effective are pre-wash stain removers?
- Which fabrics burn faster?
- How can the growth of mould on fruit be slowed down?
- Which concrete mixture is strongest?
- What type of fishing line is the strongest?
- Does the thickness of a rubber band affect how far it stretches?
- What type of paper aeroplane flies furthest?
- What is the best recipe for soap bubble mixture?
- Do tall people jump higher and further than short people?
- What type of fabric keeps you warmest in winter?

1.4.2 Writing an aim

Your investigation should have a clear and realistic aim. Your aim should be very specific. The aim of an investigation is its purpose, or the reason for doing it. Some examples of aims are:

- to find out how the weight and shape of paper aeroplanes affects how far they fly
- to compare the effect of different fertilisers on the growth of pea plants
- to find out whether different coloured lights affect the growth of algae in an aquarium
- to find out how exposing iron to salty water affects how quickly it rusts.

'To find out if the weight of paper planes makes them fly better' is not a suitable aim because 'fly better' has not been defined. 'Fly better' could mean fly further, fly in a straighter line or stay in the air longer. A better aim would be 'To find out how the weight of paper planes affects their flight distance and time in the air'.

When you have decided what your aim is, make sure that it is realistic. You should be able to answer 'yes' to each question below.

- Is my aim simple and clear?
- Will I be able to get the background information that I need?
- Is the equipment I need for my experiments available or can it be made?
- Is the question a safe one to investigate?

If you answer 'no' to any of these questions you need to rethink your aim.

hypothesis a suggested, testable explanation for observations or experimental results; it acts as a prediction for the investigation

1.4.3 Forming a hypothesis

A **hypothesis** is a sensible guess about the outcome of an experiment; it must be able to be supported by evidence. Your hypothesis should relate to your aim and should be testable with an experimental investigation. The results of your investigation will either support (agree with) or not support (disagree with or refute) the hypothesis. It is not possible to prove conclusively that a hypothesis is correct.

When scientists make a hypothesis, they usually carry out a number of experiments to test it. Sometimes, a number of teams of scientists test the same hypothesis with slightly different experiments. Even if the results of each experiment agree with the hypothesis, the scientists could never say that the hypothesis is proven to be correct. They would say that each experiment has provided further evidence to support the hypothesis.

Your hypothesis should be based on what you know about the topic or what you have already observed. For example, if you are trying to design the best parachute for a toy, you should read about parachutes

FIGURE 1.9 Will nylon be better than cotton? Your own experience might help you form a hypothesis.

before writing your hypothesis. You might also recall that when you are walking in the rain, a cotton T-shirt soaks up a lot of water and becomes heavy, whereas a nylon jacket does not soak up water. As a result, your hypothesis might be: 'Closely woven nylon is a better fabric to use for a parachute than loosely woven cotton'.

A statement that cannot be tested with a scientific experiment is not a suitable hypothesis. You will explore hypotheses in more depth in the subtopics 1.5 SkillBuilder — Writing an aim and forming a hypothesis, 1.7 Controlling variables and 1.8 SkillBuilder — Controlled, dependent and independent variables.

TABLE 1.1 Examples of how problems and observations can lead to hypotheses

Problem	Observation	Hypothesis
The television remote control doesn't work.	If I press the 'on' button on the remote control, the television doesn't come on.	If the batteries are flat then the remote control will not work.
My hair is sometimes dry and frizzy.	My hair is driest soon after washing it with Mum's shampoo.	If I wash my hair with Mum's shampoo my hair becomes dry.
No parrots come to our bird feeder.	There is bread in the bird feeder, and magpies and miner birds feed there.	If I feed birds bread then parrots will not eat it.

1.4.4 Ethical considerations

Some research problems may not be appropriate to investigate due to ethical considerations. Ethics have to do with what is considered to be right and wrong. Different groups in society have varying opinions about certain types of research. While many people accept that testing medicines on animals is necessary, others feel very strongly that no research should be carried out on animals. Scientists involved in medical research are often required to have their research proposals reviewed by an ethics committee. The potential benefits of the research are taken into consideration. In your investigations, you should not do research that has the potential to cause stress or harm to people or animals. Your research should not be upsetting to people. This is particularly relevant if your research involves a survey.

1.4.5 Working in groups

Working in groups has many advantages. You can divide up a task to get more work done in a short period of time. Each group member brings along their interests, expertise and skills and, if these are used effectively, the quality of the work produced will be increased. When doing practical work, each team member can have a different role so that the task can be carried out efficiently.

Group work also has some pitfalls. Resentment builds up when the work is not divided up fairly. Group members might have different ideas about the best way to carry out the project and waste time trying to come to an agreement. An effective way to avoid some of these pitfalls is to assign each group member a role at the start of the project. Think about each group member's skills and decide on roles accordingly.

on Resources

eWorkbook Observations and inferences (ewbk-4949)

assess on Additional automatically marked question sets

1.4 Exercise

learnON

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2	Questions 3, 4, 6	Questions 5, 7

Remember and understand

1. MC Which four of the following questions should you ask about your aim before it is final?
   A. Is my aim simple and clear?
   B. Will I be able to get the background information that I need?
   C. Is my aim interesting enough?
   D. Is the equipment I need for my experiment available or can it be made?
   E. Is my aim too simple?
   F. Is the question a safe one to investigate?
   G. Is my aim too long?
2. MC What does the term hypothesis mean?
   A. A question you test with an experiment
   B. A sensible guess about the outcome of an experiment based on what you know
   C. An observation you make during the experiment that may support the aim
   D. Research you undertake before commencing an experiment
3. How can you test a hypothesis?

Apply and analyse

4. MC Which of the following is a more suitable aim for an investigation about glue rather than 'To find out which glue is best'?
   A. To find out which brand of glue is the cheapest when gluing paper
   B. To find out which brand of glue takes the longest time to dry
   C. To find out which brand of glue is the strongest when gluing paper
   D. To find out which brand of glue is colourless when dry

5. MC Which four of the following would be the most suitable hypotheses?
   A. White chocolate tastes better than dark chocolate.
   B. Washing powder X removes tomato sauce stains faster than washing powder Y.
   C. Plants grow faster under red light than under green light.
   D. Sagittarians are nicer people than Leos.
   E. Playing video games increases the muscle strength in your thumbs.
   F. Science teachers perform better in IQ tests than English teachers.
   G. Science teachers are more interesting people than English teachers.

6. Consider the following table.

TABLE Examples of how problems and observations can lead to hypotheses

Problem	Observation	Hypothesis
The television remote control doesn't work.	If I press the 'on' button on the remote control, the television doesn't come on.	If the batteries are flat then the remote control will not work.
My hair is sometimes dry and frizzy.	My hair is driest soon after washing it with Mum's shampoo.	If I wash my hair with Mum's shampoo my hair becomes dry.
No parrots come to our bird feeder.	There is bread in the bird feeder, and magpies and miner birds feed there.	If I feed birds bread then parrots will not eat it.

SIS Describe how you could test each of the three hypotheses.

Evaluate and create

7. SIS Write an outline of an investigation you could do to test each of the three hypotheses from the table in question 6.

Fully worked solutions and sample responses are available in your digital formats.

1.5 SkillBuilder — Writing an aim and forming a hypothesis

online only

Why do we need to write aims and hypotheses?

When you conduct a scientific investigation, it is important to write an aim and a hypothesis. An aim is a statement of what you are trying to find out in your investigation. It is simply the reason why you are conducting the investigation. An aim that is simple and clear will allow you to focus on the investigation.

A hypothesis is an idea which is based on observation that may explain a phenomenon and it must be able to be tested. It should be related to your aim and it is a statement, not a question. A hypothesis cannot be proven correct, but the results of your experiment will either support your hypothesis or not support your hypothesis.

Select your learnON format to access:
- an overview of the skill and its application in science (Tell me)
- a video and a step-by-step process to explain the skill (Show me)
- an activity and interactivity for you to practise the skill (Let me do it)
- questions to consolidate your understanding of the skill.

on Resources

Video eLesson Writing an aim and forming a hypothesis (eles-4155)
Interactivity Writing an aim and forming a hypothesis (int-8089)
eWorkbook SkillBuilder — Writing an aim and forming a hypothesis (ewbk-4626)

1.6 Record keeping and research

LEARNING INTENTION

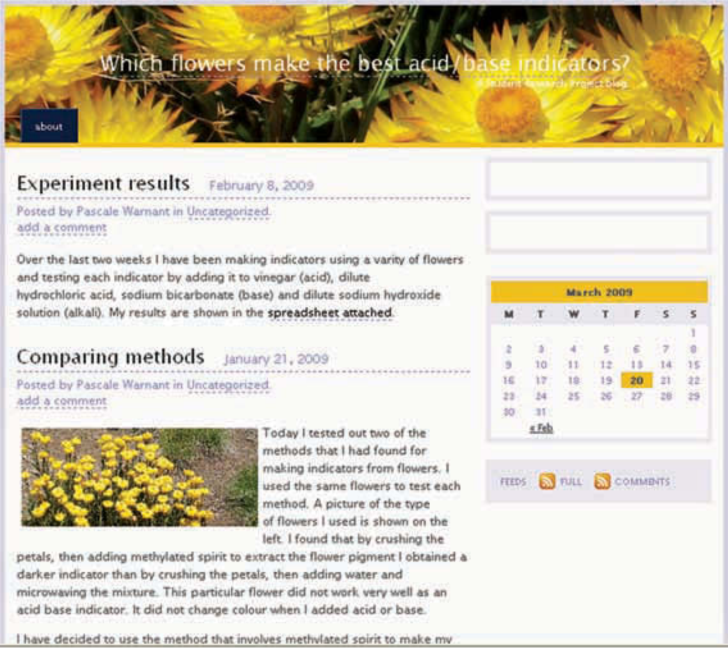
At the end of this subtopic you will know how to conduct effective research and how to keep good records of your investigation.

1.6.1 Background research

Scientists do experiments to test hypotheses, which are based on observations as well as the previous discoveries of other scientists.

Before designing their experiments, scientists do background research, which usually includes reading reports written by other scientists. Scientists also need to keep records of all their observations and any changes they make to the design of their experiments. When you conduct your own research investigation, you will probably be asked to do this by keeping a logbook.

FIGURE 1.10 Part of a blog site used by a researcher to share the results of her investigations into acid–base indicators



1.6.2 What is a logbook?

A logbook is a document in which you keep a record of all the work you do towards an investigation. Each entry should be dated like a diary. In your logbook, you might include the following items.

Information to include in your logbook:

- A timeline or other evidence of planning your time
- Notes about conversations you had with teachers, friends, parents or experts and how these conversations affected your project. Make sure you record each person's details so you can acknowledge their contribution in your report.
- Notes from research you did. Include all the details you need for your bibliography.
- A plan or rough outline of the method you will use for your experiment(s)
- Notes about any problems you encountered during your project and how you dealt with these
- Information on any changes you made to your original plan
- Results of all your experiments (these may be presented roughly at this stage)
- A plan or storyboard for your presentation if you will present your research to your class

A logbook can be written by hand on paper, on a computer, or it can even be written in an app or as a website. A blog is a website that has dated entries so it can be used as a logbook. It has the added advantage that you can invite other people, such as your friends, parents and teachers, to look at your work and post comments. You should check with your teacher on the format required for your logbook.

1.6.3 Researching your topic

Before you start your own experiments, you should find out more about your topic.

As well as increasing your general knowledge of the topic, you need to find out whether others have investigated your problem. Information already available about your topic might help you to design your experiments. It might also help you to explain your results.

Make notes on your topic as you find information. You may be able to include some relevant background information in your report.

FIGURE 1.11 Make notes on your topic.

How to use information

Make notes on information that is relevant to your research topic. Think about what you really need to know. You need information that will help you to:

- plan your experiments
- understand your results later on
- show in your report how your research relates to everyday life or why your research is important.

You will need to keep an accurate list in your logbook of the steps you have taken and the resources you have used.

The internet

The internet provides a wealth of information on almost every topic imaginable. Use a search engine such as Google or Bing. The success of your search will depend on a thoughtful choice of keywords. Don't just look at the first things that appear but scroll through the first page looking at the sources of the findings. Try to find reliable websites that are specific to your search words.

1.6.4 Reliable information

Most research is now carried out over the internet, but a great deal of information on the internet is unreliable. Reliable information is information that can be trusted. Imagine that your friend emailed you a link to a website that said that brushing your teeth with peppermint-flavoured toothpaste causes your tongue to turn green over time. How could you check that the information was reliable?

- Check the URL (uniform resource locator). This is the address you type in to access the page. The ending of the URL can be useful for assessing the reliability of a web page. A URL with an .edu ending is usually from an educational institution such as a school or university. The ending .gov is used for government websites while an .org ending usually indicates that the web page is associated with a non-profit organisation.
- Look for information about the author of the web page, the organisation associated with the web page and the date on which the information was last updated. A web page that provides no such information is less likely to be reliable. If an author's name is provided, what are their qualifications? Do they have expertise in the area they are commenting on? Are they likely to show bias? For websites associated with an organisation, is the organisation likely to benefit from a particular viewpoint about an issue?
- Check the information against other sources. Experimental results are considered reliable if the experiment, when repeated a number of times, consistently produces similar results. Similarly, the reliability of information from secondary sources can be assessed by checking it against other sources.

Using the library

Another good place to start is the school library. There are several different types of information sources in the library, including those in the following list. Ask a librarian for help.

Nonfiction books

Use the subject index catalogue to learn where to find books with information about your topic. Your library catalogue is most likely to be stored in a computer database. You might need to ask the librarian to help you use the catalogue at first. It is a good idea to browse through the contents list of science textbooks. Your topic may appear.

Reference books

These include encyclopedias, atlases and yearbooks. The index of a good encyclopedia is a great place to start looking for information.

Journals and magazines

There are quite a few scientific journals that are suitable for use by school students. They provide up-to-date information. Your library may have an index for journals, such as 'Guidelines', which you can use to find articles on your topic. You may, however, need to browse. Some journals to look for are: *New Scientist, Ecos, Australasian Science, Habitat, Popular Science, Choice* and *Double Helix*.

Information file

Many school libraries keep collections of digital files of newspaper articles on topics of interest. Ask your school librarian if you don't know how to access these resources.

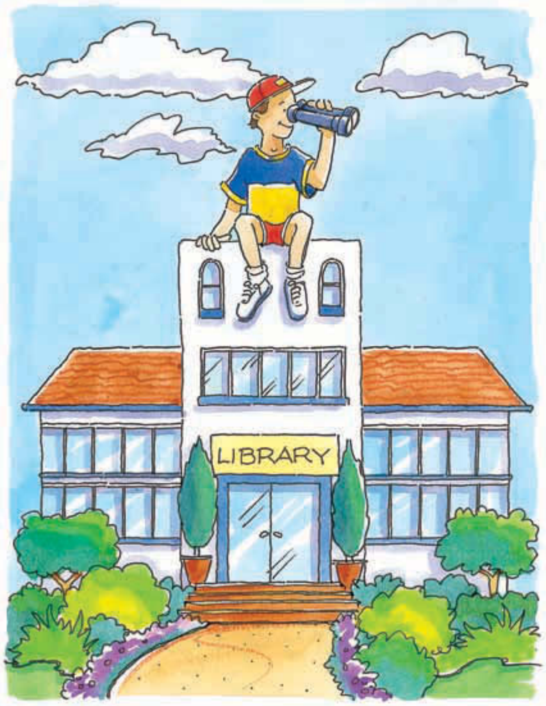
Audiovisual resources

The library may have slides, videos and audio CDs that can be used or borrowed. These resources can be located using the subject index catalogue. Your librarian may also recommend some podcasts.

Beyond the library

Information on your topic may also be available from the following sources.

FIGURE 1.12 Look for information beyond the library.



Your science teacher

This may seem obvious, but many people don't even think to ask. Your science teacher may also be able to direct you to other sources of information.

Government departments and agencies

Federal, state and local government departments and agencies may be able to provide you with information or advice on your topic. Try searching government web pages, which usually list contact details. A polite email to the appropriate department or agency is the best way to ask for help.

Industry

Information on some topics can be obtained from certain industries. For example, if you were testing glues for strength or batteries to find which ones last longest, the manufacturers might have useful information. Use the internet to find contact details. A polite email is often the best way to ask for help.

Relatives or friends

Perhaps you or a relative know somebody who works in your area of interest. Let your friends and relatives know about your intended research.

In your logbook, complete a checklist like the one in the following highlighted box to see if you have thoroughly searched sources of information.

Logbook checklist for collecting information

- ☐ The internet

School library:
- ☐ nonfiction books
- ☐ reference books
- ☐ journals and magazines
- ☐ information files
- ☐ audiovisual resources

Beyond the library:
- ☐ your science teacher
- ☐ government departments and agencies
- ☐ industry
- ☐ relatives or friends
- ☐ other sources

FIGURE 1.13 In your logbook, keep an accurate list of resources that you have used.

on Resources

assesson Additional automatically marked question sets

1.6 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2	Questions 3, 4	Question 5

Remember and understand

1. **MC** Why is a logbook a bit like a diary?
   - **A.** All entries are dated.
   - **B.** Nothing is allowed to be drawn in your logbook.
   - **C.** A logbook is always written on paper.
   - **D.** Both are written as if events will happen in the future.
2. What does the term ‘blog’ mean?

Apply and analyse

3. You can research information about science topics in science textbooks and on the internet.
   - **a.** Explain why you would not find the results of scientific research that was done last month in a science textbook.
   - **b.** Outline some advantages and disadvantages of using the internet as a source of information.
4. List the resources that you could use to research your investigation topic:
   - **a.** in your school library
   - **b.** outside the school library.

Evaluate and create

5. Imagine you are a scientist. Assess the advantages and disadvantages of maintaining a blog rather than keeping a logbook in your office.

Fully worked solutions and sample responses are available in your digital formats.

1.7 Controlling variables

LEARNING INTENTION

At the end of this subtopic you will be able to describe the differences between controlled, dependent and independent variables.

1.7.1 Dependent and independent variables

When was the last time you were on a swing? A playground swing is simply a large **pendulum**. A pendulum is a suspended object that is free to swing to and fro. Each complete swing is called an **oscillation**. The time taken for one complete oscillation of a pendulum is called its **period**. Pendulums are used mainly as measuring instruments. Their most well-known use is in clocks, such as grandfather clocks.

To answer questions scientifically, we need to perform a controlled investigation, which must also be reliable. Investigation 1.2 examines a swinging pendulum, where the variables are controlled. To ensure reliability, the measurements in the investigation need to be accurate, repeated and averaged.

FIGURE 1.14 A playground swing is simply a large pendulum.

Variables

There are several factors that affect the period of a pendulum. They include:
- the length of the pendulum
- the total mass that is swinging
- the height from which the pendulum is released.

These factors are called **variables**. The variable that you are measuring (in this case the period of the pendulum) is called the **dependent variable**. The variable that you are investigating is called the **independent variable**. In investigation 1.2, you will investigate two independent variables, the mass of the pendulum and the length of the pendulum. However, it is important that we only investigate one variable at a time. This allows a fair test.

Fair testing

Scientific investigations must be **fair tests**. In a fair test, only one variable is changed at a time — the independent variable. In the first part of investigation 1.2, the independent variable is the mass of the pendulum. All variables other than the independent variable must be controlled; that is, they must be kept the same. If they were not, you couldn't tell which variable was affecting the period of the pendulum. You might find it helpful when designing your own investigations to use a table similar to table 1.2 to identify all the variables.

pendulum an object swinging on the end of a string, chain or rod

oscillation one complete swing of a pendulum

period the time taken for one oscillation of a pendulum

variables quantities or conditions in an experiment that can change

dependent variable a variable that is expected to change when the independent variable is changed. The dependent variable is observed or measured during the experiment.

independent variable the variable that the scientist chooses to change to observe its effect on another variable

fair test a method for determining an answer to a problem without favouring any particular outcome — another name for a controlled experiment

TABLE 1.2 Experiment: How does mass affect the period of a pendulum?

Independent variable	• The mass of the pendulum
Dependent variable	• The period of the pendulum
Controlled variables	• The length of the pendulum • The angle of release • The method of release

elog-0590

INVESTIGATION 1.2

The period of a pendulum

Aim

To investigate the effects of mass and length on the period of a pendulum

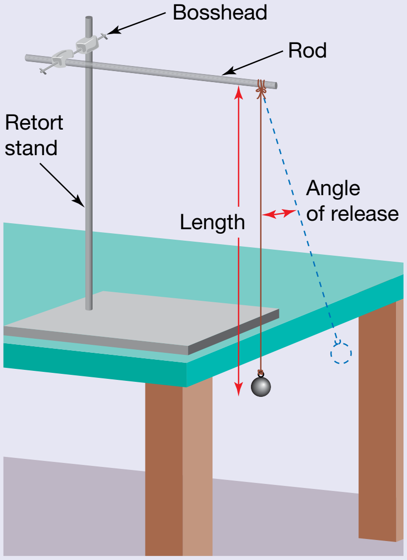
Materials

- length of string (at least 80 cm long)
- set of slotted masses
- retort stand with bosshead
- pair of scissors
- a one-metre ruler
- stopwatch or clock with a second hand

Method

Part 1: The effect of mass

1. Write a hypothesis for this part of the investigation.
2. Set up your pendulum so it can swing freely. Start with the largest possible length and the smallest weight.
3. Copy the table in the results section into your logbook, and record the mass and the length of the pendulum in it. The length should be measured from the top of the pendulum to the bottom of the swinging mass, as shown in the diagram.
4. Pull the mass aside so that the angle of release is about 20°. Take note of the height from which the mass is released so that this angle of release is used throughout the experiment.
5. Release the pendulum. Measure the time taken for 10 complete swings of the pendulum. Repeat your measurement at least twice to find the average time for 10 swings.
6. Repeat this procedure for three larger masses, completing the table as you go.



Part 2: The effect of length

7. Write a hypothesis for this part of the investigation.
8. Construct a table like table 1.2 to identify all of the variables that need to be considered for an investigation of the effect of length on the period of a pendulum.
9. Construct a second table in which to record your measurements. Remember that this time you'll be testing four different lengths without changing the mass. Use the same procedure as you did in part 1 for measuring the period.

Results

Part 1: The effect of mass

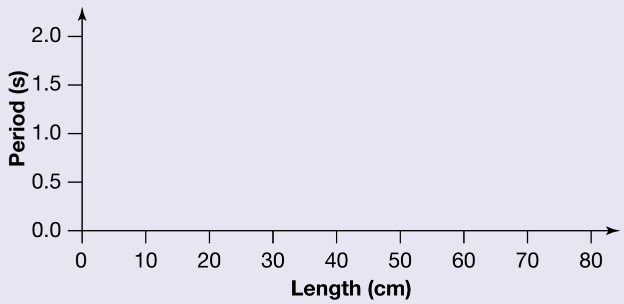
1. Record the length of your pendulum.
   Length of pendulum = ______ cm
   Angle of release = 20°
2. Record all the measurements in your table and calculate the average time taken for one complete swing (the period).

TABLE Results of investigation 1.2, part 1

Time taken for 10 complete swings (seconds)					
Mass (grams)	**Trial 1**	**Trial 2**	**Trial 3**	**Average**	**Period (seconds)**

Part 2: The effect of length

3. Record your measurements for part 2 of the investigation in a table.
4. Draw a line graph to show how the period of the pendulum is affected by its length. Remember to add a heading to your graph.



Discussion

1. How does the mass of the pendulum affect its period?
2. How does the length of the pendulum affect its period?
3. The period of most standard clock pendulums is one second. Use your graph to predict the length of a standard clock pendulum.
4. Explain why it is a good idea to measure the time for 10 swings rather than just one.
5. Suggest one aspect that could be done next time to improve this investigation.

Conclusion

What can you conclude about the effects of mass and length on the period of a pendulum?

on Resources

eWorkbook Fair testing (ewbk-4950)

assess on Additional automatically marked question sets

1.7 Exercise

learn on

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Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 5	Questions 2, 4, 6	Questions 3, 7

Remember and understand

1. What is a variable?
2. Complete the sentences to describe the difference between a dependent variable and an independent variable.
   During an experiment, the researcher purposely alters the ___________ variable. The ___________ variable is then an outcome or value that results from the change in the _______________ variable.

Apply and analyse

3. Why is it important to control variables in a scientific investigation?
4. A metronome is an 'upside-down' pendulum. To make the period of the metronome longer, should you move the sliding mass up or down?
5. Identify the independent and dependent variables in:
   a. part 1 of investigation 1.2
   b. part 2 of investigation 1.2.
6. In investigation 1.2 you conducted three trials for each measurement and calculated an average. List two reasons for the repetition.

A metronome's period is changed by moving the sliding mass up or down. A metronome is an upside-down pendulum.

Evaluate and create

7. Predict whether the angle of release affects the period of a pendulum and write down your hypothesis. Perform an investigation to test your hypothesis and write a brief report. In your conclusion, state clearly whether your results supported your hypothesis.

Fully worked solutions and sample responses are available in your digital formats.

1.8 SkillBuilder — Controlled, dependent and independent variables

online only

What is the difference between controlled, dependent and independent variables?

In order to answer a question scientifically, a controlled investigation needs to be performed. In a controlled investigation every variable except the one being tested is held constant, which stops the results being affected by an uncontrolled factor. The variable that you are investigating is called the independent variable. The variable that you are measuring is called the dependent variable.

Select your learnON format to access:
- an overview of the skill and its application in science (Tell me)
- a video and a step-by-step process to explain the skill (Show me)
- an activity and interactivity for you to practise the skill (Let me do it)
- questions to consolidate your understanding of the skill.

on Resources

Video eLesson Controlled, dependent and independent variables (eles-4156)

Interactivity Controlled, dependent and independent variables (int-8090)

eWorkbook SkillBuilder — Controlled, dependent and independent variables (ewbk-4630)

1.9 Scientific reports

LEARNING INTENTION

At the end of this subtopic you will understand how to write a scientific report.

1.9.1 Getting approval

Almost all scientists need the approval of their employer before they commence an investigation. As a student, you should not commence an investigation until your plan has been approved by your teacher.

1. Title

Choose a title in the form of a question — you may decide to change it before your work is completed.

2. The aim or problem

Briefly state what you intend to investigate or the question that you intend to answer.

Aim: To study the behaviour of slaters

Problem: What makes algae grow in an aquarium?

3. Hypothesis

Using the information that you know or have discovered while deciding on your aim and question, make an educated guess about the answer to your problem or what you expect to find out. It is important to be creative and objective, and to use logical reasoning when devising a hypothesis and testing it.

4. Outline of experiment

Explain how you intend to test your hypothesis, and briefly outline the experiments you intend to conduct.

5. Equipment

List any equipment you need for your experiments.

6. Resources

List the sources of information that you have used or intend to use. This list should include library resources, organisations and people.

1.9.2 Performing your experiments

Once your teacher has approved your plan, you may begin your experiments. Detail how you conducted your experiments in your logbook. All observations and measurements should be recorded. Use tables where possible to record your **data**. Use graphs to display your data.

Some information about using tables, graphs and data loggers is provided in subtopic 1.14.

Where appropriate, measurements should be repeated and an average value determined. All measurements — not just the averages — should be recorded in your logbook.

Photographs should be taken if appropriate.

FIGURE 1.15 All observations and measurements should be recorded.

data information collected which can be used for studying or analysing

You might need to change your experiments if you get results you don't expect. If things go wrong, record what happened. Knowing what went wrong allows you to improve your experiment and technique. Any major changes should be checked with your teacher.

1.9.3 Writing your report

Check with your teacher about what is required — teachers might not want all the following sections, or might want a poster or some other format. You can begin writing your report as soon as you have planned your investigation, but it cannot be completed until your observations are complete. Your report should be typed or neatly written on A4 paper. It should begin with a table of contents, and the pages should be numbered. Your report should include the following headings (unless they are not applicable to your investigation).

Abstract

Briefly summarise your experiments and your main conclusions. Even though this appears at the beginning of your report, it is best not to write it until after you have completed the rest of your report.

Introduction

Present all relevant background information. Include a statement of the problem that you are investigating, saying why it is relevant or important. You could also explain why you became interested in the topic.

Aim

State the purpose of your investigation — that is, what you are trying to find out.

Hypothesis

Using the knowledge you already have about your topic, make a guess about what you will find out by doing your investigation.

Materials and method

Describe in detail how you carried out your experiments. Begin with a list of the equipment used and include photographs of your equipment if appropriate. The description of the method must be detailed enough to allow somebody else to repeat your experiments. It should also convince the reader that the variables in your investigation are well controlled. Labelled diagrams can be used to make your description clear. Using a step-by-step outline makes your method easier to follow.

Results

Observations and measurements (data) are presented in this section. Wherever possible, present data as a table so that they are easy to read. Graphs can be used to help you and the reader interpret data. Each table and graph should have a title. Ensure that you use the most appropriate type of graph for your data (see sections 1.10.2 and 1.10.3).

Discussion

Discuss your results here. Begin by stating what your results indicate about the answer to your question. Explain how your results might be useful. Outline any weaknesses in your design or difficulties in measuring here. Explain how you could improve your experiments. What further experiments are suggested by your results?

Conclusion

This is a brief statement of what you found out and may link with the final paragraph of your 'Discussion'. It is a good idea to read your aim again before you write your conclusion. Your conclusion should also state whether your hypothesis was supported. Don't be disappointed if it is not supported. Some scientists deliberately set out to reject hypotheses!

Bibliography

Make a list of books and other printed or audiovisual material to which you have referred. The list should include enough detail to allow the source of information to be easily found by the reader. Arrange the sources in alphabetical order.

For each printed resource, list the following information in the order shown:

- author(s) (if known)
- title of book or article
- publisher or name of journal or magazine (if not in title)
- place of publication (if given)
- date of publication
- chapter or pages used.

For example:

Coventry, John., *Reptiles of Victoria: A Guide to Identification and Ecology,* CSIRO Publishing, Australia, 2019, page 36.

For websites, list the following:

- name of article or page of website
- author
- name of website
- date the site was updated
- URL address
- date accessed.

For example:

Bridge Building and Safe Design, John Daly, Safe Design Australia, last updated October 2018, www.safedesignaustralia.com.au/bridge-building-safe-design/, accessed 25 May 2020.

Acknowledgements

List the people and organisations who gave you help or advice. You should state how each person or organisation assisted you.

on Resources

eWorkbook Scientific reports (ewbk-4951)

assess on Additional automatically marked question sets

1.9 Exercise

learn on

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Question 1	Question 2	Questions 3, 4

Remember and understand

1. Complete the table by identifying which section of an investigation report the content should be located.

Content	Investigation report section
The purpose of the experiment	
A brief summary of your investigation and findings	
A table showing all the measurements you recorded	
A list of the books and other resources you used to find information for your project	
A diagram of the equipment you used	
A statement that relates the results back to the aim and outlines what your results show	

Apply and analyse

2. When scientists write up their investigations for publication in a scientific journal, the abstract is one of the most important parts of the report. Explain why the abstract is usually read by many more people than the full report.
3. Explain why it is important for scientists to publish their investigations in scientific journals and to read the reports written by other scientists.

Evaluate and create

4. There have been instances where scientists have faked their results or committed other types of scientific misconduct.
   a. Enter the words 'scientific misconduct' in a search engine to find examples of such instances.
   b. Why do you think that some scientists might be tempted to fake or fabricate their results?
   c. Explain why cases of scientific misconduct are damaging to all scientists.
   d. What do you think might happen to scientists who are found to have faked their results?

Fully worked solutions and sample responses are available in your digital formats.

1.10 Presenting your data

LEARNING INTENTION

At the end of this subtopic you will be able to use different types of diagrammatic, graphical and physical representations of data, and consider their strengths and limitations.

1.10.1 Presenting your data

Observations and measurements obtained from an investigation are called data. Data can be qualitative or quantitative.

- **Qualitative data** is expressed in words. It is also known as categorical data — you can think of this data falling into categories. It is descriptive and can be easily observed but not measured. There are two types of qualitative data:

qualitative data categorical data that examines the quality of something (e.g. colour or gender) rather than a measurement or quantity

- Ordinal data can be ordered or ranked. This could be levels (1st, 2nd, 3rd …) or opinions (strongly agree, agree, disagree, strongly disagree).
- Nominal data cannot be organised in a logical sequence. This could include colours or brand names.

- **Quantitative data** (or numerical data) can be precisely measured and have values that are expressed in numbers. There are two types of quantitative data:
  - Continuous data can take any numerical value, such as the temperature of a substance.
  - Discrete data can only take on set values that can be counted, such as the number of students with green eyes.

Having collected the data, it is important to present them clearly in a way that another person reading or studying them can understand. Tables and graphs are a great way to organise data.

1.10.2 Using tables

When data are organised in a table, they are easier to read and trends are more easily identified. An example of a simple table is shown in table 1.3; it includes all the features you need to remember when constructing a table.

Always include a title for your table.

TABLE 1.3 Temperature of the Earth at different depths

Depth (km)	Temperature (°C)
0	15
1	44
2	73
3	102
4	130
5	158
6	187
7	215
8	242

Include the measurement units in the headings.

The column headings show clearly what has been measured.

Use a ruler to draw lines for rows, columns and borders.

Enter the data in the body of the table. Do not include units in this part of the table.

You may need to construct more complex tables, such as table 1.4, to present your research project results.

TABLE 1.4 Do large paper aeroplanes fly further than small paper aeroplanes?

Labels

	Width of paper (cm)	21	15	9
	Length of paper (cm)	14	10	6
Distance (m)	Trial 1	4.5	6.2	3.2
	Trial 2	4.9	5.9	3.6
	Trial 3	4.6	5.8	3.5
	Average	4.7	6.0	3.4

Units

quantitative data numerical data that examines the quantity of something (e.g. length or time)

1.10.3 Using graphs

Organising data as a graph is a widely recognised way to make a clear presentation. Graphs make it easier to read and interpret information, find trends and draw conclusions. Just like tables, graphs should always have a heading.

A graph, especially a line graph, can also be used to find values other than those used in the investigation. This can be done by interpolation or extrapolation (see sections 1.10.4 and 1.10.5).

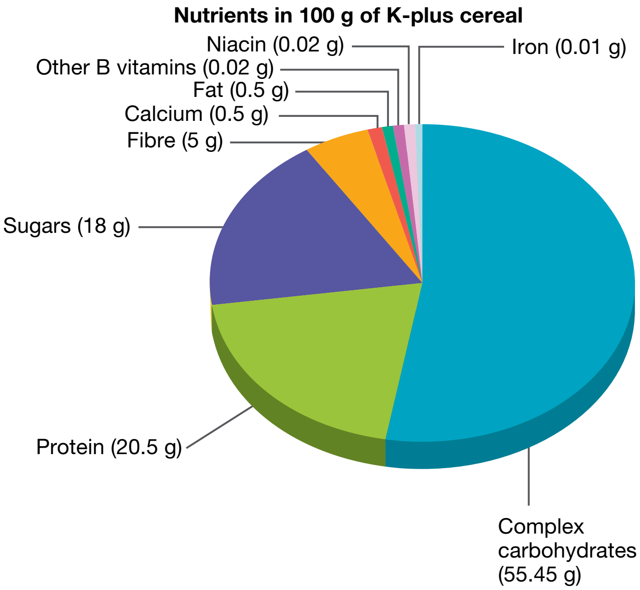
Types of graphs

Five different types of graphs commonly used in scientific reports are pie charts, column or bar graphs, divided bar graphs, histograms and line graphs.

Pie charts (or sector graphs)

A pie chart (also known as a sector graph) is a circle divided into sections that represent parts of the whole. This type of graph may be used when the data can be added as parts of a whole. The example in figure 1.16 shows the food types, vitamins and minerals that make up the nutrients in a breakfast cereal.

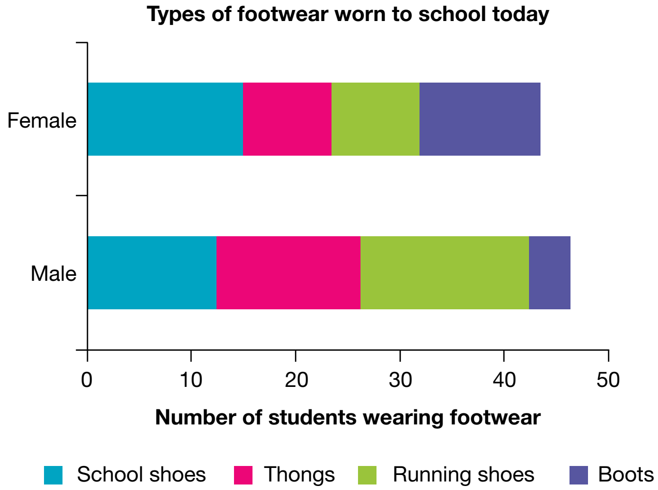
FIGURE 1.16 A pie chart



Divided bar graphs

Divided bar graphs are also used to represent parts of a whole. However, the data are represented as a long rectangle, rather than a circle, divided into sections. The example in figure 1.17 shows the type of footwear worn to school today by male and female students.

FIGURE 1.17 A divided bar graph



Column graphs and bar graphs

A column graph (sometimes called a bar graph) has two axes and uses rectangles (columns or bars) to represent each piece of data. The height or length of the rectangles represents the values in the data. The width of the rectangles is kept constant. This type of graph can be used when the data cannot be connected and are therefore not continuous — that is, when one piece of data is qualitative and the other is quantitative.

Figure 1.18 shows data on the average height to which different balls bounced during an experiment. Each column represents a different type of ball.

Figure 1.19 shows the lengths of different metal bars when heated. Each bar represents a different metal.

FIGURE 1.18 A column graph

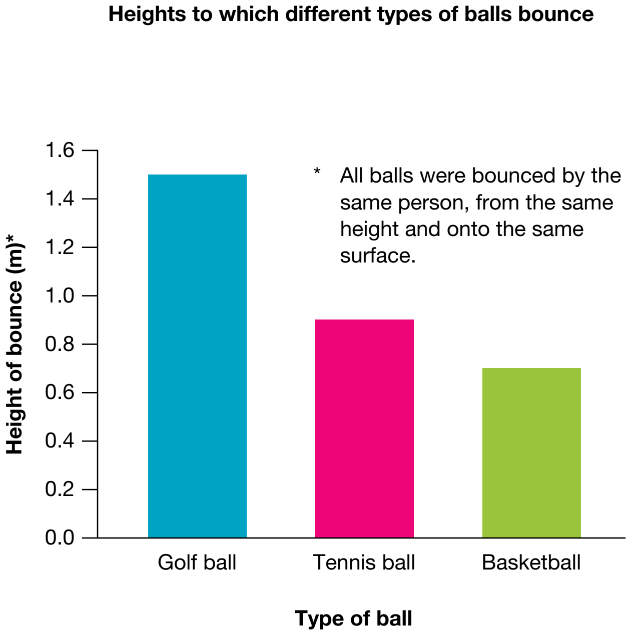
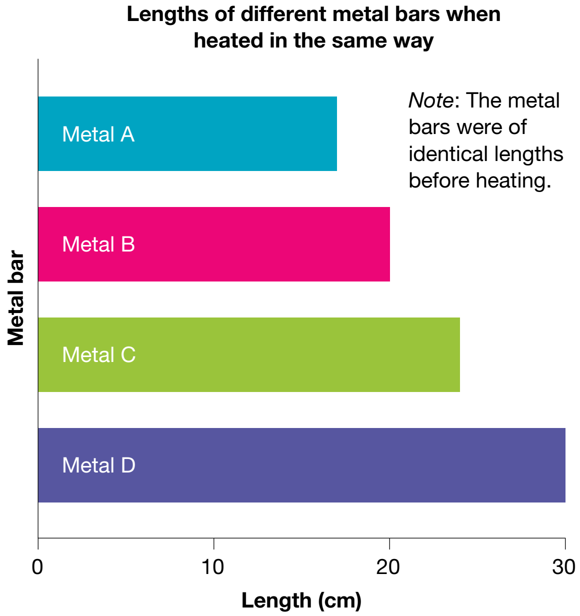


FIGURE 1.19 A bar graph



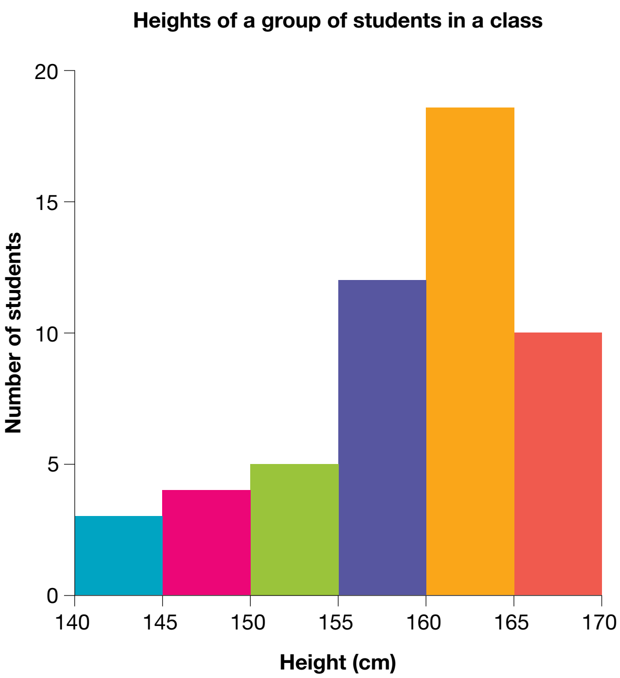
Histograms

Histograms are similar to column graphs except the columns touch because the data are continuous. They are often used to present the results of surveys. In figure 1.20, each column represents the number of students of a particular height.

Line graphs

A line graph has two axes — a horizontal axis and a vertical axis. The horizontal axis is known as the x-axis, and the vertical axis is known as the y-axis. A line graph is formed by joining a series of points or drawing a **line of best fit** through the points. Each point represents a set of data for two variables, such as height and time. Two or more lines may be drawn on the same graph. Line graphs are used to show continuous data — that is, data in which the values follow on from each other. The features of line graphs are shown in figure 1.21.

FIGURE 1.20 A histogram



line of best fit a smooth curve or line that passes as close as possible to all plotted points on a graph

FIGURE 1.21 Features of a line graph

1. Grid

Graphs should always be drawn on grid paper so values are accurately placed. Drawing freehand on lined or plain paper is not accurate enough for most graphs.

2. Title

Tell the reader what the graph is about! The title describes the results of the investigation or the relationship between variables.

3. Setting up and labelling the axes

Graphs represent a relationship between two variables. When choosing which variable to put on each axis, remember that there is usually an independent variable (which the investigator chooses) and a dependent variable. For example, if students wish to find out how far a runner could run in 15 seconds, they may choose to measure the distance covered every 5 seconds. The time of each measurement was chosen by the students and is the independent variable. The distance measured is therefore the dependent variable. Usually the independent variable is plotted on the *x*-axis and the dependent variable on the vertical *y*-axis.

After deciding on the variable for each axis, you must clearly label the axes with the variable and its units. The unit is written in brackets after the name of the variable.

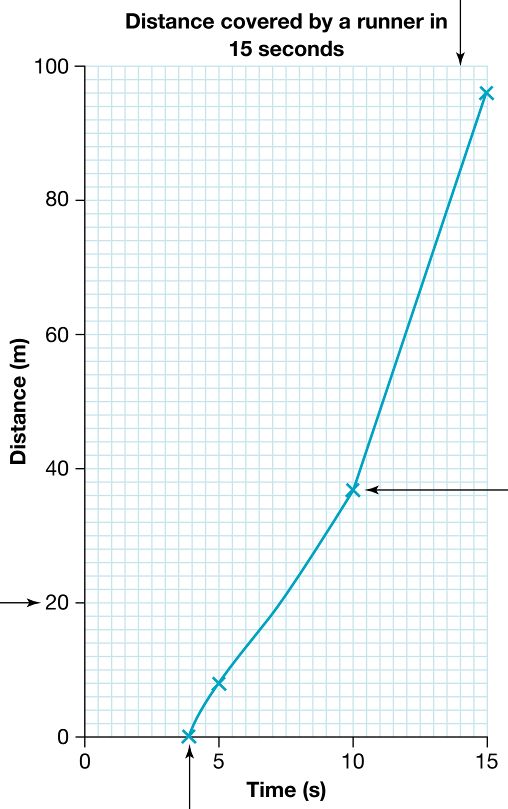


TABLE 1.5 Data table

Distance (m)	Time (s)
0	4
8	5
37	10
96	15

4. Setting up the scales

Each axis should be marked into units that cover the entire range of the measurement. For example, if the distance ranges from 0 m to 96 m, then 0 m and 100 m could be the lowest and highest values on the vertical scale. The distance between the top and bottom values is then broken up into equal divisions and marked. The horizontal axis must also have its own range of values and uniform scale (which does not have to be the same scale as the vertical axis).

The most important points about the scales are:

- they must show the entire range of measurements
- they must be uniform, that is, show equal divisions for equal increases in value.

5. Putting in the values

A point is made for each pair of values (the meeting point of two imaginary lines from each axis). The points should be clearly visible. Include a point for (0, 0) only if you have the data for this point.

6. Drawing the line

A line is then drawn through the points.

A line that follows the general direction of the points is called a 'line of best fit' because it best fits the data. It should be on or as close to as many points as possible. Some points follow the shape of a curve, rather than a straight line. A curved line that touches all the points can then be used.

The type of data you graph may lead you to expect either a straight line or a curve. For example, you might expect the increase in temperature of water being boiled to be a straight line because the temperature increases at a steady rate. A graph of the growth rate of a red panda (see page 48) would be curved and irregular because pandas have growth spurts. Inspecting the data will help you decide whether your line should be straight or smooth and curved.

1.10.4 Interpolation

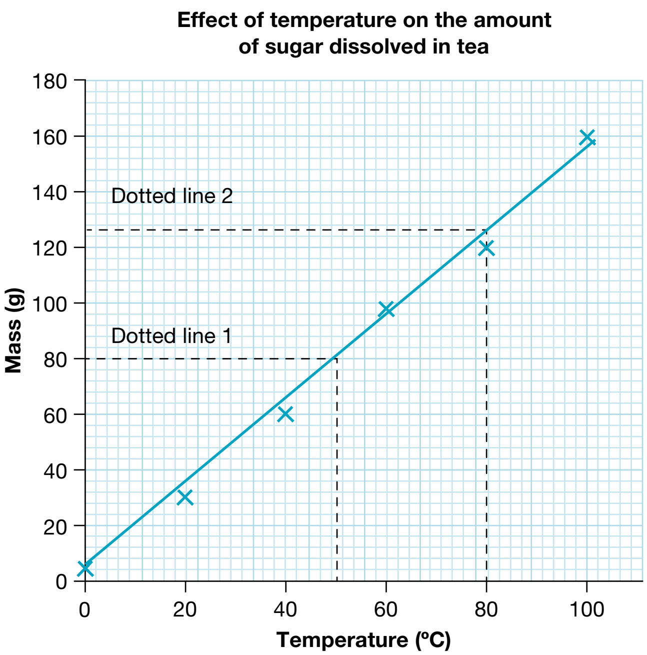
Line graphs can be used to estimate measurements that were not actually made in an investigation. Table 1.6 shows the results of an experiment in which a student measured how many spoons of sugar dissolved in a cup of tea at various temperatures. Once a line of best fit has been drawn, we can determine the mass of sugar that would dissolve at temperatures within the range that were investigated. Predicting values from within the range of the experiment like this is called interpolation.

TABLE 1.6 Amount of sugar that dissolves in one cup of tea at different temperatures

Temperature (°C)	Mass of sugar dissolved (g)
0	4
20	30
40	60
60	98
80	120
100	160

The student did not measure how much sugar dissolved at 50 °C, but we can work this out by interpolation. First we need to plot the data collected in the experiment. Then we read off the graph the amount of sugar that would dissolve at 50 °C (shown by dotted line 1 in the graph in figure 1.22). The same procedure can be used to work out the water temperature that would be needed to dissolve 130 g of sugar in one cup of tea. This is shown by dotted line 2.

FIGURE 1.22 Using a line graph for interpolation



1.10.5 Extrapolation

In many cases it is also possible to assume that the two variables will hold the same relationship beyond the values that have been plotted. By extending a line of best fit past the range tested we can make predictions on data outside of the range tested. This is called extrapolation. Consider table 1.7, which shows the results obtained when different masses were attached to a spring and the increase in length of the spring was measured.

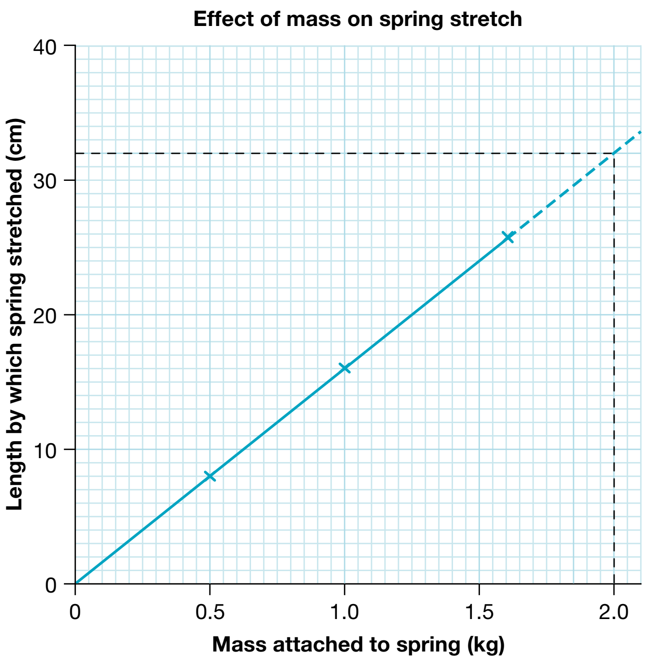
TABLE 1.7 Amount a spring stretched when various masses were attached

Mass attached to the spring (kg)	Length by which spring stretched (cm)
0.0	0
0.5	8
1.0	16
1.6	26
?	32

If you want to predict the mass needed to stretch the spring by 32 cm, you need to plot the data on a graph and extrapolate the value.

The data in table 1.7 are plotted on the graph (figure 1.23). Values have been plotted up to a mass of 1.6 kg and an increase in length of 26 cm. The line on the graph has been projected onwards (as the dotted lines show). This extrapolation shows that a mass of 2 kg will stretch the spring 32 cm. It should be noted that, unlike interpolation, extrapolation is not a very reliable technique. If possible always try to test values directly.

FIGURE 1.23 Using a line graph for extrapolation



SAMPLE PROBLEM: Drawing a line graph

A student conducted an experiment to see how temperature affected the amount of sugar that would dissolve in a cup of tea. Each cup contained the same volume of tea, and the sugar was stirred in at an equal rate for each cup. The results obtained are shown in the table 1.8.

Graph the data in the table.

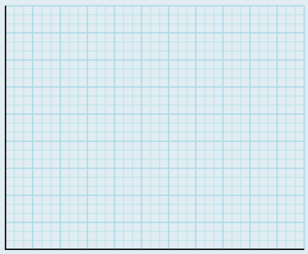
TABLE 1.8 Amount of sugar that dissolves in one cup of tea

Temperature (°C)	Mass of sugar dissolved (g)
0	4
20	30
40	60
60	98
80	120
100	160

THINK

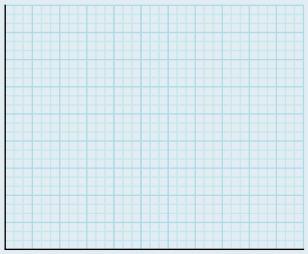
WRITE

1. Set up the grid.



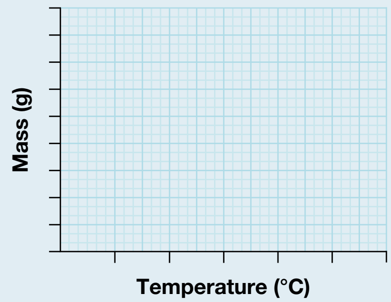
2. Give the graph a title.

Effect of temperature on the amount of sugar dissolved in tea

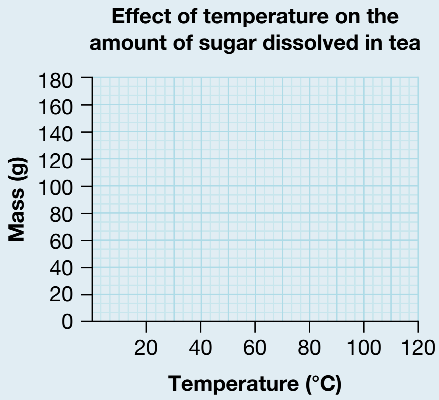


3. Set up the axes and label them.

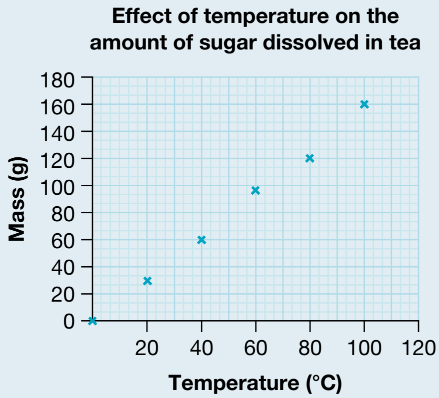
Effect of temperature on the amount of sugar dissolved in tea



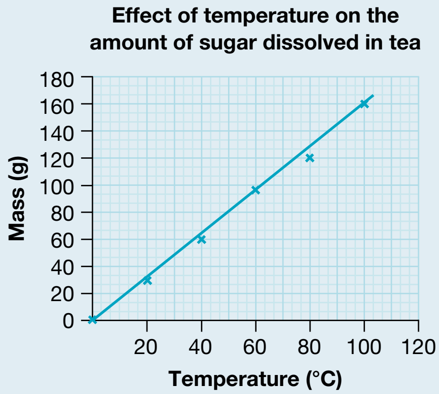
4. Place the scales on the axes.



5. Plot each pair of values as a point marked with an x. Make sure each point is clearly visible. Don't forget to plot (0, 4) because you have the data for this point.



6. Draw a line of best fit; that is, a line drawn in between the points so that some points are on the line, some are below it and some are above.



on Resources

eWorkbooks	Scientific drawing skills (ewbk-4952) Data analysis (ewbk-4953)
assess on	Additional automatically marked question sets

1.10 Exercise

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To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 3	Questions 2, 5	Questions 4, 6

Remember and understand

1. Define the term interpolation.

Apply and analyse

2. Would you choose a column graph or a histogram to best represent a set continuous, numerical data? Explain your reasoning.

Evaluate and create

3. The table shows the uses of plastics in Australia.
   a. Construct a pie chart using the information in the table.
   b. MC Which category uses the largest amount of plastic in Australia?
      A. Building
      B. Packaging and materials handling
      C. Transport
      D. Agriculture
      E. Electrical/electronic

TABLE Uses of plastics in Australia

Use	Percentage (%)
Agriculture	4.0
Building	24.0
Electrical/electronic	8.0
Furniture and bedding	8.0
Housewares	4.0
Marine, toys and leisure	2.0
Packaging and materials handling	31.0
Transport	5.0
Others	14.0

4. The data in the table relate the speed of a car to its stopping distance (the distance the car travels after the brakes are applied).

TABLE Relationship between the speed of a car and its stopping distance

Speed of car (m/s)	Stopping distance (m)
10	12
20	36
30	72
40	120

   a. Construct a graph of the information in the table shown.
   b. MC Which of the following could be a conclusion drawn from the information in the graph?
      A. The slower the speed of the car, the greater the stopping distance.
      B. The faster the speed of the car, the greater the stopping distance.
      C. The stopping distance is the independent variable.
      D. The faster the speed of the car, the smaller the stopping distance.

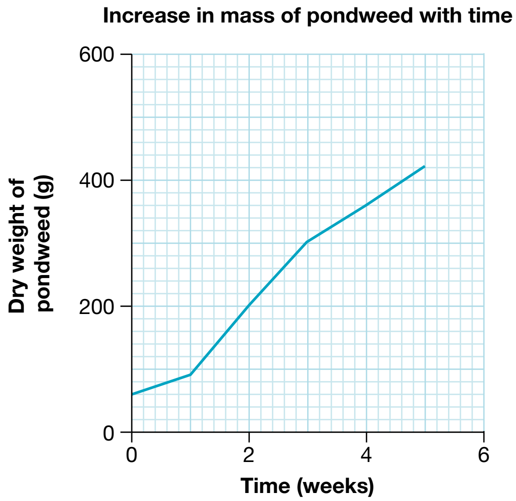
5. The boiling point of water changes with air pressure. For example, water does not boil at 100 °C at the top of Mount Everest, where the air pressure is less than the pressure at sea level. The following data show the boiling point of water at various air pressure values.

TABLE Boiling point of water at different air pressures

Air pressure (kPa)	Boiling point of water (°C)
1	20
7	40
21	60
45	80
101	100
200	120

a. Construct a graph of the information in the table.
b. Describe the shape of the graph.
c. What is the pressure of the atmosphere at sea level?
d. MC Would it take a longer or shorter time to boil water at the top of Mount Everest compared with at sea level?
   A. It would take less time because air pressure is lower. The lower the air pressure, the lower the boiling point of water.
   B. It would take more time because air pressure is lower. The lower the air pressure, the higher the boiling point of water.
   C. It would take more time because air pressure is higher. The higher the air pressure, the higher the boiling point of water.
   D. It would take less time because air pressure is higher. The higher the air pressure, the lower the boiling point of water.

6. The graph shows the increase in mass of a growing pondweed.
   a. What was the mass of the plant after three weeks of growth?
   b. How long did it take for the plant to grow to 250 grams?
   c. MC What would be a reasonable prediction for the mass of the plant after six weeks of growth?
      A. 500 g
      B. 300 g
      C. 1 kg
      D. 100 g
   d. Can you be sure that your prediction for part (c) is accurate? Suggest why it may not be accurate.
   e. Extrapolations are more reliable than interpolations. True or false? Justify your response.



Fully worked solutions and sample responses are available in your digital formats.

1.11 SkillBuilder — Constructing a pie chart

online only

What is a pie chart?

A pie chart, or pie graph, is a graph in which slices or segments represent the size of different parts that make up the whole. The size of the segments is easily seen and can be compared. Pie graphs give us an overall impression of data.

Select your learnON format to access:
- an overview of the skill and its application in science (Tell me)
- a video and a step-by-step process to explain the skill (Show me)
- an activity and interactivity for you to practise the skill (Let me do it)
- questions to consolidate your understanding of the skill.

on Resources

Video eLesson Skillbuilder: Constructing a pie graph (eles-1632)
Interactivity Skillbuilder: Constructing a pie graph (int-3128)
eWorkbook Skillbuilder — Constructing a pie chart (ewbk-4634)

1.12 SkillBuilder — Creating a simple column or bar graph

online only

What is a column or bar graph?

Column graphs show information or data in columns. In a bar graph the bars are drawn horizontally and in column graphs they are drawn vertically. They can be hand drawn or constructed using computer spreadsheets.

Select your learnON format to access:
- an overview of the skill and its application in science (Tell me)
- a video and a step-by-step process to explain the skill (Show me)
- an activity and interactivity for you to practise the skill (Let me do it)
- questions to consolidate your understanding of the skill.

on Resources

Video eLesson Skillbuilder: Creating a simple column or bar graph (eles-1639)
Interactivity Skillbuilder: Creating a simple column graph (int-3135)
eWorkbook Skillbuilder — Creating a simple column or bar graph (ewbk-4636)

1.13 SkillBuilder — Drawing a line graph

online only

What is a line graph?

A line graph displays information as a series of points on a graph that are joined to form a line. Line graphs are very useful to show change over time. They can show a single set of data, or they can show multiple sets, which enables us to compare similarities and differences between two sets of data at a glance.

Select your learnON format to access:

- an overview of the skill and its application in science (Tell me)
- a video and a step-by-step process to explain the skill (Show me)
- an activity and interactivity for you to practise the skill (Let me do it)
- questions to consolidate your understanding of the skill.

on Resources

Video eLesson Skillbuilder: Drawing a line graph (eles-1635)

Interactivity Skillbuilder: Drawing a line graph (int-3131)

eWorkbook SkillBuilder — Drawing a line graph (ewbk-4638)

1.14 Using data loggers

LEARNING INTENTION

At the end of this subtopic you will be able to identify different types of data loggers that can monitor investigations and produce data.

1.14.1 What is a data logger?

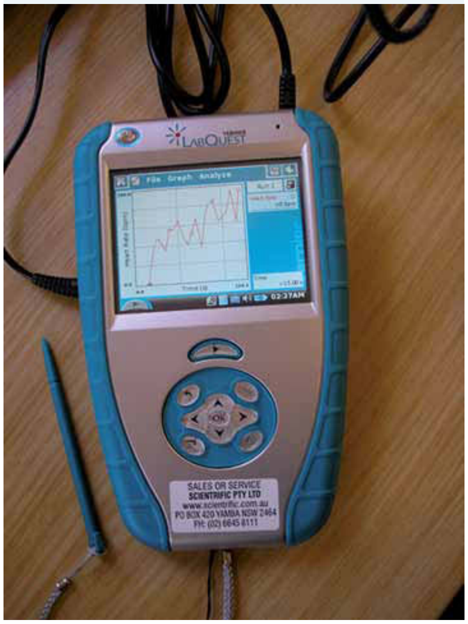
A data logger is a type of scientific recording instrument. Many devices record data, for example fitness monitors and smart watches. A data logger collects and stores measurements that are called data. It has to be attached to a measuring instrument called a **sensor**. The sensor does the measuring and sends the measurements to the data logger.

The real advantage of working with a data logger is that it can store thousands of individual measurements. The measurements can be taken in quick succession or over a long period of time, and the data logger can be programmed to do this automatically. This is why scientists often use data loggers in their work.

Data loggers also tend to be portable and battery-powered, and can therefore be used for applications such as remote weather monitoring and car crash testing. You may have been in a car that has driven over two closely placed rubber strips on the road — these strips are connected to a data logger used to count traffic.

Of course, to be useful, the stored measurements must be easy to access. That is why the data logger is also attached to either a computer or a graphics calculator. The computer or calculator takes the data and, using special software that comes with the data logger, shows the data as a table, a graph or both.

FIGURE 1.24 Some data loggers have their own touch screen and work like mini computers.



sensor device connected to an instrument such as a data logger that measures and sends information

Other uses for data loggers

Data loggers can be used for just about any experiment where measurements are taken. All that is needed is the appropriate sensor to be plugged in. It is even possible to plug in several sensors to take different measurements at the same time.

FIGURE 1.25 More basic data loggers require the use of a computer to analyse the results.

Some of the many different sensors that are available include:

- temperature sensors capable of measuring up to several hundred degrees Celsius
- light intensity sensors
- soundwave sensors (microphones)
- motion sensors
- magnetic field sensors
- acceleration sensors
- force sensors
- electric current and voltage sensors
- humidity sensors
- blood pressure sensors
- heart rate sensors.

FIGURE 1.26 A data logger for measuring blood pressure

One type of sensor that isn't necessary is a time sensor (stopwatch) because the data logger has its own inbuilt clock that is very accurate. In fact, one of the most useful things about data loggers is their ability to collect measurements at very small and precise time intervals, even as many as a thousand measurements in one second!

1.14.2 Data loggers in temperature measurement

In investigation 1.1 in section 1.1.3 the measuring instrument you used was a thermometer. You looked at the thermometer every 30 seconds and observed the temperature, which you wrote down in a table. You then made a line graph of temperature against time. If you had used a data logger with a temperature sensor instead of the thermometer, it could have taken the temperature every second and sent it to a computer that automatically tabulated the temperature data and graphed it as well.

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1.14 Exercise

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Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Question 1	Question 2	Question 3

Remember and understand

1. Match the word on the left to the correct statement on the right.

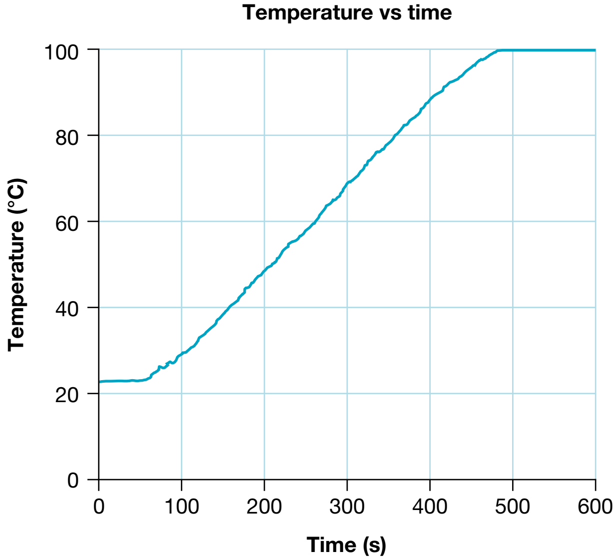
Word	Meaning
a. Sensor	**A.** You may need to download the data from the data logger to one of these.
b. Data logger	**B.** Piece of information
c. Computer	**C.** These are plugged into the data logger and take the measurements.
d. Data logger software	**D.** Allows you to input data into the data logger or computer by touching it with your finger or a stylus
e. Touch screen	**E.** Allows you to process the data collected by the data logger
f. Data	**F.** Collects and stores data from sensors connected to it

Apply and analyse

2. Sensors are devices that take the measurements that the data logger collects. Outline scientific investigations that could use data collected by sensors that measure:
   a. electric current
   b. heart rate
   c. motion
   d. sound waves
   e. light intensity.

Evaluate and create

3. The graph shows data collected by a data logger for an experiment in which water was heated to boiling point in a beaker. A temperature sensor was used to take the measurements.
   a. How long did the whole experiment take?
   b. Approximately how long after the experiment began did the heating of water begin?
   c. What was the temperature of the water when heating began?
   d. What was the temperature of the water when heating finished?
   e. Approximately how long after the experiment began did the water begin to boil?
   f. Between 100 and 400 seconds, at what rate (in degrees per second) did the water temperature rise?
   g. The water continued to be heated even when its temperature reached boiling point; yet its temperature did not rise beyond 100 °C. What has happened to all the energy that was being put into the water if it isn't causing the water temperature to rise? (*Hint:* Think about what happens to water while it is boiling.)



Fully worked solutions and sample responses are available in your digital formats.

1.15 Famous scientists

LEARNING INTENTION

At the end of this subtopic you will be able to describe the discoveries and achievements of four famous scientists.

1.15.1 Famous science investigations

Einstein, Newton, Curie and Pasteur. These are all names that are familiar to us because their contributions to science changed the world. Below are some facts about their lives and some insights into their discoveries.

on Resources

Video eLesson Career spotlight: scientist (eles-0766)

SCIENCE AS A HUMAN ENDEAVOUR: Sir Isaac Newton

Sir Isaac Newton (1642–1727) is probably most well known for his laws of gravitation, which explain the motion of the planets around the sun. According to some historians, his ideas about gravity arose after an apple fell on his head. We'll probably never know if this is true.

Isaac Newton was sent to Cambridge University at the age of 18. When the university closed down in 1665 as a result of the Great Plague, young Isaac went home for two years. There he developed his laws of gravitation and his three laws of motion. During his life, he also made discoveries about the behaviour of light and invented a whole new branch of mathematics, called calculus. Much of the scientific knowledge that has been acquired since the seventeenth century is built upon Newton's discoveries during that amazing two-year period.

FIGURE 1.27 Sir Isaac Newton

on Resources

Video eLesson Isaac Newton (eles-1771)

SCIENCE AS A HUMAN ENDEAVOUR: Albert Einstein

Albert Einstein (1879–1955) is most well known for his theory of relativity (there are actually two theories of relativity) and the equation $E = mc^2$, which describes how mass can be converted into energy.

Albert Einstein was certainly a slow starter. Although he was fascinated by mathematics, Einstein performed badly at school and left at the age of 15. He returned later and trained as a teacher in Switzerland. Einstein often failed to attend lectures and passed university exams by studying the notes of his classmates.

Einstein's first job was as a junior clerk in a patent office. His work was not demanding and he spent a lot of time doing 'thought' experiments.

FIGURE 1.28 Einstein's first wife, Mileva, was a mathematician. He discussed many of his new ideas with her.

At the age of 26, Einstein began to publish his ideas. These ideas altered our view of the nature of the universe by changing existing laws and discovering new ones.

Einstein explained the photoelectric effect, in which light energy is transformed into electrical energy, and received the Nobel Prize in Physics in 1921 for this.

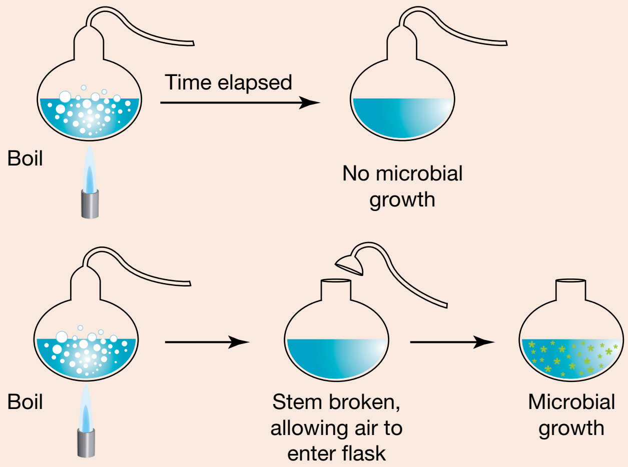
Einstein's theories of relativity were so different from earlier theories that they were not believed or understood by most scientists. His theory of special relativity explains the behaviour of objects that travel at speeds close to the speed of light. His theory of general relativity explains the effect of gravity on light and predicts that time 'slows down' in the presence of large gravitational forces. These theories provide useful clues about the development and future of the universe.

Einstein's theories suggested that mass could be converted into energy. This idea led to the development of the atomic bomb and nuclear power. Einstein, who was Jewish, fled Germany in 1933 to live and work in the United States. He was an active opponent of nuclear weapons and was involved in the peace movement long before atomic bombs destroyed Hiroshima and Nagasaki at the end of World War II.

SCIENCE AS A HUMAN ENDEAVOUR: Louis Pasteur

Louis Pasteur (1822–1895) proved that infectious diseases were caused by microbes. His ideas became known as 'germ theory'. He also developed several vaccines that made people immune to diseases such as rabies and smallpox. In doing this he has been responsible for saving the lives of millions of people and countless animals.

FIGURE 1.29 One of Pasteur's experiments



Pasteur began his scientific career in physics and chemistry, but became interested in microbes when he was using light to investigate the differences between chemicals in living and non-living things.

Pasteur's next challenge was to rescue the French wine industry. Wine (and beer) became sour very quickly and this was beginning to have an impact on the French economy, which relied heavily on the export of wine. Pasteur showed that the souring was caused by acids produced by the action of bacteria in the wine. Pasteur invented a process that rapidly heated some of the ingredients of the wine. The rapid heating killed most of the offending microbes without altering the flavour of the wine. The process, known as pasteurisation, was later adapted to slow down the souring of milk.

DISCUSSION

Louis Pasteur conducted many of his experiments on animals. Many of the experiments would now be considered cruel; however, the experiments saved many human and animal lives.

Present the arguments for and against the use of animals in such experiments.

Were the animal experiments justified? Write a brief statement supporting your opinion.

on Resources

Interactivity Pasteur's experiment (int-3420)

SCIENCE AS A HUMAN ENDEAVOUR: Marie Curie

Marie Curie (1867–1934) became the first scientist to win two Nobel Prizes when she was awarded the Nobel Prize in Chemistry in 1911 for her discovery of two new elements: polonium and radium. Radium was used in the treatment of cancer until cheaper and safer radioactive materials were developed. Marie Curie's first Nobel Prize, for the study of radioactivity, was shared with her husband, Pierre, and fellow scientist Antoine-Henri Becquerel in 1903.

FIGURE 1.30 Marie Curie with husband Pierre in her laboratory

As a child, Marie Sklodowska (her birth name) wanted to study science. However, girls were forbidden to attend university in her native country of Poland. She worked as a private tutor for three years to earn enough money to study at the University of Paris, where she met her future husband, Pierre. They were very poor and spent most of their money on laboratory equipment, leaving very little money for food; in fact, they often couldn't afford to eat. After Pierre was knocked down and killed by a speeding wagon. Marie continued their research in radioactivity, pioneering the development of radioactive materials for use in medicine and industry. She became the first female teacher at the University of Paris and worked hard to raise money for scientific research.

on Resources

assesson Additional automatically marked question sets

1.15 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3, 4	Questions 5, 8	Questions 6, 7

Remember and understand

1. **MC** Louis Pasteur worked in many fields of science during his career. Which of the following did he achieve?
   A. The discovery that infectious diseases are caused by microbes
   B. The development of the theories of gravity and motion
   C. The isolation of two new elements, radium and polonium
   D. The development of the theory of relativity

2. MC Sir Isaac Newton worked in many fields of science during his career. Which of the following did he achieve?
   A. The discovery that infectious diseases are caused by microbes
   B. The development of the theories of gravity and motion
   C. The isolation of two new elements, radium and polonium
   D. The development of the theory of relativity
3. MC Marie Curie was the first scientist to win two Nobel prizes. Which of the following did she achieve?
   A. The discovery that infectious diseases are caused by microbes
   B. The development of the theories of gravity and motion
   C. The isolation of two new elements, radium and polonium
   D. The development of the theory of relativity
4. MC Albert Einstein worked in many fields of science during his career. Which of the following did he achieve?
   A. The discovery that infectious diseases are caused by microbes
   B. The development of the theories of gravity and motion
   C. The isolation of two new elements, radium and polonium
   D. The development of the theory of relativity

Apply and analyse

5. Make a quick list of your 'Top 3' scientists of all time. For each one, answer the following questions.
   a. What impact does their work have on your life?
   b. Did they just happen to be in the 'right place at the right time'?
   c. Did they work under adverse conditions?
   d. Did their work save lives?
   e. Did their work have any destructive influence?
   f. What other special qualities make them great?
6. Is it fair to select the single 'greatest' scientist of all time? Explain your answer.

Evaluate and create

7. Imagine that you are one of the three scientists you chose as the greatest scientists of all time. Write a short speech (3–5 minutes) about your life and work, and deliver it to your class. Illustrate your speech with models, diagrams or photographs.
8. Write a biography similar to the four presented in this section about one of the following scientists:
   - Michael Faraday (1791–1867)
   - Charles Darwin (1809–1882)
   - Lise Meitner (1878–1968)
   - Barbara McClintock (1902–1992)
   - Peter Doherty (1940–)
   - Stephen Hawking (1942– 2018).

Peter Doherty (1940–): Veterinarian and immunologist

Fully worked solutions and sample responses are available in your digital formats.

1.16 Project — An inspiration for the future

Scenario

The Florey Medal was established in 1998 by the Australian Institute of Policy and Science in honour of the Australian Nobel Prize–winning scientist Sir Howard Florey, who developed penicillin. It is awarded biennially to an Australian biomedical researcher for significant achievements in biomedical science and human health advancement.

In a similar spirit, the Australian Academy of Science (AAS) hopes to establish an award for outstanding science students. The AAS wishes to name the medal after an Australian scientist who provides the greatest inspiration for young people considering a future career in science. After months of consultation, they have narrowed the choices down to the following:

- David Unaipon 1872–1967: Inventor
- Fred Hollows (1929–1993): Ophthalmologist
- Andrew Thomas (1951–): Astronaut
- Fiona Wood (1958–): Plastic surgeon and burns specialist
- Ian Frazer (1953–): Immunologist
- Graeme Clark (1935–): Otolaryngeal surgeon and engineer

FIGURE 1.31 Andrew Thomas (1951–): Astronaut and engineer

FIGURE 1.32 Fiona Wood (1958–): Plastic surgeon and burns specialist

FIGURE 1.33 Graeme Clark (1935–): Otolaryngeal surgeon and engineer

Your task

You will create an 8–10 minute podcast in the format of an interviewer discussing with a number of different people which of these scientists would be the best choice to name the AAS medal after. The interviewees (played by group members) should be people who would be likely to have an interest or stake in the award. Examples could include a member of the AAS medal panel, the Minister for Industry, the head of a university science department or science education department, a high school science teacher, or even a high school science student. Each interviewee should have their own preference as to which scientist should be selected and at least four scientists should be discussed during the interview.

on Resources

ProjectsPLUS An inspiration for the future (pro-0071)

1.17 Review

Access your topic review eWorkbooks

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-4973	ewbk-4975	ewbk-4977

on Resources

1.17.1 Summary

Investigating skills and safety

- There are many materials and procedures in a science laboratory that can be dangerous. To ensure safety, always follow the teacher's instructions and wear appropriate safety clothing.
- Use filter funnels when pouring substances into test tubes from containers without lips.
- Look up the warnings that are associated with the chemicals you are using and adhere to the relevant safety instructions.

Planning your own investigation

- When planning your own investigation consider your interests and think of a question that you might like to investigate.
- All investigations should start with an aim that outlines the purpose of the investigation. Aims should start with 'to find out', 'to compare', 'to investigate' or some other statement of what you intend to investigate.
- A hypothesis is a sensible guess about the outcome of an experiment. When forming your own hypotheses do some research and use logic to make an educated guess.
- Hypotheses must be a statement that can be disproven. If your hypothesis cannot be disproven there is no point in completing the investigation!
- Ethical considerations must be taken into account when deciding on an investigation. An investigation should not harm or be upsetting to people or animals.

Record keeping and research

- A logbook can be used to keep track of your investigations.
- Each entry in your logbook should be dated like a diary.
- When researching information about the topic you are investigating, use multiple sources such as books, websites, journals and scientific magazines.
- Check that the information you find is reliable. You can do this by researching the author's qualifications or legitimacy of the book/website.

Controlling variables

- In an investigation there will be multiple variables.
- The variable that you measure is called the dependent variable.
- The variable that you purposefully alter to record the effect it has on the dependent variable is called the independent variable.
- All other variables should be kept constant. These variables are called controlled variables.
- It is very important that all variables that you are not purposefully altering are kept constant so that you can be sure that the change in the dependent variable is caused by the change in the independent variable.

Scientific reports

- Scientific reports must contain certain sections so that they can be read and understood by people worldwide.
- Abstracts are brief descriptions of the investigation, including the main conclusions.

- Introductions present all relevant background information that needs to be understood before reading the rest of the report.
- Materials are a list of the materials used in the investigation.
- The method is a detailed description of the steps taken throughout the investigation. It should be clear enough that another person could replicate the investigation by following the steps.
- Results state the observations and data obtained throughout the investigation.
- The discussion is where the results are discussed and put into context. The meaning behind the results should be explained in this section.
- The conclusion is a brief statement of what was learned in the investigation.
- The bibliography is a list of the resources used in the investigation.

Presenting your data

- The data obtained in an investigation can be difficult to read and understand when it is written as numbers on a page.
- To more easily understand the data collected it should be presented visually in graphs and tables.
- Pie charts are a useful way of representing percentages of a whole. The segments of a pie chart represent the percentage of the whole that it accounts for.
- Column and bar graphs are used to compare categories.
- Histograms are used to compare continuous data.
- Interpolation is the prediction of a value from a line of best fit using a value that is within the range tested.
- Extrapolation is the prediction of a value from a line of best fit using a value that is outside the range tested. Extrapolation is not a very reliable method of predicting data.

Using data loggers

- Data loggers are instruments that record data digitally. This reduces the human error in their measurements making them a reliable source of data.
- Some data loggers are also able to plot the data they record to provide accurate graphs automatically.

Famous scientists

- Sir Isaac Newton (1642–1727) was an incredibly influential scientist and mathematician who developed the theory of gravitation that is still used to this day.
- Albert Einstein (1879–1955) is known for developing the theory of relativity, which describes the relationship between energy and matter through the equation $E = mc^2$.
- Louis Pasteur (1822–1895) identified that infection diseases are caused by microbes, developing a 'germ theory', which he then used to develop vaccines for many deadly diseases. His work saved the lives of millions of people and animals.
- Marie Curie (1867–1934) was the first scientist to win two Nobel Prizes. The first was for her groundbreaking work on radioactivity and the second for the discovery of two new elements, radium and polonium.

1.17.2 Key terms

accuracy how close an experimental measurement is to a known value
beaker container for mixing or heating substances
calibrate to check or adjust a measuring instrument to ensure accurate measurements
corrosive describes a chemical that wears away the surface of substances, especially metals
data information collected which can be used for studying or analysing
dependent variable a variable that is expected to change when the independent variable is changed. The dependent variable is observed or measured during the experiment.
fair test a method for determining an answer to a problem without favouring any particular outcome — another name for a controlled experiment
filter funnel used with filter paper to separate solids from liquids
flammable describes substances such as methylated spirits that burn easily

hypothesis a suggested, testable explanation for observations or experimental results; it acts as a prediction for the investigation
independent variable the variable that the scientist chooses to change to observe its effect on another variable
line of best fit a smooth curve or line that passes as close as possible to all plotted points on a graph
measuring cylinder used to measure volumes of liquids accurately
oscillation one complete swing of a pendulum
pendulum an object swinging on the end of a string, chain or rod
period the time taken for one oscillation of a pendulum
precision how close multiple measurements of the same investigation are to each other
qualitative data categorical data that examines the quality of something (e.g. colour or gender) rather than a measurement or quantity
quantitative data numerical data that examines the quantity of something (e.g. length or time)
safety glasses plastic glasses used to protect the eyes during experiments
sensor device connected to an instrument such as a data logger that measures and sends information
toxic describes chemicals that are dangerous to touch, inhale or swallow
test tube thin glass container for holding, heating or mixing small amounts of substances
variables quantities or conditions in an experiment that can change

on Resources

Digital document	Key terms glossary (doc-34946)
eWorkbooks	Study checklist (ewbk-4966) Literacy builder (ewbk-4967) Crossword (ewbk-4969) Word search (ewbk-4971)
Practical investigation eLogbook	Topic 1 Practical investigation eLogbook (elog-0592)

1.17 Exercise

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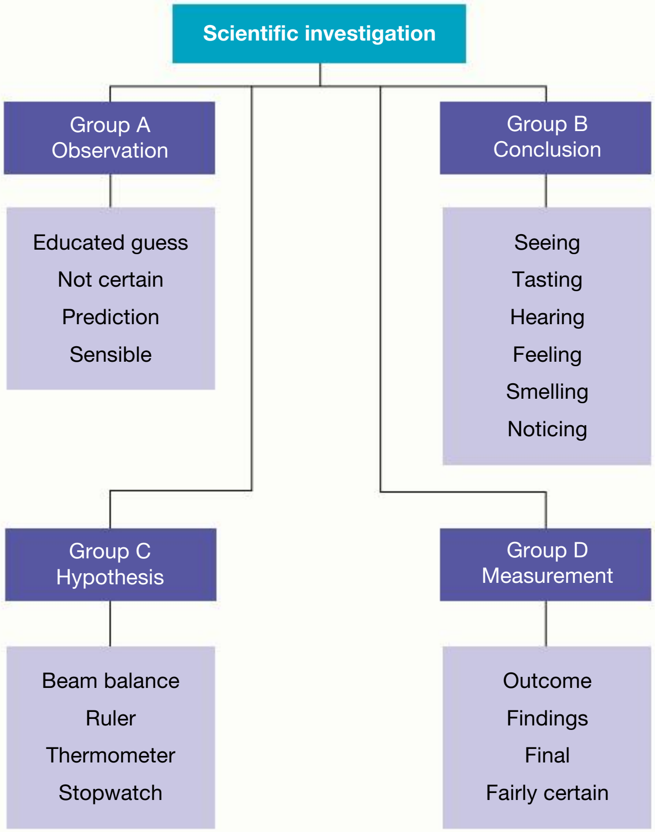
Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3	Questions 4, 7	Questions 5, 6

Remember and understand

1. The affinity diagram shown organises some of the ideas used by scientists into four groups. Each category name is a single word and represents an important part of scientific investigations. However, the category names have been jumbled up. What are the correct categories for groups A, B, C and D?



Apply and analyse

2. Bahir was sick of being bitten by mosquitoes. He counted several bites each evening when he sat outside to have dinner. He had heard that burning a citronella candle was a good way to keep mosquitoes away. Design an experiment to test Bahir's idea. List the independent and dependent variables, and the controlled variables needed to make this a fair test. Suggest a control for your experiment.

Evaluate and create

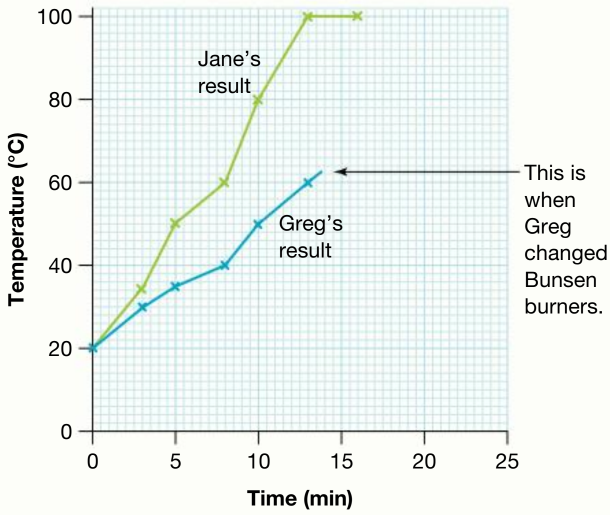
3. Four students each measured the temperature in the same classroom using a thermometer. Their results are shown in the table given.

TABLE Temperature as measured by each of four students in the same classroom

Student	Temperature (°C)
1	23.5
2	24.0
3	25.0
4	22.0

   a. Construct a bar graph of these results.
   b. Propose some possible reasons for the differences between measurements.
4. Jane and Greg decided to test how quickly water would boil when using either the yellow flame or the blue flame of the Bunsen burner. They set up identical experiments, except that Jane used a blue flame and Greg used a yellow flame. Their results are graphed below.
   a. Suggest a title for the graph.
   b. How long did it take for Jane's water to boil?

c. What was the temperature of Greg's water when Jane's water boiled?
d. In your own words, explain how you worked out the answers to parts (b) and (c).
e. Jane removed her beaker and Greg quickly placed his beaker over Jane's Bunsen burner. Assuming that the temperature of Greg's beaker did not drop while swapping Bunsen burners, predict the time at which his water would boil. Using your own words, explain how you predicted this.
f. Is this a valid method of investigation?



5. Singalia and Sallyana are two red panda cubs that were born at Sydney's Taronga Zoo. The table shows their masses during their first 22 weeks. The photograph shows one of the cubs being weighed.

TABLE Change in red panda cubs' masses (grams) over 22 weeks

Week	Singalia	Sallyana
1	213	219
2	285	290
3	330	349
4	365	377
5	403	408
6	465	452
7	536	514
8	564	576
9	594	610
10	650	637
11	703	680
12	714	740
13	814	796
14	872	812
15	956	806
16	1111	786
17	1043	890
18	1130	1000
19	1163	1083
20	1182	1162
21	1225	1218
22	1335	1270

a. Graph both sets of data onto a grid. Use different symbols for the points for each panda and label each line with the panda's name. You may have to extend the vertical axis to fit in the scale for the pandas' masses (or convert the masses to kilograms and plot in kilograms).
b. Describe the growth of each of the panda cubs. How do they compare with each other?
c. How long did it take the cubs to double their mass measured in week 1?
d. Did the pandas grow at the same rate during the 22 weeks?
e. Which were the fastest and slowest growth periods for each panda?
f. What age was each of the cubs when it reached 1 kg?
g. At what age would you predict each cub to reach 1.5 kg? Explain how you made your prediction. What assumption did you make to answer the question?

6. This table shows the winning times for the men's 400 m freestyle swimming event. The data are from various Olympic Games from 1896 to 2016.

TABLE Olympic Games winning times for the men's 400 m freestyle swimming

Year	Name, country	Time (min:s)
1896	Paul Neumann, Austria	8:12.60
1908	Henry Taylor, Great Britain	5:36.80
1920	Norman Ross, USA	5:26.80
1932	Buster Crabbe, USA	4:48.40
1948	Bill Smith, USA	4:41.00
1960	Murray Rose, Australia	4:18.30
1972	Bradford Cooper, Australia	4:00.27
1984	George DiCarlo, USA	3:51.23
1996	Danyon Loader, New Zealand	3:47.97
2000	Ian Thorpe, Australia	3:40.59
2004	Ian Thorpe, Australia	3:43.10
2008	Tae-Hwan Park, Korea	3:41.86
2012	Sun Yang, China	3:40.14
2016	Mack Horton, Australia	3:41:55

a. Are data available for each Olympics every 4 years?
b. Construct a line graph of the times for the men's 400 m freestyle over these years. Take into account your answer to part (a).
c. Use your graph to estimate the winning time for this event in the 1956 Melbourne Olympic Games. Is this an example of interpolation or extrapolation?
d. Discuss how the winning times have changed over the 120-year period.
e. Suggest some reasons for the change in winning times.
f. Discuss how you believe the winning times for the men's 400 m freestyle might change over the next 40 years.

7. Create a storyboard that tells the story of the main events in the life of one of these famous scientists.
a. Albert Einstein   b. Sir Isaac Newton   c. Marie Curie   d. Louis Pasteur

Fully worked solutions and sample responses are available in your digital formats.

on Resources

eWorkbook Reflection (ewbk-3038)

teachon

Test maker
Create customised assessments from our extensive range of questions, including teacher-quarantined questions. Access the assignments section in learnON to begin creating and assigning assessments to students.

RESOURCE SUMMARY

on Resources

Below is a full list of **rich resources** available online for this this topic. These resources are designed to bring ideas to life, to promote deep and lasting learning and to support the different learning needs of each individual.

1.1 Overview

eWorkbooks
- Topic 1 eWorkbook (ewbk-4961)
- Student learning matrix (ewbk-4963)
- Starter activity (ewbk-4964)

Practical investigation eLogbooks
- Topic 1 Practical investigation eLogbook (elog-0592)
- Investigation 1.1: Milk now or later? (elog-0588)

Weblink
- CSIRO

1.2 Investigating skills

eWorkbooks
- Safety in the laboratory (ewbk-4947)
- Safety rules (ewbk-4948)

Video eLesson
- How to light a Bunsen burner (eles-2360)

Interactivity
- Using equipment (int-0200)

Weblink
- Robert Bunsen

1.3 SkillBuilder — Using a Bunsen burner

eWorkbook
- Skillbuilder — Using a Bunsen burner (ewbk-4622)

Video eLesson
- Using a Bunsen burner (eles-4154)

Interactivity
- Using a Bunsen burner (int-8088)

1.4 Planning your own investigation

eWorkbook
- Observations and inferences (ewbk-4949)

1.5 SkillBuilder — Writing an aim and forming a hypothesis

eWorkbook
- SkillBuilder — Writing an aim and forming a hypothesis (ewbk-4626)

Video eLesson
- Writing an aim and forming a hypothesis (eles-4155)

Interactivity
- Writing an aim and forming a hypothesis (int-8089)

1.7 Controlling variables

eWorkbook
- Fair testing (ewbk-4950)

Practical investigation eLogbook
- Investigation 1.2: The period of a pendulum (elog-0590)

1.8 SkillBuilder — Controlled, dependent and independent variables

eWorkbook
- Skillbuilder — Controlled, dependent and independent variables (ewbk-4630)

Video eLesson
- Controlled, dependent and independent variables (eles-4156)

Interactivity
- Controlled, dependent and independent variables (int-8090)

1.9 Scientific reports

eWorkbook
- Scientific reports (ewbk-4951)

1.10 Presenting your data

eWorkbooks
- Scientific drawing skills (ewbk-4952)
- Data analysis (ewbk-4953)

1.11 SkillBuilder — Constructing a pie chart

eWorkbook
- Skillbuilder — Constructing a pie chart (ewbk-4634)

Video eLesson
- Skillbuilder: Constructing a pie graph (eles-1632)

Interactivity
- Skillbuilder: Constructing a pie graph (int-3128)

1.12 SkillBuilder — Creating a simple column or bar graph

eWorkbook
- Skillbuilder — Creating a simple column or bar graph (ewbk-4636)

Video eLesson
- Skillbuilder: Creating a simple column or bar graph (eles-1639)

Interactivity
- Skillbuilder: Creating a simple column graph (int-3135)

1.13 SkillBuilder — Drawing a line graph

eWorkbook
- Skillbuilder — Drawing a line graph (ewbk-4638)

Video eLesson
- Skillbuilder: Drawing a line graph (eles-1635)

Interactivity
- Skillbuilder: Drawing a line graph (int-3131)

1.15 Famous scientists

Video eLessons
- Career spotlight: scientist (eles-0766)
- Isaac Newton (eles-1771)

Interactivity
- Pasteur's experiment (int-3420)

1.16 Project — An inspiration for the future

ProjectsPLUS
- An inspiration for the future (pro-0071)

1.17 Review

eWorkbooks
- Topic review Level 1 (ewbk-4973)
- Topic review Level 2 (ewbk-4975)
- Topic review Level 3 (ewbk-4977)
- Study checklist (ewbk-4966)
- Literacy builder (ewbk-4967)
- Crossword (ewbk-4969)
- Word search (ewbk-4971)
- Reflection (ewbk-3038)

Practical investigation eLogbook
- Topic 1 Practical investigation eLogbook (elog-0592)

Digital document
- Key terms glossary (doc-34946)

To access these online resources, log on to **www.jacplus.com.au**.

SkillBuilder — Using a Bunsen burner

1.3.1 Tell me

Why use a Bunsen burner?

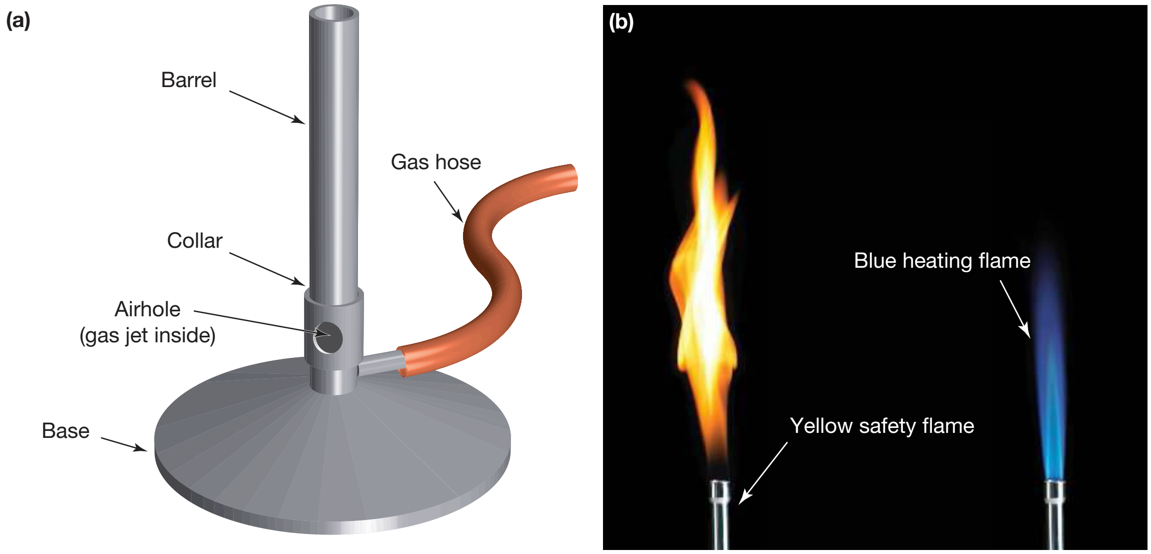
Many experiments in the laboratory require heating using a Bunsen burner. A Bunsen burner provides heat when a mixture of air and gas is lit. Although the same amount of gas comes out of the gas jet located inside the barrel, attached to the base of the burner, the amount of air and hence oxygen is able to be varied by changing the size of the airhole by rotating the collar. Bunsen burners heat objects or liquids with a naked flame, and therefore there are precautions that must be taken to ensure the safe usage of a Bunsen burner.

The Bunsen burner must be ignited using the yellow or safety flame, with the airhole closed, so that the flame can be seen. The blue flame of the Bunsen burner, seen when the airhole is open, is used for heating but it is difficult to see. Because the flame appears at the top of the Bunsen burner, the barrel can become hot and may cause burns to skin if touched. Do not handle the barrel; allow it to cool at the end of an experiment. Use the base of the Bunsen burner if the burner needs to be moved or handled; it is designed not be become hot.

What is the application of Bunsen burners in science?

Bunsen burners provide heat, the amount of which can be changed by adjusting the airhole on the collar. It is the ease of adjusting the path and intensity of the flame that makes the Bunsen burner so versatile and useful in the science laboratory. This allows liquids in test tubes to be heated evenly and without boiling over.

FIGURE 1 a. The components of a Bunsen burner **b.** The yellow visible flame is known as the safety flame and is less hot than the blue flame.



1.3.2 Show me

How do we use a Bunsen burner?

Materials

- Bunsen burner
- matches or Bunsen burner lighter
- heatproof mat
- safety glasses
- lab coat

CAUTION

Ensure long hair is tied back and wear a lab coat and safety glasses.

Method

Step 1

Place the Bunsen burner on a heatproof mat.

Check that the gas tap is in the 'off' position.

Step 2

Connect the rubber hose to the gas tap.

Step 3

Close the airhole of the Bunsen burner collar.

Step 4

Light a match and hold it a few centimetres above the barrel.

Step 5

Turn on the gas tap and a yellow flame will appear.

Step 6

Adjust the flame by moving the collar until the airhole is open and a blue flame appears.

on Resources

eWorkbook SkillBuilder — Using a Bunsen burner (ewbk-4622)

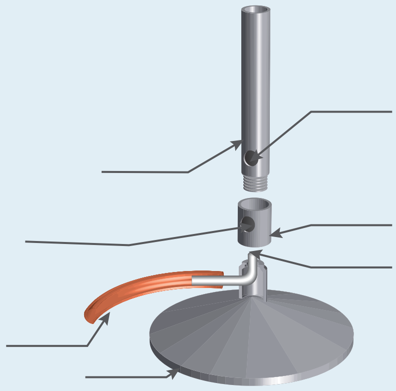
Interactivity Using a Bunsen burner (int-8088)

1.3.3 Let me do it

Complete the following activities to practise this skill.

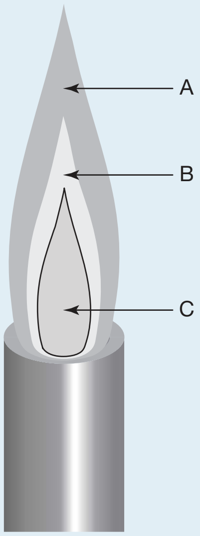
1.3 ACTIVITIES

1. The diagram of the Bunsen burner provided has the parts separated so you can see them clearly.



a. Name each of the parts of the Bunsen burner.
b. Describe the function of the third and fourth labels from the top and the effect on the flame.

2. a. Give two reasons why the blue flame can be hazardous.
b. Why is the yellow flame also referred to as the 'safety flame'?
c. Which is the hottest part of the flame in the diagram that follows, at label A, B, or C?



3. Identify if each of the following statements is true or false.
a. Always wear safety glasses and a lab coat when using a Bunsen burner.
b. If you have long hair, always tie it back when using a Bunsen burner.
c. Always light the Bunsen burner with the airhole fully opened.
d. Always light a match and hold it above the Bunsen burner barrel before turning on the gas tap.
e. Always leave the Bunsen burner on the blue flame when you are not heating anything.
f. Always leave the Bunsen burner on the blue heating flame when you are heating something.
g. Always extinguish a Bunsen burner flame by turning off the gas tap.
h. If the Bunsen burner goes out accidentally, turn the gas tap off immediately.

Checklist

I have:

- identified the main parts of the Bunsen burner
- tied long hair back, worn a lab coat and safety glasses
- identified that the yellow flame is used for lighting the Bunsen burner and the blue flame is used for heating
- allowed the Bunsen burner to cool before touching it after an experiment.

SkillBuilder — Writing an aim and forming a hypothesis

1.5.1 Tell me

Why do we need to write aims and form hypotheses?

In science, we conduct investigations to gather data and results and draw conclusions. Every investigation requires an aim — a short statement of what we are trying to achieve. Alongside an aim, the ability to formulate predictions is important in science. This is done through the use of a hypothesis. Being able to write aims and hypotheses are vital skills for any scientist.

What is the application of aims and hypotheses in science?

A hypothesis is an idea that is based on observation, which can be tested in an investigation by experiment or data. Investigations can involve testing, field work, using models or simulations, finding and using information for various sources and conducting surveys.

The aim is a question or a statement about the direction of the scientific investigation. It provides a purpose of the investigation.

A hypothesis is an educated prediction of the outcome of an investigation, which can be supported or unsupported through the results of an investigation.

1.5.2 Show me

How do we write aims and form hypotheses?

Materials

- an idea for an investigation that interests you such as finding out if the bushfood, warrigal greens (scientific name: *Tetragonia tetragonioides*) grows best from seeds or from cuttings. Warrigal greens are an indigenous crop to Australia and New Zealand; the leaves are a tasty alternative to spinach.

Method

Step 1

To write an aim, you need to first identify your independent and dependent variables. The independent variable is what you are changing: Using seeds or cuttings from warrigal greens.

The dependent variable is what you are examining: The growth of warrigal greens.

Step 2

It often helps to write your idea as a scientific question; for example, how are warrigal greens best grown?

Step 3

Use this to develop your aim. An aim usually is in one of two formats:

a. to _____________ **the independent variable** on **the dependent variable**
b. to _____________ if **the dependent variable** is affected by the **independent variable**.

For this investigation, some example aims may be:

- to compare the difference between the use of seeds and cuttings on the growth of warrigal greens
- to observe if the growth of warrigal greens is affected by the use of seeds or cuttings during planting
- to determine whether warrigal green seeds or warrigal green cuttings result in the greatest amount of plant growth.

Step 4

Refine your aim into a hypothesis, in this case written as an íf' and 'then' statement. This should again link your variables. For example, if the same number of warrigal seeds and cuttings are planted and the two crops compared after one month, then the cuttings will produce a greater weight of picked leaves.

Step 5

Check that your hypothesis is able to be tested or backed up by data. In this case the two crops of leaves can be weighed and compared.

on Resources

eWorkbook SkillBuilder — Writing an aim and forming a hypothesis (ewbk-4626)

Interactivity Writing an aim and forming a hypothesis (int-8089)

1.5.3 Let me do it

Complete the following activities to practise this skill.

1.5 ACTIVITIES

1. Decide if the statements below are true or false.
   a. The aim of an investigation starts with an idea or problem.
   b. The aim is written as an if–then statement.
   c. The hypothesis is written as a question.
   d. The hypothesis must be able to be tested by experiment results or data.
2. A student was interested in investigating how to grow the bushfood warrigal greens, using seeds, to produce a plentiful crop in the shortest amount of time. The student observed that some plant seeds germinate only when soaked in water or exposed to smoke.
   a. Write an aim for the student's investigation.
   b. From your aim, write a hypothesis for an investigation.
   c. Describe how your hypothesis could be tested.

3. a. Decide if each of the options below is written as an aim, a hypothesis or neither and then circle your choice.
      i. To determine how much rubbish is collected from my school in one day.
      ii. If the different colours of new cars purchased this year were calculated, then the most popular colour would be black.
      iii. Chocolate is the most popular snack food at my school.
      iv. If the temperature drops below five degrees Celsius for three days in a row then it will rain on the fourth day.
      v. To investigate how tall a wall mirror should be in order for me to see my full height (185 cm) from one metre away.
   b. For any of the options in part a, that is neither an aim nor a hypothesis, rewrite it as a possible hypothesis.

Checklist

I have:

- chosen an idea or problem that is not too general
- rewritten the idea as a question to form the aim
- developed my aim into a hypothesis in the form of an if–then statement
- checked to see if my hypothesis is able to be tested or backed up by data.

SkillBuilder — Controlled, dependent and independent variables

1.8.1 Tell me

What is the difference between controlled, dependent and independent variables?

In order to answer a question scientifically, a controlled investigation needs to be performed. In a controlled investigation every variable except the one being tested is held constant, which stops the results being affected by an uncontrolled factor. The variable that you are investigating is called the independent variable. The variable that you are measuring is called the dependent variable.

What is the application of variables in science?

In many branches of science research, questions are being asked such as what is the best way of doing this, how can this be done faster or more efficiently, how can we cure this disease? In order to answer complicated questions, investigations must be carried out that are well thought out and planned so that the results can be trusted and repeated.

When creating scientific questions, developing aims and formulating hypotheses, it is vital to know which variables are which. Understanding variables ensures that a fair test is created and your questions, aims and hypotheses are specific and targeted.

1.8.2 Show me

How do you identify and use controlled, dependent and independent variables?

Materials

- 2 thermometers or temperature probes
- 2 identical glasses or beakers
- ice-cube trays that make cube-shaped iceblocks
- ice-cube trays that make spherical-shaped iceblocks
- 1 L of water
- measuring cylinder

Method

Step 1

Determine which variable you are changing and testing in your investigation; this is the independent variable. In this investigation, the aim is to investigate which iceblock's shape is most successful at reducing the temperature of the water.

Therefore, the independent variable is the shape of the iceblocks.

Step 2

Determine which variable you are measuring in your investigation. In this case it is the temperature of the water.

Step 3

Ensure a fair test is created by making sure all other variables are controlled. Consider all the factors that need to be controlled: the amount of water, the volume of the iceblock, the initial temperature of the water, the number of iceblocks and the time.

Step 4

Conduct the investigation.

Determine the volume of water needed to fill the spherical ice-cube tray by filling it using the measuring cylinder and recording the volume.

Using the measuring cylinder, fill the cube-shaped ice-cube tray with the same volume of water as used to fill the spherical ice-cube tray. Freeze both trays overnight for the same amount of time.

Step 5

Fill each glass to half its volume with water using the measuring cylinder to ensure each glass has the same volume in it. Add the thermometer or temperature probe to each glass. At the same time, add two spherical iceblocks to one glass but ensure it does not overflow and add the same number of cube iceblocks to the other glass ensuring that the water does not overflow.

Step 6

Measure and record the temperature in each glass until it stops falling and starts to rise. Repeat the experiment using the remaining iceblocks.

on Resources

eWorkbook SkillBuilder — Controlled, dependent and independent variables (ewbk-4630)

Interactivity Controlled, dependent and independent variables (int-8090)

1.8.3 Let me do it

Complete the following activities to practise this skill.

1.8 ACTIVITIES

1. For the previous investigation:
   a. identify the independent variable
   b. identify the dependent variable
   c. identify three controlled variables.
2. The investigation can be used to determine which iceblock cools a drink to the lowest temperature.
   a. Describe how this could be done.
   b. What is the dependent variable in this case?
3. To investigate various ways of keeping cut flowers alive, several different substances were added to the water in three identical vases. The substances were 5 g of sugar, 5 g of salt and 5 g of vinegar. A fourth vase was set up using only water with nothing added. A bunch of flowers was divided up so that there were the same number of individual flowers in each of the four vases.
   a. Identify the independent variable.
   b. Identify the dependent variable.
   c. Which two variables are controlled?
   d. Why was one vase set up with only water in it?

Checklist

I have:

- identified the dependant variable
- identified the independent variable
- identified the controlled variables.

SkillBuilder — Constructing a pie chart

1.11.1 Tell me

What is a pie graph?

A pie chart, or pie graph, is a graph in which slices or segments represent the size of different parts that make up the whole. The size of the segments is easily seen and can be compared. Pie graphs give us an overall impression of data.

How are pie graphs useful?

Pie graphs give us an overall impression of data. They are useful for comparing proportions of categories. However, if there are more than eight segments, the graph becomes difficult to read and it is better to use a bar graph. Unlike line graphs, pie graphs are not useful for showing a trend over time.

A good pie graph:

- has a clear and accurate title that explains the purpose of the graph
- has segments that are either labelled directly or indicated by means of a colour key
- includes percentages or raw figures
- has segments drawn clockwise from largest to smallest, starting at 12 o'clock with the largest and finishing at 12 o'clock with the smallest, unless there is 'other', which is always last
- includes the source of the data.

What is the application of pie graphs in science?

Pie graphs are used in scientific applications when a quick and easily understood representation of data is required. Pie graphs are usually easily understood even if an understanding of the science behind the data is not understood, and so are effective in communicating results of discreet data that are part of a whole.

1.11.2 Show me

How to complete a pie graph

Materials

- paper
- a pencil
- a protractor
- a ruler
- coloured pencils
- a data set — in this case, energy generated from renewables in New Zealand (table 1)

Model

TABLE 1 Percentage of electricity generated from renewables in New Zealand by energy source (2010)

Renewable energy	Percentage (%)
Hydro	28
Bioenergy and solar	20
Wind	2
Geothermal	50

Note: In 2011, 77% of all electricity generated in New Zealand came from renewable resources.

Source: New Zealand Energy Data File 2012

Method

Step 1

Order the statistics from largest to smallest. If there is an 'other' category, put it last.

The largest amount of renewable energy is generated by geothermal so it is at the top of the table, as per the example that follows.

Renewable energy	Percentage (%)
Geothermal	50
Hydro	28
Bioenergy and solar	20
Wind	2

Step 2

If there are raw figures, convert them to percentages. You divide each category by the total figure and multiply by 100.

The categories are already percentages and add to 100%.

Step 3

Convert the percentage to degrees of a circle by multiplying by 3.6. (100 per cent of the circle = 360 degrees, so 1 per cent of the circle = 3.6 degrees.)

TABLE 2 Converting percentages to degrees in circle

Renewable energy	Percentage (%)	Degrees in circle (percentage × 3.6)
Geothermal	50	180
Hydro	28	100.8
Bioenergy and solar	20	72
Wind	2	7.2

Step 4

Using a protractor or digitally, construct a circle to fit your page. Draw a straight line from the centre of the circle to 12 o'clock.

Step 5

Use the protractor to mark the first and largest segment, working clockwise. To do this, place the 0 degrees line on the protractor along the line you have just drawn. Now mark in the second largest group. Use the protractor to mark each of the other segments in descending size, marking the 'other' category last.

Step 6

Label and colour each segment, making sure you include the percentage.

Step 7

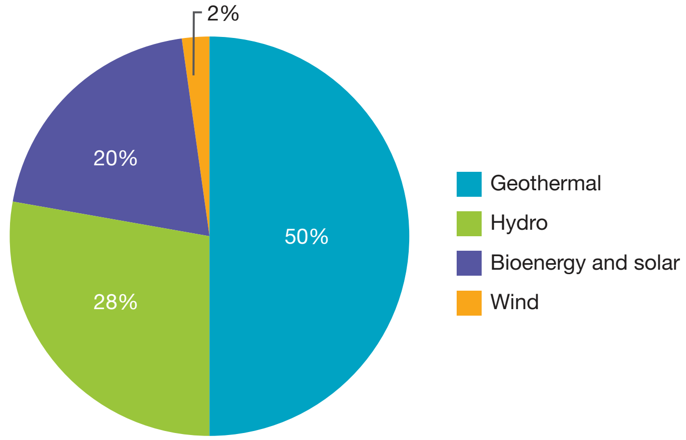
Provide a clear title and source.

on Resources

eWorkbook Skillbuilder — Constructing a pie chart (ewbk-4634)

Interactivity Skillbuilder: Constructing a pie chart (int-3128)

FIGURE 1 Percentage of electricity generated from renewables in New Zealand by energy source (2010)



Source: New Zealand Energy Data File 2012

1.11.3 Let me do it

Complete the following activities to practise this skill.

1.11 ACTIVITIES

1. Use the data in table 3 to create a pie graph. Use the checklist to ensure you cover all aspects of the task.

TABLE 3 Source of electricity worldwide, 2010

Source of electricity	Percentage (%)
Coal	42
Oil	5
Natural gas	21
Nuclear	13
Hydro	16
Other	3

Source: Based on data from OECD 2011, *Factbook 2011–2012: Economic, Environmental and Social Statistics*, OECD Publishing, http://dx.doi.org/10.1787/factbook-2011-49-en

2. Once you have created your pie graph, apply the skills you have developed in this SkillBuilder to answer the following questions.
   a. What is the most common source to produce electricity?
   b. Are renewables or non-renewables the main source of electricity?
   c. Name a renewable that is part of the 'other' category.
   d. In Iceland 70 per cent of all electricity is produced from hydropower and 30 per cent is produced from geothermal power. Is this similar to or different from the world trend?
   e. Research the sources of energy production for another country. Compare your results to Australia and Iceland.

Checklist

I have:

- provided a clear title and source
- plotted the data accurately and labelled each segment
- included the percentages
- shown largest to smallest clockwise from 12 o'clock with 'other' last.

SkillBuilder — Creating a simple column or bar graph

1.12.1 Tell me

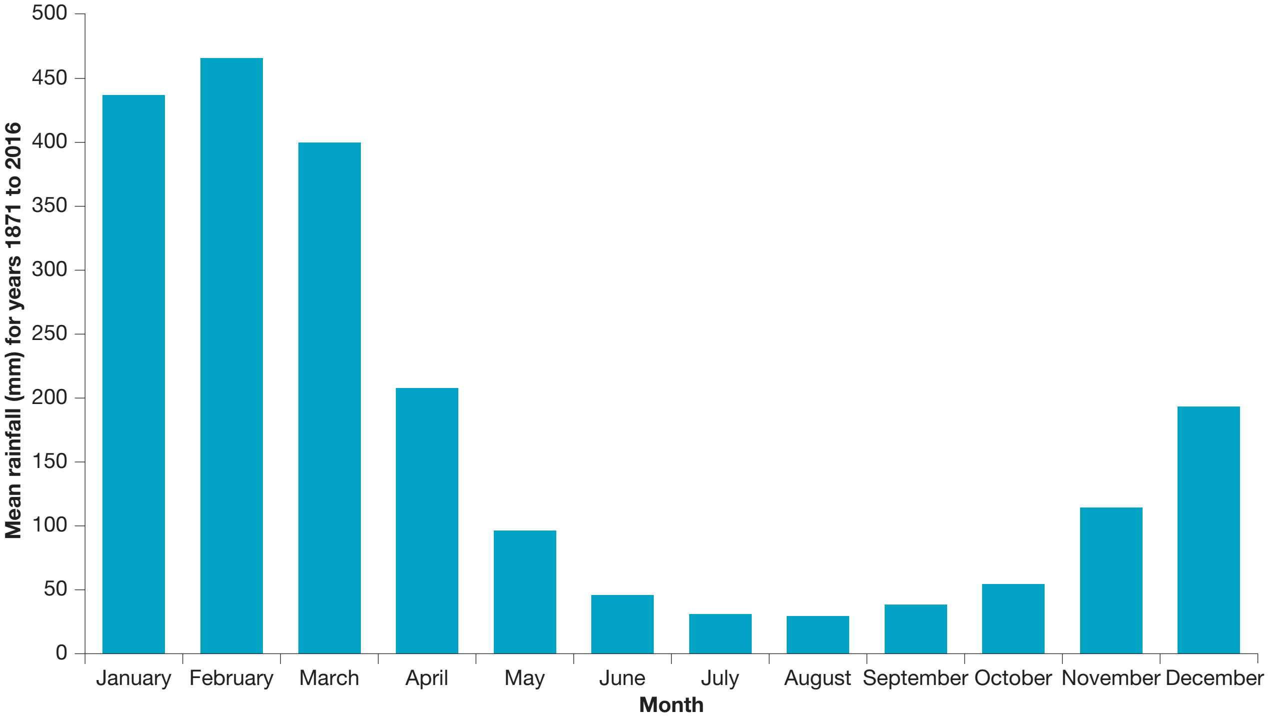
What are column or bar graphs?

Column graphs show information or data in columns. In a bar graph the bars are drawn horizontally and in column graphs they are drawn vertically. They can be hand drawn or constructed using computer spreadsheets.

How are column graphs useful?

Column graphs are useful for comparing quantities. They can help us understand and visualise data, see patterns and gain information. For example, we can use them to help understand rainfall patterns in different months (see figure 1).

FIGURE 1 Rainfall at Darwin Airport



Source: © Bureau of Meteorology

A good column graph has:

- ruled axes
- labelled axes
- a space between each column
- a title
- the source of information.

What is the application of column or bar graphs in science?

Column or bar graphs are useful to compare or investigate one or more numerical variables across different categories. There are different types of column or bar graphs including individual, clustered and stacked.

1.12.2 Show me

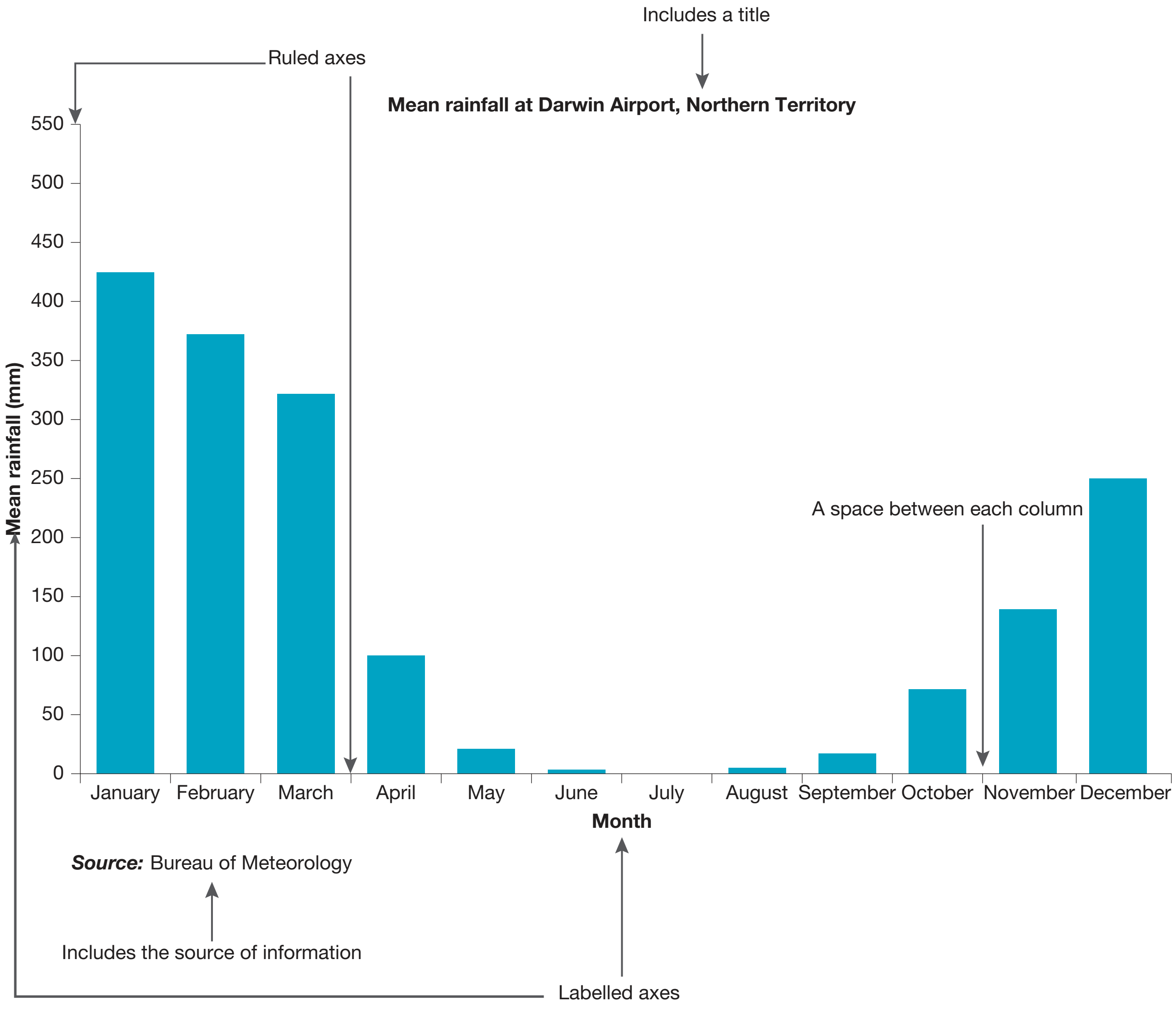
How to complete a column graph

Materials

- a table of data (table 1)
- graph paper
- a pencil
- a ruler.

Model

FIGURE 2 A labelled column graph



Method

Step 1

Examine the data. Decide on the scale to use for your vertical axis. For this example the vertical axis should start at zero and increase at intervals to suit the data. As the highest rainfall for any month for Cardwell is 465.9 mm, intervals of 50 would be suitable. For this exercise you could use 1 cm to represent 50 mm of rainfall. Draw your vertical axis according to the scale you have devised.

TABLE 1 Mean monthly rainfall for the years 1871 to 2016, Cardwell, Queensland

Statistics	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Mean rainfall (mm) for years 1871 to 2016	438.5	465.9	400	208.6	94.7	47	32.4	29.2	38.5	54.4	115.2	193.5

Source: © Bureau of Meteorology

Step 2

Decide on the width and spacing of the columns and draw your horizontal axis to fit. Ensure that each column is the same width.

Step 3

For each column, mark the meeting point of the two pieces of information with a dot, then use your ruler to neatly complete the column. Shade it in using colour.

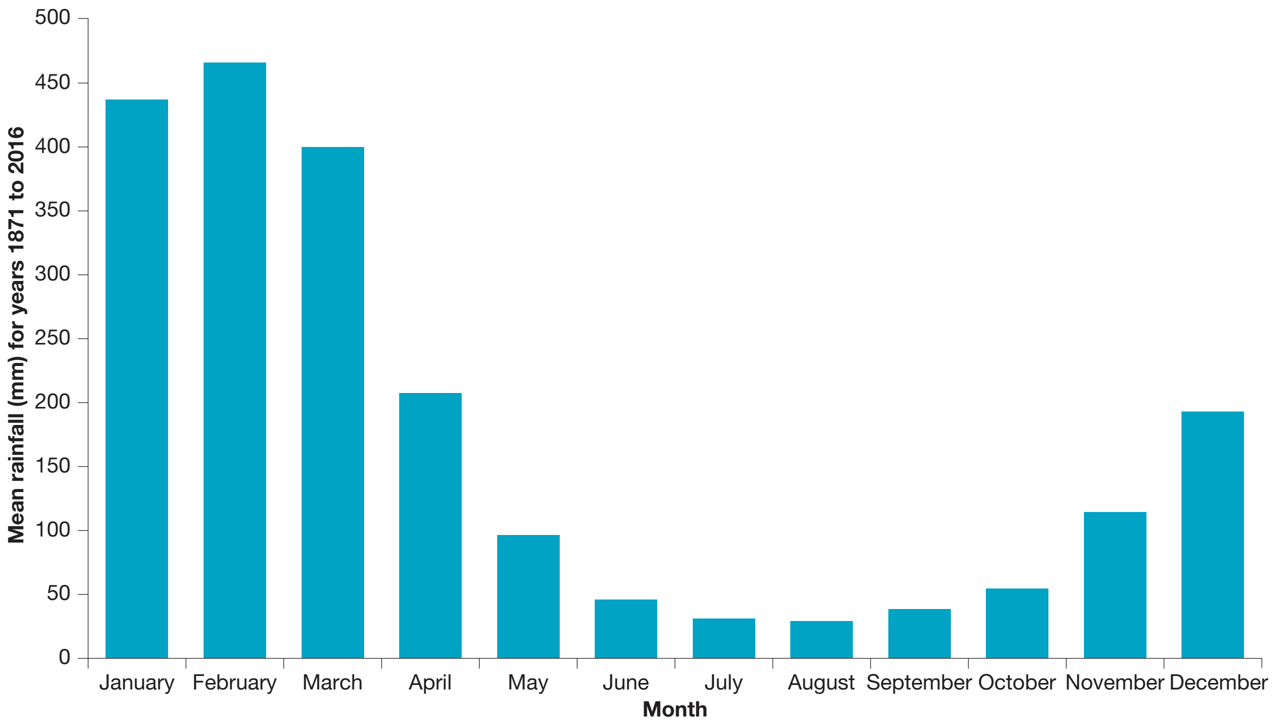
Step 4

Label the vertical and horizontal axes and give the graph a title. Include a key if necessary.

Step 5

Provide the source beneath your graph, to enable the reader to locate the source data if they wish.

FIGURE 3 Mean monthly rainfall for the years 1871 to 2016, Cardwell, Queensland



Source: © Bureau of Meteorology

on Resources

eWorkbook SkillBuilder — Creating a simple column or bar graph (ewbk-4636)

Interactivity Skillbuilder: Creating a simple column graph (int-3135)

1.12.3 Let me do it

Complete the following activities to practise this skill.

1.12 ACTIVITIES

1. Using the data in table 2, construct your own graph of average monthly rainfall for Innisfail, Queensland.

TABLE 2 Mean rainfall (mm) for the years 1881 to 2016, Innisfail, Queensland

Statistics	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Mean rainfall (mm) for years 1881 to 2016	507.3	590.1	662.2	456.3	302.2	189	137.6	116.9	86.1	87.7	157.9	262.6

2. Once you have constructed your graph, apply the skills you have learned in this SkillBuilder to answer the following questions.
   a. Which month has the most rainfall?
   b. Which month is the driest?
   c. Imagine you are a filmmaker, planning to film on location in Innisfail for three months. As rain would cause problems for your filming schedule, which months would be best for your requirements?

Checklist

I have:
- ruled axes
- labelled axes
- a space between each column
- included a title
- included the source of information.

SkillBuilder — Drawing a line graph

1.13 Tell me

What is a line graph?

A line graph displays information as a series of points on a graph that are joined to form a line. Line graphs are very useful to show change over time. They can show a single set of data, or they can show multiple sets, which enables us to compare similarities and differences between two sets of data at a glance.

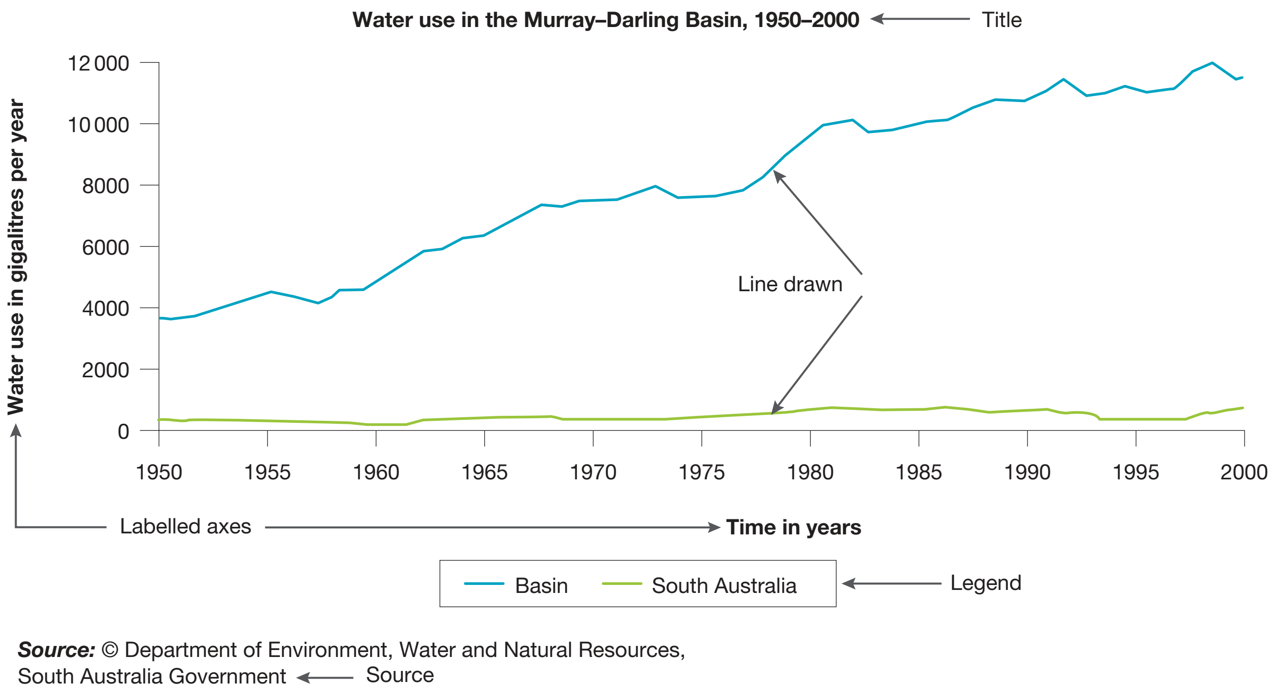
How are line graphs useful?

Line graphs are very useful to show change over time. They can show a single set of data, or they can show multiple sets based on a common theme such as water use in the Murray–Darling Basin compared to water use in South Australia (see figure 1). This enables us to compare similarities and differences between two sets of data at a glance.

A good line graph has:

- been drawn in pencil
- an appropriate scale to show the data clearly
- labelled axes
- small dots joined by a line to make a smooth curve
- a legend, if necessary
- a clear and accurate title that explains the purpose of the graph
- the source of the data.

FIGURE 1 Water use in the Murray–Darling Basin



What is the application of line graphs in science?

Line graphs are very useful in science to show change over time for continuous data such as the increase in temperature when heating water with a Bunsen burner. Line graphs can show a single or multiple sets of data, which allows comparison and trends in data to be observed.

1.13.2 Show me

How to complete a line graph

Materials

- data
- graph paper
- a pencil
- a ruler

Model

TABLE 1 Use of rainwater tanks by household, 2001–2010

Year	Use of rainwater tanks by household (%)
2001	16
2004	17
2007	19
2010	26

Source: © Australian Bureau of Statistics

Method

Step 1

Select the data you wish to compare or interpret (table 1).

Draw a horizontal and vertical axis using a ruler.

Evenly space and then label the years along the horizontal axis. Look carefully at your range of data and work out appropriate increments for the vertical axis, then evenly space and label this information on the axis. Start at zero where the axes join. For the table 1 data, an increment of 5 percentage points would be appropriate.

Step 2

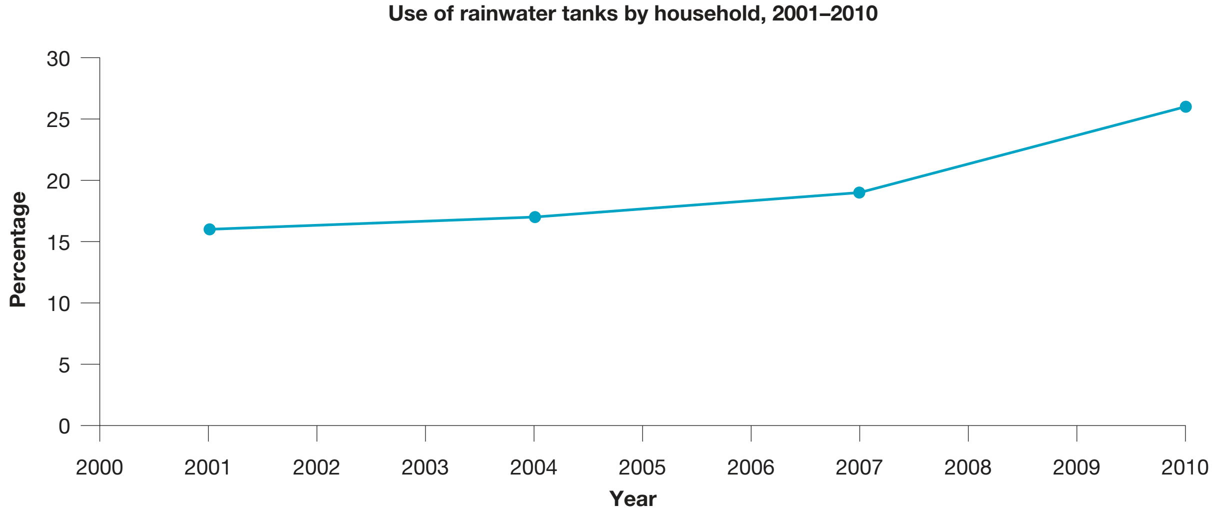
Label the X and Y axes. In this case, the X axis would be labelled 'Year', and the Y axis would be labelled 'Percentage'.

Plot the statistics. Draw a dot at the point where the year on the horizontal axis meets the relevant position on the vertical axis. Once you have plotted all the statistics, join the dots. This can be done freehand or using a ruler.

Step 3

Add a title and a source to the graph.

FIGURE 2 Use of rainwater tanks by household, 2001–2010



Source: © Australian Bureau of Statistics

on Resources

eWorkbook SkillBuilder — Drawing a line graph (ewbk-4638)

Interactivity Skillbuilder: Drawing a line graph (int-3131)

1.13.3 Let me do it

Complete the following activities to practise this skill.

1.13 ACTIVITIES

1. Use the data in table 2 to create a line graph. Use the checklist to ensure you cover all aspects of the task.

TABLE 2 Daily residential water consumption for South Australia

Year	Daily residential water consumption (litres)
2001	539
2002	502
2003	532
2004	460
2005	465
2006	440
2007	413
2008	410
2009	395

Source: SA Water, Annual Reports

2. Based on what you have learned in this SkillBuilder and referring to your graph, apply your skills to answer the following questions.
   a. In which year is water consumption lowest?
   b. Describe the pattern shown by the graph.
   c. What reasons might explain the changes from 2001 to 2009?
   d. When water restrictions were lifted in 2011, predict what happened to water consumption.

e. If the government made every household adopt water saving measures in 2022, what might happen to water consumption?
f. Find statistics for water consumption for your area and compare these to another area.
g. Explain how useful the graph was in helping you understand the changes that occurred to water consumption in South Australia compared to reading a table of figures.

Checklist

I have:

- labelled the axes
- provided a clear title and source
- plotted the data accurately
- joined the points with a smooth line.

2 Language of learning

LEARNING SEQUENCE

online only

2.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

2.1.1 Introduction

What do you know about 'big picture' learning? Your brain may have trouble taking on a whole concept or big idea at once … so instead you could choose to break a concept down into smaller pieces and 'nibble away' at a concept over time. To do this, it often helps to be able to map out your learning journey so that you know where you are going.

FIGURE 2.1 Information stored in the brain is like a map, connecting different ideas as roads connect towns and cities.

2.1.2 Think about learning

1. Which coloured hat should you 'wear' to think creatively?
2. What's the difference between a 'fat' and a 'skinny' question?
3. What can you do to make a good first impression?
4. How do we communicate our feelings without using words?
5. Who gave dinosaurs their names and why?
6. What do emotions have to do with memory?

2.1.3 Science inquiry

The three-floor thinking model

On what floor is your thinking?

First-floor thinkers gather information. It is on this floor that the groundwork is laid.

Second-floor thinkers process the information. On this floor, thinkers decide which information is relevant and which is not, and then try to make some sense of it. This may involve brainstorming and playing with the ideas, looking for patterns or analysing data.

Third-floor thinkers apply information. They understand what needs to be done and complete it. On this floor, tasks are prioritised and further ideas are synthesised or evaluated. This may also be the floor for assembling the parts and adding the creative finishing touches.

FIGURE 2.2 Are you on your first, second or third thinking floor?

Investigate, design and create

1. Select a project topic from one of the following and use the three-floor thinking model to gather, process and apply your information. Invent, design and construct a model of a device or method that would help to:
   a. identify a range of common rock types
   b. sort household wastes
   c. recycle household wastes
   d. test the effectiveness of detergents
   e. test the effectiveness of toothpaste.
   Include information on the chemical and physical properties of your selected topic.
2. Use the three-floor thinking model to gather, process and apply information about an example of how science informs laws and guidelines about health or our environment. Present your findings as an advertisement that incorporates multimedia or animation to effectively communicate the relevant scientific understanding behind the law or guideline. You may select one of the following examples or identify your own example. Some examples of laws and guidelines influenced by our scientific knowledge include:
   - quarantine laws
   - food handling laws
   - bushfire safety guidelines
   - laws about wearing seatbelts
   - chemical storage guidelines
   - fire restriction laws.

first-floor thinkers thinkers who gather information

second-floor thinkers thinkers who process information

third-floor thinkers thinkers who apply information

Resources

eWorkbooks Topic 2 eWorkbook (ewbk-5212)
Student learning matrix (ewbk-5214)
Starter activity (ewbk-5215)

learnON Access and answer an online Pre-test and receive **immediate corrective feedback** and **fully worked solutions** for all questions.

2.2 Problem solving with thinking hats

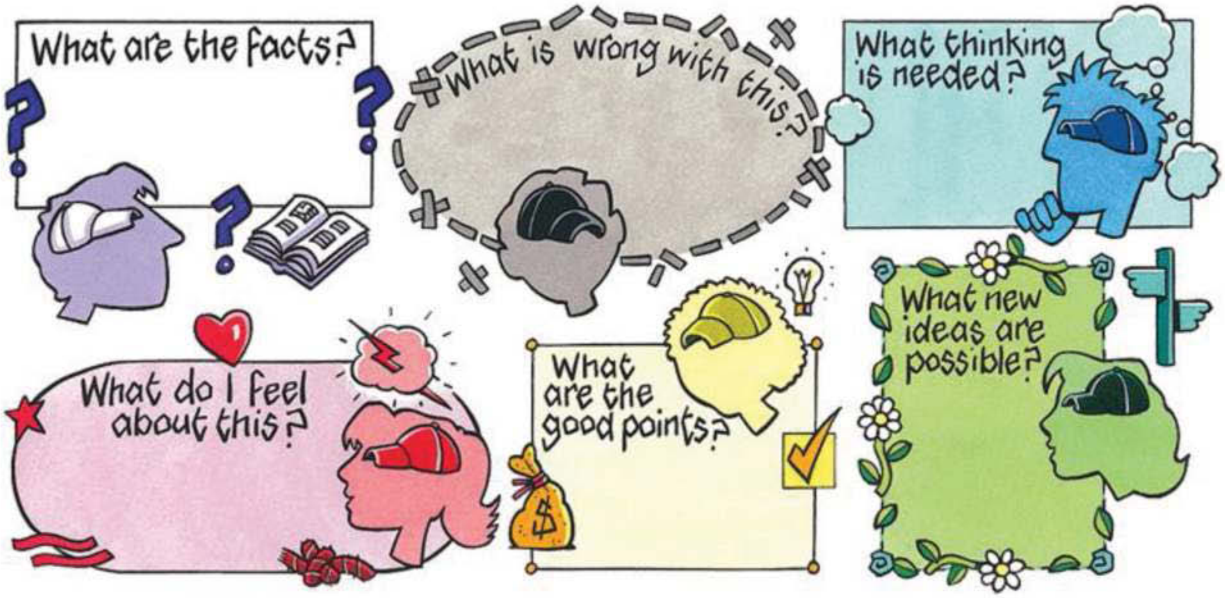
LEARNING INTENTION

At the end of this subtopic you will be able to effectively use thinking hats to problem solve.

2.2.1 Thinking with different hats

There are number of very useful tools that can help develop your thinking. One of these was created by a great thinker by the name of Edward de Bono. He created the idea of using different coloured **thinking hats** for different types of thinking. These hats don't even have to be on your head. The idea behind each hat just needs to be *in* your head.

FIGURE 2.3 The six coloured thinking hats provide different ways of thinking about a problem.



The six thinking hats

- White thinking hat looks for information or facts
- Black thinking hat looks for problems
- Blue thinking hat looks at the thinking process
- Red thinking hat examines feelings or uses intuition
- Yellow thinking hat considers the positive
- Green thinking hat looks for creative solutions

thinking hats a thinking tool developed by Edward de Bono using different coloured hats for different types of thinking

2.2.2 What is the problem?

If there is a problem, this often suggests that something could be improved or made better. Your *black thinking hat* is a good hat to put on for thinking about this.

Once you have pinpointed your problem, you can start thinking about what end results or outcomes you would like. It is sometimes helpful to consider the hurdles that may impede your success and how high you will need to jump to overcome them!

FIGURE 2.4 Working in a team is often the most effective way to approach a solution to a problem.

Writing a problem statement to help you focus on the issue is often useful. For example, you may state 'who', 'does' (action verb) and 'what' for your problem. However you express it, it's important that you take ownership of the problem and phrase it in your own words.

2.2.3 What are the facts?

This is the time to put on your *white thinking hat* and move into your first-floor thinking room. It is here that you lay the groundwork. If you are accurate, persistent and thorough in this stage, then your progress through the other phases is likely to be much smoother. Start with what you already know about the problem. Ask yourself questions about who, where, when, why, how and what has been tried so far. You can document this initial information as a KND chart (what do we Know?, what do we Need to know? and what do we need to Do?) in a table or columns with these title headings.

FIGURE 2.5 First-floor thinking gathers facts.

2.2.4 After the facts

Once you're clear about what the problem is, you need to look at it from different perspectives by using your *red thinking hat*. Remember that there is usually more than one side to a problem. When you are finding your information, consider different points of view so that you can better understand the issue. It is also useful to talk to others to find out how they feel about it.

During this phase, the information that you find may require you to modify or rephrase your problem statement.

2.2.5 What are some possible solutions?

Now it is time to move up to your second floor of thinking and put on your blue and yellow thinking hats.

With your *blue thinking hat* on, you can think about what you now know and try to make sense of it. You can use target maps to determine what is relevant to possible solutions and what is not.

Then you can put on your *yellow thinking hat*. This is when you and your team can become a real 'think tank'. You may find thinking keys and visual thinking tools very useful in this creative part of problem solving. Some of the really useful keys are the 'What if' and the 'Forced relationship' keys, which allow you to creatively think of scenarios and relationships to solve a problem. Most brainstorming webs help you to develop your creative thinking. Brainstorming can be well recorded on mind maps, cluster maps or single bubbles.

FIGURE 2.6 Second-floor thinking processes information.

2.2.6 Which is the best idea?

Your critical thinking becomes very important in selecting the best possible solution to your problem. Many of the **habits of mind** may help you to use intellectual behaviours that support the development of critical thinking. This is when task-specific graphic organisers such as priority grids can help you to structure your thinking, organise your ideas and stay focused.

Selection criteria can also be useful to help you to select the most appropriate alternative or idea. These may include consideration of an idea's usefulness in achieving something, effects that it may have or how feasible it is.

habits of mind types of thinking behaviours promoted by Bena Kallick and Arthur Costa

2.2.7 Your action plan

You are up on the third floor now. This is where your *green thinking hat* can be put to good use. The time has come to divide and prioritise tasks and check your timelines. You can use thinking process maps to help both creative and critical thinking. You may use them to decide what needs to be done and then to order or sequence this within a time frame. Visual maps that may help you with this include timelines and flowcharts.

FIGURE 2.7 Third-floor thinking applies information.

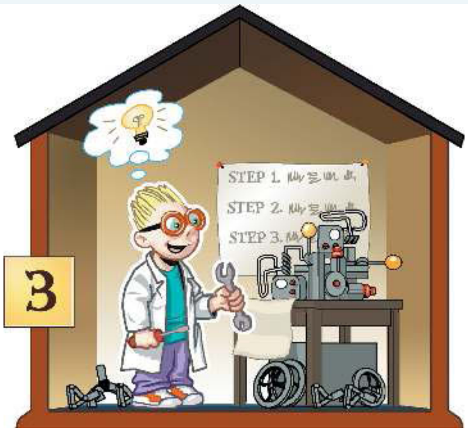
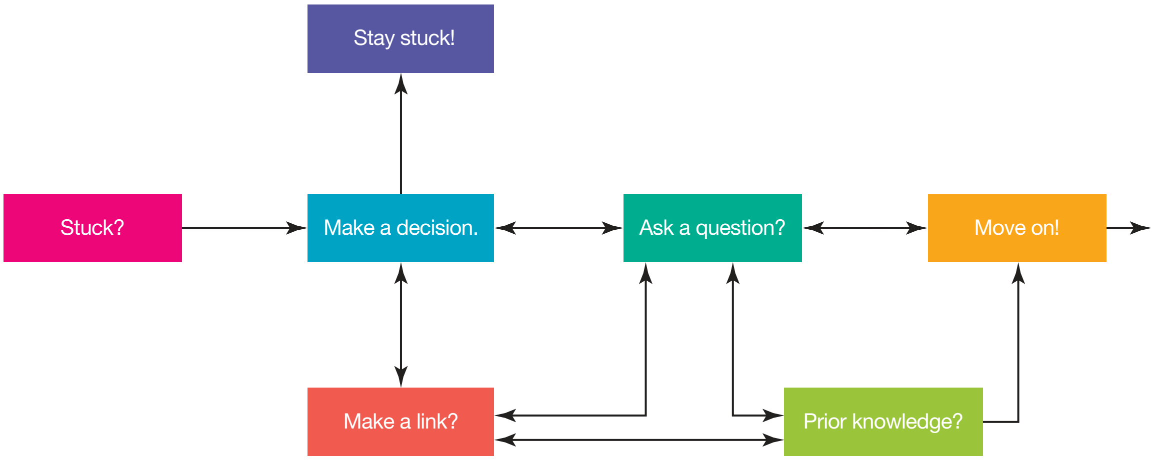


FIGURE 2.8 When you are working on trying to solve a problem, it is easy to get 'stuck'. The important thing is not to give up and to develop your own strategies to help you 'move on'.



DISCUSSION

a. Some believe that teaching people to think critically is the best training for informed and intelligent democratic citizens. Do you agree with this idea? Why or why not? Show your responses in a SWOT analysis (strengths, weaknesses, opportunities, threats).

b. Is asking questions, probing assumptions and seeking reasons valued in all cultures? Give examples to support your response.

Resources

eWorkbook Thinking keys (ewbk-5236)

assessON Additional automatically marked question sets

2.2 Exercise

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Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 4, 6	Questions 3, 7, 8	Questions 5, 9, 10

Remember and understand

1. Which thinking hat and thinking floor are used for fact finding?
2. How can yellow thinking hats and visual tools help you to solve problems?
3. State the difference between the black and white thinking hats.
4. Which visual tools may help you develop your action plan?
5. Suggest a way that a problem statement can be constructed.

Apply and analyse

6. Suggest how target maps can help you in the problem-solving process.
7. **a.** Appropriate use of language can also help you to clarify problems. Some personal problem statements may begin as shown below. For each of these, complete the sentence to describe a personal problem that may be experienced by someone your age.
   - 'I feel angry when …'
   - 'It worries me that …'
   - 'I'd love to be able to …'
   - 'I hate it when …'
   - 'It stresses me that …'

   b. Select one of these problems and go through the problem-solving stages 2–6 shown in this subtopic.
8. **a.** Brainstorm examples of problems that would fit under each of the following problem categories.
   - **i.** What is unjust in Australia?
   - **ii.** What takes too long?
   - **iii.** What costs too much?
   - **iv.** What is disorganised?

   b. Select one of these problems to research and put together a suggested action plan to solve it.

Evaluate and create

9. **a.** Brainstorm a list of at least ten things that need improving at your school.
   b. For each item, suggest a reason it needs to be improved.
   c. Select one of these things to investigate and creatively problem solve.
10. Select one of the following categories of problems and then focus on one problem that is relevant to it. Use your creative problem-solving skills to come up with an action plan.
    a. Social problems (examples include drug abuse, bullying, racism)
    b. Environmental problems (examples include pollution, endangered species, bushfires, droughts, floods)
    c. Global problems (examples include terrorism, disease/health, national disasters)

Fully worked solutions and sample responses are available in your digital formats.

2.3 The language of understanding

LEARNING INTENTION

At the end of this subtopic you will be able to describe different words to describe various ways of thinking and learning, and develop questions and use visual thinking tools to solve problems and deepen understanding.

2.3.1 Choosing your words carefully

The words that you use to communicate reveal a lot about you — your beliefs and assumptions, and your feelings about yourself and others. When speaking to others, try to use language that is inclusive (language that doesn't make people feel left out and uncomfortable), avoid putting yourself or others down, refrain from labelling others and use proactive rather than reactive language. For example, instead of saying 'There's nothing I can do about it', say 'Let's think of the alternatives'.

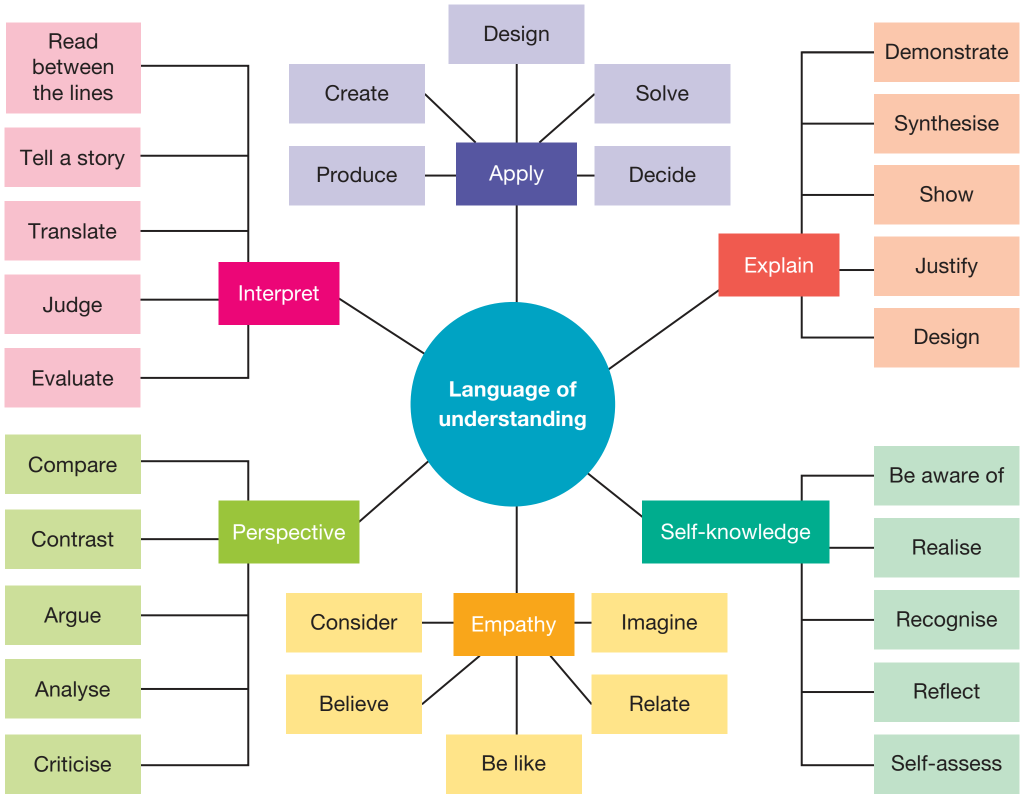
Understanding language

When you are trying to make sense of words associated with understanding, it is helpful to divide them up into categories:

- **apply** — How and where can I use this knowledge?
- **explain** — Why is it so? How does it work?
- **self-knowledge** — What are my weaknesses? How do I best learn?
- **interpret** — What does this mean?
- **perspective** — Is it reasonable? Whose point of view is this?
- **empathy** — What are others aware of that I am missing?

An awareness and working knowledge of these types of thinking can increase the depth of your understanding.

FIGURE 2.9 The following diagram shows the different categories of the language of understanding.

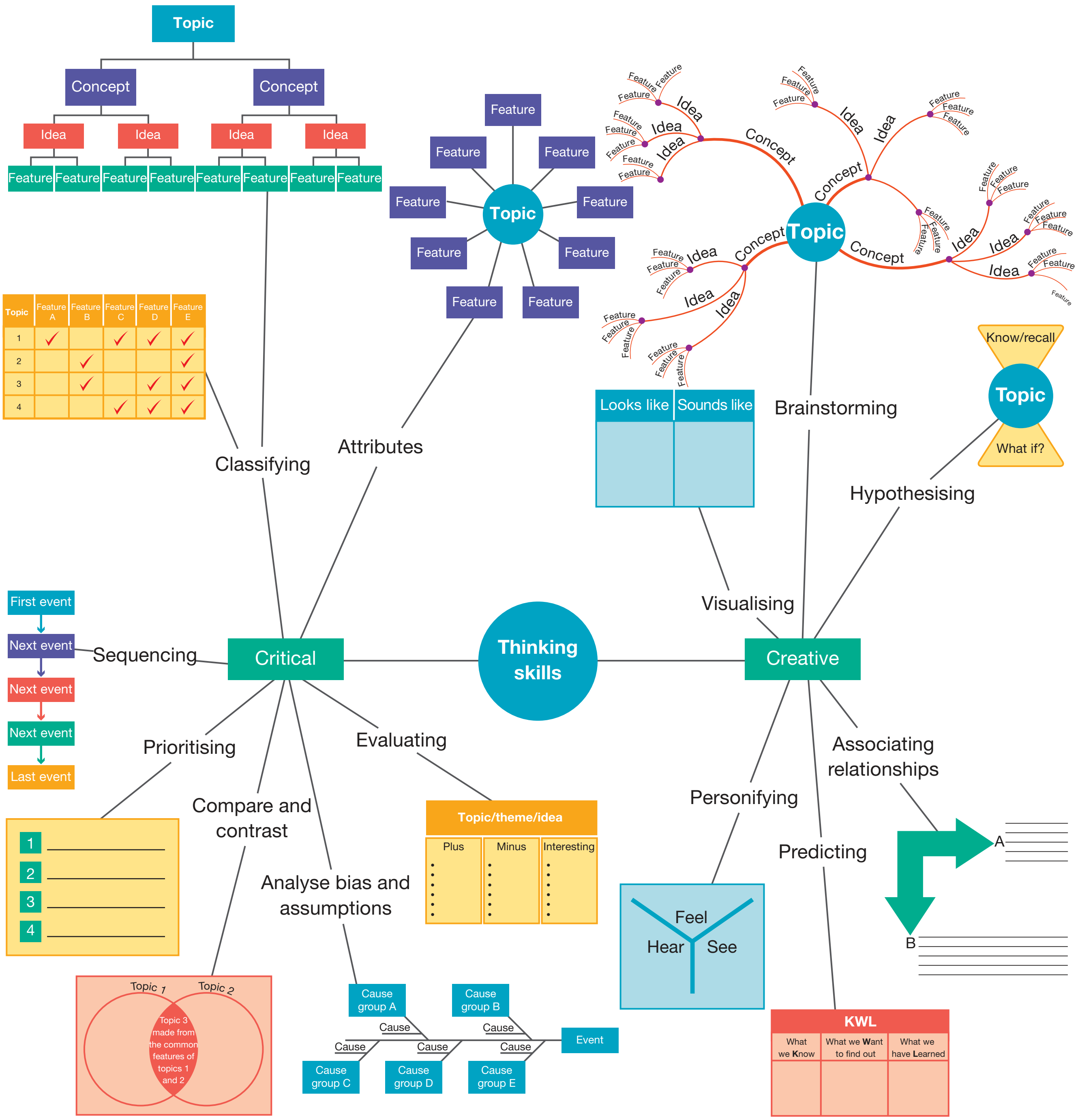


2.3.2 Is your learning bag packed?

One of the goals of learning is to make information portable, so that it can be used in new situations and locations. Transfer of learning occurs when learning is taken into new contexts and applied in innovative ways.

At first glance, transfer of learning may seem to be difficult and out of reach. You may need to use your critical and creative thinking to make the task more manageable. Visual thinking tools can provide you with opportunities to practise these types of thinking.

FIGURE 2.10 Examples of critical and creative thinking tools



'Fat' and 'skinny' questions

If you don't ask the right question, you won't get the right answer! 'Skinny' questions usually require only a brief, simple response. For example, 'Name your best friend' or 'Have you had science class yet?'

'Who influences you and how?' is an example of a 'fat' question. These questions take time to think through. They require deeper understanding, discussions and explanations that include relevant examples.

ACTIVITY: Multicultural Australia

Australia is a multicultural country because it includes people from many different cultural groups.

a. In teams, identify examples of two different cultural groups in Australia.
b. Use a thinking tool (as shown in figure 2.10) to record what you already Know, what you Want to find out and what you have Learned, after researching the different perspectives each of these cultural groups.
c. Suggest three 'fat' questions that would help you to deepen your understanding of the different cultural perspectives.
d. Create a class collage of the different cultural perspectives.

on Resources

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2.3 Exercise

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Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Question 1	Question 2	Question 3

Remember and understand

1. Suggest ways that you can use language positively when you communicate with others.

Apply and analyse

2. For each question below, provide a response and suggest which type of understanding it belongs to.
   a. Why is it illegal to smoke cigarettes in restaurants and other public areas?
   b. What are the different points of view about stem cell research?
   c. What would it be like to be a genetic engineer?

Evaluate and create

3. Metacognition is the act of 'thinking about your own thinking'. This is when you notice and scrutinise what you are thinking. It also involves thinking about how you are thinking. Answer the following:
   - What am I thinking about?
   - What does this mean?
   - What caused me to think about this?
   - What have I learned?
   - How do I know that I'm right?
   - How might I think about this differently?

Fully worked solutions and sample responses are available in your digital formats.

2.4 At first glance

LEARNING INTENTION

At the end of this subtopic you will be able to describe ways in which you can communicate with others more effectively.

2.4.1 Rapid rapport

Your understanding can be influenced by trust. When you meet someone for the first time, you may be lucky enough to have **rapport**; however, trust needs time to develop. Your verbal and nonverbal communication can influence not only how others see you, but also how you see yourself.

You meet someone for the first time and want to make a good impression. In fact, you *really* want to make a good first impression! Good rapport may be initiated by non-verbal signals such as eye contact, mirroring behaviour, posture or breathing. In fact, non-verbal cues are thought to make up about 65 per cent of your first impression. Only 35 per cent is due to verbal cues such as words, pace, inflection, pitch and volume.

FIGURE 2.11 When you meet someone for the first time, what sorts of things make a good impression on you? What sorts of things make a bad impression?

If you want to develop rapport, then you can pay attention to another person's body language and subtly mirror it. For example, you could mirror their gestures, postures, muscle tension and facial expressions. You can also show active listening skills in both verbal and non-verbal ways.

2.4.2 Listening skills

The big bad Ws

Are you a good listener? Do you really listen to what the other person is saying, or do you:

- *want* to interrupt?
- *want* to have your own conversation within (rehearsing what you want to say)?
- *wait* for an opportunity to make public only your own wishes and wants?

FIGURE 2.12 Listening is a very important scientific skill.

Three Ps of listening skills

When you are listening, do you:

- *pause* and not talk over the other person?
- *probe* what they are really saying? Are there generalisations, omissions or distortions in their comments? Do you need to ask questions to gain clarity about what they really mean?
- *paraphrase* what they have said to show that you have been listening and to develop rapport?

rapport a relationship of mutual trust and understanding

ACTIVITY: Another perspective

In this activity you will research and think about how scientists observe animals in the wild.

Scientists often observe animals in their natural wild habitat. Some animals react aggressively to the presence of humans, although the scientists make painstaking efforts to be unobserved. Often the presence of humans changes the animals' normal behaviour.

1. Find out more about scientific observations of animals in the wild and summarise your findings into a PMI chart (plus, minus, interesting).
2. **a.** State and justify your opinion about scientists observing animals in the wild.
   b. Suggest comments that a scientist involved may have regarding your opinion.
3. Use your imagination to write a story from the perspective of the animal being observed.

on Resources

Video eLesson This car workshop owner is showing good listening skills when talking with a customer (eles-2563)

2.4.3 What are you saying?

Whether you are talking informally or giving a formal presentation, it's good to consider how you communicate your thoughts, emotions and attitudes. For instance, when you are having a conversation, do you map what you or the other person is saying in your mind? This can help to clarify and give structure to your shared dialogue.

If you look at a road map, you see that locations are indicated by different fonts (e.g. larger or coloured letters) and areas are indicated by colours or shading. In a conversation, your non-verbal signs indicate parts that have greater influence or meaning (e.g. when you increase your volume or alter your tone). There are often hidden meanings (assumptions and beliefs) below the surface of language. Can you think of any examples?

ACTIVITY: Active listening

In this activity you will practise and develop active listening skills.

There are many ways to help you develop your active listening skills. Some people use the PACTS method:

Paraphrase or play back what has been said in your own words.

Affirm or appreciate what has been said.

Clarify or check on specific details of what has been said.

Test options and prompt talk that tempts new ideas.

Seek out and be sensitive to the talker's feelings.

Practise the PACTS method by completing the following tasks:

1. Research a scientific discovery, summarising your findings into a cluster map or mind map.
2. In a team of three, decide who will be persons A, B and C.
   - Person A talks about 'their scientific discovery' for two minutes, while person B listens.
   - Person B then paraphrases what person A has said, asks questions to clarify, and provides affirming comments to show what they appreciated.
   - Person C shares their PMI chart with persons A and B and the team discusses it.
4. Now, swap roles, with person A watching and recording a PMI chart on what happens between person B and person C. Person B talks about 'their scientific discovery' for two minutes, while person C listens. Repeat the steps from the previous exercise.
5. Individually reflect on what you have learned, and how you could use this to become a more effective listener.

on Resources

assess on Additional automatically marked question sets

2.4 Exercise

learn on

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Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Question 1	Question 2	Question 3

Remember and understand

1. Which of the three Ps can be used to demonstrate that you have been listening attentively?

Apply and analyse

2. a. Score yourself between 0 and 4 on the following questions (where 0 is *never* and 4 is *always*).
   i. I fidget when someone is talking to me.
   ii. I finish other people's sentences.
   iii. I talk over other people.
   iv. My body language suggests that I'm not interested in what people are saying.
   v. I interrupt when someone else is talking.
   vi. I don't look at the speaker when they are talking to me.
   vii. I think about what I will say next, rather than listening to the person talking.
   viii. While listening, I sneak a look at my watch.

   b. Comment on what you have learned from this quiz and what you could do to be a more effective listener.

Evaluate and create

3. a. Think about an occasion when you met someone for the first time. List the sorts of things you noticed about them in the first few minutes.
   b. Compare your list with others. Use a Venn diagram to show any similarities and differences.
   c. Discuss the similarities and suggest reasons for your shared first impressions. Use a cluster map to summarise the key points.
   d. Outline whether the features of a good first impression are always the same or if they change in different situations.
   e. Use a diagram, sketch or cartoon of yourself to describe the first impressions that you give to others.
   f. On the basis of this activity, are you likely to change anything you do or say prior to meeting someone you want to impress? Write these ideas down and think about how you can incorporate them into situations when meeting someone for the first time.

Fully worked solutions and sample responses are available in your digital formats.

2.5 Coded communication

LEARNING INTENTION

At the end of this subtopic you will be able to distinguish between verbal and nonverbal communication.

2.5.1 Turning on your transmission

Interpersonal communication is the transmission of information between two or more people. The sender encodes the message and the receiver decodes the message. Verbal communication involves speaking or writing the words, whereas nonverbal communication relies on other methods.

FIGURE 2.13 Communication can be verbal and nonverbal.

2.5.2 Verbal communication

Verbal communication includes not only what we say, but also how we say it. We often modify our verbal messages to match our perceptions of the intended receiver. You can learn a lot about the attitudes of others not only by what they say or write, but also by interpreting how they communicate it.

2.5.3 Nonverbal communication

Nonverbal communication can be divided into three general categories: kinesics, personal space and paralinguistics. **Kinesics** involves the use of body movements or actions to convey a specific meaning or idea and is often referred to as body language. Personal space is the 'invisible' physical area surrounding your body that you regard as your personal territory. **Paralinguistics** involves *how* or the *way* that something is said.

interpersonal communication communication with others

kinesics the use of bodily movements or actions to convey a specific meaning or idea

paralinguistics how something is said that may modify meaning

FIGURE 2.14 Nonverbal communication conveys information through actions and expressions rather than words.

Resources

Video eLesson What nonverbal communication is this woman showing? (eles-2564)

ACTIVITY: Do you get the message?

In this activity you will investigate how to identify and create emotions through the use of body language.

1. Look at the body posture, gestures and facial expressions of the people in the photos and select the attitude or emotion that best matches them from the following list.
   - curiosity
   - empathy
   - enthusiasm
   - puzzlement
   - welcome
   - suspicion
   - confused
   - upset
   - shyness
   - determination
   - confidence
   - happiness
   - excitement
   - scared
   - anger
   - rejection

2. In teams:
   - **a.** Write the terms listed in question 1 onto different cards.
   - **b.** Shuffle the cards and place the pack facedown.
   - **c.** Take turns to pick up a card and mime (act out) the emotion for other members of the team to guess.
   - **d.** Keep scores for each team member to see who gets the most correct.
   - **e.** Brainstorm other examples of emotions or attitudes and write these on additional cards.
   - **f.** Repeat steps (b) to (d) with your new set of cards.
   - **g.** Were some emotions or attitudes easier to guess than others? Suggest reasons for this.
   - **h.** Suggest how this activity may be used to increase the effectiveness of your communication with others.

Resources

assesson Additional automatically marked question sets

2.5 Exercise

learnON

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Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2	Questions 3, 4, 7	Questions 5, 6

Remember and understand

1. Describe what is meant by 'interpersonal communication'.
2. What is the difference between verbal and nonverbal communication?

Apply and analyse

3. Is verbal communication related only to what we say? Explain.
4. Use a cluster map to show details of the three general categories of nonverbal communication.

Evaluate and create

5. a. Describe examples of appropriate and inappropriate methods of verbal and nonverbal communication. Summarise your ideas into a visual thinking map such as a mind map or cluster map.
   b. Compare your examples with others and reflect on similarities and differences.
   c. Suggest how you may be able to use the information gained to improve your communication with others.
6. Identify three advertisements that include 'scientific claims' to support a particular product or practice.
   a. State the scientific claim.
   b. Investigate other resources to see whether there is unbiased evidence to support the claim.
   c. Describe any verbal or nonverbal communication that is used to support the scientific claim.
   d. Design a 'fair test' that could be used to collect evidence that may support or disprove the scientific claim used in the advertisement.
   e. Construct a PMI chart about the advertisement based on how effectively it provides data to support the scientific claim made.
   f. Based on your findings, in which ways could you improve:
      i. the advertisement so that it is more scientifically accurate
      ii. the product so that it more effectively meets the scientific claim?
7. Find out more about kinesics, personal space and paralinguistics. Describe some rules or guidelines that could be used to make your communications with each other more effective (you may wish to discuss your ideas with others).
   Present your findings and discussion summary as a communication guideline or rule book, cards, brochure or poster.

Fully worked solutions and sample responses are available in your digital formats.

2.6 Telling tales

LEARNING INTENTION

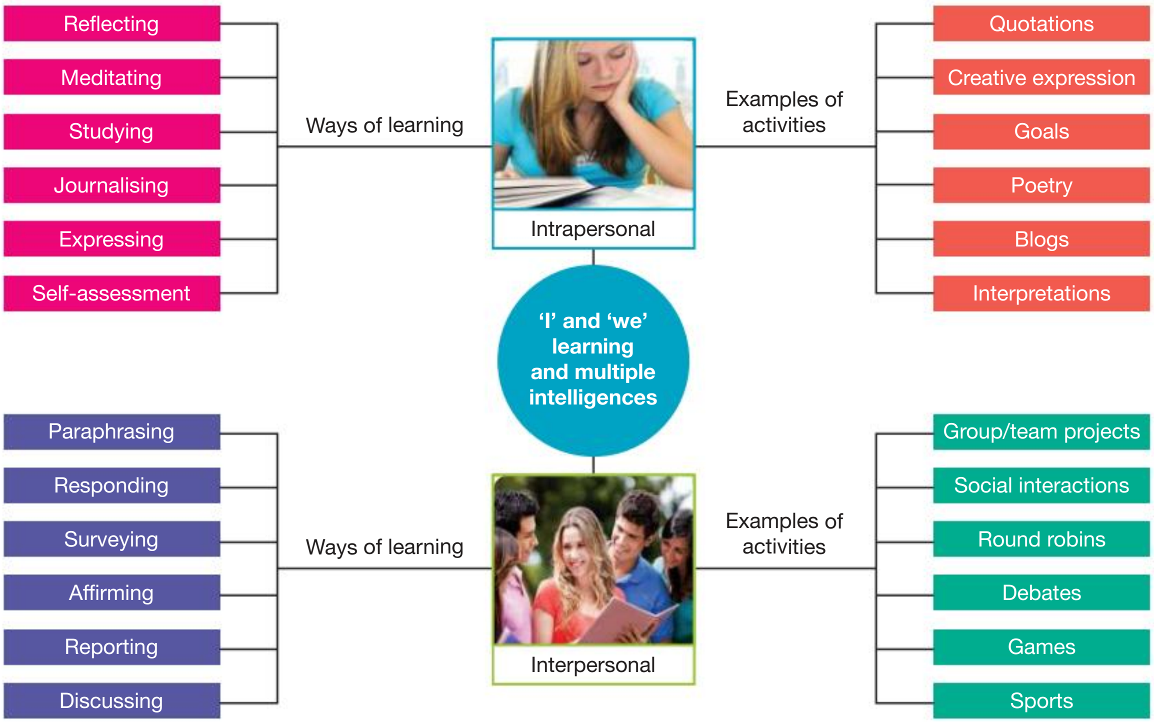
At the end of this subtopic you will be able to distinguish between intrapersonal and interpersonal intelligences.

2.6.1 Interpersonal and intrapersonal

To be an effective learner, you need to develop both 'I' and 'we' learning. This means that you need to consider activities and strategies that tap into both your **intrapersonal** and **interpersonal intelligences**.

Intrapersonal and interpersonal intelligences deal with people — yourself and others. Some may suggest that these two intelligences are intimately related because you cannot fully know others until you know yourself!

FIGURE 2.15 Interpersonal ('we') and intrapersonal ('I') learning



2.6.2 Morals — learning how to live together

The idea of morals and ways of behaving may have originated from not wanting others to experience something that we would not like to experience ourselves. By identifying with others and treating them with the respect and care that we would want ourselves, we can become valued members of our communities.

This can also lead to a happier life for both yourself and those around you.

One way morals have been passed down over many generations has been by telling stories. Many fairytales and fables have such messages woven into them.

intrapersonal intelligences one of the multiple intelligences that involves 'I' learning, which can be developed through reflecting, self-assessment and creative expression

interpersonal intelligences one of the multiple intelligences that involves 'we' learning, which can be developed through team projects, social interactions, debates and games

Telling tales

Hans Christian Andersen (1805–1875) was one of the first known creators of fairytales and wrote more than a hundred stories. A number of his stories dealt with the main character feeling uncomfortable with themselves or wishing to be somewhere or something else. You may know two of his stories: *The Little Mermaid* and *The Ugly Duckling*.

Aesop's fables are further examples of stories with morals that suggest ways or behaviours to help people live and get on together. *The Crow and the Pitcher* is one example. Other examples of some fables and their morals are shown table 2.1.

FIGURE 2.16 Statue of Hans Christian Andersen

CASE STUDY: Using stories to learn

The Crow and the Pitcher

The Crow and the Pitcher is a fable about a crow dying of thirst. The crow found a pitcher and excitedly flew down to drink from it. Sadly, when he got there, it contained only a very small amount of water at the bottom that he could not reach. He tried all sorts of ways to get to the water, but his efforts were in vain. Then he had a brainwave; he collected some stones and dropped them one by one into the pitcher. Finally, the water level rose high enough for him to drink it. His life had been saved.

The Ugly Duckling

The Ugly Duckling is a story about a very ugly baby 'duck'. It is about viewing the world from different perspectives. The other ducks teased her and made fun of her because they thought that she was so ugly. As she got older, however, instead of growing into an adult duck, she became a beautiful swan. It was a pity that she didn't have the classification knowledge that you will have by the end of Year 8. She would have been saved a lot of pain and suffering — but then she also would have if the ducks had shown some empathy!

TABLE 2.1 Examples of Aesop's fables and their morals

Fable	Moral of the story
The Boy and the Nettles	Whatever you do, do with all your might.
The Crow and the Pitcher	Little by little does the trick.
The Dancing Monkeys	Not everything you see is what it appears to be.
The Eagle and the Fox	Treat others as you would like to be treated.
The Four Oxen and the Lion	United we stand, divided we fall.
The Fox and the Goat	Look before you leap.
The Mule	Every truth has two sides.
The Wolf and the Kid	It is easy to be brave from a safe distance.

2.6.3 Tell a tale

Did your parents or older sibling read to you when you were little? Reading or being read to stimulates your imagination and takes you on an emotional journey. Stories can help you to learn about other people and how they communicate, express themselves, think and feel, and ways that they can support each other.

Stories can also help you to discover more about yourself. You may explore your strengths and vulnerabilities, and your likes and dislikes. Stories can even help you to develop your imagination and creativity, and to think up your own ideas and be flexible in your thinking. This type of open-ended thinking can open up lots of new possibilities, rather than focusing on a single right answer. As a storyteller, you can provide a framework for your reader's imagination to flourish.

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2.6 Exercise

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Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Question 1	Questions 2, 3	Question 4

Remember and understand

1. What is the purpose of a fable?

Apply and analyse

2. Aboriginal and Torres Strait Islander peoples have traditional stories that are passed from one generation to the next. Find examples of traditional stories:
   a. used as a basis to understand their ecosystem
   b. used to describe their special relationship with the land, native flora and fauna
   c. about the formation of Australian landform features (e.g. the Twelve Apostles, Cradle Mountain, Pinnacles, Flinders Ranges or Warrumbungles).

Evaluate and create

3. Use the 'thinking floor model' (refer to figure 2.2 in subtopic 2.1) to collect information, organise it and then construct your own story on one of the following.
   - Why Australian flora and fauna are different from those of many other countries
   - Why kangaroos have a pouch and hop
   - The impact of cane toads on our native animals
   - Why southern Australian koalas have different sized ears from northern Australian koalas
   - How cutting down trees can affect the survival of other Australian organisms
   - How to encourage children (and adults) to appreciate, respect and take care of one of the following:
     - the diversity of living things on our planet
     - their environment
     - their bodies.
4. Identify a product you would like to sell and develop an advertising campaign that includes claims from scientific perspectives and uses storytelling.

Fully worked solutions and sample responses are available in your digital formats.

2.7 Cartoon quest

LEARNING INTENTION

At the end of this subtopic you will be able to use visual thinking tools to plan your own story and understand how animations and cartoons can help us understand scientific concepts.

2.7.1 Telling the 'story' …

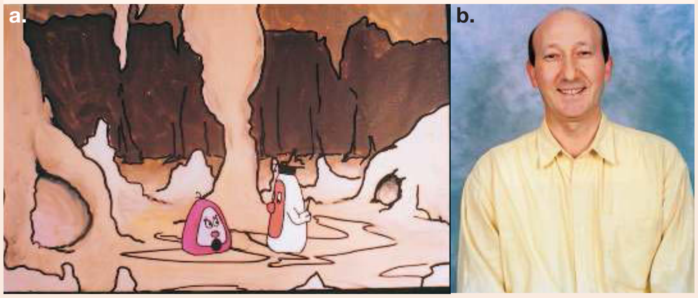
You may be wondering how telling fairytales and fables fits into the seriousness of learning science and being an effective scientist. No matter how clever you are or how much you can remember or understand, it is very important for you to be able to communicate your ideas to others effectively. Wouldn't it be great if you could have lots of fun at the same time?

One man who has found a way to do this is Bruno Annetta, a film-maker, graphic designer, actor and science teacher. Through his animated cartoons, Bruno can communicate scientific ideas effectively *and* share his excitement about the wonders of science. An image from his animation *The Life of a Red Blood Cell* is shown here.

CASE STUDY: Using stories to understand science

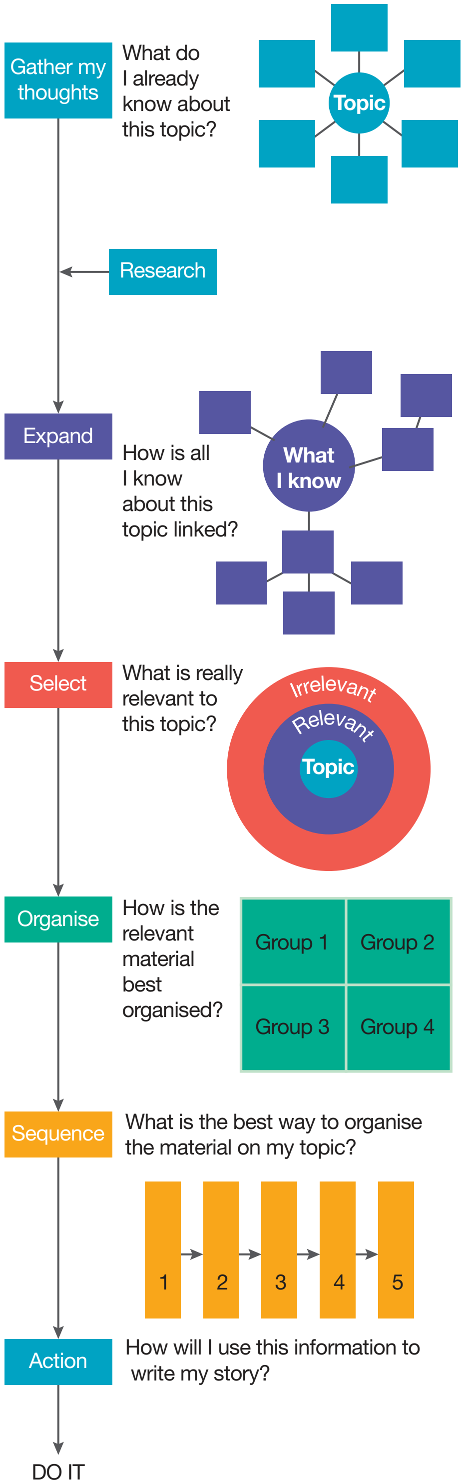
'I've always found it easier to remember information by doing something with it that was personal to me. The basic idea for the film *The Life of a Red Blood Cell* came out of me trying to remember the circulatory system when I first encountered it in Year 9 (Form 3). I created the animation in my head and later turned that idea into a film.'

FIGURE 2.18 a. In *The Life of a Red Blood Cell*, we follow the red blood cell as it goes from the bone marrow, where it is formed, into the blood circulatory system and starts its journey. **b.** Bruno Annetta



'I believe that, through the use of animation, humour, music and storytelling, learning can be fun and easy. I have used science in the making of animated films. An understanding of light, lenses and different coloured filters is crucial in exposing film correctly. I believe that through combining the sciences with the arts, one has a richer and more fulfilling life.'

FIGURE 2.17 Planning your story



CASE STUDY: Scenes from *Foodchain*

This is a musical and wacky animated look at a food chain from a freshwater ecosystem. It starts with a zoom in to a small section of pond in front of a child fishing. A series of cartoon character organisms are encountered and information is presented in the form of images, song and comical dialogue.

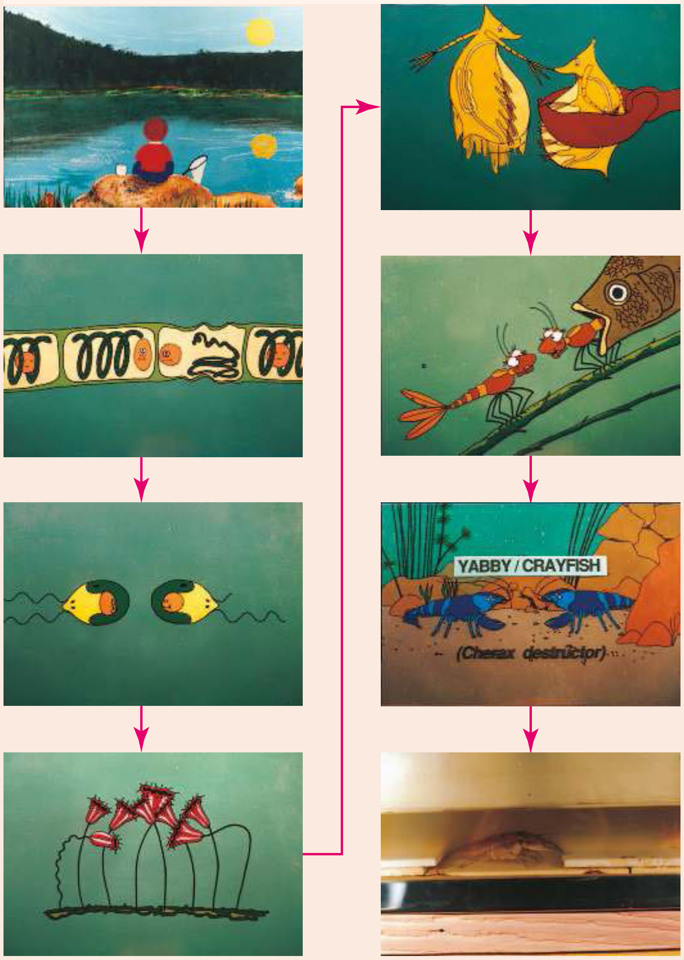
The zoom takes us to a microscopic view of *Spirogyra crassa* (commonly called filamentous algae). The 'crass' nuclei refer to chloroplasts, sugar production and aerobic respiration. They also allude to the fact that they are a 'duck's dinner'.

We are then introduced to *Chlamydomonas* (a mobile single-celled plant), which is the first organism of the food chain being investigated. Through their dialogue we learn about *Euglena* and are introduced to the terms 'autotroph' and 'heterotroph'.

Vorticella 'suck in' the *Chlamydomonas* and lead us to the second level of the food chain — the first-order consumer. Eight *Vorticella* clinging to a twig sing an opera tune — 'O sole mio'. They each represent a different note from an octave. Their scientific name is *Vorticella octava*.

The names and personalities have been carefully chosen to aid memory of each organism and their scientific name. *Daphnia magna* (water flea) are portrayed as 'toffy', upper middle-class women.

FIGURE 2.19 Stills from the animation *Foodchain*



Damselfly nymphs feed on *Daphnia* and are portrayed as street-smart young girls.

Incidental characters such as the Australian pygmy perch are introduced to allow discussion to flow into food webs.

Yabbies are presented as 'true blue' Aussies and scavengers (scientific name — *Cherax destructor*). The story ends with one of the yabbies being caught by the child who we saw sitting on the bank at the start of the video. This finishes the food chain with 'man' as the last organism.

Videomicroscopy of the real organisms is provided at the end of the program, along with their scientific names.

on Resources

assesson Additional automatically marked question sets

2.7 Exercise

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au .

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2	Questions 3, 4	Question 5

Remember and understand

1. In which part of the body is a red blood cell formed?
2. Describe how Bruno Annetta shares his passion for science and learning.
3. Use information in the *Foodchain* cartoon (figure 2.19) to answer the following questions.
   a. What is the scientific name for filamentous algae?
   b. What is special about *Euglena*?
   c. What is the name of an organism that eats *Chlamydomonas*?
   d. How did Bruno use music to help you remember the species name *Vorticella octava*?
   e. What is the common name for *Daphnia magna*?

Apply and analyse

4. How can 'telling stories' help you in your learning of science and being a scientist?

Evaluate and create

5 a. Select one of the following topics for a story: skin cells, neurons, chloroplasts, nucleus, amoeba, fungi, muscle tissue, connective tissue, white blood cells, swine flu, solar-powered cars, oxygen, electronic optics, mitosis.
   b. Brainstorm and list the key ideas or facts that could be included in your story.
   c. Construct a storyboard or flowchart to show how your story will be sequenced.
   d. Add more details (picture, songs, words) to your story.
   e. Present your story to the class as a cartoon, PowerPoint presentation, animation, storybook, or in some other creative way.

Fully worked solutions and sample responses are available in your digital formats.

2.8 Unlocking meaning

LEARNING INTENTION

At the end of this subtopic you will be able to explain that many scientific words have a root word (often from Greek), which give clues to the words meaning, and you will be able to use prefixes and suffixes in scientific terms.

2.8.1 Name me a dino …

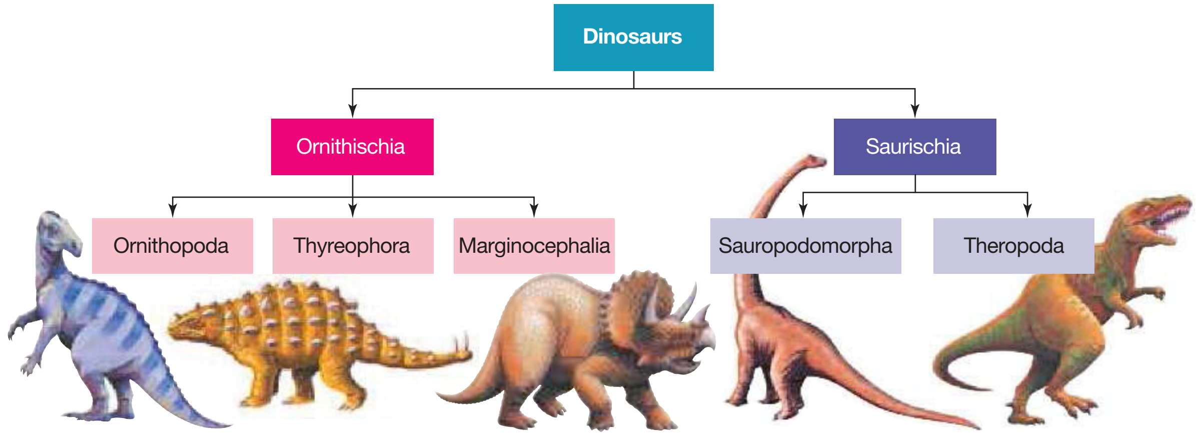
Scientists use a language that may appear alien, but once you find some of the keys and can unlock the meaning of words, it starts to make sense.

Tyrannosaurus, Pterosaurus, Stegosaurus … Did you ever wonder why the dinosaurs had such big names? Do you know what they mean? The term 'dinosaur' was actually decided on by British anatomist and palaeontologist Sir Richard Owen in 1842.*Dino* means 'terrifying' and *saur* means 'lizard'. Some dinosaurs were named for their unusual head or body features, others for their teeth or feet, or after a person or place.

prefix letters that are placed at the start of a word to convey a specific meaning

suffix letters that are placed at the end of a word to convey a specific meaning

FIGURE 2.20 Did you ever wonder how dinosaurs got their names?



Example:
Iguanodon
Weight: 5000 kg.
Length: over 9 m,
up to 5 m tall.

Example:
Ankylosaurus
Weight: up
to 4000 kg.
Length: over 10 m.

Example:
Triceratops
Weight: up to 11000 kg.
Length: over 9 m.

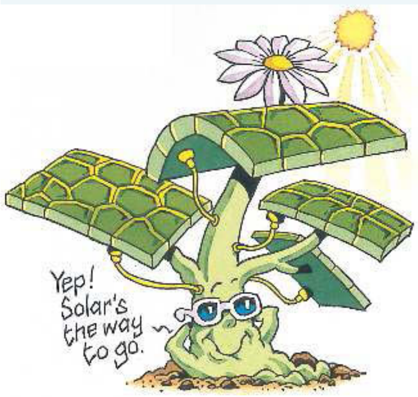
Example:
Brachiosaurus
Length: up to 24 m,
up to 12 m tall.

Example:
Tyrannosaurus rex
Weight: up to 8000 kg.
Height: over 6m.

2.8.2 Unlocking patterns

Many scientific terms, like others in our language, begin with a particular **prefix** and end with a specific **suffix**. These can give you hints as to what the words mean. For example, the terms 'chlorophyll' and 'chloroplast' both begin with *chloro*, which comes from the Greek word *chloros*, meaning 'green'. Chlorophyll is the green pigment found in the chloroplasts of plant cells. This green pigment captures light energy so that plants can make their own food using the process of photosynthesis (*photo* = 'light' and *synthesis* = 'to make'). The presence of chlorophyll in the chloroplasts is the reason that they (and plants) appear green.

FIGURE 2.21 Chloroplasts in plants allow them to produce energy from sunlight.



Leucoplasts (*leuco* = 'white') and chromoplasts (*chromo* = 'colour'), like chloroplasts, are plastids found in plant cells. Leucoplasts are not coloured as they do not contain coloured pigments. Chromoplasts are coloured and contain pigments other than chlorophyll. They are responsible for pigment synthesis and storage and are found in the coloured parts of plants, such as fruit and petals, giving them their characteristic colours. These pigments can be extracted and used as plant dyes.

Chemicals such as those in foods that you eat also have clues in their names that help you to work out what they are made of. You may have heard of glucose, sucrose and starch. Gluc*ose* and sucr*ose* are both sugars. Glucose is a *mono*saccharide (*mono* = 'one' and *saccharide* = 'sweet'). Sucrose is a disaccharide and is made up of two monosaccharides. Starch is a *poly*saccharide and is made up of many monosaccharides.

There are other prefixes that provide you with clues about size and number. A microscope (*micro* = 'small' + *scope* = 'view') and megafauna (*mega* = 'large' + *fauna* = 'animal') are examples of terms that indicate size in their names. Can you figure out which numbers are indicated in the following words: *uni*cellular, *bi*nary, *di*chotomous, *tri*pod, *quad*rant, *deci*mal, *centi*grade, *milli*pede?

2.8.3 'Cell speak'

Later, when you study different types of blood cells, you will come across terms containing the suffix or prefix *cyte*. This is a variation of *cyto*, which means 'cell'. Examples of terms that you may come across include:

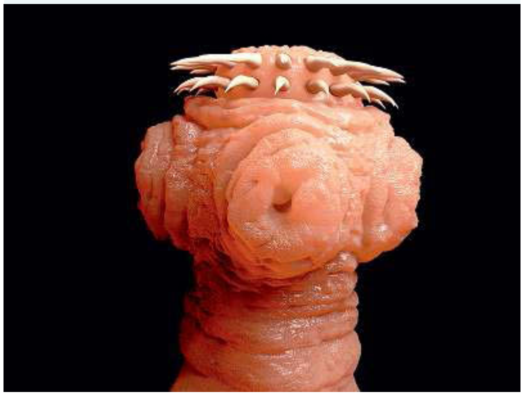
monocytes	cytosol	phagocytosis
phagocytes	cytoplasm	endocytosis
leucocytes	cytology	exocytosis.
lymphocytes	cytoskeleton	
erythrocytes	cytotoxic	

FIGURE 2.22 Erythrocytes (red blood cells) and leucocytes (white blood cells)

2.8.4 Inside or within

In science, you will learn about endoskeletons, endocytosis, endoplasmic reticulum, the endocrine system and endoparasites. The prefix *endo* in these words tells you that they all have something to do with 'inside' or 'within'. Even without knowing their full definitions, you can begin to see patterns and get an idea as to what they may refer to.

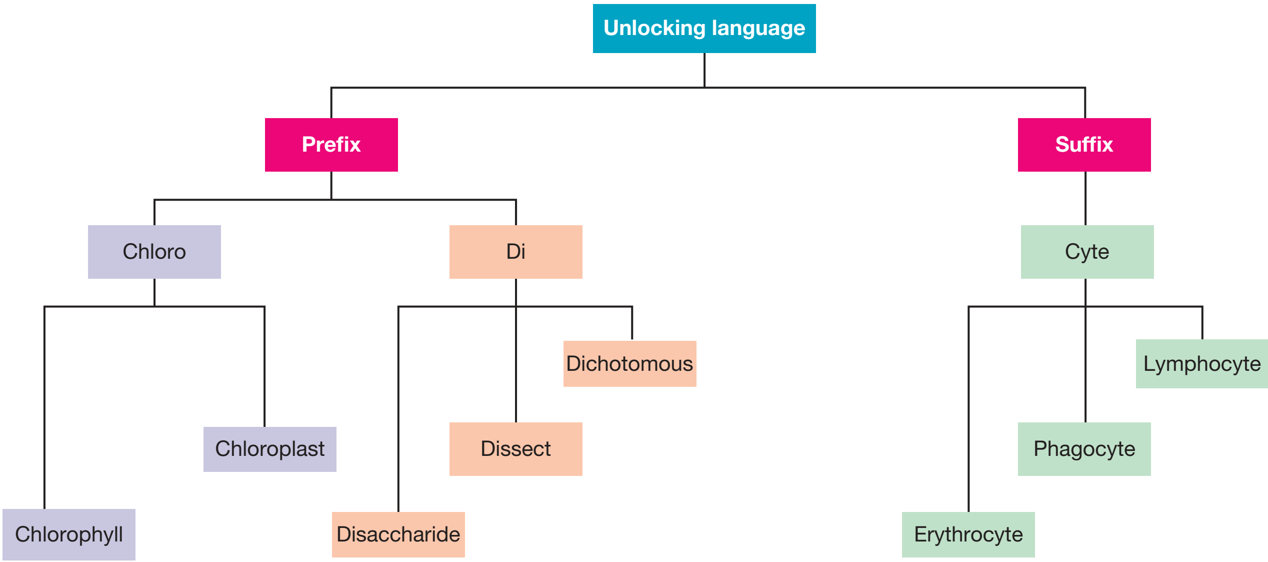
FIGURE 2.23 Tapeworms are endoparasites and live inside their host. You can see the hooks and suckers that this tapeworm uses to attach itself to its host.



2.8.5 Numbers or words?

In science you also need to know the difference between two different ways of describing your data. One of these is *qual*itative and the other is *quant*itative. Qualitative data describe your observations in words (describing the 'qualities' of the data), whereas quantitative data use numbers (or 'quantities').

FIGURE 2.24 The prefixes and suffixes of scientific terms often give you hints as to what they mean.



on Resources

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2.8 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 5, 6, 8, 12, 16	Questions 3, 7, 10, 11, 13, 14, 17	Questions 4, 9, 15, 18, 19

Remember and understand

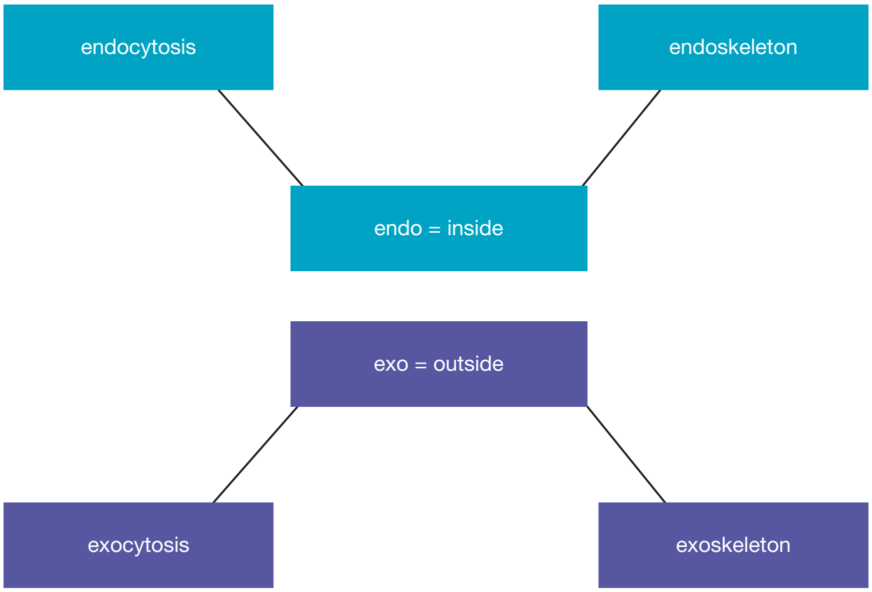
1. Suggest what type of animal may have *saur* in its name.
2. Outline the difference between the terms ‘prefix’ and ‘suffix’.
3. Identify the shared meaning between the terms:
   a. chlorophyll and chloroplast
   b. monocytes, leucocytes and erythrocytes.
4. a. Where are you likely to find leucoplasts, chromoplasts and chloroplasts?
   b. Describe how they differ.
5. Outline the difference between qualitative and quantitative data.
6. Suggest the suffix that sugars may share in their names.
7. Distinguish between monosaccharides, disaccharides and polysaccharides.
8. If you came across two words and one began with *micro* and the other began with *mega*, predict what the difference between them would be.

Apply and analyse

9. a. Carefully examine the following dinosaur names and discuss with a partner any clues that may help you predict their meaning. *Triceratops, Spinosaurus, Ceratosaurus, Heterodontosaurus, Pentaceratops, Microdontosaurus, Microceratops*
   b. Find out the meaning behind the dinosaur names listed above.
   c. Based on your findings, comment on any patterns and suggest groups you could divide them up into.
10. Find out about the life and scientific contributions of Sir Richard Owen. Summarise his top three contributions.
11. Research examples of Australian megafauna. Report on clues within their names that help describe what they may have looked like.
12. Find out what palaeontologists do, investigate their distinct ways of working and representing their specialised knowledge, and give an example of a contribution that an Australian palaeontologist has made to our understanding of ancient life in Australia.
13. Find out prefixes for one, two, three, four, ten and hundred that have originated from Latin or Greek words. State an example of a scientific term that is used for each.
14. Find out the meaning of and similarities and differences between the following:
   a. microscopes, telescopes, periscopes
   b. millimetre, centimetre, nanometre, kilometre
   c. binary fission, dichotomous key, binocular
   d. *Tyrannosaurus, Pterosaurus, Stegosaurus*
   e. anatomist, scientist, palaeontologist
   f. cardiac, renal, pulmonary
   g. dehydrated, deoxygenated, denatured.
15. Throughout history, coloured pigments from plants and animals have been used by humans. Find out about two plant and two animal examples. Identify the scientific names of the pigments and what they mean.
16. Chlorine is an element. Suggest what colour it may be.

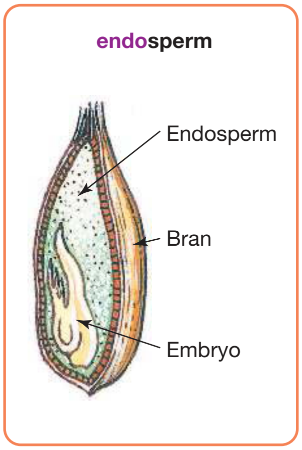
Evaluate and create

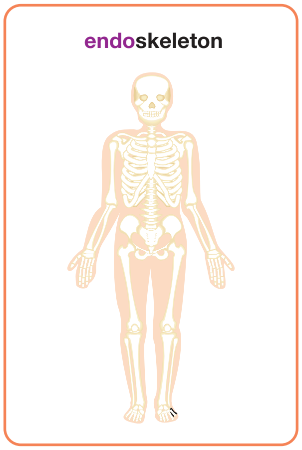
17. Find out the definition and two key points for each of the ‘endo’ and ‘exo’ words shown in the diagram.



18. Choose a couple of elements from the chemistry periodic table. Research the history behind the names of the elements and present your findings visually.

19. a. Find at least five examples of scientific terms that begin with the following prefixes: *endo, bio, anti, chloro, thermo, bi, hetero.*
    b. Create your own set of scientific terminology cards, using a particular colour for each prefix and adding a diagram or image for each that provides a hint of its meaning.
    The illustration shows what your cards may look like.
    c. Design a game that uses the cards to teach students about scientific terminology. Include an instruction brochure or rule book with your game.





Fully worked solutions and sample responses are available in your digital formats.

2.9 Total recall?

LEARNING INTENTION

At the end of this subtopic you will be able to describe a model of how information is processed in your brain and outline some strategies that can be used to enhance your memory and learning.

2.9.1 What is memory?

on Resources

Video eLesson Teen brain (eles-0224)

Watch a video to look inside the teen brain and discover why teenagers excel at impulsive behaviour and how it defies adult understanding. The latest science says their brains are physically unable to control some of these impulses until they are around 25 years old.

If a friend gave you her phone number, how long could you remember it without writing it down? While learning is about gaining new knowledge, memory is about retaining and then retrieving that learned information. For us to remember something, we have to be able to **record** the experience and **store** it in an appropriate part of the brain. If we are unable to **retrieve** or pull out that information, we have forgotten it.

2.9.2 Building memories

Modelling memory?

Scientists construct models to communicate ideas. Models can be concrete (e.g. a plastic model of the brain) or symbolic (e.g. a map or diagram). Models help learners to bring previous knowledge into their working memory. This assists learners to attach meaning to, and make sense of, their new learning.

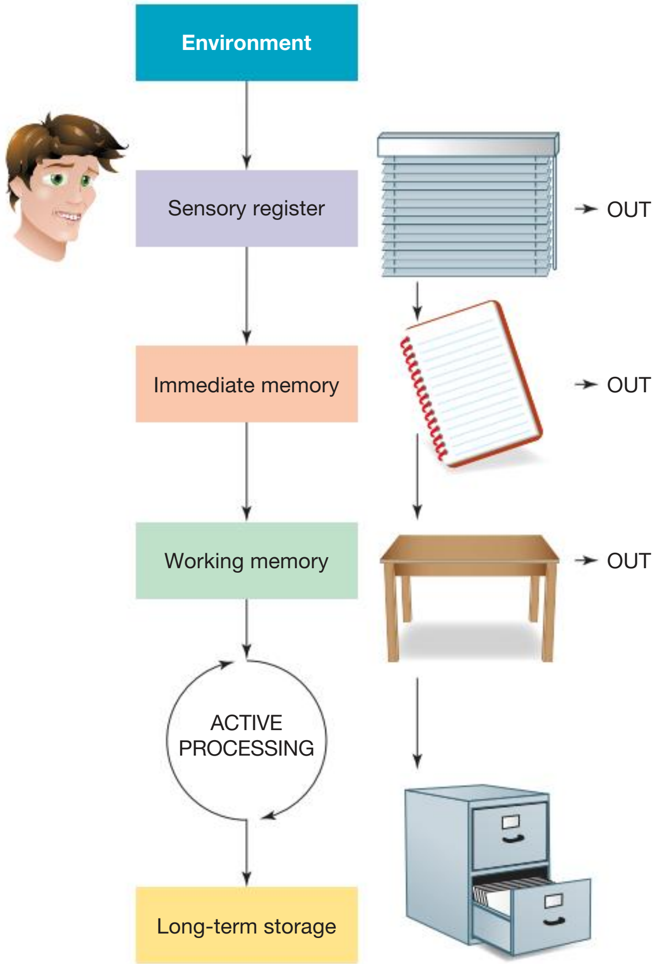
A model can be used to represent various stages in how information is processed by your brain. Shown in figure 2.25 is a simplified version of an information processing model. While this model has many limitations, it provides a framework that can be used to help you attach previous knowledge to new learning about the stages of memory.

record the first step in forming a memory

store storage of a memory in the appropriate part of the brain

retrieve the ability to recall memories

FIGURE 2.25 The information processing model provides a simplified explanation of how your brain deals with external stimuli (information) from your environment.



Filtering

What was that? You use your senses (e.g. sight and hearing) to detect various stimuli in your environment. Incoming information is filtered through a system called the **sensory register** (shown in figure 2.25 as venetian blinds). This system filters incoming information on the basis of its importance to you. Your sensory register involves your **thalamus** (a part of the limbic system of your brain) and a portion of your brain stem called the **reticular activation system** (RAS). The more important the information is to your survival, the higher the chance that it will get through for further processing in your brain. This is what allows you to form memories.

sensory register a system in the brain that filters incoming information on the basis of importance

thalamus part of the brain at the top of the brain stem that passes sensory information to key areas in the brain for processing

reticular activation system a part of the brain that filters incoming information on the basis of importance

Resources

Video eLesson Neural activity in the brain (eles-2565)

EXTENSION: Memories are patterns of connections

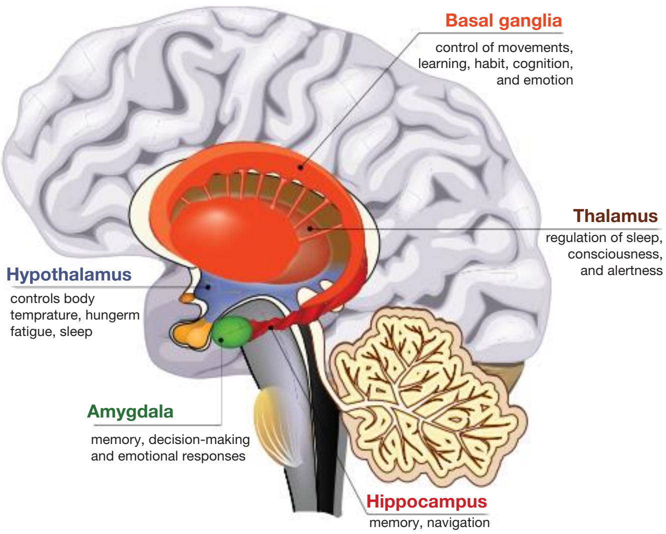
Memory is not stored in just one place in your brain. It is currently thought that memories exist as patterns of connections at the synapses between the brain's neurons. To store a particular memory, nerve signals travel along a specific pathway through certain synapses. Each time this memory is remembered, nerve signals are reactivated to again travel along this pathway.

FIGURE 2.26 Neurons in the brain

Short-term memory

Before any information is stored in long-term storage, it needs to pass through your temporary short-term memory. Examples of short-term memory include immediate memory (shown as a notepad in figure 2.25) and working memory (shown as a table in figure 2.25).

FIGURE 2.27 The limbic system



'Notepad' memory

Information that has made it past your thalamus moves to your immediate memory where a decision is made about what to do with it. Your past experience helps to determine its importance. An example of the length of time information will stay in this type of memory is when you temporarily remember a phone number and ring it. After this time, the information may be lost or, if considered important enough, moved to your working memory.

'Working table' memory

It is within your working memory that information generally captures your focus and demands attention. There is a limited capacity (amount of information dealt with) and time limit for this type of memory. Research suggests that this capacity changes with age. Between the ages of 5 and 14 years there is a range of about 3–5 'chunks' that can be dealt with at one time; after this age it increases to about 5–7 chunks. This limited capacity is one of the reasons why you need to memorise songs, poems or other information in stages. By memorising a few lines at a time and repeating them (or rehearsing them) you are able to increase the number of items in your working memory. This is an example of chunking.

Studies have suggested that the time limit in working memory is about 10–20 minutes. This is often the amount of time you can spend on one activity. This time, however, can be influenced by interest and motivation. Both of these can have emotional elements and also involve a special part of your brain called the **amygdala**.

Long-term memory

Even if information has made it through your sensory register, it doesn't mean that you will remember it. You will remember information only if you have stored it in **long-term storage** (shown in figure 2.25 as a filing cabinet). It is the job of your **hippocampus** to encode information and send it to one or more of the long-term storage areas in your brain. This encoding takes time and is usually done during deep sleep.

amygdala emotional centre of the brain that processes primal feelings, such as fear and rage

long-term storage a function of the brain that enables memories to be stored, sorted and retrieved

hippocampus area of the brain stem able to transfer information between short- and long-term memory

Memories are not stored as a whole or in one place. When you retrieve and reconstruct memories, storage areas distributed throughout your brain are activated. While long-term storage can be thought of as *where* your memories are stored in your brain, your long-term memory relates to the dynamic process of *sorting* and *retrieving* the information.

2.9.3 Remember to learn

Your past experiences influence new learning. What you already know acts as a filter to help you focus on things that have meaning and ignore those that don't. Your self-concept (how you see yourself in the world) is also shaped by your past experiences. It is your self-concept that often determines how much attention you will give to new information.

You can transfer things from your short-term memory into your long-term memory by rehearsing information (practising) and applying meaning to it. The two key questions asked in the decision of whether to move information into long-term memory (as shown in figure 2.28) are:

- Does it make sense?
- Does it have meaning?

I don't understand! This is the type of comment made when a learner is having trouble making sense of new learning. Determining whether new information 'makes sense' is related to whether the new information fits in with what you already know.

Why do I have to know this? Whether the new information 'has meaning' relates to whether it is relevant to you and whether you consider that the purpose of remembering it is worthwhile. You can improve the chance that you remember something by making connections between the new learning and your previous knowledge.

FIGURE 2.28 If both sense and meaning are present, there is a very high chance that the information will be sent to long-term storage.

Is meaning present?		Is sense present? No	Is sense present? Yes
	Yes	Moderate to high	Very high
	No	Very low	Moderate to high

2.9.4 Memory aids

Have you used a **mnemonic** in your learning today? A mnemonic is something that helps you to remember something else. It may take the form of a word, poem, story or image. Here are some examples:

- *Tell a tale:* Make up a story using the words or information that you need to learn.
- *Link it:* Link the words or pieces of information together with images.
- *First letter:* Acronyms use the first letters of the words to make a new word. This example shows how this can help you remember some of the memory systems for different types of learning:
  Spatial memory
  Procedural memory
  Episodic memory
  Working memory
  Semantic memory

mnemonic a strategy to help you to remember things

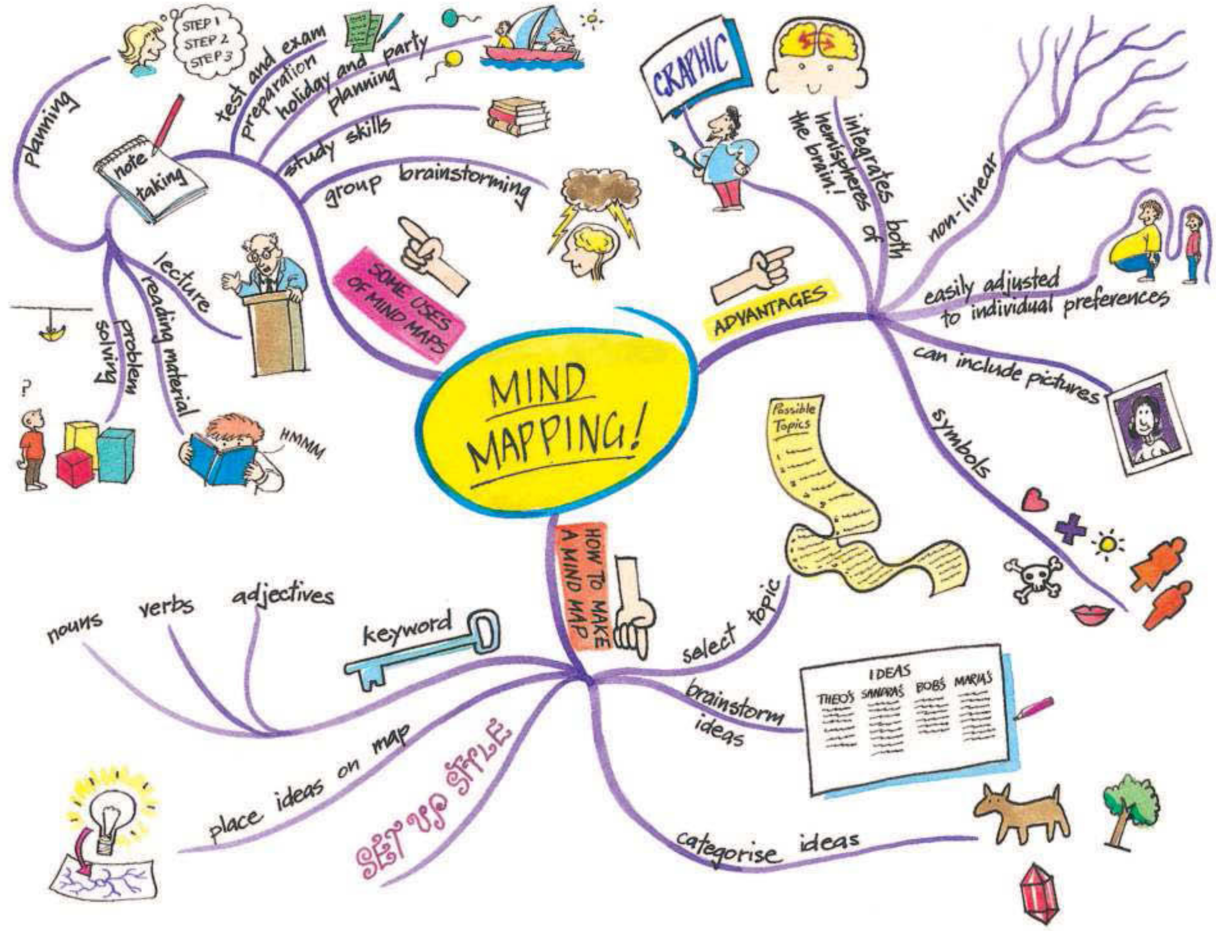
2.9.5 Mind mapping

Mind maps help create memory (learning) in a way similar to that of the brain by presenting information in a visual and connected form. Mind maps contain information in a predigested form that the memory can most easily assimilate and access.

Why use them?

Mind maps appeal to the right side of the brain, which processes colours, relationships, pictures and symbols. Using mind maps can increase your understanding of information and boost your recall of it dramatically.

FIGURE 2.29 Mind mapping can help you find sense and meaning in your learning.



on Resources

assess on Additional automatically marked question sets

2.9 Exercise

learnon

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Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3, 4, 6, 10	Questions 5, 7, 8, 11, 15, 16	Questions 9, 12, 13, 14, 17, 18

Remember and understand

1. Give two reasons scientists use models.
2. What is the key role of the sensory register in the information processing model?
3. Identify the part of the brain involved in transferring information from short-term to long-term memory.
4. Outline the difference between long-term storage and long-term memory.
5. State the approximate capacity and time limits of working memory.
6. List the five different memory systems described in this subtopic.
7. What is a mnemonic? Give an example.
8. State the two questions 'asked' to determine whether information moves into long-term memory.
9. Suggest the advantage of traumatic or emotionally charged events being remembered more deeply.

Apply and analyse

10. Research a chemical that can affect memory and outline its effects.
11. a. Get a pencil and paper and then concentrate on the number below for 7 seconds. After 7 seconds, look away and write the number down. Did you get it right? Compare this with others.

    5167340

    b. Now repeat the procedure with the number below. Did you get it right? Compare this with others and suggest a reason for any differences between results.

    3847918362
12. Although we all use the same senses to collect information from our environment, they do not contribute equally to our learning. Learners develop preferences for certain senses over others. This is where terms such as 'visual', 'auditory' and 'kinaesthetic' learners originate.
    a. Research each of these types of learning and develop a set of questions that can be used to determine which preferences you and others in your class have.
    b. Discuss the impact that these differences can have on your learning.
    c. Suggest how you can use this knowledge to be a more effective learner.
13. Find out the possible effects of the following chemicals on learning: adrenaline, phenylalanine, norepinephrine, calpain and choline.

Evaluate and create

14. Find out more about memory drugs. Construct a PMI chart to summarise and share your opinion.
15. Write a newspaper article, cartoon or blog on ways to improve your memory.
16. Research and report on each of the following statements related to drugs and memory.
    a. Drugs that have an effect on memory should be illegal.
    b. Everyone should have access to drugs that erase memories.
    c. Research on drugs that alter memories should be stopped.
17. Find out more about the information processing model; then, in teams of eight, discuss how you could act it out. Include the following roles: sensory register, immediate memory, working memory, long-term storage (two people), incoming information (three people).
18. Research the structure and function of the thalamus, amygdala or hippocampus and construct a model to communicate your findings to others.

Fully worked solutions and sample responses are available in your digital formats.

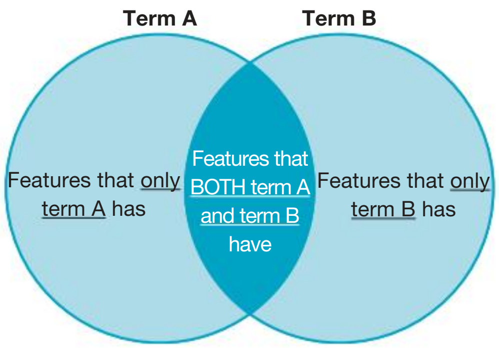
2.10 Thinking tools — Venn diagrams

2.10.1 Tell me

What is a Venn diagram?

A Venn diagram is a useful thinking tool that can show similarities and differences between two separate topics, terms or ideas — for instance, if you were comparing two terms, and you were asked what are the similarities and differences between term A and term B.

FIGURE 2.30 A Venn diagram



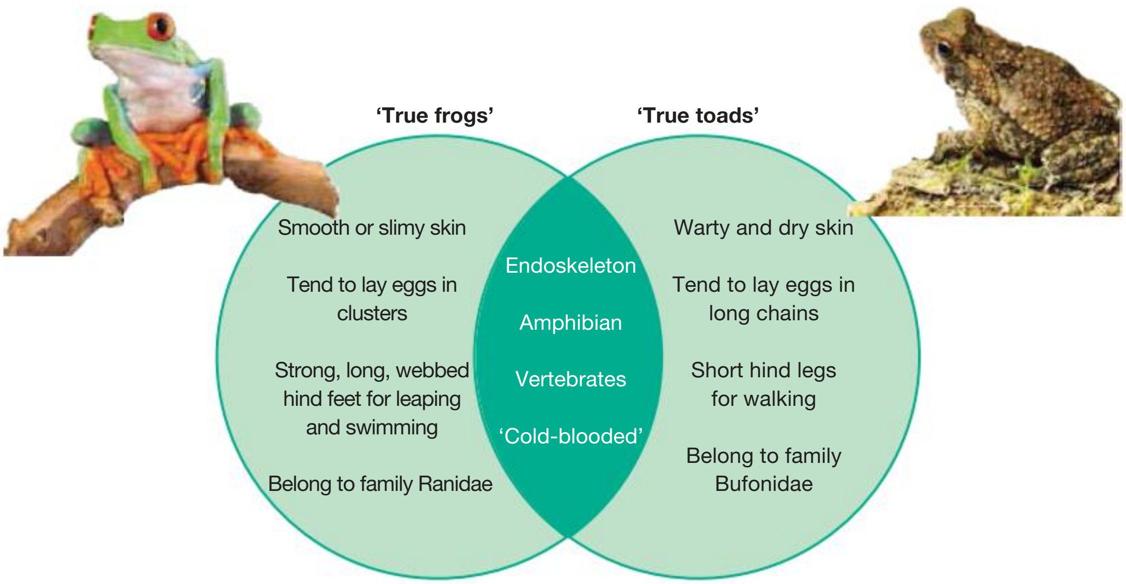
2.10.2 Show me

To create a Venn diagram:

1. draw two circles that overlap in the middle
2. write one of the words that you are comparing above each circle
3. write the things that they have in common in the overlapped middle section
4. write the differences between them in each of the non-overlapped sections.

For example, the Venn diagram in figure 2.31 shows similarities and differences between frogs and toads.

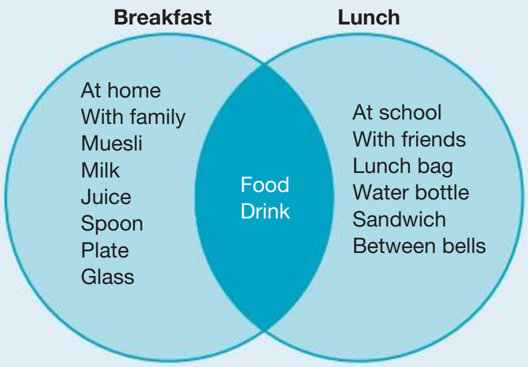
FIGURE 2.31 A Venn diagram of frogs and toads



2.10.3 Let me do it

2.10 ACTIVITIES

1. Using the Venn diagram provided construct your own Venn diagram about your breakfast and lunch during school days.



2. Construct Venn diagrams on the following topics:
   a. 'school day activities' and 'weekend activities'
   b. 'books' and 'movies'
   c. 'fruits' and 'vegetables'.
3. Research the meanings of the words below and then construct a Venn diagram to show similarities and differences between them.
   a. 'chlorophyll' and 'chloroplast'
   b. 'leucocyte' and 'erythrocyte'
   c. 'prefix' and 'suffix'
   d. 'endoparasite' and 'ectoparasite'
   e. 'cilia' and 'flagella'
   f. 'plant cells' and 'animal cells'
   g. 'vertebrates' and 'invertebrates'
4. a. Carefully observe the information in the following boxes, then construct Venn diagrams to compare the different types of dinosaurs.

Microceratops
- Name means 'small-horned face'
- Only 76 cm long
- Lived about 83–65 million years ago

Heterodontosaurus
- Name means 'different-toothed lizard'
- Had three types of teeth
- 2.2 m long
- Lived about 208–200 million years ago

Pentaceratops
- Name means 'five-horned face'
- Had three horns on its head
- 8 m long
- Lived about 75–65 million years ago

Triceratops
- Name means 'three-horned face'
- 'Frilled' dinosaur
- Had three horns on its head
- 8 m long
- Lived about 75–65 million years ago

Microdontosaurus
- Name means 'tiny-toothed lizard'
- 8 m long
- Lived about 75–65 million years ago

   i. *Microceratops and Triceratops*
   ii. *Triceratops* and *Pentaceratops*
   iii. *Microdontosaurus* and *Heterodontosaurus*
   iv. *Microdontosaurus* and *Microceratops*

   b. Suggest the meanings of the prefixes *micro, tri, penta* and *hetero*.
   c. What do you think the prefix *donto* might refer to? Justify your response.

Fully worked solutions and sample responses are available in your digital formats.

2.11 Review

Access your topic review eWorkbooks

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-5224	ewbk-5226	ewbk-5228

on Resources

2.11.1 Summary

Problem solving with thinking hats

- The coloured thinking hats can be used to tackle problems from six different directions.
- Each coloured hat corresponds to a different type of thinking:
  - White: What are the facts?
  - Black: What's wrong with this?
  - Blue: What thinking is needed?
  - Red: What do I feel about this?
  - Yellow: What are the good points?
  - Green: What new ideas are possible?

The language of understanding

- The following words can be used to assess your own knowledge or understanding of a concept:
  - Apply — How and where can I use this knowledge?
  - Explain — Why is it so? How does it work?
  - Self-knowledge — What are my weaknesses? How do I best learn?
  - Interpret — What does this mean?
  - Perspective — Is it reasonable? Whose point of view is this?
  - Empathy — What are others aware of that I am missing?
- Questions can be classified as 'skinny' or 'fat'. 'Skinny' questions require only a brief, simple response; whereas 'fat' questions are deeper, requiring more time to think through.

At first glance

- Rapport is initiated by nonverbal signs such as eye contact, mirroring behaviour, posture and breathing.
- The three Ps of listening skills are:
  - Pause
  - Probe
  - Paraphrase.

  When you are listening you should use these to ensure you are comprehending what the other person is saying to you.

Coded communication

- Interpersonal communication is the transmission of information between two people.
- The sender encodes the message and the receiver decodes the message.
- Communication can be both verbal and nonverbal.
- Verbal communication includes what we say and how we say it.
- Nonverbal communication involves all forms of communication that are not spoken. This includes body language, movements and expressions.

Telling tales

- Stories are useful ways of communicating messages because they can stick in the memory better than direct messages.
- Fables are stories that contain a moral. The moral is a lesson that is demonstrated within the story. An example is *The Ugly Duckling*, which contains the moral that we should accept who we are and not feel the need to conform to be something we are not.

Cartoon quest

- Cartoons are another useful storytelling device that can be used to communicate messages.
- Cartoons allow things to be seen from different perspectives, making them a powerful educational technique.

Unlocking meaning

- We have developed rules within the English language that enable us to determine meaning from seemingly obscure names.
- Prefixes are a letter or group of letters that can be attached to the start of a word to provide meaning. An example is *micro*, which means small.
- Suffixes are a letter or group of letters that can be attached to the end of a word to provide meaning. An example is *saur*, which means lizard.
- Prefixes and suffixes can be combined to provide meaning behind names. For example, dinosaur is the combination of the prefix *dino* (meaning terrifying) and the suffix *saur* (meaning lizard). Put together, dinosaur can be interpreted to mean 'terrifying lizard'.

Total recall?

- Memory is a complex system that changes day by day.
- Our brain uses filtering to determine the importance of the information collected by our senses. This ensures that only important information proceeds to long-term storage.
- The area of the brain that is responsible for long-term storage is the hippocampus.
- Memories are not stored individually in a certain place. Fragments are stored in different places and a memory is retrieved when the brain connects the different fragments along a pathway.
- The two factors that influence whether information is sent to long-term storage are the presence of meaning and the presence of sense. If a piece of information makes sense to you and you can see how it is meaningful, it has a much greater chance of proceeding to long-term storage.

2.11.2 Key terms

amygdala emotional centre of the brain that processes primal feelings, such as fear and rage
first-floor thinkers thinkers who gather information
habits of mind types of thinking behaviours promoted by Bena Kallick and Arthur Costa
hippocampus area of the brain stem able to transfer information between short- and long-term memory
interpersonal communication communication with others
interpersonal intelligences one of the multiple intelligences that involves 'we' learning, which can be developed through team projects, social interactions, debates and games
intrapersonal intelligences one of the multiple intelligences that involves 'I' learning, which can be developed through reflecting, self-assessment and creative expression
kinesics the use of bodily movements or actions to convey a specific meaning or idea
mnemonic a strategy to help you to remember things
long-term storage a function of the brain that enables memories to be stored, sorted and retrieved
paralinguistics how something is said that may modify meaning
prefix letters that are placed at the start of a word to convey a specific meaning
rapport a relationship of mutual trust and understanding
record the first step in forming a memory
reticular activation system a part of the brain that filters incoming information on the basis of importance

retrieve the ability to recall memories
second-floor thinkers thinkers who process information
sensory register a system in the brain that filters incoming information on the basis of importance
store storage of a memory in the appropriate part of the brain
suffix letters that are placed at the end of a word to convey a specific meaning
thalamus part of the brain at the top of the brain stem that passes sensory information to key areas in the brain for processing
thinking hats a thinking tool developed by Edward de Bono using different coloured hats for different types of thinking
third-floor thinkers thinkers who apply information

on Resources

Digital document Key terms glossary (doc-34982)

eWorkbooks Study checklist (ewbk-5217)
Literacy builder (ewbk-5218)
Crossword (ewbk-5220)
Word search (ewbk-5222)

2.11 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 4, 7, 12	Questions 2, 5, 6, 9, 13	Questions 3, 8, 10, 11

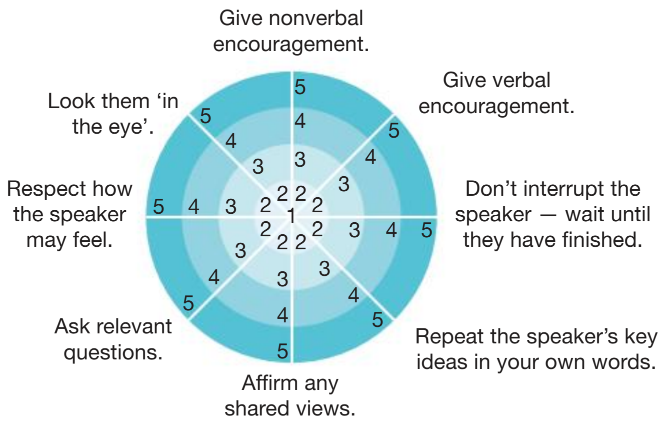
Remember and understand

1. What are the two factors that increase the likelihood of information being sent to long-term storage?
2. Describe the six different thinking hats and their uses.
3. a. Outline the difference between fat and skinny questions.
   b. Provide two examples of each type of question.

Apply and analyse

4. a. Consider the most recent presentation you gave and mark yourself on a scale of 1 to 5 on each of the following points (1 = never and 5 = always).
      - I spoke in a clear voice that communicated the information effectively.
      - I was well organised.
      - I knew the relevant information about my topic and was confident in presenting it.
      - My presentation was interesting and entertaining.
      - I made sure to look at the audience throughout the presentation.
      - I had positive body language and was standing upright.
   b. Describe what you like about how others present information.
   c. From your experiences in presenting and communicating ideas (and observing others), describe things that you could do to be a more effective communicator.

5. Sit with a partner and position yourself ‘Eye-to-Eye and Knee-to-Knee’. This will help you to maintain eye contact and will promote active listening. While positioned this way, take turns to tell each other about the sort of things that you think are important to make a good first impression. Use the active listening wheel below to score how effectively you think you actively listened and then score your partner for their active listening. Discuss what you found easy or difficult, and what you would try next time to enhance your listening skills (1 = never and 5 = always).



6. Use the following table to reflect about yourself (1 = never and 5 = always).

TABLE Matrix for self-reflection

Honest	1	2	3	4	5
Caring	1	2	3	4	5
Creative	1	2	3	4	5
Logical	1	2	3	4	5
Independent	1	2	3	4	5
Cooperative	1	2	3	4	5
Playful	1	2	3	4	5
Adventurous	1	2	3	4	5

7. What are you and what do you prefer ...?

I am a:

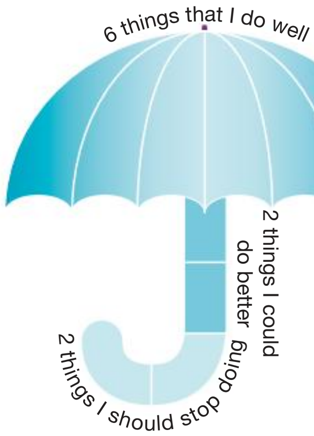
Doer ⟷ Thinker
Night person ⟷ Morning person
Listener ⟷ Talker
Follower ⟷ Leader

I prefer:

Quiet ⟷ Noise
Dark ⟷ Light
To work alone ⟷ To work in teams

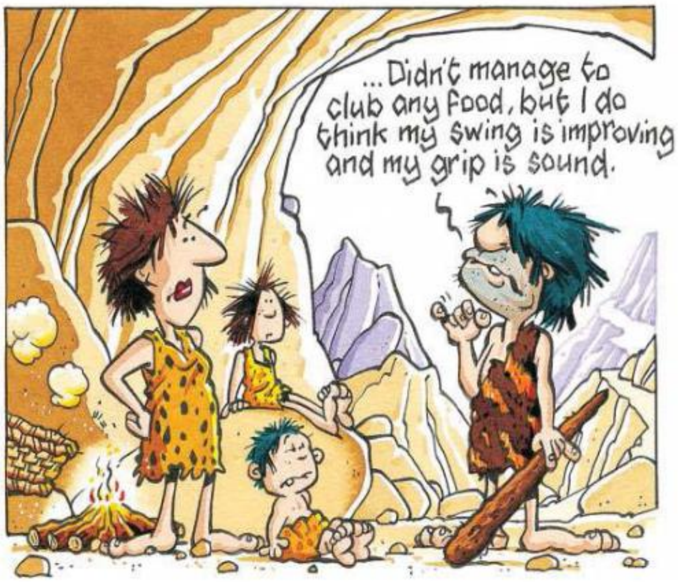
8. Use diagrams and thinking tools to describe yourself in the past, present and future. Explain how and why you arrived there.

9. Use the reflection umbrella to list six things that you do well, two things you could do better and two things that you should stop doing.



Evaluate and create

10. Carefully study the cartoon given.
    a. Paraphrase what the caveman is saying.
    b. Predict what his wife will say in return.
    c. Suggest what the caveman may say to his wife's comment.
    d. Describe a time when you were in a similar situation.
    e. Create your own cartoon to describe a situation in which you effectively learned something.



11. a. Suggest how people remembered and communicated ideas before pen and paper.
    b. What evidence is there that humans have tried to pass knowledge from generation to generation?
    c. Which type of memory system would have been most useful to cave people? Justify your selection with examples.
    d. Suggest examples of inventions that would have been useful to cave people.
    e. Design and construct an 'invention' for cave people. Describe how and when it would be used.

12. a. Undertake this self-analysis reflection by rating the statements on a scale of 0 to 5.
(0 = never; 1 = rarely; 2 = sometimes; 3 = often; 4 = usually; 5 = always)
b. Identify your:
i. top three strengths
ii. lowest three scoring criteria.
c. Suggest how you could go about improving your three lowest scoring criteria.

Criteria	Score
I tried to have an open mind and think flexibly.	0 1 2 3 4 5
I understood what I was to do.	0 1 2 3 4 5
I asked when I was not sure what was expected of me.	0 1 2 3 4 5
I persisted, even when the going was tough.	0 1 2 3 4 5
I used my time effectively.	0 1 2 3 4 5
I was well organised.	0 1 2 3 4 5
I contributed to team discussions.	0 1 2 3 4 5
I encouraged others.	0 1 2 3 4 5
I actively listened to others.	0 1 2 3 4 5

13. Complete the following sentence. The most important thing that I learned during this topic was …

Fully worked solutions and sample responses are available in your digital formats.

Resources

eWorkbooks Personal learning (ewbk-5210)
Reflecting on individual and group activities (ewbk-5211)
Reflection (ewbk-3038)

teachon

Test maker
Create customised assessments from our extensive range of questions, including teacher-quarantined questions.
Access the assignments section in learnON to begin creating and assigning assessments to students.

RESOURCE SUMMARY

on Resources

Below is a full list of **rich resources** available online for this topic. These resources are designed to bring ideas to life, to promote deep and lasting learning and to support the different learning needs of each individual.

2.1 Overview

eWorkbooks
- Topic 2 eWorkbook (ewbk-5212)
- Student learning matrix (ewbk-5214)
- Starter activity (ewbk-5215)

2.2 Problem solving with thinking hats

eWorkbook
- Thinking keys (ewbk-5236)

2.4 At first glance

Video eLesson
- This car workshop owner is showing good listening skills when talking with a customer (eles-2563)

2.5 Coded communication

Video eLesson
- What nonverbal communication is this woman showing? (eles-2564)

2.9 Total recall?

Video eLessons
- Teen brain (eles-0224)
- Neural activity in the brain (eles-2565)

2.11 Review

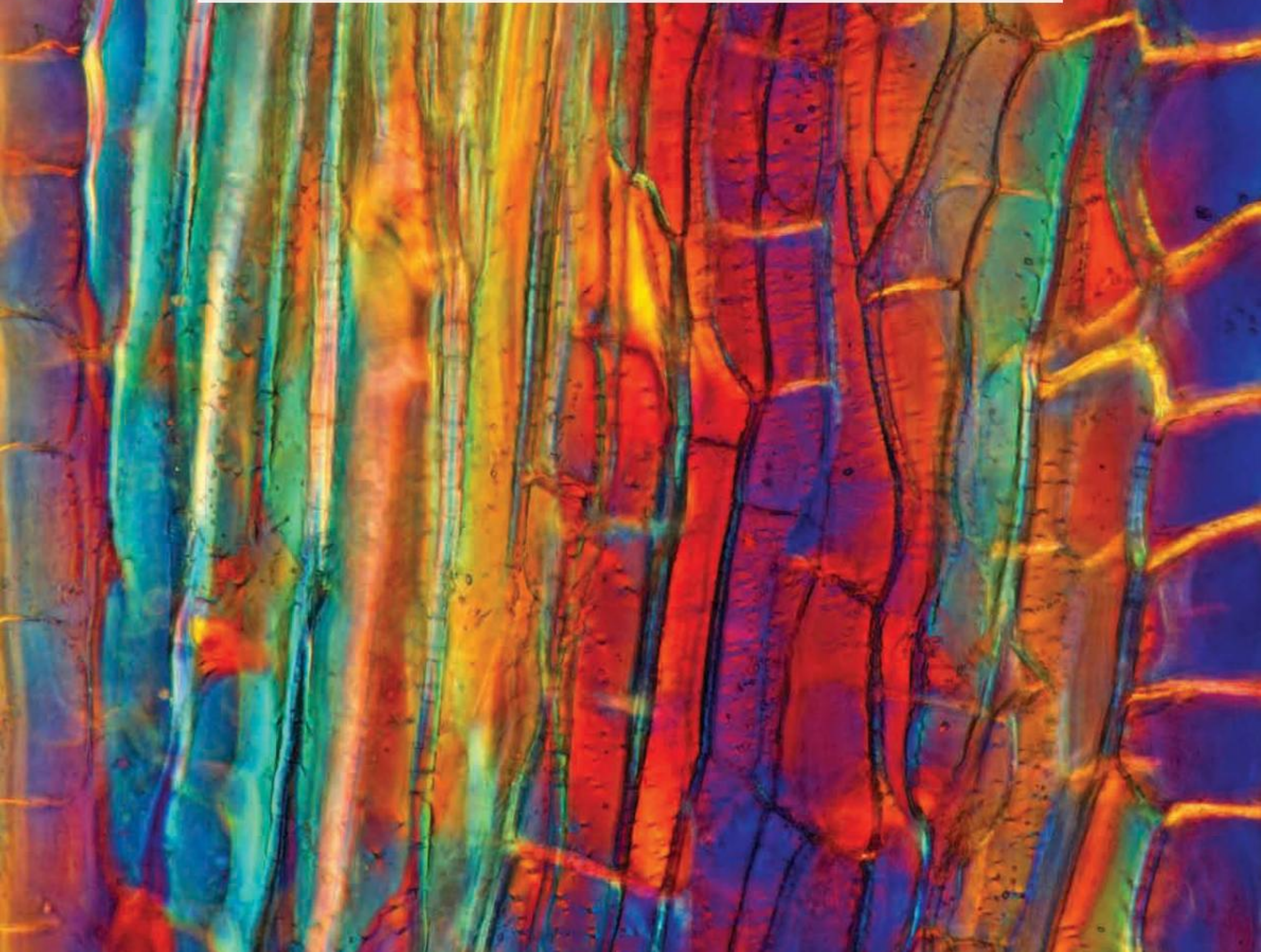
Digital document
- Key terms glossary (doc-34982)

eWorkbooks
- Topic review Level 1 (ewbk-5224)
- Topic review Level 2 (ewbk-5226)
- Topic review Level 3 (ewbk-5228)
- Study checklist (ewbk-5217)
- Literacy builder (ewbk-5218)
- Crossword (ewbk-5220)
- Word search (ewbk-5222)
- Personal learning (ewbk-5210)
- Reflecting on individual and group activities (ewbk-5211)
- Reflection (ewbk-3038)

To access these online resources, log on to **www.jacplus.com.au**.

3 Cells — the basic units of life

LEARNING SEQUENCE



3.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

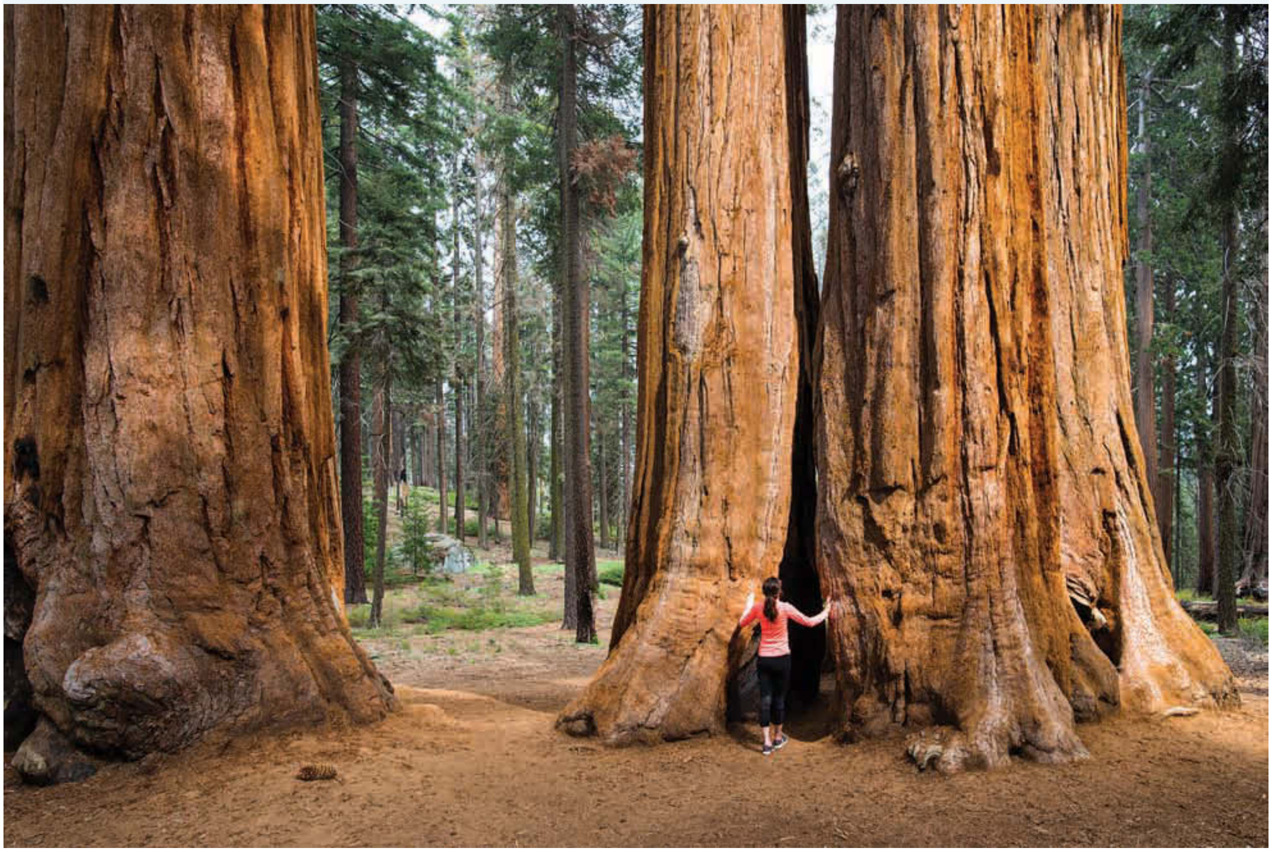
3.1.1 Introduction

Cells are the basic units of all living things. The first cell appeared on Earth about 3.6 billion years ago. Bacteria living near hydrothermal vents in our oceans may share some similar features to these ancestral cells. The cellular machinery within each of these bacteria enables them to survive extremely high temperatures and to derive their energy from minerals and chemical laden superheated liquid that spews from the vents.

On Earth today, there are many different types of organisms. Some of these organisms are made up of a single cell (unicellular) like those of bacteria mentioned earlier, while others are made up of many cells (multicellular). The evolutionary twists and turns taken from these single-celled organisms to the largest ever land animals, the sauropod dinosaurs, or to the tallest tree, the giant sequoia, *Sequoiadendron giganteum*, or the largest colony of fungus, the humongous fungus (*Armillaria ostoyae*) spanning 8.9 square kilometres in Oregon, have been plentiful.

The cells that make up organisms differ not just in their number, but also in their size, shape, and contents. The cell that makes up one type of unicellular organism may be different from that of another type of unicellular organism. The cells that make up multicellular organisms are also different. The structure of different types of cells and how they are organised within multicellular organisms are well suited to their specific tasks within the organism. No matter the difference, the features of the cell(s) that make up organisms all share the ultimate goal — to keep the organism alive.

FIGURE 3.1 *Sequoiadendron giganteum*. The oldest tree of this species was over 3200 years making it one of the oldest living organisms. They grow to an average height of 50–85 metres, with trunk diameters ranging 6–8 metres.



on Resources

Video eLesson Robert Hooke and cells (eles-1780)

Watch this video from 'The story of science' to see how microscopes allowed us to understand that every organism on Earth is composed of cells.

3.1.2 Think about cells

1. How can you make small things look bigger?
2. Which are bigger: viruses or bacteria?
3. What does Theodor Schwann have to do with cells?
4. Why are beaches tested for the presence of bacteria *E. coli*?
5. How does a cell become a clone?
6. Why don't all cells look the same?

3.1.3 Science inquiry

Who am I?

Microscopes are responsible for opening a whole new world to us. They have allowed us to see beyond our own vision. The more developed these microscopes become, the more detail and wonder we are able to observe — but often, rather than answering our questions, they provide us with many more.

The three photos in figure 3.2 show parts of different animals. They were taken with a scanning electron microscope, which allows us to see more detail of the surface of specimens.

FIGURE 3.2 Different animal parts taken with a scanning electron microscope

Observe, think and share

1. Look carefully at the photos of each animal part in figure 3.2, and think about:
   a. what they could be
   b. what they may do
   c. what animal they may belong to.
2. Talk through your suggestions with a partner, adding all of the details that you have both observed onto a sheet of paper.
3. Two of these photos show parts of one type of animal, and the other image is from a different animal. Does that information change the way that you look at the details? Which animal do you think two of the parts belong to? Brainstorm to decide which animal the other part could belong to.
4. Suggest other sorts of information that may be helpful in determining which animals these parts belong to and what they are used for.

on Resources

eWorkbooks	Topic 3 eWorkbook (ewbk-4065) Student learning matrix (ewbk-4088) Starter activity (ewbk-4067)
Practical investigation eLogbook	Topic 3 Practical investigation eLogbook (elog-0431)
learnon	Access and answer an online Pre-test and receive **immediate corrective feedback** and **fully worked solutions** for all questions.

3.2 A whole new world

LEARNING INTENTION

At the end of this subtopic you will understand that our knowledge and understanding of cells has improved as a result of continued scientific investigation, human inventions and technological advancement. This work by scientists lead to the creation of scientific theories such as the cell theory.

Science as a human endeavour

3.2.1 The discovery of cells

A whole new world was discovered just over 400 years ago when an English inventor and scientist used magnifying lenses to observe the basic units of which all living things are made. This led to a new way of thinking about living things that required a new scientific language, new classifications and new inventions to find out more about this new world.

In the seventeenth century, Robert Hooke looked at thin slices of cork under a **microscope** that he had made himself from lenses. He observed small box-like shapes inside the cork. He called the little boxes that he saw **cells**. Microscopes opened up a whole new world that had never been seen before.

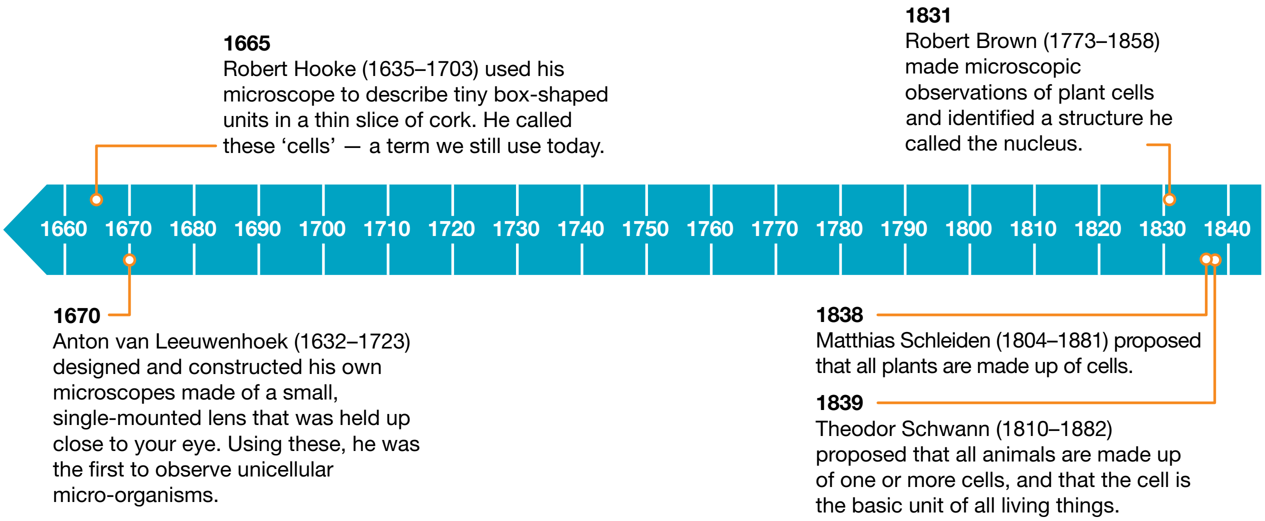
microscope an instrument for viewing small objects

cell the smallest unit of life. Cells are the building blocks of living things. There are many different sizes and shapes of cells.

cell theory a theory that states that all living things are made up of cells and that all cells come from pre-existing cells

int-3392

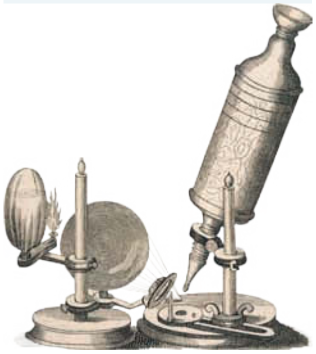
FIGURE 3.3 Timeline showing the development of microscope and **cell theory**



Using microscopes to carefully observe different living things showed that they were all made up of cells. Observations also showed that many of these cells shared common features, such as the presence of a structure called the nucleus.

As the magnification provided by microscopes increased, it was seen that although cells shared similar basic structures, there could also be differences between them. Groups of organisms could be made up of cells that differed from the cells of other groups. Some organisms were made up of a single cell (unicellular), whereas others were made up of many cells (multicellular). Different types of cells were also observed within an individual multicellular organism.

FIGURE 3.4 An early microscope used by Robert Hooke



Cell theory

1. All organisms are composed of cells.
2. The cell is the basic unit of structure and organisation in organisms.
3. All cells come from pre-existing cells.

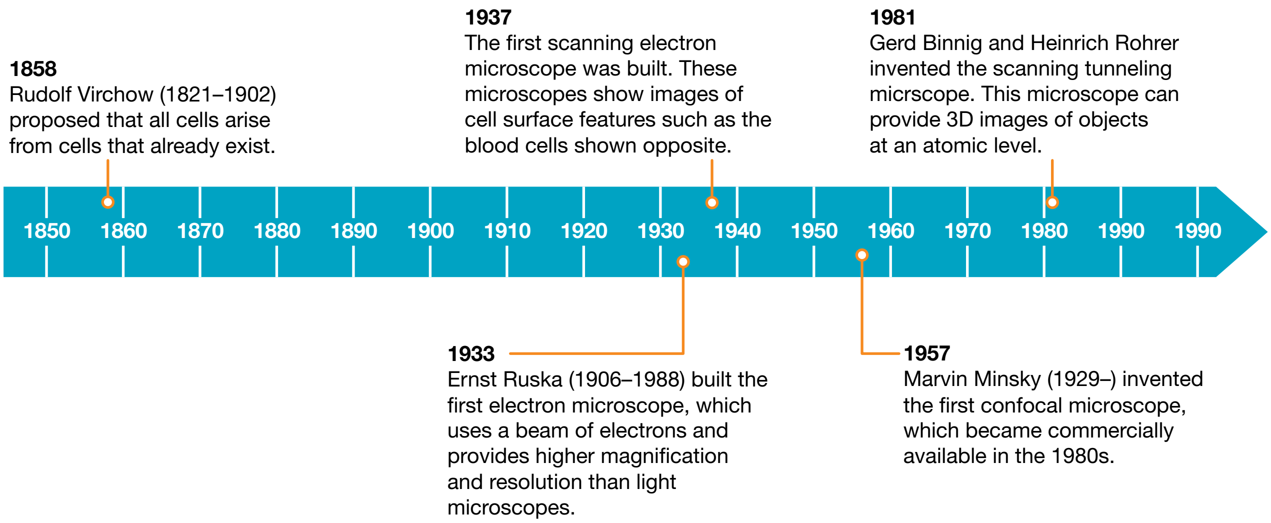
on Resources

Video eLesson Historic bacteriologists Van Leeuwenhoek, Pasteur and Koch (eles-2026)

WHAT DOES IT MEAN?

The word microscope comes from the Greek words *micrós*, meaning 'small', and *skopein*, meaning 'to view'.

FIGURE 3.3 *(continued)*



3.2.2 Little, littler, littlest …

With the development of instruments such as microscopes, scientists needed to find words to describe some of the tiniest lengths and time scales in nature. They wanted some simple names to describe, for example, a billionth of a billionth of a metre.

In the microscopic world, there is often a need to describe things in much smaller terms than the units of measurement that you already know, such as metre, centimetre and millimetre. In describing cells, other units of measurement, such as micrometre (µm, also called micron) and nanometre (nm), are often used.

FIGURE 3.5 Different units of measurement are used to describe different sizes.

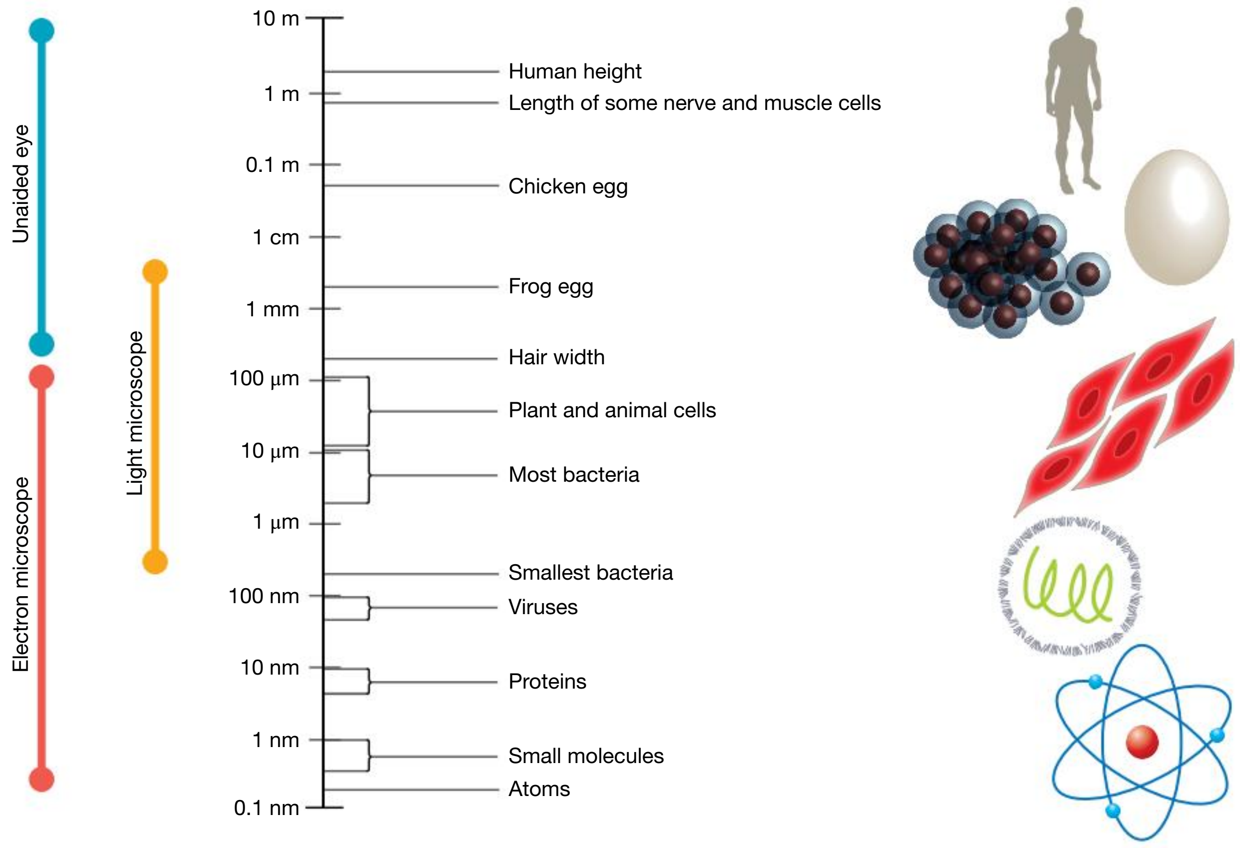


TABLE 3.1 Units of measurement that are often used to describe cells and molecules

Unit	Symbol	No. units in 1 m
Millimetres	mm	1000
Micrometres	µm	1 000 000
Nanometres	nm	1 000 000 000

CASE STUDY: Scientists who study cells

There are many different types of scientists who study cells. Examples include bacteriologists, cell biologists, clinical microbiologists, cytologists, electron microscopists, genetic scientists, medical microbiologists and virologists.

SAMPLE PROBLEM: Evidence-based conclusions

Sam is a virologist, a scientist who studies viruses. In a talk to students, Sam is asked if she uses a microscope to see viruses or if she can see them without using a microscope.
Do you think Sam would need a microscope to see a virus? Use evidence to support your conclusion.

THINK

- Viruses are between 50 and 100 nm in size.
- The naked eye can only see things that are greater than 100 μm (or 100 000 nm).
- Since viruses are much smaller than 100 μm, Sam must use a microscope to see the virus.
- Sam would need to use an electron microscope.

WRITE

Sam would need to use a (electron) microscope as viruses are much too small to be seen with the naked eye. Viruses are less than 100 nm in size and the naked eye can only see things that are bigger than 100 000 nm (100 μm).

3.2.3 Present day

A new generation of three-dimensional microscopes are being developed that provide even further details of objects. Superfast electron microscopes enable scientists to capture movement of atoms. Newly invented portable microscopes are becoming important field tools in research and diagnosis of diseases.

FIGURE 3.6 a. Portable microscope for spotting and tracking disease **b.** Looking like a grotesque eyeball, this handheld microscope magnifies your specimens to two hundred 200 times their normal size.

a.

b.

on Resources

eWorkbook History of the light microscope (ewbk-4053)

assess on Additional automatically marked question sets

3.2 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2	Questions 3, 5	Questions 4, 6

Remember and understand

1. Match the scientist with their cell discovery contribution in the table provided.

Scientist	Cell discovery contribution
a. Anton van Leeuwenhoek	**A.** Built the first electron microscope
b. Robert Hooke	**B.** Proposed that all plants are made up of cells
c. Robert Brown	**C.** Proposed that all animals are made up of cells
d. Matthias Schleiden	**D.** Designed and constructed microscopes and was the first to observe unicellular microscopic organisms
e. Theodor Schwann	**E.** Proposed that all cells arise from cells that already exist
f. Rudolf Virchow	**F.** Used the term 'cell' to describe the tiny box-like units in cork
g. Ernst Ruska	**G.** Used the term 'nucleus' to describe a structure found in plant cells

2. Identify:
   a. a feature that all living things have in common
   b. two units often used to describe cells.

Apply and analyse

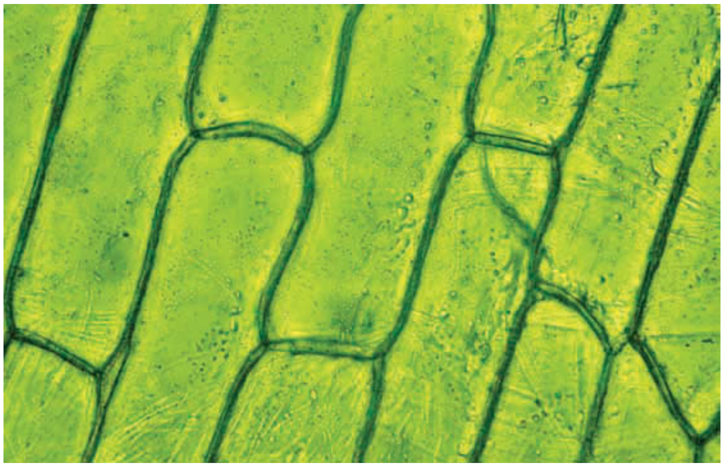
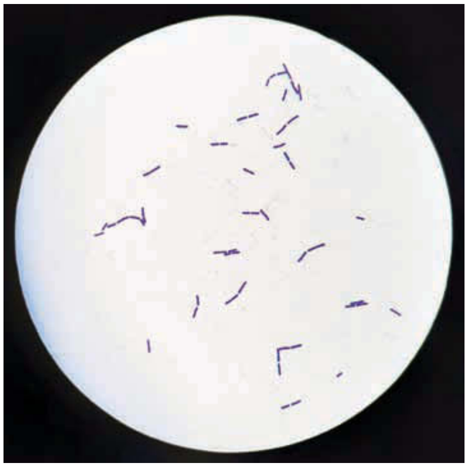
3. Use the timeline in figure 3.3 to answer the following questions.
   a. In which year did Hooke use the term 'cells' to describe his observation of cork slices?
   b. In which year did Ruska build the electron microscope?
   c. How many years were between:
      i. Hooke first using the term 'cells' and Ruska building the first electron microscope
      ii. Leeuwenhoek's first observation of unicellular microscopic organisms and Schwann's suggestion that all animals are made up of cells?
   d. Credit for developing the cell theory that 'all living things are made up of cells and that cells come from pre-existing cells', is usually attributed to three scientists. Who are they?
   e. Suggest how the development of the microscope has contributed to our understanding of cell structure.
   f. Suggest possible uses for portable microscopes.
4. Use figure 3.5 to complete the table.

TABLE Size of different objects in different units

Object	Size in nanometres (nm)	Size in micrometres (μm)	Size in millimetres (mm)
Frog egg			
Hair (width)			
Plant cell		100	
Bacteria		10	
Protein	10		

Evaluate and create

5. SIS A student is presented with two slides with different cells on each. The teacher asks the student to identify which cell is the bacterium and which cell belongs to the plant. They have access to a light microscope and the images are seen here.

   a. Which feature could be used to identify the different cells?
   b. Which cell do you think is the plant cell? Explain why you reached this conclusion.
   c. What data should be collected to support your conclusion in for part b) above?

6. SIS To determine the average size of an elephant skin cell, two methods were suggested. These are outlined below:
   Method 1 required ten Asian and ten African elephants to have one skin sample taken and measured to create an average using a light microscope.
   Method 2 required one Asian and one African elephant to have ten skin samples taken and all of these were used to create the average. These would be measured using a range of light and electron microscopes.
   a. In a table like the one provided, compare and contrast these two methods in terms of accuracy, reliability, validity, and fairness (fair test).

TABLE Comparison of methods to determine cell size

	Method 1	Method 2
Accuracy		
Reliability		
Validity		
Fairness (fair test)		

   b. Create your own experimental design to determine the effect of elephant type on the average size of elephant skin cells. Remember to include:
      i. What will change?
      ii. What will stay the same?
      iii. What will be measured?
      iv. How will the test be reliable?

Fully worked solutions and sample responses are available in your digital formats.

3.3 Focusing on a small world

LEARNING INTENTION

At the end of this subtopic you will be able to identify different types of microscopes, and understand their specific purposes. You will be able to describe how microscopes work.

light microscopes instrument for viewing very small objects. A light microscope can magnify things up to 1500 times.

electron microscopes instrument for viewing very small objects. An electron microscope is much more powerful than a light microscope and can magnify things up to a million times.

monocular microscope a microscope with a single eyepiece through which the specimen is seen using only one eye

binocular microscope a microscope with two eyepieces through which the specimen is seen using both eyes

stereo microscope a type of binocular microscope through which the detail of larger specimens can be observed

Science as a human endeavour

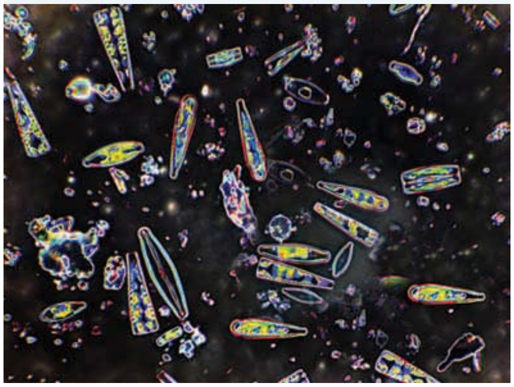
3.3.1 Types of microscopes

The two main types of microscopes are light microscopes and electron microscopes. **Light microscopes** use light rays whereas **electron microscopes** use small particles called electrons to illuminate the specimen being viewed.

Electron microscopes

Transmission electron microscopes (TEM) show the internal structures of cells whereas scanning electron microscopes (SEM) show images of the surface features of the specimen. New electron microscope technologies are being developed, such as superfast electron microscopy, which enables scientists to capture the movement of electrons, and a variety of three-dimensional microscopes that have exciting research and medical applications.

FIGURE 3.7 This electron micrograph shows examples of diatoms, which belong to a group of photosynthetic, single-celled algae.



Light microscopes

You may have light microscopes at your school. These may be either a **monocular microscope** (using one eye) or **binocular microscope** (using two eyes). It is important that the specimen you observe is very thin, so that the light can pass through it. However, one type of binocular microscope, a **stereo microscope**, allows you to see the detail of much larger specimens. Stereo microscopes can be used to observe various objects including living organisms or parts of them.

FIGURE 3.8 What's in your water? These images show zooplankton viewed through a scanning electron microscope. **a.** Chaetognath **b.** Daphnia **c.** A rotifer

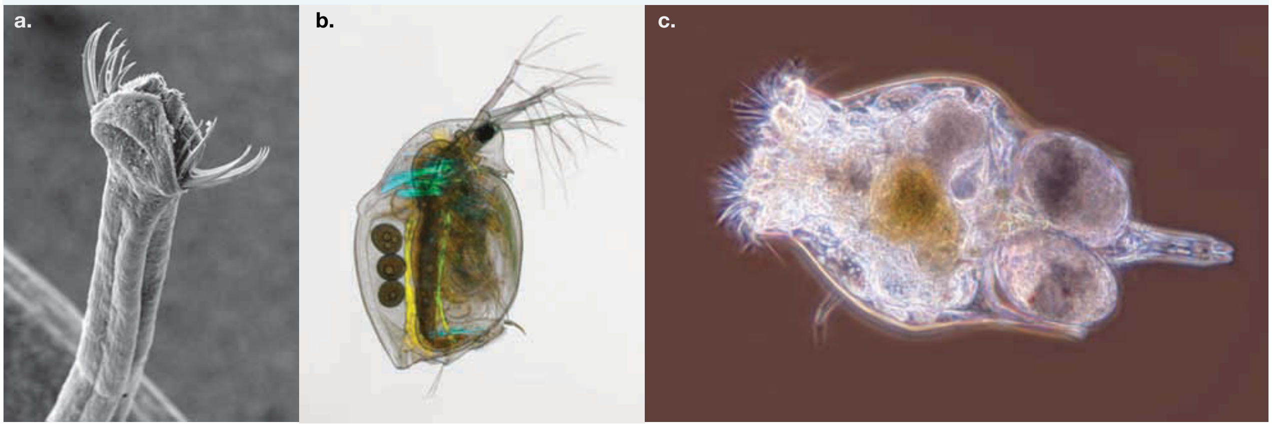


FIGURE 3.9 Scanning electron microscope

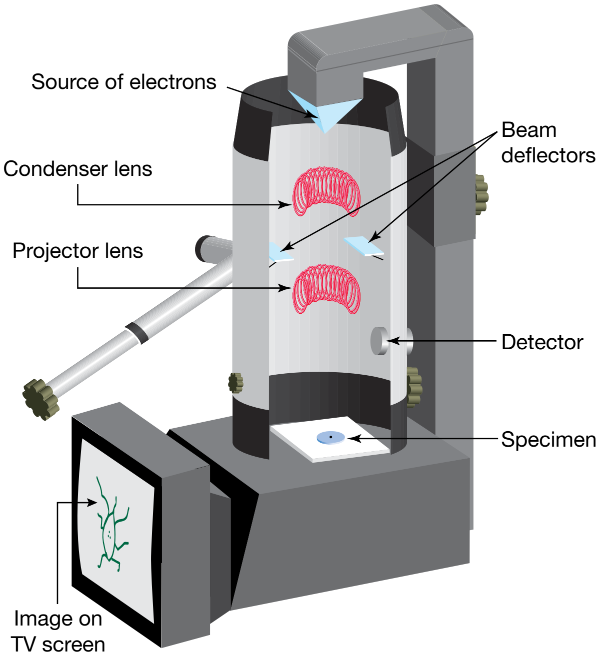
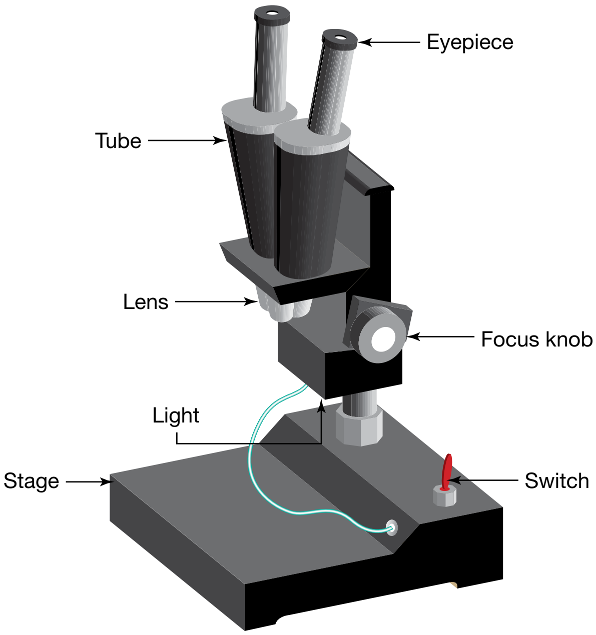


FIGURE 3.10 Stereo light microscope



Comparing microscopes

TABLE 3.2 Some comparisons between light microscopes and electron microscopes

Type of microscope	Magnification (how many times bigger)	Resolution (how much detail can be seen)	Advantage(s)	Disadvantage(s)	Examples of detail that can be seen
Light microscope	Up to × 2000	Up to about 500 times better than the human eye	Samples prepared quickly; coloured stains can be used; living cells can be viewed	Limited visible detail	Shapes of cells; some structures inside cells, e.g. nucleus and chloroplasts
Electron microscope	Up to × 2 000 000	Up to about 5 million times better than the human eye	High magnification and resolution	Only dead sections can be viewed; specimen preparation is difficult; very expensive	All parts of cells; viruses

3.3.2 Award-winning images

Microscopes are used not just to observe images of organisms, but also in many other areas of science. Some microscope images win awards recognising not just expertise but also creativity. For example, the Nikon Small World Photomicrography Competition invites photographers and scientists to submit images of all things visible under a microscope. The figures shown examples of some of the 2019 winner and honourable mentions.

FIGURE 3.11 Turtle embryo imaged with fluorescence and stereo microscopy

FIGURE 3.12 Alligator embryo developing nerves and skeleton

FIGURE 3.13 Small white-hair spider

FIGURE 3.14 The heart of a geranium dissectum

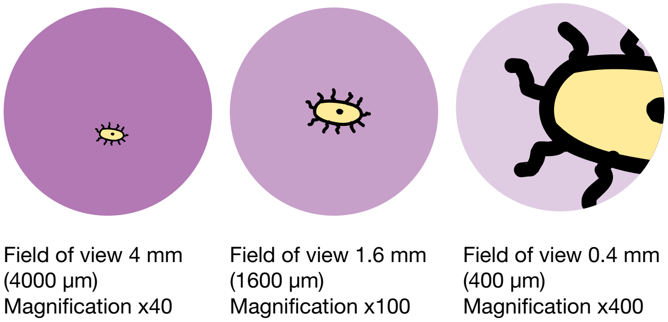
3.3.3 Magnification

The two lenses that determine the **magnification** of your microscope are the eyepiece lens and the objective lens. Each lens has a number on it that signifies its magnification. Multiplying the eyepiece number by the objective lens number will give you the magnification of the microscope. For example:

- eyepiece lens (ocular) magnification is ×10
- objective lenses magnification is ×40
- the total magnification of the microscope is = ×400.

int-5702

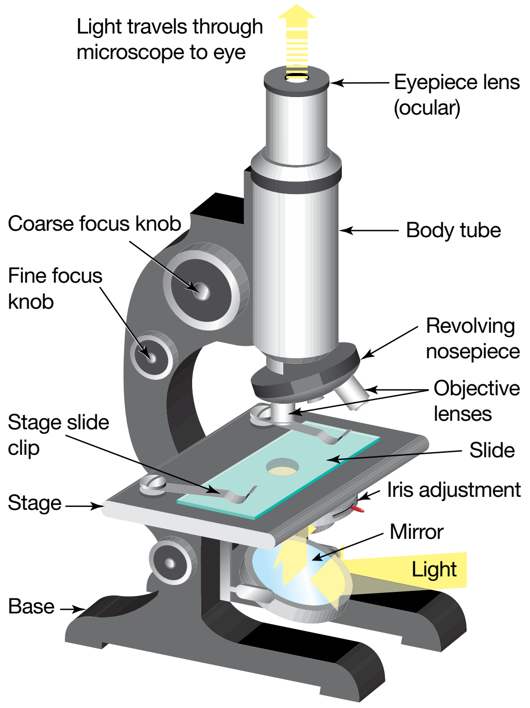
FIGURE 3.15 As the field of view gets smaller, the magnification gets larger.



magnification the number of times the image of an object has been enlarged using a lens or lens system. For example, a magnification of two means the object has been enlarged to twice its actual size.

int-3390

FIGURE 3.16 The monocular light microscope



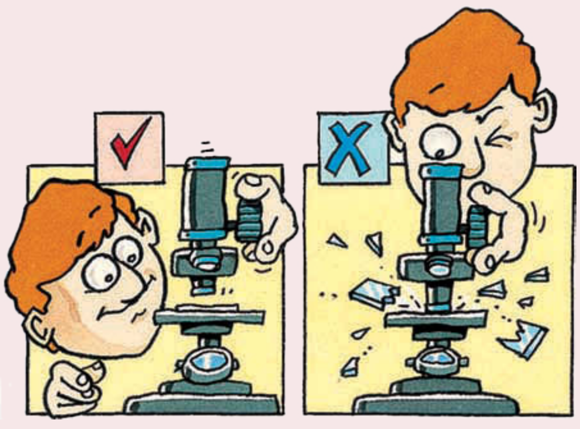
Important points to remember when using a microscope

1. When lifting the microscope, put one hand on the body of the microscope and one hand under its base.
2. The microscope should be used on a flat surface and not too close to the edge.
3. Take care that the light intensity is not too high, or it might damage your eye.
4. When you have finished using the microscope, return the shortest objective lens into position.
5. Remove the slide, and ensure that the stage is clean.
6. Make sure that when your microscope is not in use, it is always clean and carefully put away.

Using a microscope

1. Adjust your mirror so the appropriate amount of light passes through the hole in the stage.
2. Place the glass microscope slide (with a single hair specimen on top) onto the stage.
3. While watching from the side, use the coarse focus knob to adjust the objective lens or stage, until they are just apart, or just above the slide. Moving it too close may shatter the slide.
4. While looking through the eyepiece lens, carefully turn the coarse focus knob, moving the stage and objective lens apart, until the specimen is seen clearly.
5. Carefully use the fine focus knob so that you can see the details of your specimen as clearly as possible. Each time you change the objective lens, adjust only with the fine focus knob.
6. Sketch what you see.
7. Suggest by how many times your specimen has been magnified.

FIGURE 3.17 How to focus your microscope — and how not to!



elog-0390

INVESTIGATION 3.1

Getting into focus with an 'e'

Aim

To practise focusing a monocular light microscope

Materials

- 1 cm square piece of newsprint containing the letter 'e'
- monocular light microscope
- microscope slide
- clear sticky tape
- 1 cm square piece of a coloured magazine or newspaper picture
- hair strands (from different individuals)
- spatula
- selection of white powders and crystals (e.g. flour, salt, sugar, baking soda)
- different brands or types of spices and leaf tea
- fibres (e.g. cotton, linen, silk, wool, nylon)

Method

1. Carefully stick the 1 cm square of newsprint onto a clean microscope slide using sticky tape.
2. Using the microscope directions, get the paper into focus using the coarse focus knob and the lowest power objective lens (smallest magnification).
3. Carefully move the slide until you have a letter 'e' in focus.
4. Change to a higher level of magnification by rotating to a higher power objective lens.
5. Draw a sketch of what you see under x100 or x400 magnification in the results section. Remember not to shade the image, outline only.
6. Record how many e's would fit across the field of view. Use this to estimate the size of the 'e' by dividing the size of the field of view by the number of e's that would fit across the field of view.
7. Move the slide towards you. Record which direction the 'e' moves.
8. Move the slide to the left. Record which direction the 'e' moves.
9. Using sticky tape, stick a selection of sample specimens onto microscope slides.
10. Repeat steps 2–6 for each specimen.

Results

1. In which direction did the paper under the microscope move when you moved the slide (a) towards you and (b) to the left?
2. What does the letter 'e' look like under the microscope? Draw a pencil sketch of what you see.
3. Record the magnification that you use and estimate how much of the viewed area is covered by the letter 'e' at this magnification.
4. View your taped specimens using low power under the microscope and record your observations. Include detailed descriptions, the magnification used and an estimate of size next to your diagrams.

Discussion

1. Did changing the magnification change the amount of detail you could see on the 'e' and the specimens?
2. What occurred when the slide was moved (a) towards you and (b) to the left? Can you suggest a reason for this? (*Hint*: Look at how a light microscope works.)
3. Suggest what the letters 'P' and 'R' would look like under the microscope.
4. Summarise your microscopic observations of the sample specimens. Identify ways in which they were similar and ways in which they were different.
5. Propose a research question that you could explore using a light microscope, and describe how you could investigate it.

Conclusion

On the basis of your experience, suggest advantages and disadvantages associated with light microscopes.

Resources

eWorkbook In focus (ewbk-4055)

assesson Additional automatically marked question sets

3.3 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3, 10, 12, 13	Questions 4, 7, 8, 9, 14	Questions 5, 6, 11, 15

Remember and understand

1. Identify whether the following statements are true or false. Justify any false responses.

Statement	True or false
a. A light microscope can produce a greater magnification than an electron microscope.	
b. Only dead sections can be viewed on an electron microscope.	
c. Viruses can be viewed on a light microscope.	
d. Resolution refers to how many times bigger a specimen is, whereas magnification refers to how much detail you can see.	
e. More detail can be seen in thicker specimens when using a monocular light microscope.	

2. Suggest why it is important not to have the light intensity setting too high on a light microscope.
3. Explain the importance of watching from the side of the microscope while using the coarse focus knob.
4. As the field of view of your microscope gets smaller, what happens to the magnification?
5. When you are looking down the microscope, what happens when you move the microscope slide
   a. to the left
   b. to the right
   c. towards you
   d. away from you?

Apply and analyse

6. Use figure 3.15 to answer the following questions. (*Note*: 1000 μm = 1 mm)
   a. Estimate the length of the specimen shown in the diagram at ×40, ×100 and ×400 magnification.
   b. Describe the differences in your observations of the three different magnifications.
7. Create Venn diagrams to distinguish between:
   a. a monocular microscope and a stereo microscope
   b. a light microscope and an electron microscope
   c. a transmission electron microscope and a scanning electron microscope
   d. resolution and magnification
   e. field of view and magnification.
8. If a specimen is 1 mm in length, how big will it appear if it is magnified ×100?
9. If a specimen takes up the entire field of view at ×100, how much of it will be seen at ×400?
10. **a.** Sketch a line diagram or take a photo of your microscope and label as many of its parts as you can, using figure 3.16.
    b. Compare your labelled microscope figure with figure 3.16.

11. Copy and complete the table provided.

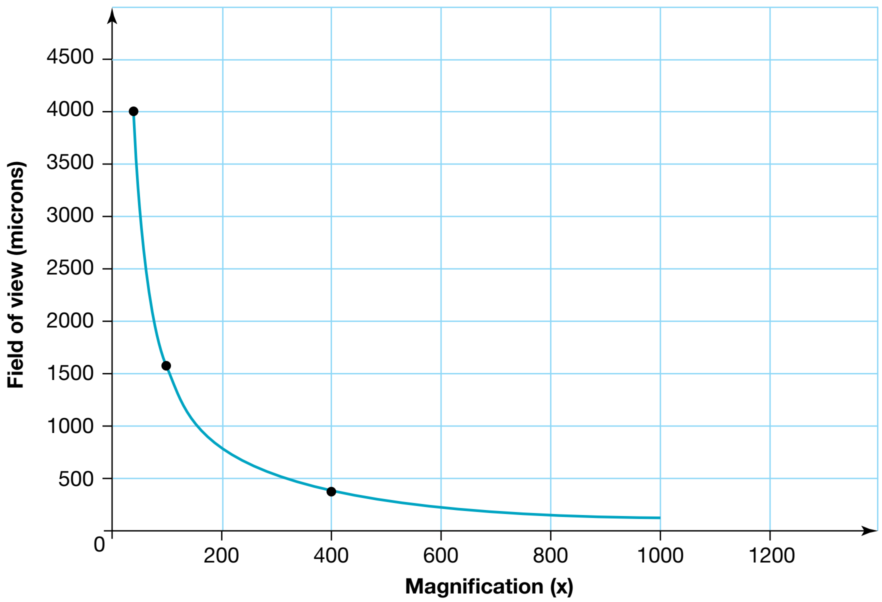
Ocular lens (eyepiece)	Objective lens	Magnification
×5	×5	×25
×5	×10	
×10		×100
	×40	×400

12. Match the part of the microscope with its function.

Part	Function
a. Objective lens	**A.** Where the slide is placed
b. Slide	**B.** Thin piece of glass where the specimen is placed
c. Stage clip slide	**C.** Magnifies the image
d. Iris adjustment	**D.** Allows large adjustments to the distance between the stage and objective lens, which helps bring images into focus
e. Coarse focus knob	**E.** Adjusts the amount of light reaching the eyepiece
f. Stage	**F.** Allows small adjustments to the distance between the stage and the objective lens, which helps bring the image into closer focus
g. Fine focus knob	**G.** Holds the slide in place

Evaluate and create

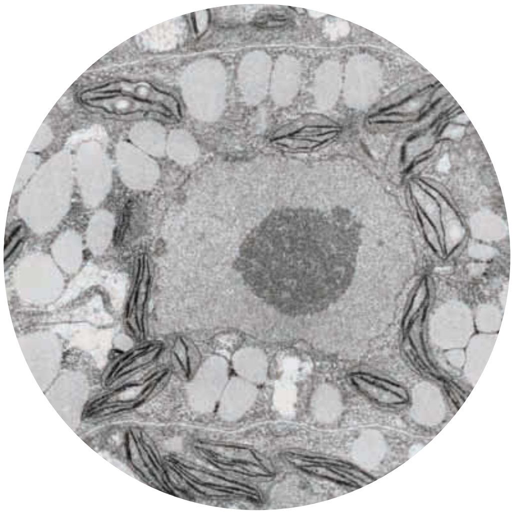
13. Design and make a poster that shows either how a microscope should be used or what happens when you use it the wrong way.
14. **SIS** This graph shows how the field of view changes with magnification under a light microscope.



a. This graph is missing a title. How would you title this graph?
b. Some light microscopes have an additional objective lens called an oil immersion lens. This can magnify x100.
  i. Assuming the eyepiece is x10, what would the total magnification be if you were using this lens?
  ii. Use the graph to determine how big the field of view would be.
c. The oil immersion lens increases resolution. What does the term resolution mean?

15. SIS Determine which of the following plant cell images, a or b, is taken with a light microscope and which is taken with an electron microscope. Use evidence from the images to support your conclusion.

a.



b.

Fully worked solutions and sample responses are available in your digital formats.

3.4 Form and function — Cell make-up

LEARNING INTENTION

At the end of this subtopic you will recognise that some organisms consist of a single cell. You will also identify structures within cells and describe their function.

3.4.1 Similar, but different

Cells are the building blocks that make up all living things. Organisms may be made up of one cell (**unicellular**) or many cells (**multicellular**). These cells contain small structures called **organelles** that have particular jobs within the cell and function together to keep the organism alive.

unicellular made up of only one cell

multicellular made up of many cells

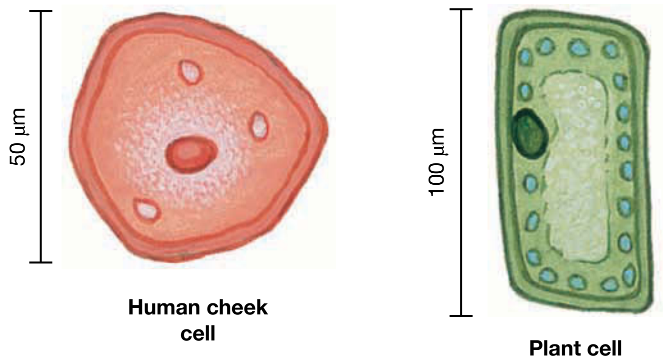
organelles any specialised structure in a cell that performs a specific function

Cells can be categorised on the basis of the presence and absence of particular organelles and other structural differences. Organisms can be classified by the different types of cells they are made up of.

How big is small?

The size of cells may vary between organisms and within a multicellular organism. Most cells are too small to be seen without a microscope. Cells need to be very small because they have to be able to quickly take in substances they need and remove wastes and other substances. The bigger a cell is, the longer this process would take.

FIGURE 3.18 The most commonly used unit is the micrometre (μm).



Very small units of measurement are used to describe the size of cells. The most commonly used unit is the **micrometre** (µm). One micrometre equals one millionth (1/1 000 000) of a metre or one thousandth (1/1000) of a millimetre. Check out your ruler to get an idea of how small this is! Most cells are in the range of 1 µm (bacteria) to 100 µm (plant cells).

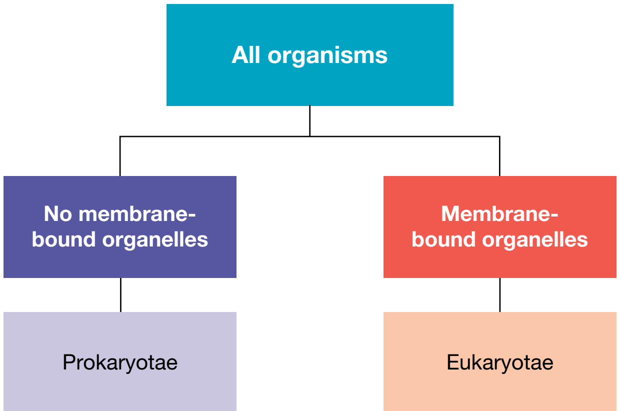
Advances in technology are creating an increased need for the use of the **nanometre** (nm) as a unit. One nanometre equals 1 billionth (1/1 000 000 000) of a metre. Investigating the organelles within cells and the molecules they react with requires this level of measurement.

Nanotechnology is a rapidly developing field that includes studying and investigating cells at this 'nano level'. While it requires lots of creative, exciting and futuristic 'what if' thinking, it also involves an understanding of the basics of information and ideas that are currently known.

3.4.2 Have it or not?

Prokaryotes such as bacteria were the first type of organism to appear on Earth. The key difference between prokaryotes and all other kingdoms is that members of this group do not contain a nucleus or other membrane-bound organelles. The word prokaryote comes from the Greek terms *pro*, meaning 'before', and *karyon*, meaning 'nut, kernel or fruit stone', referring to the cell nucleus.

FIGURE 3.19 Prokaryotes and eukaryotes



micrometre one millionth of a metre

nanometre one billionth of a metre

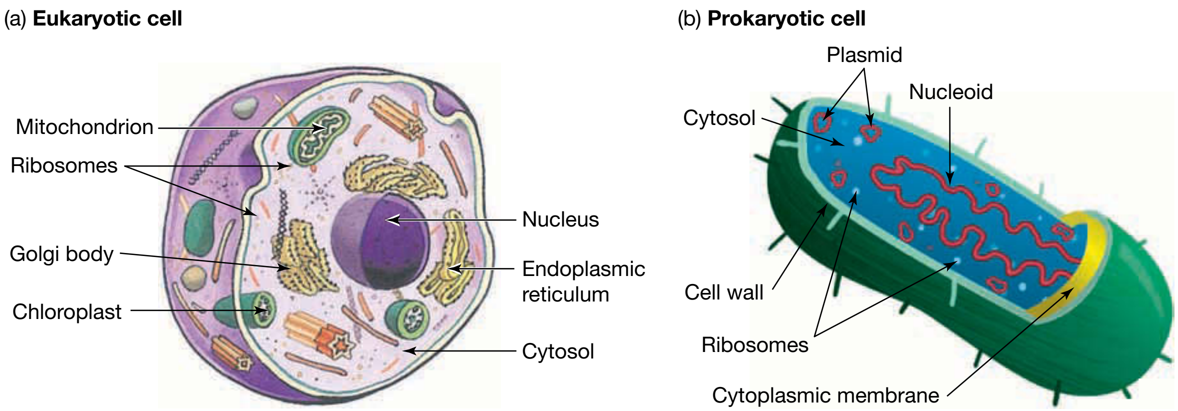
nanotechnology a science and technology that focuses on manipulating the structure of matter at an atomic and molecular level

prokaryote any cells or organisms without a membrane-bound nucleus (e.g. bacteria)

eukaryote any cells or organisms with a membrane-bound nucleus (e.g. plants, animals, fungi and protists)

Eukaryotic organisms made up of eukaryotic cells appeared on Earth billions of years later. As *eu* is the Greek term meaning 'good', **eukaryote** can be translated as 'true nucleus'. Members of the kingdoms Animalia, Plantae, Fungi and Protoctista are eukaryotes and are made up of cells containing a nucleus and other membrane-bound organelles.

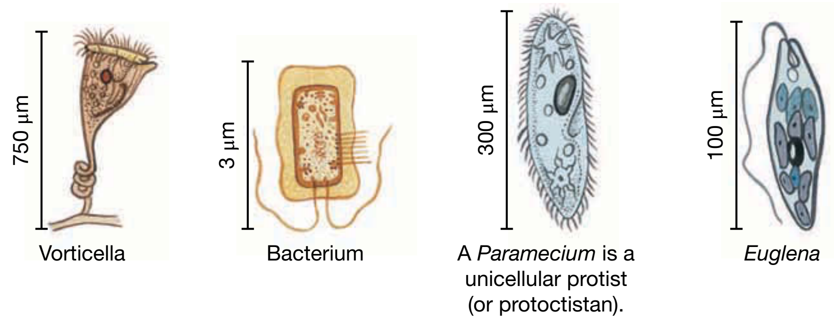
FIGURE 3.20 Eukaryotic cells **a.** contain a nucleus and membrane-bound organelles, whereas prokaryotic cells **b.** do not.



3.4.3 What do we share?

What most cells have in common is that they are made up of a **cell membrane** containing a fluid called **cytosol** and small structures called **ribosomes**. The collective term used to describe the cytosol and all the organelles suspended within it is **cytoplasm**. The hundreds of chemical reactions essential for life that occur within the cytoplasm are referred to as the cell's **metabolism**. The ribosomes are where proteins such as enzymes, which regulate the many chemical reactions important to life, are made. The cell membrane regulates the movement of substances into and out of the cell. This enables the delivery of nutrients and substances essential for reactions, and the removal of wastes.

FIGURE 3.21 Different sizes



on Resources

Video eLesson Inside cells (eles-0054)

3.4.4 Five Kingdoms?

Living things can be divided into five kingdoms — **Animalia** (animals), **Plantae** (plants), **Fungi** (for example, mushrooms), **Protoctista** (also called Protista) and **Prokaryotae** (also called Monera). While this system provides an opportunity to classify organisms into these groups (figure 3.23), information from currently developing technologies means that it will not be long until a new extended classification system evolves.

FIGURE 3.22 The five kingdoms of living things

cell membrane the structure that encloses the contents of a cell and allows the movement of some materials in and out

cytosol the fluid found inside cells

ribosomes small structures within a cell in which proteins such as enzymes are made

cytoplasm the jelly-like material inside a cell. It contains many organelles such as the nucleus and vacuoles

metabolism the chemical reactions occurring within an organism that enable the organism to use energy and grow and repair cells

Animalia the kingdom of organisms that have cells with a membrane-bound nucleus, but no cell wall, large vacuole or chloroplasts (e.g. animals)

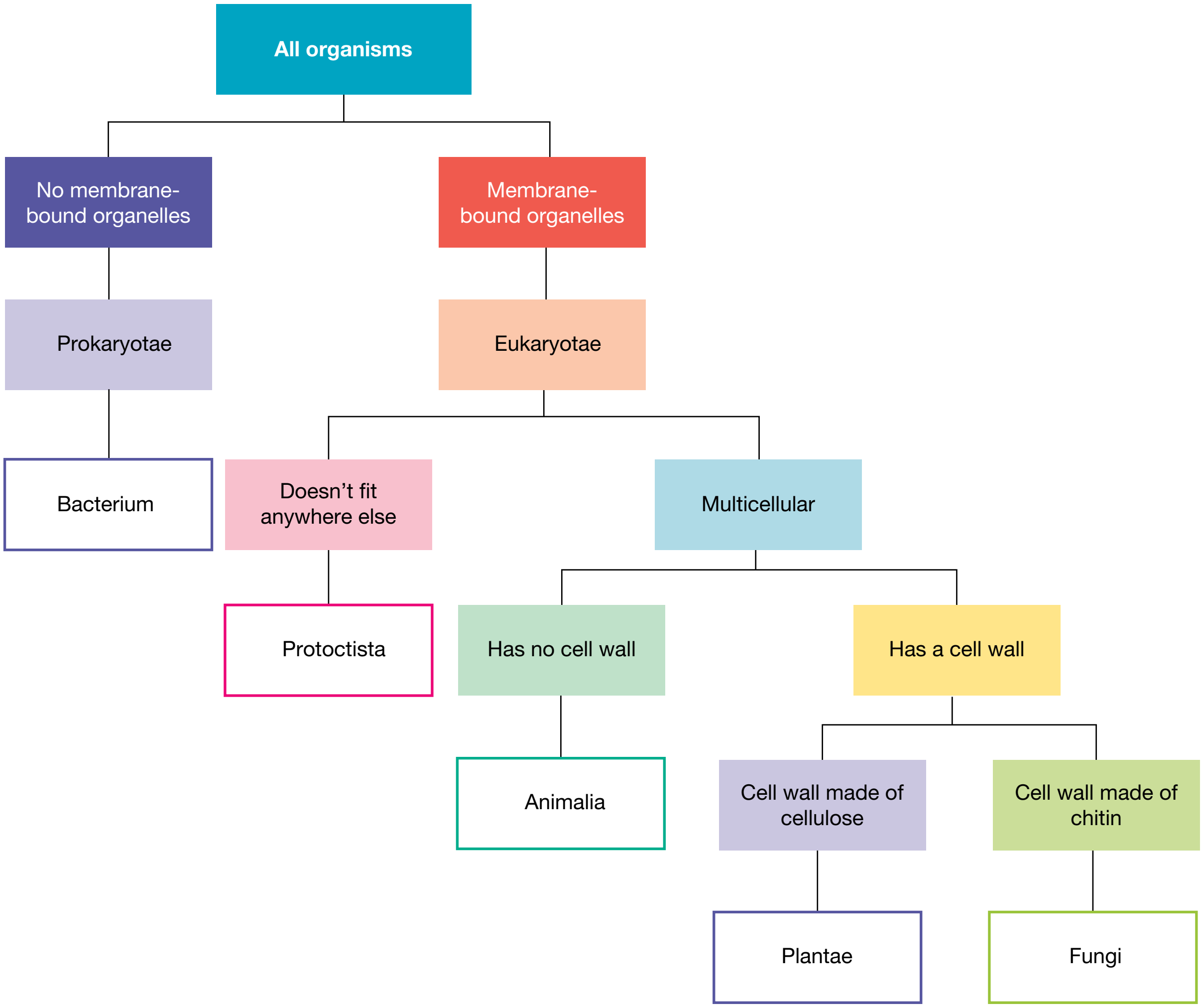
Plantae the kingdom of organisms that have cells with a membrane-bound nucleus, cell wall, large vacuole and chloroplasts (e.g. plants)

Fungi the kingdom of organisms made up of cells that possess a membrane-bound nucleus and cell wall, but no chloroplasts (e.g. mushrooms). Some fungi can help to decompose dead and decaying matter.

Protoctista the kingdom of organisms made up of cells that possess a membrane-bound nucleus but vary in other features and do not fit into other groups (e.g. protozoans). Also called *Protista*

Prokaryotae the kingdom of unicellular organisms made up of a single cell that does not possess a membrane-bound nucleus or other membrane-bound organelles (e.g. bacteria). Also called *Monera*

FIGURE 3.23 A key characteristic used to classify organisms into kingdoms is the structure of their cells.



WHAT DOES IT MEAN?

The prefix *uni-* comes from the Latin term meaning 'one'. The prefix *multi-* comes from the Latin term meaning 'many'.

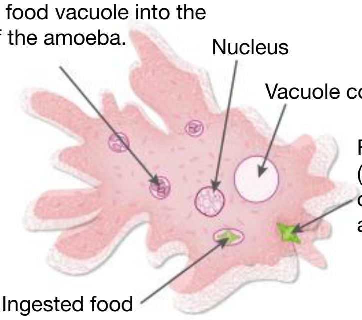
3.4.5 All on my own

Unicellular organisms such as bacteria and some protists such as *Amoeba, Euglena* and *Paramecium* need to carry out all the required processes themselves. They even reproduce themselves by dividing into two. This process is called **binary fission**.

To live long enough to reproduce, unicellular organisms need to be able to function on their own. They need to obtain their nutrients and remove their wastes. The solution to this requirement has resulted in the wonderful diversity of unicellular organisms that are alive on Earth today or have lived in our planet's history.

binary fission reproduction by the division of an organism (usually a single cell) into two new organisms

FIGURE 3.24 Unicellular organisms



3.4.6 Specialist workers

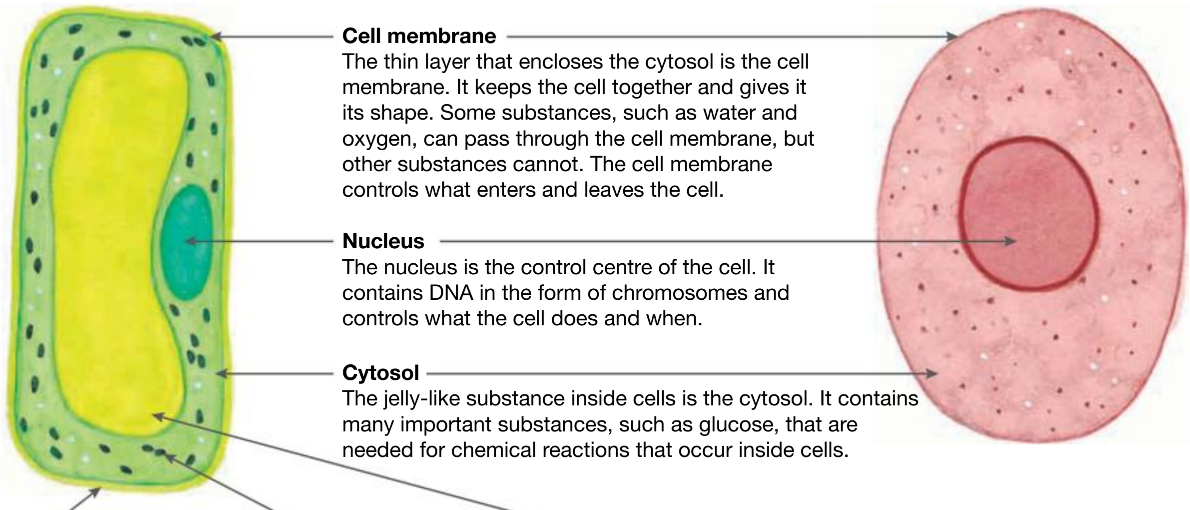
Multicellular organisms are made up of many different types of cells that have different jobs to do. Each of these different types of cells has a particular structure so that it is able to do the job it is specialised for. This may include the presence and number of particular organelles or additional external structures to assist with movement (such as flagella or cilia).

cellulose a natural substance that keeps the cell wall of plants rigid

cell sap the mixture inside a plant's vacuoles

int-3393

FIGURE 3.25 Different types of cells have particular structures enabling specialised tasks.



Cell wall
The tough covering around plant cells is the cell wall. It gives plant cells strength and holds them in shape. Plant cell walls are made of a substance called **cellulose**. Water and dissolved substances can pass through the cell wall. Animal cells do not have a cell wall.

Chloroplasts
Chloroplasts are the oval-shaped organelles found only in plant cells. Chloroplasts contain a green substance called chlorophyll. Chloroplasts use energy from the sun to make food. Not all plant cells contain chloroplasts. They are found only in leaf and stem cells.

Vacuole
The vacuole is an organelle used to store water and dissolved substances. Vacuoles can look empty, like an air bubble. Plant cells usually have one large vacuole. The mixture inside a plant's vacuoles is called **cell sap**. The red, blue and violet colours that you often see in plant leaves and flowers are due to the substances stored in vacuoles. Most animal cells don't have vacuoles.

Microfactories

Mitochondria and **chloroplasts** are examples of membrane-bound organelles found in eukaryotic cells. While all eukaryotic cells contain mitochondria, because they are all involved in **cellular respiration**, only those involved in **photosynthesis** (such as those in plant leaves) contain chloroplasts. Chloroplasts contain the green pigment **chlorophyll**. This pigment is used to trap light energy so that it can be converted into chemical energy and used by the cells.

mitochondria small rod-shaped organelles that are involved in the process of cellular respiration that results in the conversion of energy into a form that the cells can use. Singular = mitochondrion.

chloroplasts oval-shaped organelles that are involved in the process of photosynthesis that results in the conversion of light energy into chemical energy

cellular respiration a series of chemical reactions in which the chemical energy in molecules such as glucose is transferred into ATP molecules, which is a form of energy that the cells can use

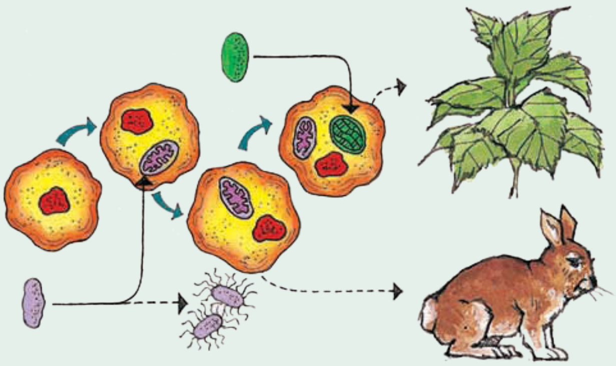
photosynthesis a series of chemical reactions that occur within chloroplasts in which the light energy is converted into chemical energy. The process also requires carbon dioxide and water, and produces oxygen, water and sugars — which the plant can use as 'food'.

chlorophyll the green-coloured chemical in plants that absorbs light energy so that it can be used in the process of photosynthesis

EXTENSION: The endosymbiotic theory

There is a theory called the endosymbiotic theory that suggests that mitochondria and chloroplasts were once prokaryotic organisms. This theory suggests that, at some time in the past, these organisms were engulfed by another cell and over time they evolved to depend on each other.

FIGURE 3.26 The origin of the eukaryotic cell? Some scientists also suggest that our nucleus may have come from a giant viral ancestor.



3.4.7 Some differences in the basic cell design in the five kingdoms

TABLE 3.4 Differences in the basic cell design in the five kingdoms

	Kingdom				
Characteristic	**Animalia** (animals: e.g. lizards, fish, spiders, earthworms, sponges)	**Fungi** (e.g. yeasts, moulds, mushrooms, toadstools)	**Plantae** (plants: e.g. ferns, mosses, conifers, flowering plants)	**Protoctista** (e.g. algae, protozoans)	**Prokaryotae** (bacteria and cyanobacteria)
Number of cells	Multicellular	Usually multicellular but some unicellular	Most multicellular	Unicellular or multicellular	Unicellular
Nucleus	Present	Present	Present	Present	Absent
Cell wall	Absent	Present	Present	Present in some	Present
Large vacuole	Absent	Absent	Present	Present in some	Absent
Chloroplasts	Absent	Absent	Present in leaf and stem cells	Present in some	Absent (but chlorophyll may be present in some)

on Resources

assesson Additional automatically marked question sets

3.4 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 4, 7, 12	Questions 2, 3, 6, 10	Questions 5, 8, 9, 11

Remember and understand

1. State why the nucleus is important to the cell.
2. Identify where enzymes are made in a cell and state why they are important.
3. SIS Emily is trying to determine if increasing the temperature of an enzyme will increase the reaction rate. She uses an enzyme that breaks down the starch in potato into sugar. She sets up three beakers. The first has 10 g potato in 200 mL water at 20 °C (room temperature). The second beaker has 10 g potato in 200 mL water and 5 g of the enzyme at 20 °C. The third beaker has 10 g potato in 200 mL water and 5 g of the enzyme heated to 30 °C. She measures the amount of glucose at the end of 10 minutes.
   a. Identify the independent and dependent variables.
   b. Is a control used in this experiment? If so, which beaker is it?
   c. Is this experiment a fair test? Provide an explanation for your decision using the definition of fair test.

Apply and analyse

Use table 3.4 to answer the following questions.

4. Complete the table by identifying which kingdoms relate to these characteristics.

Characteristics	Kingdom
Not have a cell wall, large vacuole or chloroplasts	
Have a cell wall, large vacuole and chloroplasts	
Have a cell wall, but no large vacuole or chloroplasts	
Have a cell wall and a nucleus without a membrane around it	

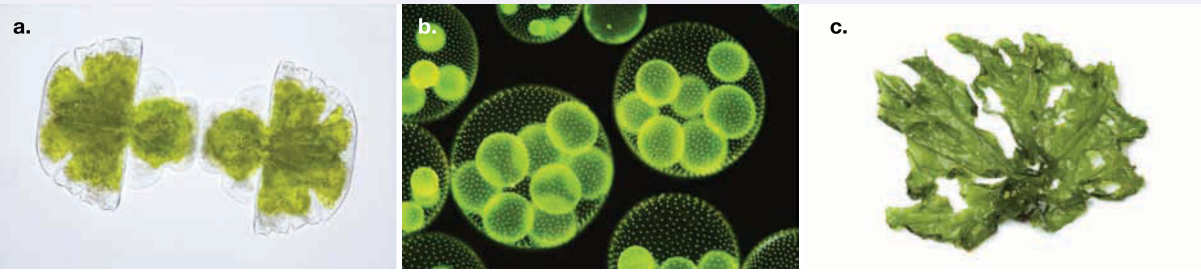
5. List two examples of each of the five kingdoms.
6. SIS Review the image given, and answer these questions.
   a. What features can you identify in the cell?
   b. Hypothesise which kingdom this cell belongs to.
   c. Can a hypothesis be incorrect?

Evaluate and create

7. Make a labelled model of a cell from one of the kingdoms. Use materials available at home, such as drink bottles, egg cartons, cottonwool, wool, cotton or dry foods.
8. **SIS** Algae have many different forms. Broadly they can be broken into three groups:
   - green algae
   - brown algae
   - red algae.

   Green algae are a group of 9000 to 12 000 species. They all have a central vacuole and chloroplasts, and some forms have flagella making them motile (able to move). They can be unicellular, form colonies or be multicellular.

   a. Desmid — a unicellular green algae, **b.** Volvox — colony formed of unicellular algae, **c.** Sea lettuce — a multicellular green algae

   Brown algae are a large group of multicellular algae including many seaweeds. They have chloroplasts surrounded by four membranes (compared to the usual two). Some also possess flagella.

   Red algae are a group of approximately 7000 species that have a lifecycle much like that of a fungus. They have no flagella and so they are non-motile. They are mainly multicellular but there are some that are unicellular. They contain chloroplasts.

   All algae have cell walls that contain cellulose.

   Harpoon weed red algae (*Asparagopsis armata*) underwater in the Mediterranean Sea, Spain

   There is much discussion over which kingdom the algae should belong and whether or not the three divisions should be grouped together.

   Which kingdom do you think the algae should belong? Justify your response using evidence from the above text.
9. **SIS** What does the endosymbiotic theory suggest? Formulate questions to ask about it. Research and report on your questions.
10. **SIS** Research and report on:
    a. examples of prokaryotic cells and interesting survival strategies
    b. mitochondrial DNA and haplogroups.
11. **SIS** Research two of the organelles or cells listed. Create a play, and construct puppet models for your characters. Present your play to the class.
    - Nucleus
    - Mitochondrion
    - Chloroplast
    - Prokaryotic cell
    - Protoctistan cell
    - Animal cell
    - Plant cell

12. Investigate the different types of cells and create your own picture book about them using the following steps.
   a. Construct a matrix table (see section 10.10 Matrixes and Venn diagrams) to show the differences between the cells of the different kingdoms.
   b. Construct a storyboard for a picture book about them.
   c. Create the picture book.

Fully worked solutions and sample responses are available in your digital formats.

3.5 Zooming in on life

LEARNING INTENTION

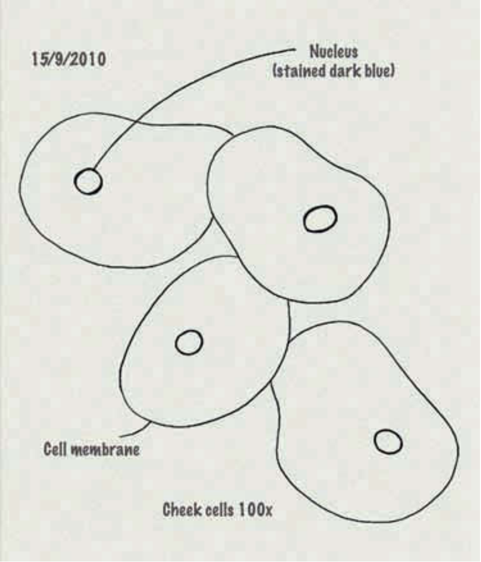
At the end of this subtopic you will understand how to prepare a specimen for viewing, including the use of dyes to highlight specific cell features. You will also be able to record images using scientific drawing techniques.

3.5.1 Sketching what you see under the microscope

Some points to remember

1. Use a sharp pencil.
2. Draw only the lines that you see (no shading or colouring).
3. Your diagrams should take up about a third to half a page each.
4. Record the magnification next to each diagram.
5. State the name of the specimen and the date of observation.
6. A written description is also often of considerable value.
7. When you are viewing many cells at one time, it is often useful to select and draw only two or three representative cells for each observation.

FIGURE 3.27 An example of a sketch of a microscope specimen



3.5.2 Preparing a specimen

Light microscopes function by allowing light to pass through the specimen to reach your eye. If the specimen is too thick, the object cannot be seen as clearly or may not be seen at all.

Careful peeling, scraping, slicing or squashing techniques can be used to obtain thin specimens of the object to be studied.

Staining a specimen

Many objects are colourless when viewed under the microscope, so specimens are often stained to make them easier to see. Methylene blue, iodine and eosin are some examples of commonly used stains.

Each stain reacts with different chemicals in the specimen. For example, iodine stains starch a blue-black colour.

Take care when using these stains, because they can stain you as well!

elog-0391

INVESTIGATION 3.2

Preparing a wet mount

Aim

To prepare a wet mount and observe micro-organisms on a microscope slide

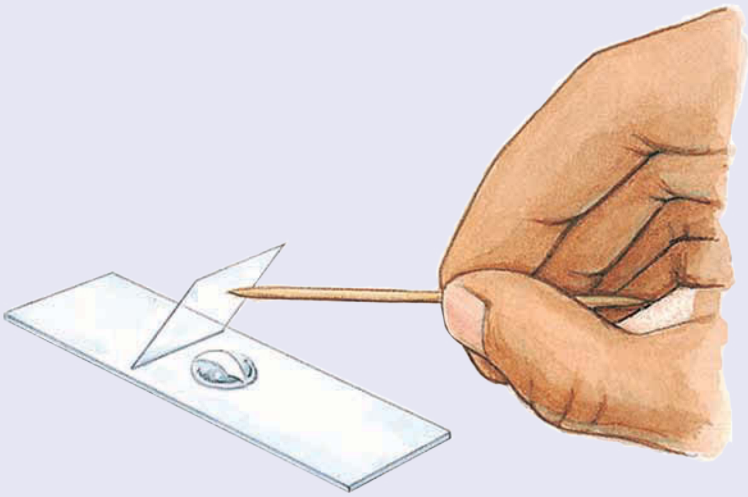
Materials

- light microscope
- coverslips
- pipette
- toothpick
- pond water
- microscope slides (well slides work best for this)
- culture of living microscopic organisms: paramecium, amoeba, rotifers, euglena

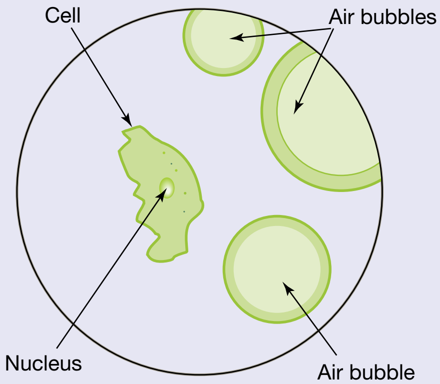
Method

1. Use the pipette to put a drop of pond water or microbe culture on a clean microscope slide.

2. Gently place a coverslip over the drop of water by putting one edge down first. Use a toothpick as shown.
3. Incorrect placement of the coverslip can result in air bubbles.



4. Use a microscope to observe the slide.



5. Once you have recorded your results, remove the coverslip, rinse and dry the slide, and then prepare a new slide specimen and repeat the steps above.

Results

Draw detailed sketches of what you see. Remember to include a title, the magnifications used and as many comments as you can.

Discussion

1. Construct a matrix to show the similarities and differences between the specimens.
2. Suggest reasons for these differences.
3. Use resources on the internet to identify your specimens.
4. Which kingdoms do you think each specimen may belong to? Provide reasons for your classification.
5. Identify two structures you observed in the investigation and find out more about their function (that is, what their 'job' is).
6. You have been observing living specimens. Identify advantages and disadvantages of using living rather than dead specimens or prepared slides.

Conclusion

Write a conclusion for this investigation.

elog-0392

INVESTIGATION 3.3

Preparing stained wet mounts

Aim

To prepare, stain and observe a specimen on a microscope slide

Materials

- light microscope
- pipette
- blotting paper
- toothpick
- scalpel
- forceps or tweezers
- microscope slides and coverslips
- water, methylene blue, iodine
- onion, ripe and unripe banana, celery stick

CAUTION

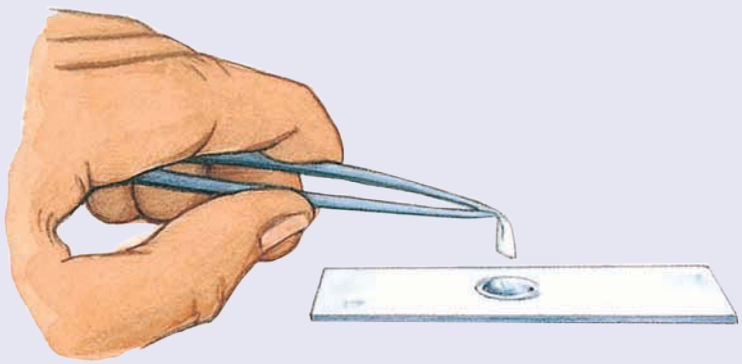
The scalpel has a very sharp blade. Handle it with care.

Method

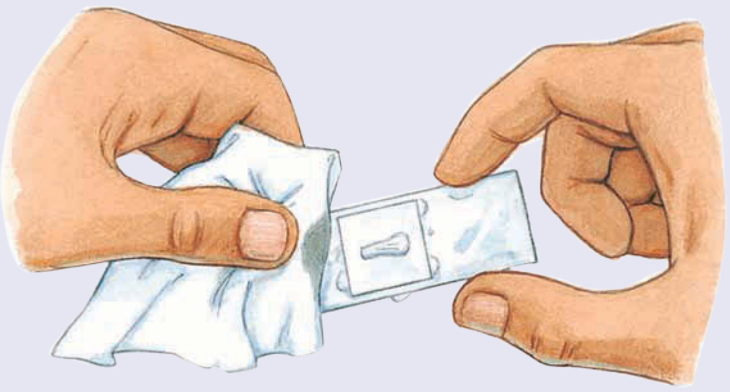
1. Use the pipette to put a drop of water on a clean microscope slide.

2. Use a scalpel and forceps to peel a small piece of the very thin, almost transparent onion skin from the inside surface of an onion. You may also be able to snap the piece of onion and peel a thin layer of skin off.

3. Use the forceps to put the thin piece of the onion skin into the drop of water on the microscope slide.



4. Gently place a coverslip over the drop of water containing the onion skin by putting one edge down first. Use a toothpick as in investigation 3.2 to avoid air bubbles. Use blotting paper to soak up any excess water outside the coverslip.



5. Use a microscope to observe the slide; first use low power and then increase the magnification.
6. Prepare another slide of onion skin, except this time add a drop of methylene blue instead of water to the slide. Make sure that you carefully blot excess stain from the slide after you add the coverslip.
7. Observe this stained onion specimen; first use low power, then view at a higher magnification.

Once you have recorded your results:

8. Remove the coverslip, and rinse and dry the slide.
9. Use the steps outlined on the previous page to prepare the following slides:
   - celery epidermis (outer layer of the celery stem) with and without methylene blue stain
   - squashed ripe and unripe banana with and without iodine.

Results

Draw detailed sketches of what you see. Remember to include a title, the magnifications used and as many comments as you can. Label any parts that you can identify.

Discussion

1. Compare the cells of the stained onion epidermis and the celery epidermis. Identify their similarities and differences. Suggest reasons for the differences.
2. Compare the cells of the stained ripe and unripe banana. Identify their similarities and their differences. Suggest reasons for the differences.
   Methylene blue is used to stain the nucleus so that it is easier to see. Iodine changes from yellow-brown to a dark blue when it combines with starch.
3. Why stains are used. Include reasons for using methylene blue and iodine that relate to your observations in this investigation.
4. Investigate the functions of the structures observed in your stained specimens. Suggest how features of these structures assist their function.

Conclusion

1. Identify strengths, limitations and improvements related to this investigation.
2. Watch the **Inside cells** animation in your Resources section to learn about cells and organelles.

on Resources

eWorkbook Preparing a stained wet mount (ewbk-4057)

assess on Additional automatically marked question sets

3.5 Exercise

learnON

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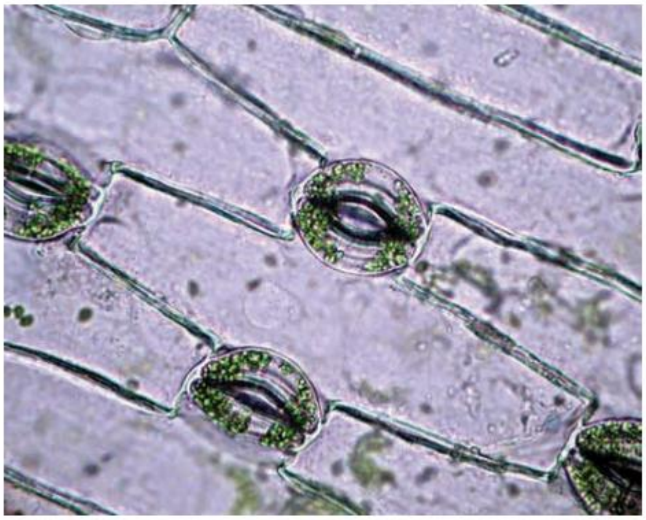
Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Question 1	Questions 2, 3	Question 4

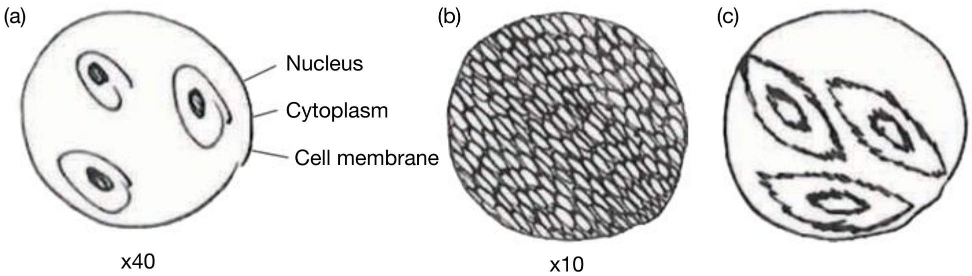
Remember and understand

1. a. Carefully observe the image of plant cells given and construct a sketch of one of the cells.
   b. Use references to suggest labels for the structures shown in your sketch.



Apply and analyse

2. SIS Carefully observe the student sketches shown. For each diagram, list what is wrong with it and suggest how it could be improved.



Evaluate and create

3. SIS Design a poster that shows others how to prepare a variety of specimens to be viewed under a microscope.

4. SIS Methylene blue has the following warning symbols on the Safety Data Sheet that need to be considered when it is used.

CAUTION

a. What do these symbols mean?
b. What precautions should be taken when using methylene blue?

Fully worked solutions and sample responses are available in your digital formats.

3.6 Focus on animal cells

LEARNING INTENTION

At the end of this subtopic you will be able to describe how cell shape and size (form) enables the functions of animal cells.

3.6.1 In all shapes and sizes

Cells within an organism may differ in their shape and size. This difference may be due to the particular jobs or functions that the cells carry out within the organism. The human body is made up of more than 20 different types of cells, with each type suited to a particular function.

Nerve cells develop long, thin fibres that quickly carry messages from one cell to another. Cells lining the trachea have hair-like cilia that move fluid and dust particles out of the lungs. Muscle cells contain fibres that contract and relax, and the human sperm cell has a tail or flagellum that helps it swim to the egg cell.

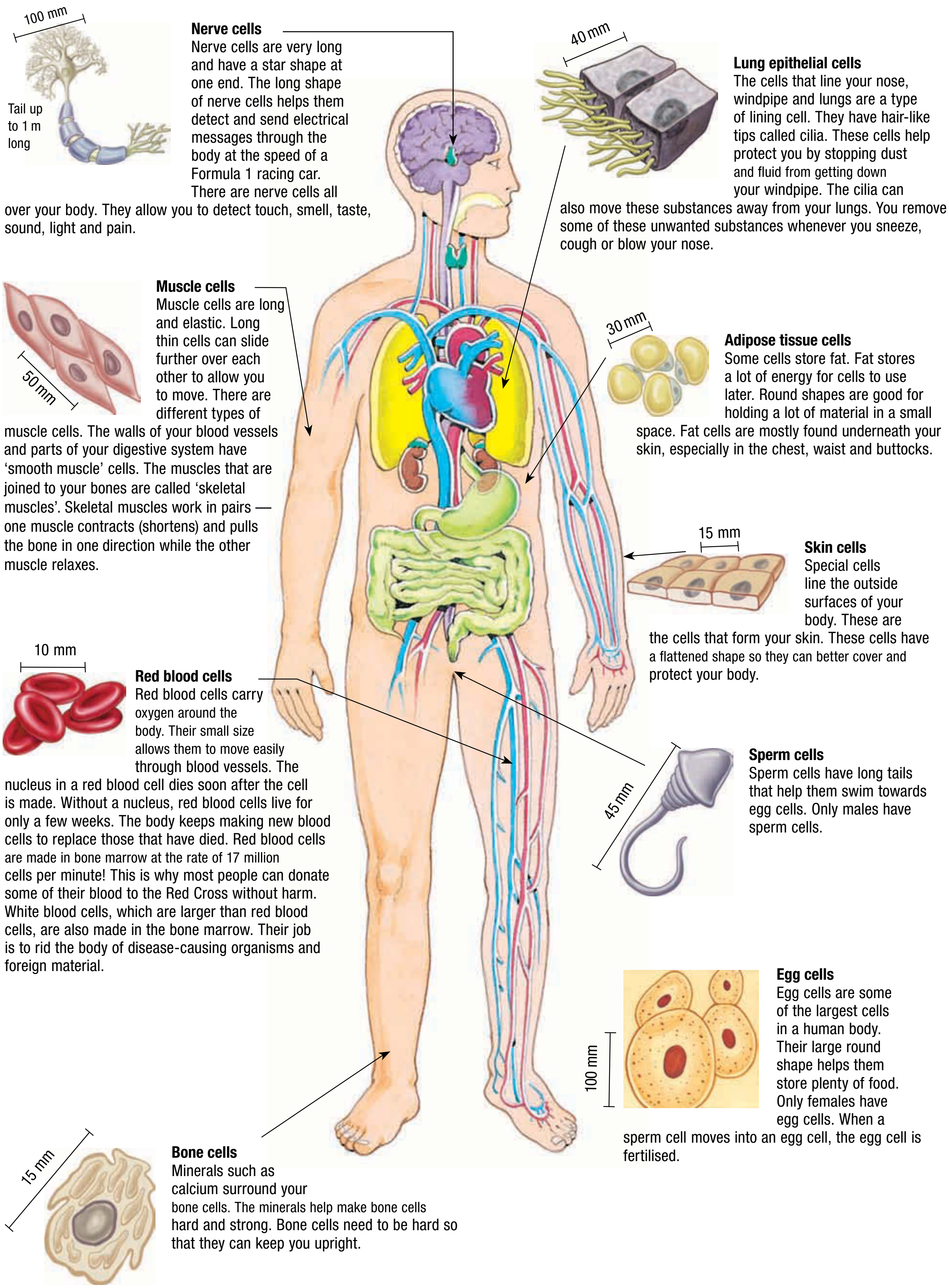
Cells can also differ in the organelles that they contain within them. Muscle cells, for example, contain many more mitochondria than other types of cells due to their high energy requirements. Red bloods cells also differ from many other types of cells because, as they mature, they lose their nucleus. This makes more room available for them to carry more oxygen throughout your body.

EXTENSION: Facts about human cells

Did you know these facts about human cells?
- Hair and nails are made of dead cells, and because they are not fed by blood or nerves you can cut them without it hurting.
- A human baby grows from one cell to 2000 million cells in just nine months.
- Red blood cells live for one to four months and each cell travels around your body up to 172 000 times.
- Some of the nerve cells in the human body can be one metre long. But that's small compared with the nerve cells in a giraffe's neck. They are two to three metres long!

int-3395

FIGURE 3.28 The human body is made up of more than 20 different types of cells, with each type suited to a particular function.



elog-0393

INVESTIGATION 3.4

Animal cells — what's the difference?

Aim

To observe the features of different types of animal cells

Materials

- light microscope
- prepared animal slides: blood cells, muscle cells, cheek cells, nerve cells

Method

Use a microscope to observe the prepared slides.

Results

Record detailed diagrams of your observations. Next to your diagrams, include details of the (a) source of the specimen, (b) type of specimen, (c) magnification used and (d) a detailed description of the specimen.

Discussion

1. Were all of the animal cells you observed the same size? Explain.
2. Did all of the cells observed contain a nucleus? Explain.
3. Identify features that all of the observed animal cells shared.
4. Identify differences between the features of the cells observed.
5. Suggest reasons for the differences between the cells.
6. Compare your cells with those in figure 3.28.
   a. Do your sketched diagrams match the structures shown in the figure? Explain.
   b. Read through the text related to the functions of the different types of cells. Do these match those you suggested in question 5? Explain.

Conclusion

Suggest how the shape or size of a cell may assist it in doing its job.

on Resources

assesson Additional automatically marked question sets

3.6 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3	Questions 4, 5, 7	Questions 6, 8

Remember and understand

1. Match the types of cells with their descriptions.

Type of cell	Description
a. Muscle cell	A. Has a long tail that helps it to swim towards the egg cell
b. Skin cell	B. Long, thin elastic cells that contract and relax

(continued)

(continued)

Type of cell	Description
c. Red blood cell	**C.** A flat cell that lines the outside surface of your body
d. Nerve cell	**D.** Very tiny cell that lacks a nucleus when mature and carries oxygen
e. Sperm cell	**E.** Very long cell, star-shaped at one end, detects and sends messages

2. Identify which features most animal cells have in common. Suggest reasons why.
3. Describe some ways in which cells may differ.
4. Suggest why the cells in a multicellular organism are not all the same. Give examples in your answer.
5. Distinguish between:
   a. skin cells and sperm cells
   b. red blood cells and nerve cells
   c. adipose tissue cells and muscle cells.

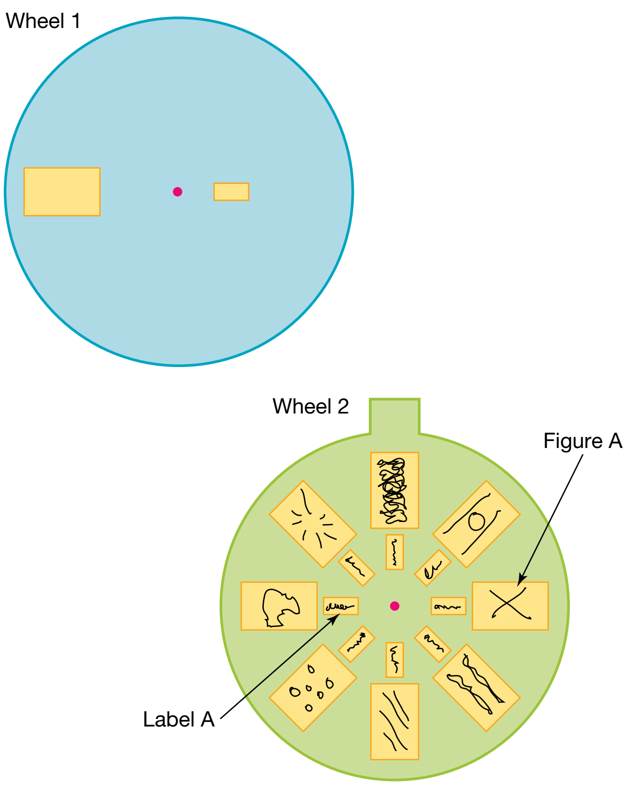
Apply and analyse

6. SIS
   a. Summarise the information from figure 3.28 into a table with the headings: 'Type of cell', 'Function', 'Shape' and 'Size'.
   b. Using these data, determine the average size of an animal cell.
   c. Use a bar graph to plot the sizes of the different types of animal cells.
   d. Identify which animal cells are 'above average' in size and which are 'below average'. Suggest reasons for the differences.
   e. Comment on the differences in other features between the cells.
7. Sperm cells have large numbers of mitochondria. Explain, with reference to the function of the sperm cell, why this is the case.

Evaluate and create

8. SIS Using your own research and the information in figure 3.28, construct a 'peep through' learning wheel that shows the structure and function of the different types of animal cells. Instructions for making a 'peep through' learning wheel are given at in figure 3.29.
   a. On an A4 piece of white paper or card draw two circles, one with a 'tab' (wheel 2) and one without (wheel 1).
   b. Cut out the two rectangular box areas as shown on wheel 1.
   c. Draw in the large and the small rectangles as shown on wheel 2.
   d. Write the animal cell types in the small boxes on wheel 2. Sketch matching diagrams of examples of these cell types in the corresponding large box opposite.
   e. Attach the two wheels, with wheel 1 on top, using a paper fastener.
   f. Rotate your wheel to view examples of types of animal cells.

FIGURE 3.29 How to make a 'peep through' learning wheel



Fully worked solutions and sample responses are available in your digital formats.

3.7 Focus on plant cells

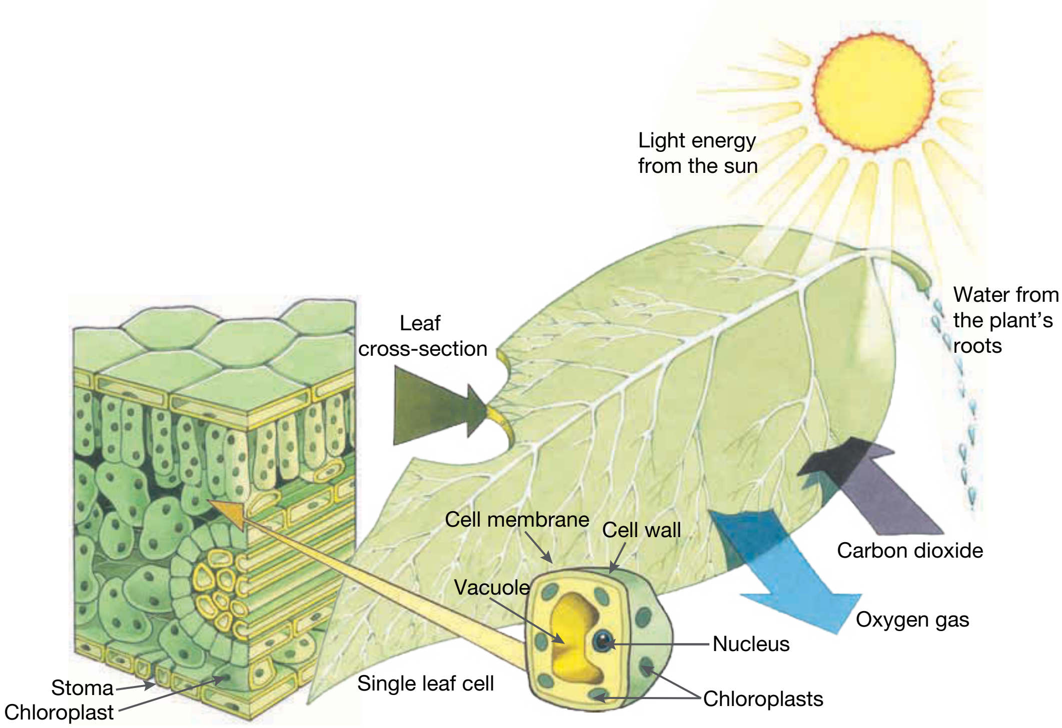
LEARNING INTENTION

At the end of this subtopic you will be able to identify and describe cells that are specialised for function in plants.

3.7.1 Have or have not

Like animal cells, plant cells have cytoplasm, a membrane and a nucleus. Unlike animal cells, plant cells have a cellulose cell wall and a large central vacuole filled with cell sap. Often plant cells also contain chloroplasts in their leaves, which enable them to make their own food in a process called photosynthesis. In this process, carbon dioxide and water move into the chloroplast, leading to the production of glucose and the release of oxygen.

FIGURE 3.30 Process of photosynthesis in the leaves of plants



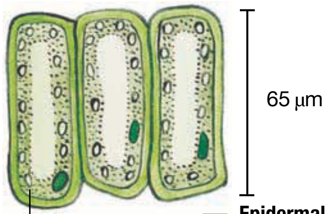
On the surfaces of leaves, there are pairs of special cells called guard cells, which surround tiny pores called stomata. The guard cells can change shape, opening or closing the stomata. Special cells on the roots extend into microscopic hairs that penetrate between soil particles. The hairs provide a large surface area through which water may be absorbed from the soil.

WHAT DOES IT MEAN?

The word xylem comes from the Greek word *xulan*, meaning 'wood'. The word phloem comes from the Greek word *phloos*, meaning 'bark'.

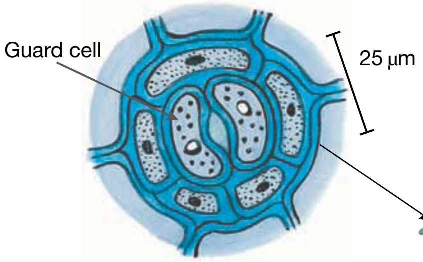
int-3396

FIGURE 3.31 Some of the types of cells found in plants



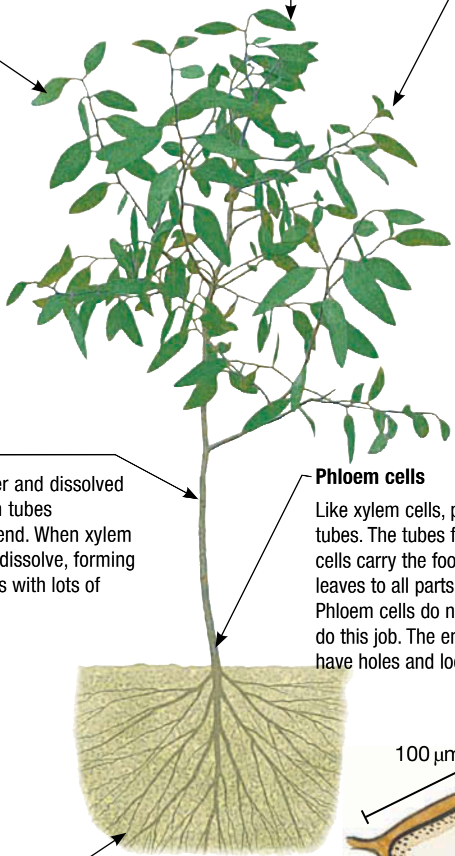
Leaf cells (palisade cells)

The main function of leaf palisade cells is to photosynthesise, so they are packed with chloroplasts and are usually green.



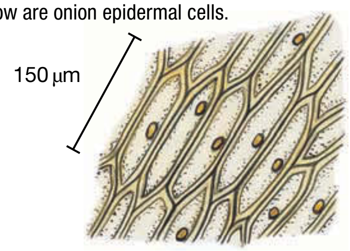
Guard cells

Guard cells are kidney-shaped cells found on the surface of leaves. They can change shape to either open or close the small hole between them. The small holes, called stomata (or stomates), allow substances such as carbon dioxide to enter the leaf. They also let water out of the leaf. Most plants open their stomata at night; they close their stomata during the day (when it is hotter) to conserve water.



Epidermal cells

Epidermal cells are found on the outside of the plant. They form an outer skin for the plant and protect the cells underneath. This explains why they need a flat shape and why they interlock like tiles. Epidermal cells do not usually photosynthesise so they lack chloroplasts. Light needs to pass through them, and they are usually transparent. The cells in the diagram below are onion epidermal cells.



Epidermal cells

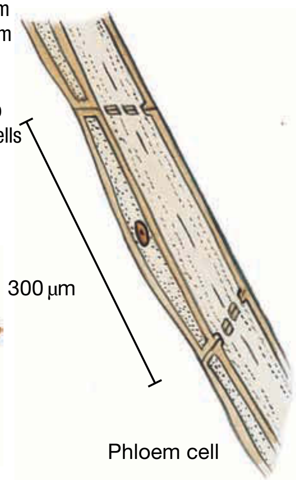
Xylem cells

Xylem cells form xylem tubes, which carry water and dissolved minerals up the plant and into the leaves. Xylem tubes are made up of dead xylem cells joined end to end. When xylem cells die, the cell walls at each end of the cells dissolve, forming a long straw-like tube. They have thick cell walls with lots of cellulose to make the xylem tubes strong.

Xylem cells

Phloem cells

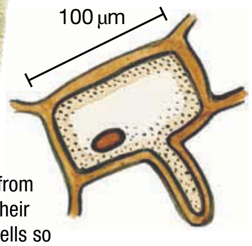
Like xylem cells, phloem cells form tubes. The tubes formed by phloem cells carry the food made in the leaves to all parts of the plant. Phloem cells do not need to die to do this job. The ends of phloem cells have holes and look like sieves.



Phloem cell

Root hair cells

Root hair cells absorb water and dissolved minerals from the soil. They have small hairs, called root hairs, on their surface. This increases the surface area of the root cells so that they can soak up water more quickly.



Root hair cell

elog-0394

INVESTIGATION 3.5

Plant cells in view

Aim

To observe the features of different types of plant cells

Materials

- light microscope
- prepared plant slides: leaf epidermal cells, root hair cells, stomata/guard cells

Method

Use a microscope to observe the prepared slides.

Results

Record detailed diagrams of your observations. Next to your diagrams, include details of the (a) source of the specimen, (b) type of specimen, (c) magnification used and (d) a detailed description of the specimen.

Discussion

1. Were all of the plant cells the same size? Explain.
2. Did all of the cells observed contain a nucleus? Explain.
3. Identify features that all of the observed plant cells shared.
4. Identify differences between the features of the cells.
5. Suggest reasons for the differences between the cells.
6. Compare your cells with those in figure 3.31.
   a. Do your sketched diagrams match the structures shown in the figure? Explain.
   b. Read through the text related to the functions of the different types of cells. Do these match your answer to question 5? Explain.

Conclusion

Suggest how the shape or size of a cell may help it to do its job.

on Resources

eWorkbook Plant transport highways (ewbk-4059)

assess on Additional automatically marked question sets

3.7 Exercise

learn on

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Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2	Questions 3, 5, 6	Questions 4, 7

Remember and understand

1. Match the types of cells with their descriptions.

Type of cell	Description
a. Guard cell	A. Sieve-like cells that form tubes that carry food made in the leaves to other parts of the plant
b. Phloem cell	B. Cells with small hairs that increase their surface area so that they can absorb more water
c. Xylem cell	C. Thick-walled cells that carry water up the plant
d. Root hair cells	D. Kidney-shaped cells that can change shape to either open or close the small hole between them, which allows gas exchange between the plant and its environment

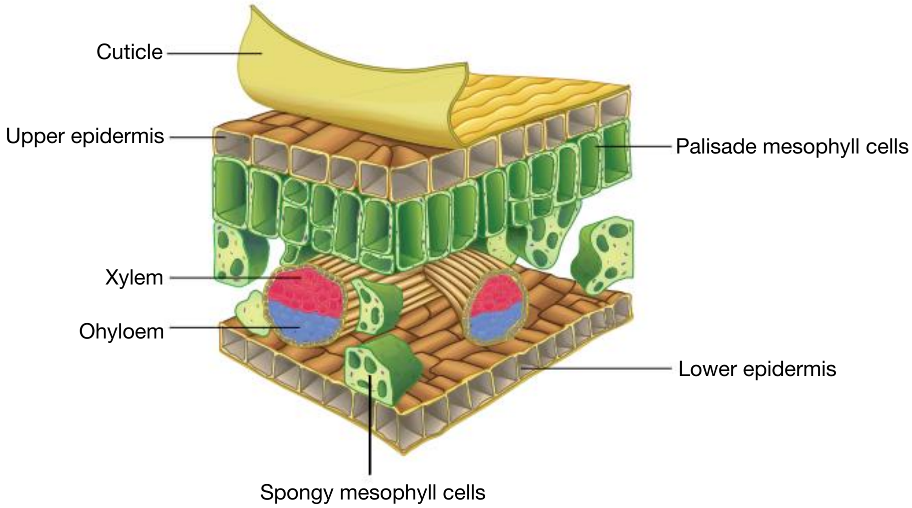
2. Describe some ways in which plant cells may differ.
3. Distinguish between:
   a. palisade cells and guard cells
   b. xylem cells and phloem cells
   c. epidermal cells and root hair cells.

Apply and analyse

4. SIS
   a. Summarise the information in figure 3.31 into a table with the headings: 'Type of cell', 'Function', 'Shape' and 'Size'.
   b. Using these data, determine the average size of a plant cell.
   c. Use a bar graph to plot the sizes of the different types of plant cells.
   d. Identify which plant cells are 'above average' in size and which are 'below average'. Suggest reasons for the differences.
   e. Comment on the differences in other features between plant cells.

Evaluate and create

5. Construct a model of a pair of guard cells, using balloons.
6. Using your own research and the information in figure 3.31, construct a 'peep through' learning wheel that shows the structure and function of the different types of plant cells. Instructions for making a 'peep through' learning wheel are given in 3.6 Exercise.
7. SIS Consider the following diagram of a leaf.



   In most leaves, sunlight hits the upper side of the leaf. The light penetrates (passes through) the upper epidermis before hitting the palisade mesophyll cells.
   a. The mesophyll cells all have chloroplasts. What is the function of chloroplasts?
   b. Suggest a reason the palisade mesophyll cells have more chloroplasts than the spongy mesophyll cells.
   c. During photosynthesis, water is taken up by the roots and combined with carbon dioxide in the air. Glucose is made and stored for future use and oxygen is released. What is the role of the large air spaces between the spongy mesophyll cells?

Fully worked solutions and sample responses are available in your digital formats.

3.8 Plant cells — holding, carrying and guarding

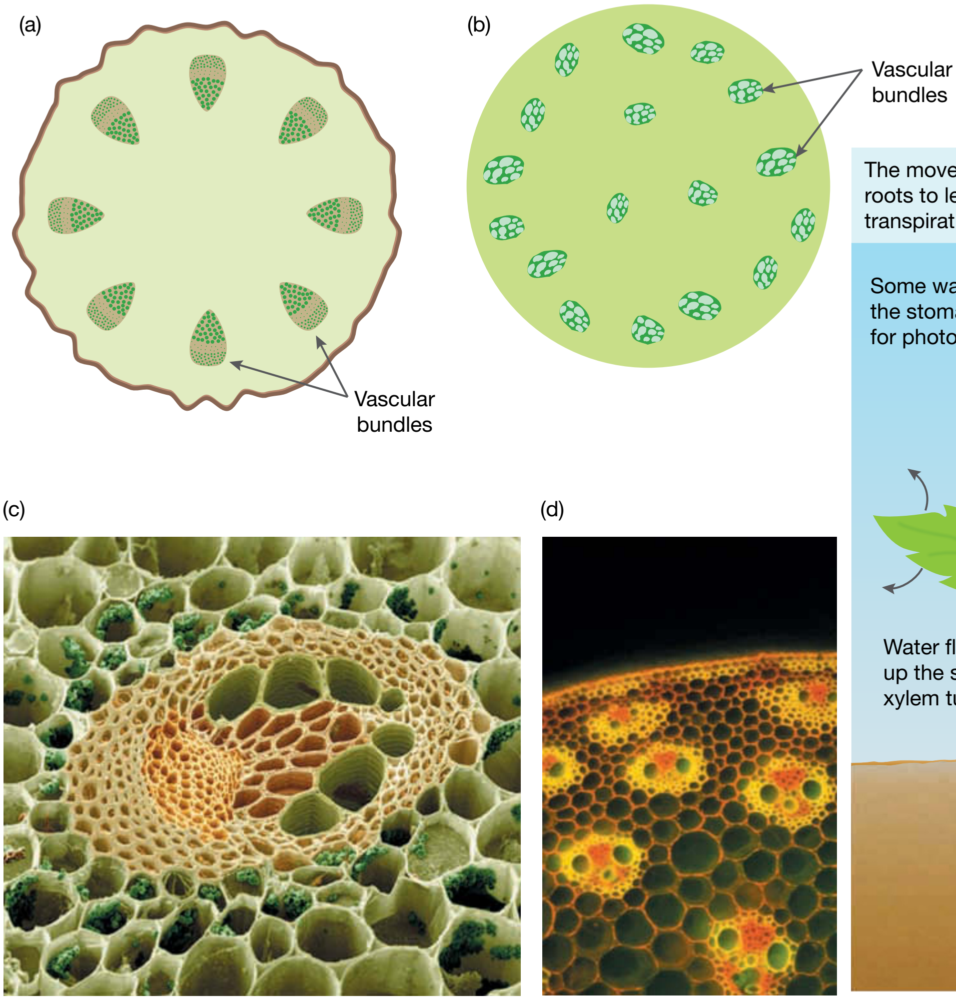
LEARNING INTENTION

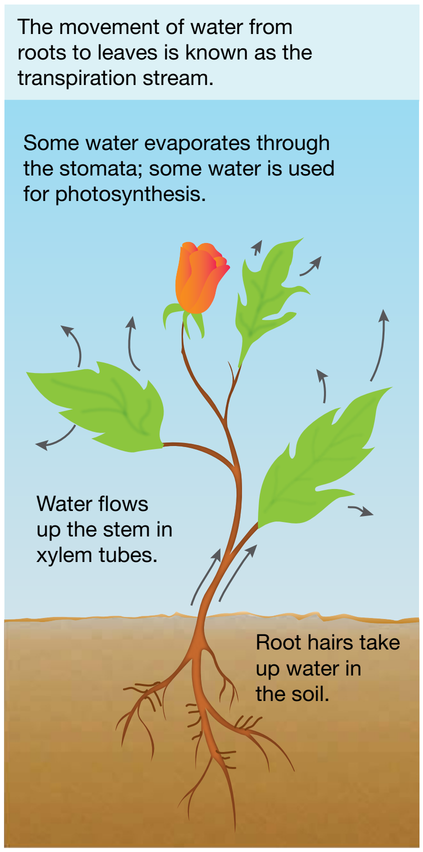
At the end of this subtopic you will be able to describe the specialised transport systems in plants.

3.8.1 Sweet transport: phloem

As in animals, plant cells can work together for a variety of functions to meet their survival needs. Plants have their own transport systems, which consist of many thin tubes made up of different types of cells. Other types of plant cells are involved in water regulation and exchange of important gases, such as oxygen and carbon dioxide, with their environment.

FIGURE 3.32 Diagrams of typical cross-sections of the stem of **a.** a young dicot and **b.** a monocot. The photographs show how the cells of **c.** a dicot (buttercup) appear when viewed under an electron microscope and **d.** a monocot (sugarcane) appear under a light microscope.





Using the process of photosynthesis, plants make sugar in their leaves. The system of thin-walled tubes that carries this sugar (in the form of glucose or sucrose) from the leaves to other parts of the plant is called **phloem**. Phloem consists of living cells called sieve tubes and companion cells. The transport of the sugar solution up and down the plant is called **translocation**.

3.8.2 Water pipes: xylem

Flowering plants also have tubes with strong, thick walls that carry water and minerals up from the roots through the stem to the leaves. These are called **xylem vessels**. These tubes are formed from the empty remains of dead cells, the walls of which are strengthened with a woody substance called **lignin**. The xylem is therefore a 'dead' one-way street, rather than a 'living' two-way highway like the other transport tubes you have studied.

Water moves up from the roots of the plant, through its stem and to its leaves, where some water may pass out of the plant as water vapour through pores called **stomata**. This movement of water is called the **transpiration stream**.

phloem a type of tissue that transports sugars made in the leaves to other parts of a plant

translocation process in which sugars and amino acids are transported within the plant by phloem tissue in plants

xylem vessels pipelines for the flow of water up plants. They are made up of the remains of dead xylem cells fitted end to end with the joining walls broken down. Lignin in the cell walls gives them strength.

lignin a hard substance in the walls of dead xylem cells that make up the tubes carrying water up plant stems. Lignin forms up to 30 per cent of the wood of trees.

stomata small openings mainly on the lower surface of leaves. These pores are opened and closed by guard cells. Singular = stoma.

transpiration stream the movement of water through a plant as a result of loss of water from the leaves

elog-0395

INVESTIGATION 3.6

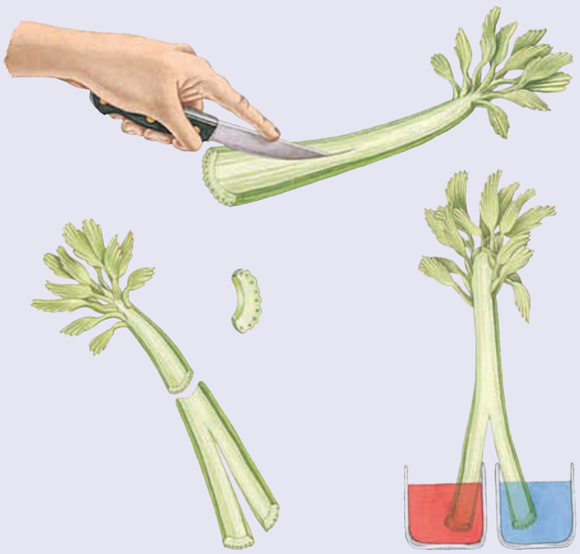
Stem transport systems

Aim

To identify xylem cells in celery

Materials

- celery stick (stem and leaves)
- knife
- two 250 mL beakers
- water
- blue food colouring
- red food colouring
- hand lens



Method

1. Slice the celery along the middle to about halfway up the stem.
2. Fill two beakers with 250 mL of water. Colour one blue and the other red with the food colouring.
3. Place the celery so that each 'side' of the celery is in a separate beaker.
4. Leave for 24 hours and then observe the celery.
5. Cut the celery stick across the stem.
6. Use the hand lens to look at the inside of the stem.

Results

1. Look at where the water has travelled in the celery. Draw a diagram to show your observations.
2. Draw a diagram to show what you can see when you cut across the stem.
3. Where are the different colours found in the stem?

4. Where are the different colours found in the leaves?
5. Draw a diagram of the whole celery stick and trace the path of the water through each side to the leaves.

Discussion

1. Explain your observations of where the water was found in the stems and leaves. Make sure you comment on the relationship between the shape of the structures and your findings.
2. Identify strengths and limitations of this investigation and suggest possible improvements.

Conclusion

What are xylem vessels and where are they found?

Extension

How could you turn a white carnation blue? Try it.

Xylem for support

The phloem and the xylem vessels are located together in groups called **vascular bundles**. The strong, thick walls of the xylem vessels are also important in helping to hold up and support the plant. The trunks of trees are made mostly of xylem. Did you know that the stringiness of celery is due to its xylem tissues?

3.8.3 Leaf doorways: stomata

Water transport occurs within the xylem vessels. Some of the water that is transported through the xylem to the leaves is used in photosynthesis. Some water is also lost as water vapour through tiny holes or pores in the leaves. These tiny pores, called stomata (or stomates), are most frequently found on the underside of the leaves. Evaporation of water from the stomata in the leaves helps pull water up the plant. Loss of water vapour through the stomata is called **transpiration**.

Guard cells in control

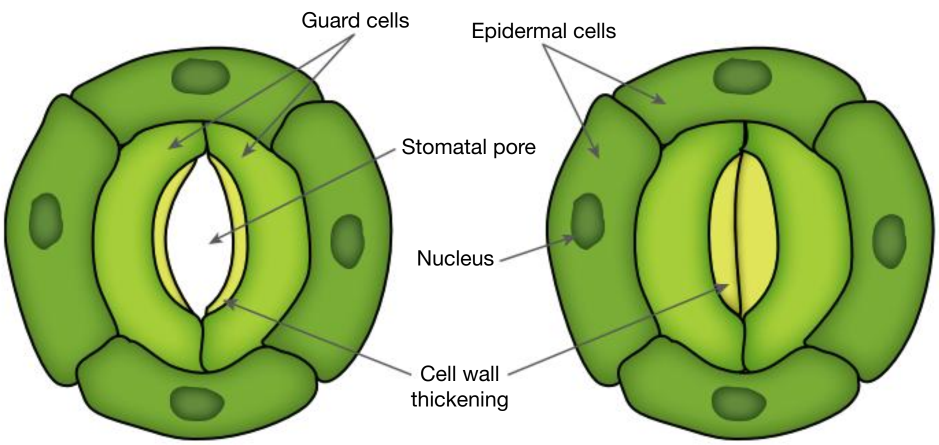
Oxygen and carbon dioxide gases also move in and out of the plant through the stomata. **Guard cells**, which surround each stoma, enable the hole to open and close, depending on the plant's needs. When the plant has plenty of water, the guard cells fill up with water and stretch lengthways. This opens the pore. If water is in short supply, however, the guard cells lose water and they collapse towards each other. The pore is then closed. This is one way in which the plant can control its water loss.

vascular bundles groups of xylem and phloem vessels within plant stems

transpiration the loss of water from plant leaves through their stomata

guard cells cells on either side of a stoma that work together to control the opening and closing of the stoma

FIGURE 3.33 Stomata can close to conserve water.



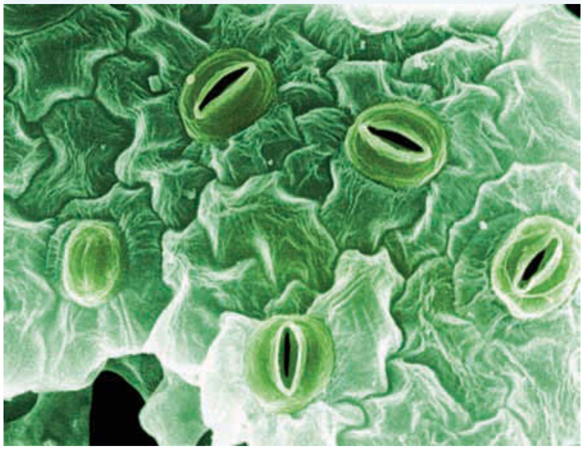
Dusty doors

Air pollution can result in particles of dust settling on the leaves of plants. This may limit the amount of light reaching the leaf and therefore reduce photosynthesis. If these dust particles block up stomata, they can also affect transpiration and gaseous exchange.

EXTENSION: Genetically engineered plants

Scientists have used genetic engineering to produce plants that glow particular colours when they have mineral deficiencies. This provides farmers with information about which soils need extra minerals added.

FIGURE 3.34 'Stomata art': the arrangement of stomata in a plant



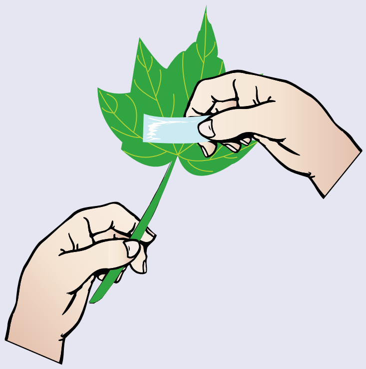
elog-0396

INVESTIGATION 3.7

Observing leaf epidermal cells

Aim

To observe leaf epidermal cells and identify stomata



Materials

- leaf
- clear sticky tape
- microscope slide
- microscope

Method

1. Put some sticky tape over a section of the underside of the leaf.
2. Press the sticky tape firmly onto the leaf.
3. Tear the tape off. Some of the lining cells should come off with the sticky tape.
4. Press the tape, sticky side down, onto a microscope slide.
5. View the sticky tape under the microscope.
6. Try to find a pair of guard cells and one of the stomata.

Results

1. Is the stoma (the opening) open or closed?
2. Make a drawing of a group of cells, including the guard cells. Include as much detail in your drawing as possible.
3. Label the guard cells and stomata.
4. Title and date your drawing. Write down the magnification used.

Discussion

1. Summarise your findings. Include comments on the relationship between the shape of the structures and their function.
2. What causes the changes in guard cells so that stomata open and close?
3. Identify strengths and limitations of this investigation and suggest possible improvements.

Conclusion

What is the function of guard cells and where are they found?

EXTENSION: Water loss

Although water makes up about 90–95 per cent of the living tissues of plants, water is often being lost to their surroundings. As much as 98 per cent of the water absorbed by a plant can be lost through transpiration.
A variety of factors affect the amount of water that plants lose. Weather is a major factor, as high temperatures, wind and low humidity can increase the evaporation of water from the stomata. It has been recorded that large trees may lose more than 400 litres of water in a day.

elog-0397

INVESTIGATION 3.8

Looking at chloroplasts under a microscope

Aim

To observe chloroplasts under a light microscope

Materials

- tweezers
- water
- moss, spirogyra or elodea
- dilute iodine solution
- light microscope, slides, coverslips

Method

1. Using tweezers, carefully remove a leaf from a moss or elodea plant or take a small piece of spirogyra.
2. Place the plant material in a drop of water on a microscope slide and cover it with a coverslip.
3. Use a light microscope to observe the leaf. Complete a drawing of a cell. Include (a) title, (b) magnification, (c) scale bar and (d) appropriate labels.
4. Put a drop of dilute iodine solution under the coverslip. (Iodine stains starch a blue-black colour.)
5. Using the microscope, examine the leaf again. Complete a drawing of a cell. Include (a) title, (b) magnification, (c) scale bar and (d) appropriate labels.

Results

1. Draw what you see before staining.
2. Label any chloroplasts that are present.

Discussion

1. Describe the colour of the chloroplasts before staining.
2. What gives chloroplasts their colour?
3. Did the iodine stain any part of the leaf a dark colour?, If so, what does this suggest?
4. Identify strengths and limitations of this investigation and suggest possible improvements.

Conclusion

What conclusions can you make about chloroplasts?

3.8.4 Moving in or out?

The movement of substances into and out of cells is controlled by the cell membrane. This enables useful substances to be delivered into the cells and waste products to be moved out. Some types of movements require energy and others do not.

Oxygen and carbon dioxide enter the cell by a process called diffusion. **Diffusion** moves substances from where they are in a high concentration to where they are in a low concentration and so does not require energy. Water moves across the membrane via a special type of diffusion called **osmosis**. This movement of water into and out of the guard cells is responsible for opening and closing the stomata.

diffusion movement of one substance through another due to a movement of particles, for example from a region of higher concentration to lower concentration

osmosis the movement of water across a semipermeable membrane from where it is in a high concentration to where it is in a low concentration

Flaccid or firm?

If too much water is lost or not enough water is available, the plant may **wilt**. When this occurs, water has moved out of the cell **vacuoles** and the cells have become soft or **flaccid**. The firmness in the petals and leaves is due to their cells being firm or **turgid**.

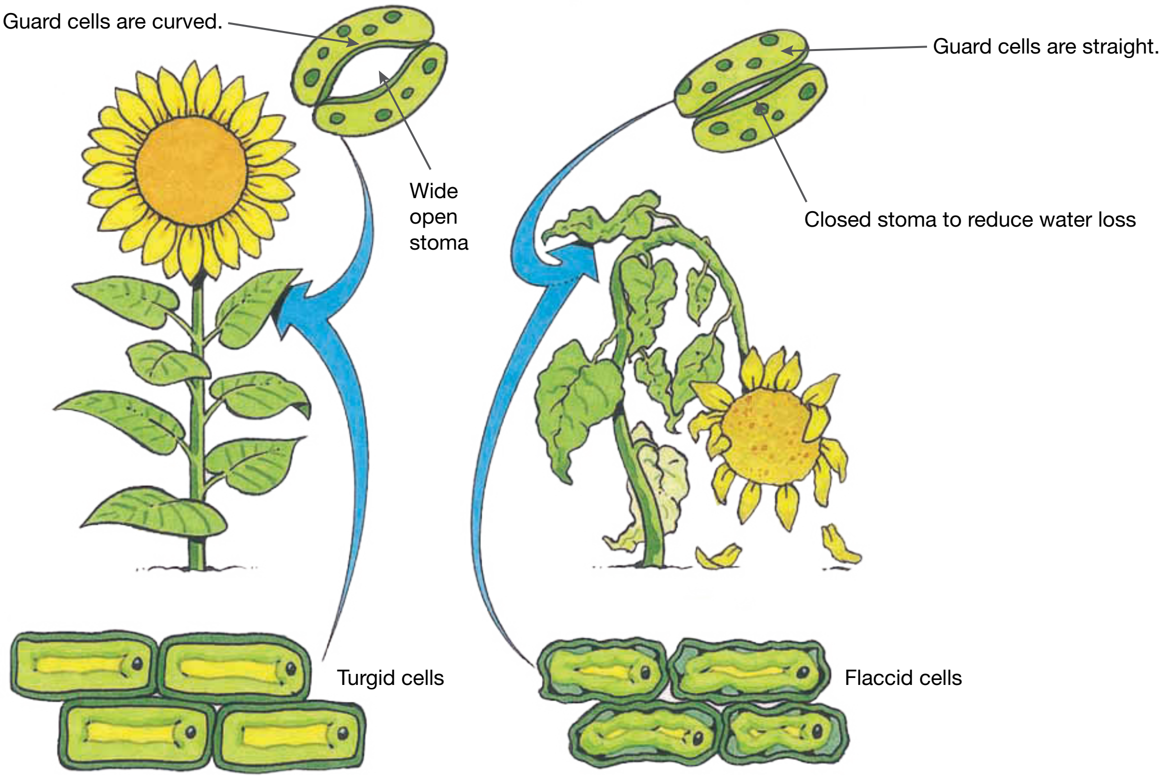
wilt plant stems and leaves droop due to insufficient water in their cells

vacuoles sacs within a cell used to store food and wastes. Plant cells usually have one large vacuole. Animal cells have several small vacuoles or none at all.

flaccid cells that are not firm due to loss of water

turgid something that is firm

FIGURE 3.35 If the cells of a plant do not contain enough water, they become flaccid and the plant wilts.



elog-0398

INVESTIGATION 3.9

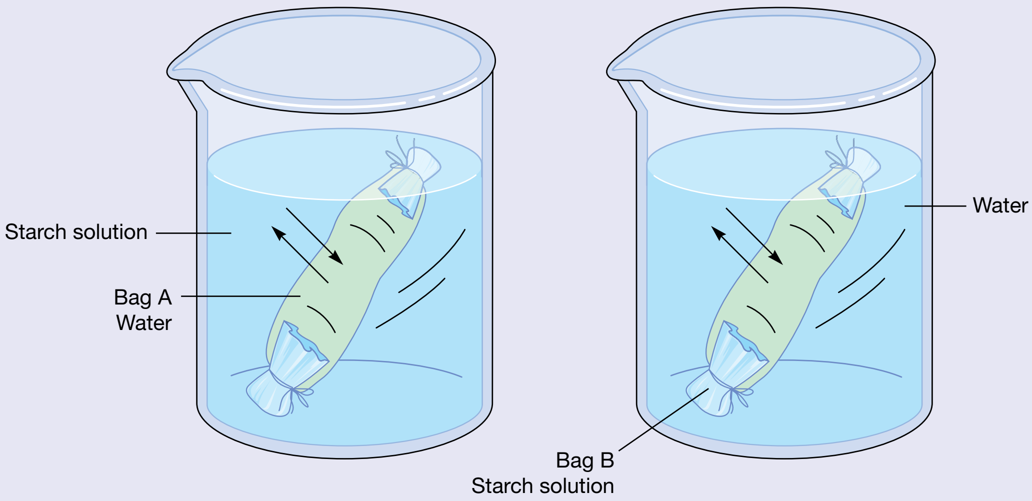
Moving in or out?

Introduction

Water moves from areas of high water concentration to areas of low water concentration. In this way, water can move from the xylem cells into photosynthetic cells so that photosynthesis can occur. In this investigation you will see how water moves across a membrane.

Aim

To make a model of a cell membrane to simulate the effect of water moving in and out of a cell



Hypothesis

What do you expect will happen to Bag A?

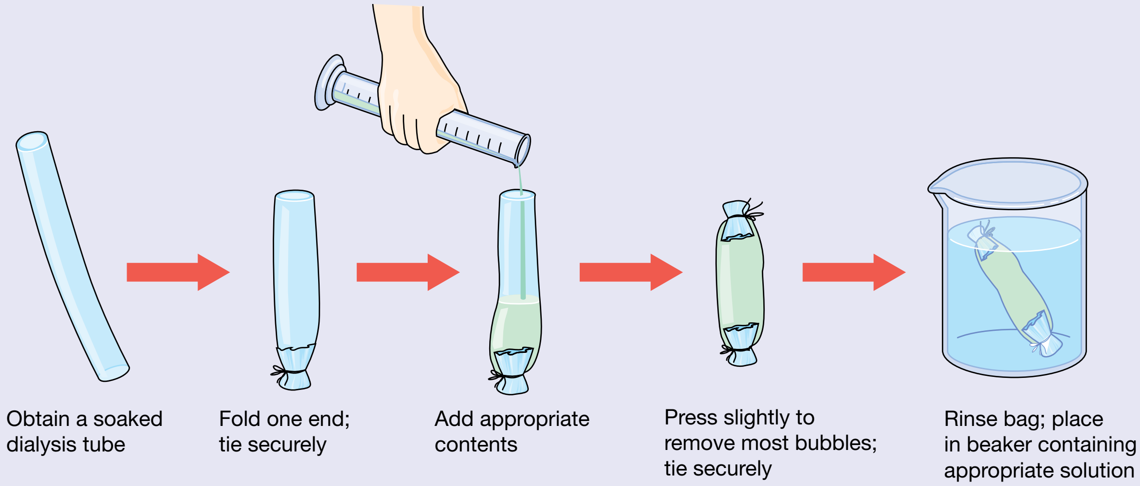
What do you expect will happen to Bag B?

Materials

- two 20 cm lengths of dialysis tubing
- scales
- starch solution
- iodine solution
- 2 beakers

Method

1. Soak the dialysis tubing in water so it becomes soft.
2. Tie a knot at one end of each piece of dialysis tubing. This will form two small bags.
3. Pour water into Bag A until it is one third full. Pour the same amount of starch solution into Bag B and add 10 drops of iodine solution.
4. Tie a knot at the top of each bag to seal them.
5. Weigh each bag and record weight in the table in the results section of this investigation.



6. Put Bag A in a beaker of starch solution. Add enough iodine to the starch solution to produce a dark blue colour.
7. Put Bag B in a beaker of water.
8. Leave the two bags undisturbed for at least two hours (or overnight).
9. Weigh the bags again. Record in the table in the results section.
10. Draw bags A and B in the beakers they were left in. On your diagram, label where blue and yellow colour can be seen.

Results

Weight	Bag A (bag of water in starch solution)	Bag B (bag of starch in water solution)
Before		
After		

Discussion

1. In this experiment, we made a model of a cell. Which part represented the cell membrane?
2. What happens to iodine when it is added to starch solution?
3. Dialysis tubing allows some substances, but not others, to pass through. Which of the following substances could pass through the dialysis tubing and which could not? What evidence supports this?
   a. Starch
   b. Water
   c. Iodine
4. Did the masses of the two bags change? What caused the change or lack of change?
5. When water moves in or out of cells by osmosis, it moves in the direction that balances the concentrations of substances inside and outside the cell. Use this information to explain why the masses of the bags changed.
6. Identify the strengths and limitations of this investigation and suggest possible improvements.

Conclusion

Write a conclusion for this practical investigation.

on Resources

eWorkbooks Leafy exchanges (ewbk-4061)
Photosynthesis (ewbk-4063)

assess on Additional automatically marked question sets

3.8 Exercise

learn on

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3, 4, 5	Questions 6, 8, 10, 13	Questions 7, 9, 11, 12

Remember and understand

1. State the name used for the tubes that carry sugar solution around the plant.
2. Describe the difference between:
   a. phloem and xylem vessels
   b. sugar and water transport in plants
   c. the arrangement of vascular bundles in dicots and monocots.
3. In what ways are the vascular bundles important to plants?
4. State two things that may happen to water in a plant.
5. On which part of the plant are stomata usually found? Can you suggest why?
6. What helps 'pull' water up a plant?

Apply and analyse

7. Describe how the guard cells assist the plant in controlling water loss.
8. Describe the difference between flaccid cells and turgid cells.
9. Copy and complete the table given.

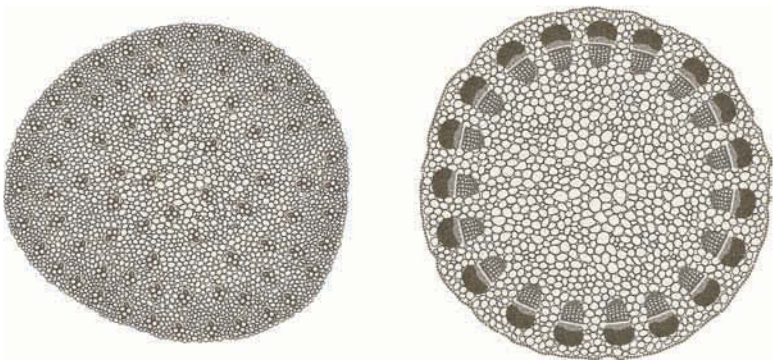
Tissue	What it carries	Direction of movement	Name of cells that form tubes	Are cells that form tubes living?
Xylem				
Phloem				

Evaluate and create

10. Carefully examine the reaction for photosynthesis as shown.

$$\textbf{Carbon dioxide + water} \xrightarrow[\text{Chlorophyll}]{\text{Light energy}} \textbf{Glucose + oxygen (+ water)}$$

   a. Suggest why water and carbon dioxide are so important to plants.
   b. Suggest why guard cells are important to plants.
   c. Predict consequences for a plant if the guard cells close the stomata for long periods of time.
11. **SIS** Grasses and trees have a very different arrangement of their vascular bundles.



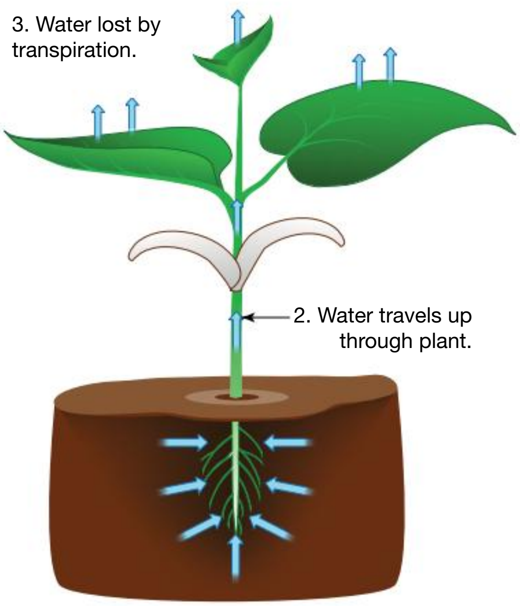
This image on the left is the organisation in a grass stem (random) and the image to the right is that of a stem that eventually becomes a tree (organised in a ring).

MC Choose the feature of trees you think this specialised arrangement leads to.

A. Roots
B. Leaves
C. Wood
D. Flowers

12. **SIS** This diagram demonstrates transpiration, the loss of water from the leaves of a plant.
   a. Hypothesise what you would expect transpiration rate to do in the following scenarios:
      i. Wind speed increases
      ii. Temperature increases
      iii. Humidity increases
   b. When a plant experiences water stress because there is not enough water, the guard cells lose water and become flaccid, thereby closing the stomata.
      i. Draw a diagram of this process.
      ii. Hypothesise what you would expect to happen to photosynthetic rate.
      iii. What dependent variable could you measure to test your hypothesis from part b) above?
      iv. Design an experiment to measure the amount of water lost through the leaves of a plant.

   Remember to include:
   - What will change?
   - What will stay the same?
   - What will be measured?
   - How will the test be reliable?



13. Write a story about a group of water molecules that travels from the soil, through a plant and then into the atmosphere as water vapour.

Fully worked solutions and sample responses are available in your digital formats.

3.9 Cell division

LEARNING INTENTION

At the end of this subtopic you will be able to describe cellular replication and its role in growth, development, repair and replacement of cells. You will be able to identify that binary fission and mitosis are both methods of cellular replication.

3.9.1 Cell division in eukaryotes

Ouch! Did you burn or cut yourself? What about those skin cells you left on the towel when you dried yourself and those hairs you left behind in your brush? Have you replaced these cells? Throughout the life of multicellular organisms, cell division takes place to enable growth, development, repair and replacement of cells. Cell division also plays an important role in reproduction.

Nucleus, chromosomes and DNA

All eukaryotic cells have a **nucleus**, which contains genetic information with instructions that are necessary to keep the cell (and organism) alive. This information is contained in structures called **chromosomes**, which are made up of a chemical called **deoxyribonucleic acid (DNA)**.

nucleus (in biology) roundish structure inside a cell that acts as the control centre for the cell; (in chemistry) the central part of an atom, made up of protons and neutrons. Plural = nuclei.

chromosomes the tiny, thread-like structures inside the nucleus of a cell. Chromosomes contain the DNA that carries genetic information.

deoxyribonucleic acid (DNA) the chemical substance found in all living things that encodes the genetic information of an organism

Mitosis

Mitosis is the name of a process involved in cell division in eukaryotic cells. Some organisms use this type of cell division to asexually reproduce. Multicellular organisms also use mitosis to produce cells for growth, development, repair and replacement.

The cells produced by mitosis are genetically identical to each other and to the original cell. They have the same number and types of chromosomes and DNA instructions. As they have identical genetic information, they are described as being **clones**.

Cytokinesis

Mitosis is a process that involves division of the nucleus. Once a cell has undergone this process, the cell membrane pinches inwards so that a new membrane forms, dividing the cell in two. This process of dividing the cytoplasm is called **cytokinesis**.

FIGURE 3.36 Mitosis is a type of cell division that produces identical cells.

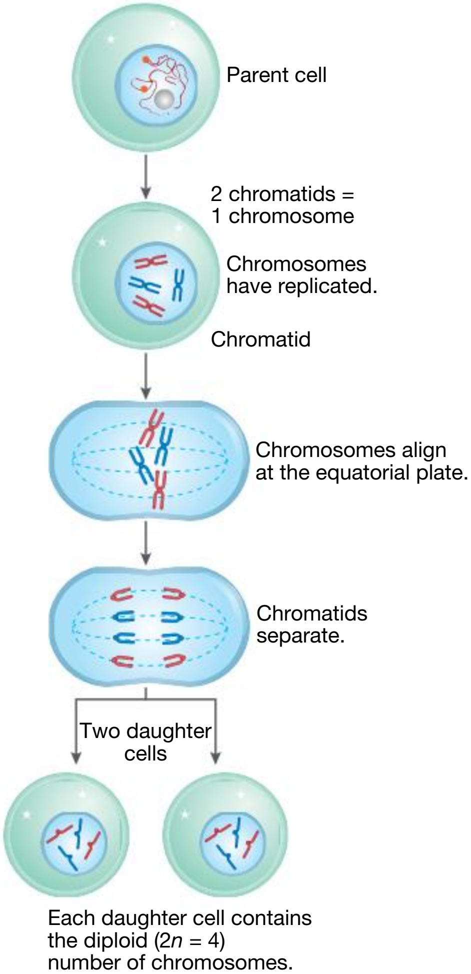
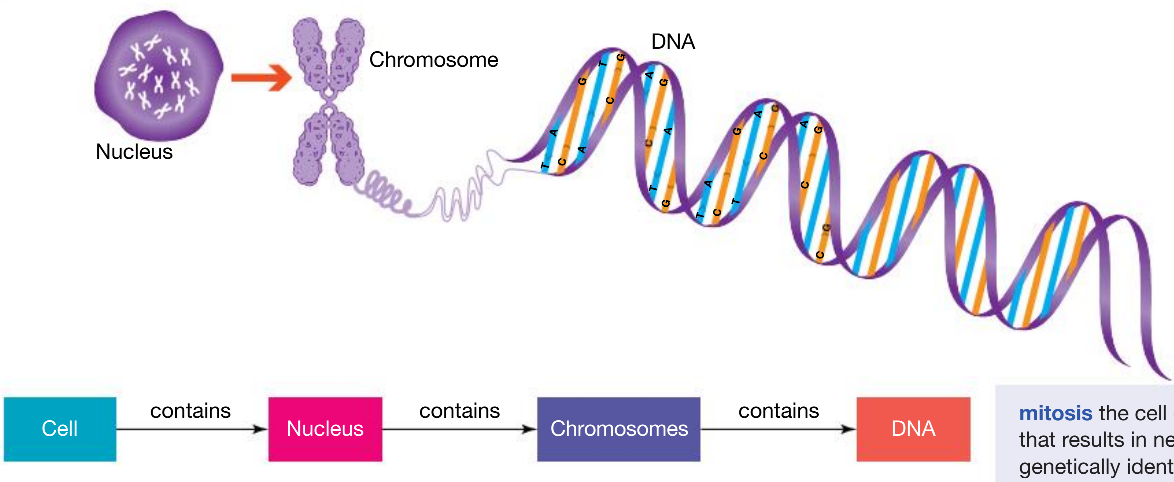


FIGURE 3.37 DNA makes up chromosomes, which are located in the nucleus of the cell.



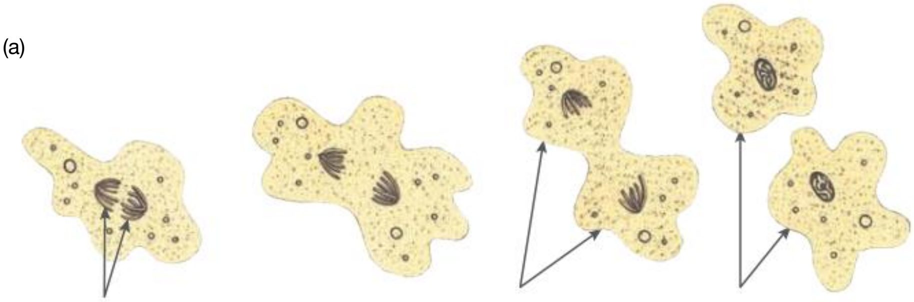
mitosis the cell division process that results in new cells, which are genetically identical to each other and to the original cell

clone an identical copy

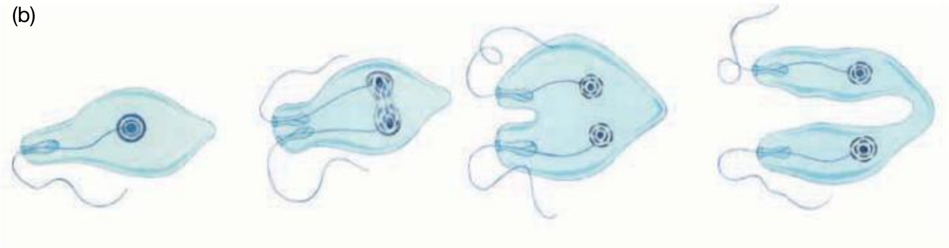
cytokinesis the division of the cytoplasm at the end of the cell division process so that one cell divides to form two

FIGURE 3.38 Eukaryotic unicellular organisms like **a.** *Amoeba* and **b.** *Euglena* divide by binary fission involving mitosis.

(a)



(b)



on Resources

Video eLesson Binary fission (eles-2028)

elog-0399

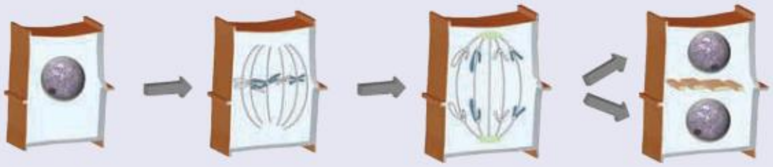
INVESTIGATION 3.10

Mitosis: Patterns of order

Introduction

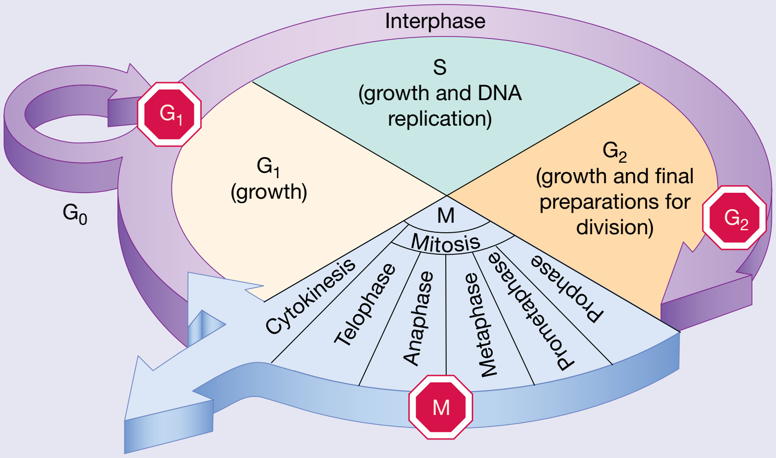
When cells need to replicate, they go through a process called mitosis. There are four stages in mitosis, which are shown here.

Mitosis



These stages make up a very small part of a cell's cycle. Between each mitosis division, cells go through a period of growth and DNA replication and at the end of it all the cell breaks in two.

The cell cycle



Aim

To observe slides showing mitosis under a light microscope

Materials

- light microscope
- prepared onion root tip cells showing various stages of mitosis

Method

1. Use a light microscope to observe the prepared slides.
2. Construct labelled diagrams to record your observations for each of the following stages: Interphase, Prophase, Metaphase, Anaphase, Telophase and Cytokinesis. Use a table like the one in the results section to record your observations.

Results

Interphase	Prophase
Metaphase	Anaphase
Telophase	Cytokinesis

Discussion

1. Why is interphase important?
2. Where does mitosis occur in plants?
3. What is being referred to when we talk about the 'parent' cell?
4. How genetically similar are the two daughter cells compared to the parent cell?

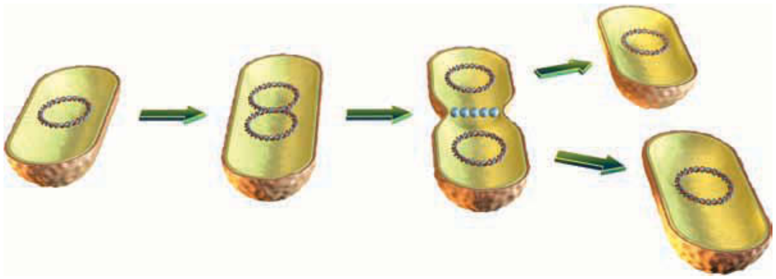
Conclusion

Summarise your understanding of mitosis.

3.9.2 Cell division in prokaryotes

Prokaryotes (such as bacteria) reproduce themselves by dividing into two using a process called binary fission. Binary fission involves the replication of the chromosome, the movement of the two resulting chromosomes to opposite ends of the cell and the cleaving of the cell in two. Although binary fission also occurs in some eukaryotes, this is much less complex in prokaryotes as they do not have a nucleus. The cells produced are clones; they are identical to each other and to the cell from which they originate.

FIGURE 3.39 Binary fission in prokaryotes



3.9.3 Using bacteria to make human proteins

Knowledge of how bacteria reproduce can be used to get them to make human proteins. Scientists can insert genetic instructions from other organisms (including humans) into bacterial cells. When these bacterial cells divide, they produce cells that also contain the inserted foreign DNA and are able to make the protein that it codes for.

This technology can be used to produce insulin, a protein used in the treatment of a type of diabetes. The rapid rate of bacterial reproduction results in many cells with the human DNA and the production of useful quantities of this important human protein.

Cell division and disease

Diseases can be divided according to whether they are infectious or non-infectious. **Infectious diseases** can be transferred from one organism to another. Tetanus and tuberculosis are examples of infectious diseases in which cells are damaged by a bacterial infection. **Non-infectious diseases** are not transferred between organisms. Cancer is an example of a non-infectious disease that can be considered as a form of uncontrolled cell division or a disease of mitosis.

Scientists use their knowledge of cell division of disease-causing organisms to control or kill them. **Antibiotics** can be used to kill bacteria inside your body. **Disinfectants** can be used to kill bacteria on surfaces of non-living objects. Disinfectants should not be used on your skin as they can damage your cells. **Antiseptics** can be used on your skin. Antiseptics that kill bacteria are referred to as **bactericidal**, and those that stop bacteria from growing or dividing (but do not kill them) are called **bacteriostatic**.

infectious diseases diseases that can be transferred from one organism to another

non-infectious diseases diseases that cannot be transferred from one organism to another

antibiotics a substance derived from a micro-organism and used to kill bacteria in the body

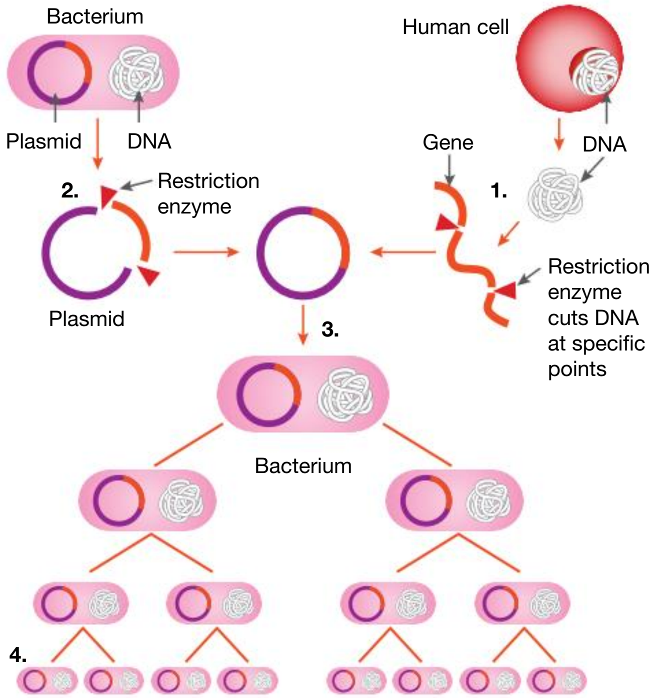
disinfectants a chemical used to kill bacteria on surfaces and non-living objects

antiseptics a mild disinfectant used on body tissue to kill microbes

bactericidal an antiseptic that kills bacteria

bacteriostatic an antiseptic that stops bacteria from growing or dividing but doesn't kill them

FIGURE 3.40 Bacteria can produce human insulin if the insulin gene is inserted into the bacterial cells.



elog-0400

INVESTIGATION 3.11

Where are those germs?

Aim

To observe a variety of micro-organisms from your local environment

Materials

- sterile cotton buds
- sticky tape
- nutrient agar plates in Petri dishes (3 per group)
- sterile Pasteur pipette
- marker pen

CAUTION

Agar plates should not be opened after incubation.

Method

1. Swipe a sterile cotton bud across a surface of your choice (such as canteen counter, computer keyboard, phone mouthpiece or bin lid).
2. Swipe the cotton bud across the surface of the agar. Be careful not to push down too hard. The cotton bud should not leave a mark on the agar.
3. Use sticky tape to seal the plate around the edge.
4. Use a marker pen to write your group's name and where you collected the sample from.
5. Use a different cotton bud to swipe a part of your body (such as the inside of your nose, your teeth, inside your ear or your scalp).
6. Swipe the cotton bud on the surface of the second agar plate, then seal and label it as before.
7. Use the sterile Pasteur pipette to collect about 1 mL of water from a location of your choice (such as a fish tank, puddle, local creek, school swimming pool or drain pipe).
8. Pour the sample of water over the surface of the agar and swish it around. Seal and label the agar as before.

9. Incubate the three plates upside down at 30 °C for 48 hours. Remove the plates from the incubator and observe the colonies of bacteria through the lid of the Petri dishes. (Do not open the Petri dishes.)

Results

Draw a diagram of each Petri dish showing the location and size of the colonies.

Discussion

1. Colonies of bacteria tend to be smooth whereas colonies of fungus appear furry and are often larger. Do you have colonies of bacteria or fungi or both on your plates?
2. Look at the other groups' plates.
   a. Which of the surfaces tested by your class had the most microbes? How can you tell?
   b. Which body part tested had the most microbes?
   c. Which of the water samples tested contained the most microbes?
3. Explain why it would be dangerous to unseal the agar plates and lift the lid to look at the colonies of microbes.
4. Design an experiment to test whether antibacterial surface spray really does kill bacteria.

Conclusion

Write a conclusion for this investigation.

ACTIVITY: Investigating bacteria

- Design an experiment to test whether antibacterial surface spray really does kill bacteria. Justify your strategy.
- Research examples of genetic engineering in which bacteria have foreign DNA inserted into them so that they produce human proteins. Communicate your findings as a newspaper article. What beliefs and values do you hold about this type of engineering? How is this different to what others think?

on Resources

assesson Additional automatically marked question sets

3.9 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3, 11, 14	Questions 4, 6, 7, 9, 12, 15	Questions 5, 8, 10, 13, 16

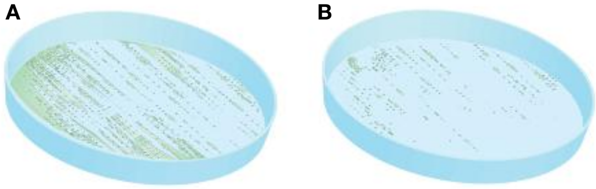
Remember and understand

1. Provide three reasons for cell division.
2. Suggest the relationship and sequence of the following: nucleus, DNA, cell, chromosome.
3. State a feature that the daughter cells produced by mitosis share with the parent cell.
4. If a cell is described as being a clone, what does this mean?
5. Identify a type of unicellular organism that:
   a. uses mitosis to reproduce
   b. does not use mitosis to reproduce.
6. Identify the difference between mitosis and cytokinesis.

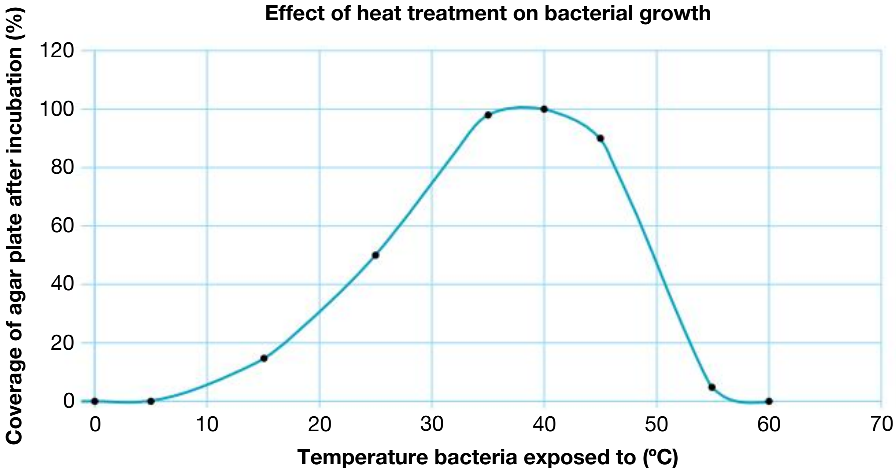
7. Suggest a way that scientists can apply their knowledge of cell reproduction to benefit humans.
8. Outline the differences between disinfectants, antiseptics and antibiotics.

Apply and analyse

9. **SIS** Charlotte wanted to find out if antibacterial soap really works. She prepared two agar plates. She swiped her fingers over the surface of plate A. She then washed her hands with antiseptic soap and swiped her fingers over the surface of plate B. She incubated both plates. Her results are shown here.



   a. Write a conclusion for Charlotte's experiment.
   b. Which plate was the control?
   c. What were the independent and dependent variables in this experiment?
   d. Which variables need to be controlled in this experiment so that it is a fair test?
10. *Clostridium perfringens* is one of the fastest growing bacteria, having an optimum generation time of about 10 minutes, which means the population of bacteria doubles every 10 minutes under optimal conditions.
   a. If you started with 200 bacteria, plot on a graph how many bacteria there would be over a one-hour period.
   b. Find out more about the structure and reproduction of this bacterium.
   c. Find out why it is sometimes referred to as a 'flesh-eating' bacterium.
   d. Write a story that includes features of *Clostridium perfringens* as a key part of the storyline.
11. **SIS** This is a graph showing the amount of bacteria grown after being heat treated and then left to incubate on a Petri dish for 24 hours.



   a. What is the best temperature for bacterial growth?
   b. Suggest a reason food is cooked to reduce the likelihood of being affected by this bacterium.
12. Before mitosis begins, the DNA in the cell is replicated. Suggest why this replication step needs to occur.
13. Suggest the advantages and disadvantages of being a clone.

Evaluate and create

14. *Entamoeba histolytica* is a unicellular organism that is a cause of diarrhoea among travellers to developing countries.
   a. Find out more about the disease that it causes, its life cycle and what you can do to avoid being infected by it.
   b. Prepare a brochure, poster or PowerPoint presentation that could be used to inform travellers.
15. **SIS** Investigate cell division in *Amoeba, Euglena* or *Paramecium* and create an animation to show how they reproduce.

16. a. Find out why *Escherichia coli* (*E. coli*) counts at beaches are often reported in newspapers.
b. How is the concentration of *E. coli* measured?
c. Find out more about the structure and reproduction of *E. coli*.
d. Create a model of this organism.

Fully worked solutions and sample responses are available in your digital formats.

3.10 Skin 'n' stuff

LEARNING INTENTION

At the end of this subtopic you will be able to describe the structure and function of skin. You will be able to explain the effects of sunburn and skin cancer.

3.10.1 Skin deep

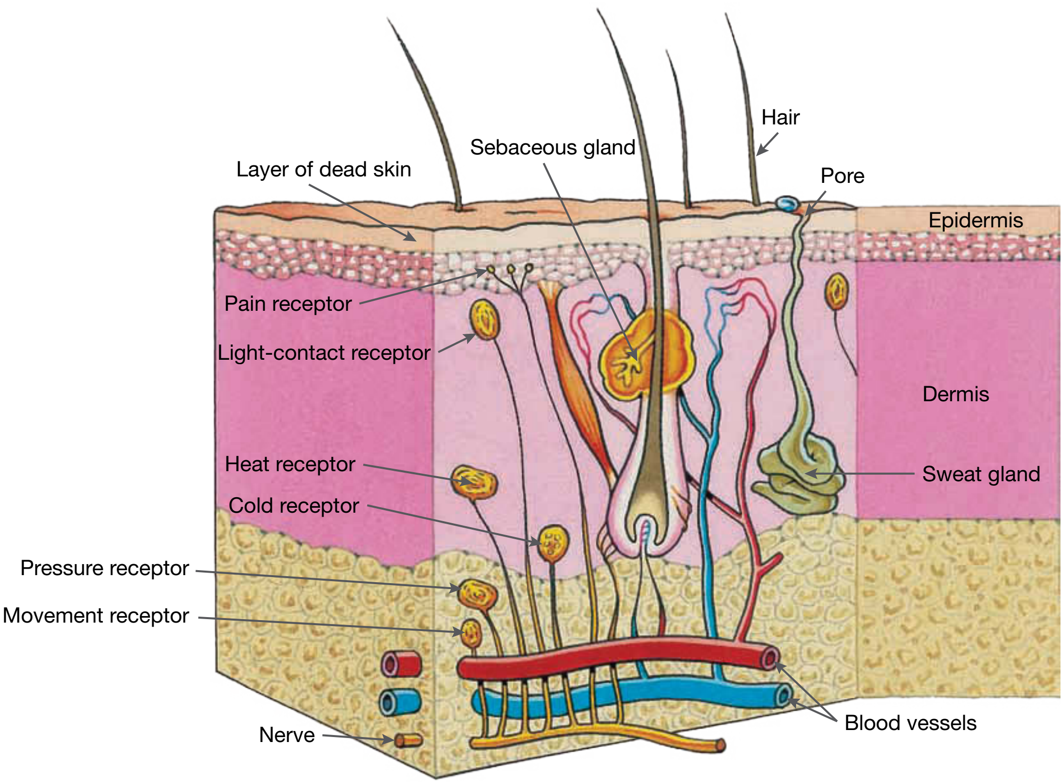
Your skin is made up of lots of cells that work together to keep you alive. A type of cell division called mitosis enables you to make skin cells for growth, repair and replacement. But what happens when something goes wrong?

Your skin is the largest organ of your body. As well as holding the insides of your body in, it also:

- protects your body from microbes that could cause disease
- is almost completely waterproof
- protects the inside of your body from chemicals and harmful radiation from the Sun
- detects heat, cold, pain, pressure and movement
- helps control your body temperature
- forms vitamin D in sunlight
- releases water and other waste products.

Your skin varies in thickness between about 0.5 millimetres and 5 millimetres. The thickest part is on the soles of your feet. Skin consists of three layers.

FIGURE 3.41 The skin is divided into three layers.



The **epidermis** is the top layer. It contains several layers of cells. At the very top is a layer of dead skin cells, which flake off continually. At the bottom of the epidermis, new cells are always being produced. They push upwards on the older cells, moving them towards the surface. Below the epidermis is the **dermis**, which contains **receptors** for the sense of touch. It also contains **sweat glands** and many small blood vessels. Beneath the dermis is a thicker layer of fatty tissue, which acts as an insulator to help keep the body temperature constant. This fat has been stored by the body and can be used when needed to provide extra energy.

When you get hot, it is important that your body cools itself down so the blood remains at its constant temperature of about 37 °C. Your sweat glands produce a liquid that is released through the **pores** at the surface of your skin. When the water in your sweat **evaporates**, it takes some of the heat out of your body.

3.10.2 Are you ticklish?

Are you more ticklish on some parts of your skin than others?

Below the surface of your skin there are many receptors that are attached to nerves. The nerves send messages to the brain. There are different receptors for heat, cold, light contact, pain, pressure and movement. They are all receptors to the sense of touch.

The light-contact receptors are nearer to the surface and closer together in some parts of your skin than others. It is those parts that are most sensitive to tickling. Some parts of the skin are also more sensitive to pain, heat, cold, pressure and movement than others. Your sensitivity depends a lot on how close together the receptors are and how deep they are.

CASE STUDY: Sweat doesn't smell?

Sweat doesn't actually smell until it is consumed by the bacteria that live on the surface of your skin. The regions around your armpits and external sex organs are warm and moist, providing ideal conditions for bacteria to grow and feed on the sweat. This is why these areas can get smelly.

3.10.3 Sun sense

Being sun smart in Australia is a must. Along with the obvious pain of sunburn, exposure to ultraviolet rays leads to skin cancer. Skin cancer is the most common form of cancer in Australia. In fact, two out of three Australians are likely to get skin cancer at some time during their lives. The most serious forms of skin cancer are responsible for about 2000 deaths each year in Australia.

What is cancer?

As the body's cells die, new cells are made to replace them. In a healthy person, just the right number of new cells are formed using mitosis. Cancer can be considered as a disease of mitosis. Damage to the DNA in a cell can cause the normal regulatory processes in cell division to be ignored or overridden. This can result in uncontrolled cell division — a condition we call **cancer**.

This uncontrolled cell division can form a mass of cells called a **tumour**. The cells of a tumour are not specialised and cannot do the jobs of the cells that they are replacing. Some tumours still respond to the body's control mechanisms and do not spread to other parts of the body. These tumours are called **benign**. Others have uncontrolled cell growth and do spread, damaging vital organs. These are called **malignant** tumours or cancer. If cancer is detected early, the diseased cells can be removed or destroyed by chemotherapy or radiation. However, once cancer spreads, it is very difficult to control.

epidermis the outermost layer of the skin

dermis the medical name for the deeper part of the skin

receptors specialised structures that sense or receive stimuli

sweat gland a tiny, coiled tube in the skin through which water and salt are removed from the body, helping to control body temperature

pores small openings in the skin. Perspiration reaches the surface of the skin through pores

evaporates changes state from a liquid to a gas. Evaporation occurs only from the surface of a liquid.

cancer a disease resulting in the uncontrolled growth of body cells, forming tumours

tumour an abnormal growth

benign a tumour that does not spread to other parts of the body

malignant a type of tumour that damages cells and can spread to other parts of the body

FIGURE 3.42 Ways to protect your skin from the Sun

What causes skin cancer?

The main cause of skin cancer is exposure to the Sun. The ultraviolet radiation reaching Earth from the Sun is not visible. Ultraviolet radiation, which is also the cause of sunburn, is at its peak in the middle of the day when the Sun is directly overhead. Ultraviolet radiation causes cancer in the cells of the epidermis, the top layer of the skin, because it damages the cells' genetic material.

on Resources

Video eLesson A cure? (eles-0070)

3.10.4 Early detection

The key to curing skin cancer is early detection. Even melanomas can be cured in more than 95 per cent of patients if they are detected quickly. If you see a new lump or spot, or a changing freckle or mole, see a doctor promptly.

The three main types of skin cancer include the following.

Squamous cell carcinoma

- Less common and more dangerous than basal cell carcinoma
- Appears as a red, scaly sore
- Usually found on the hands, forearms, face and neck, but can spread to other parts of the body
- Mostly affects people over the age of 40 who have been exposed to the sun for many years
- Kills about 500 Australians each year

Basal cell carcinoma

- Most common form of skin cancer and also the least dangerous
- Appears as a red, flaky lump on the skin
- Rarely spreads to other parts of the body but needs to be treated before it grows large or forms a deep sore

FIGURE 3.43 Squamous cell carcinoma

FIGURE 3.44 Basal cell carcinoma

Melanoma

- Least common but most dangerous form of skin cancer
- First sign is a change in size, shape or colour of a freckle or mole, or the appearance of a new spot on normal skin
- Can spread quickly to other parts of the body
- Most common in adults aged between 30 and 50 years, usually caused by long periods of exposure to the sun during childhood and adolescence
- Cause of the most deaths from skin cancer — about 1500 each year in Australia

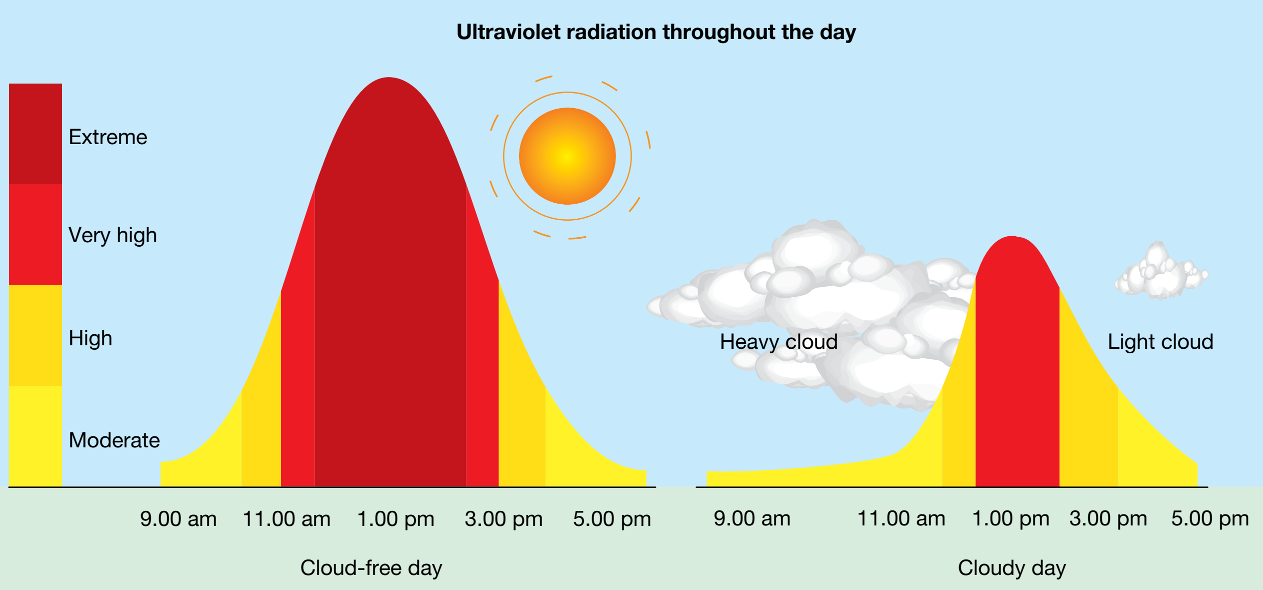
FIGURE 3.45 Melanoma

3.10.5 Some questions about fun in the sun

Q:	***Is a suntan healthy?***
A:	No. A suntan is evidence that you have been exposed to the sun for too long. A suntan will not protect you from skin cancer. Fake suntan lotions do not offer protection from skin cancer either.
Q:	***Do I need to worry about sunburn or skin cancer when it's cloudy?***
A:	Yes. Although clouds block out a lot of the Sun's visible light, they do not block out enough ultraviolet radiation to protect your skin completely, especially during summer. The graphs show that light cloud cover has little effect on the harmful ultraviolet radiation reaching the ground on a summer's day in Melbourne. Heavy cloud, however, decreases the amount of ultraviolet radiation reaching the ground by over 90 per cent.
Q:	***Do I need to use sunscreen when I wear a hat?***
A:	Yes. The Sun's radiation is reflected from the ground and from water. Snow and sand reflect a lot of radiation, even on cloudy days. In addition, many hats, including baseball caps, do not protect you from direct radiation. Wide-brimmed hats or 'legionnaire' hats provide the best protection because they shade the neck and ears.

Q:	*What does SPF 30+ mean?*
A:	SPF stands for 'sun protection factor'. It allows you to estimate how long you can stay in the sun before your skin starts to go red. This period can be estimated by multiplying the amount of time that it takes your skin to redden by the SPF factor. For example, if your unprotected skin starts to burn after 10 minutes in the hot sun, proper use of SPF 4 sunscreen would allow you to remain in the sun for 10 × 4 = 40 minutes before burning starts. After that 40 minutes, you would burn, even with more sunscreen applied. An SPF water-resistant 30+ sunscreen reapplied every 2 hours would allow you to remain in the sun for at least 10 × 30 = 300 minutes before burning starts. SPF 30+ sunscreen blocks out about 97 per cent of the Sun's radiation.
Q:	*What does 'broad spectrum' mean?*
A:	The Cancer Council Victoria recommends a broad spectrum SPF 30+ (or higher) sunscreen. Broad spectrum sunscreens offer protection from the two different types of ultraviolet radiation that reach Earth's surface: UVA and UVB.

FIGURE 3.46 These graphs show how the ultraviolet radiation reaching the ground changes on a typical summer day in Melbourne.



CASE STUDY: Treating skin cancer with plants

An Australian drug company called Peplin has developed a gel made from a common weed called *Euphorbia peplus*, which has been used successfully to treat some skin cancers. The plant contains a cancer-fighting chemical. Peplin has found a way of extracting this chemical from the plant and making it into a gel that can be applied to skin cancers. When the gel was tested, it cleared most skin lesions after just two days.

3.10.6 Other injuries to the skin

Any damage to the skin may lead to difficulty in protecting the inside of our bodies from the outside world. Cuts, abrasions and burns are risks and should be carefully avoided.

Burns

A **burn** is defined as damage to skin. First-degree burns are those that damage the epidermis of the skin. Second-degree burns are those that result in damage to the epidermis and the dermis. Third-degree burns result in damage to the underlying tissues, nerves, sweat glands and hair follicles as well as the two dermal layers.

burn any damage to the skin; combustion of a substance with oxygen in a flame

FIGURE 3.47 Degree of skin burn depends on how much of the skin structure is affected.

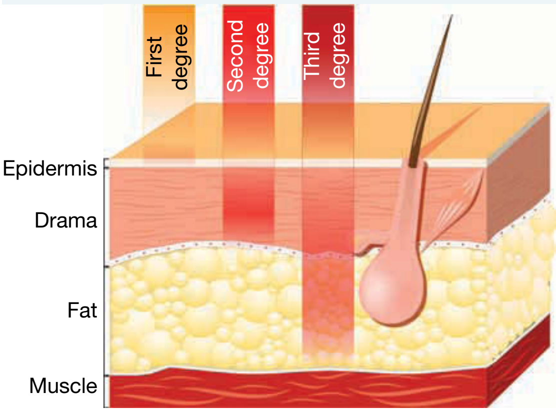


FIGURE 3.48 Paramedic cooling a third-degree burn

EXTENSION: Spray-on skin?

Burns can now be treated with skin that is literally sprayed on! Dr Fiona Wood (Australian of the Year in 2005) pioneered the development of 'spray-on skin'. Using the patient's own skin cells, it can be sprayed onto burnt areas and reduces scarring.

FIGURE 3.49 Dr Fiona Wood, pioneer of 'spray-on skin'

FIGURE 3.50 'Spray-on skin' in action

DISCUSSION

- Construct a mind map that shows links between key scientific terms that are relevant to skin cancer. Use this map as a framework to create a song or poem about skin cancer that will increase awareness of types, causes, detection and prevention.
- Discuss the validity of the following statements.
  - Cancer can be considered a disease of mitosis.
  - Melanoma are less dangerous than carcinoma.

on Resources

assess on Additional automatically marked question sets

3.10 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3, 5, 6, 7, 8	Questions 4, 10, 11, 13, 14, 17	Questions 9, 12, 15, 16, 18, 19

Remember and understand

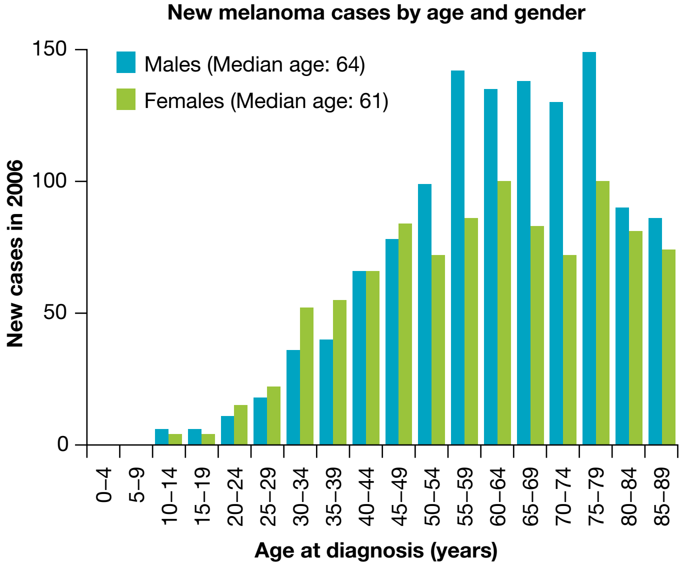
1. Identify the most serious form of skin cancer and how it is caused.
2. Outline the difference between a benign tumour and a malignant tumour.
3. State which part of the Sun's radiation is the major cause of skin cancer and sunburn.
4. Identify the most dangerous time of day to be out in the sun.
5. Describe what you should look for on the skin when checking for signs of skin cancer.
6. List five ways that you can help protect yourself from skin cancer.

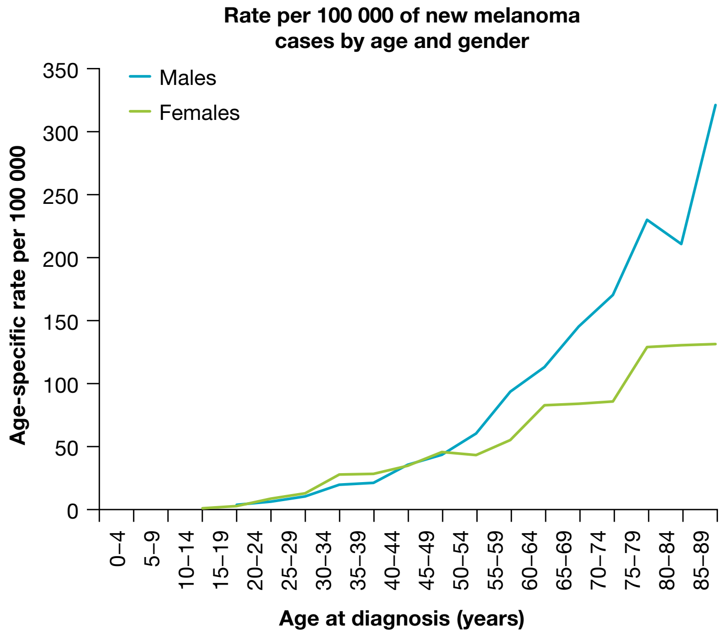
Apply and analyse

7. Melanomas occur mostly in adults over the age of 30. Why is it so important that young children and adolescents are aware of the dangers of the Sun's radiation?
8. Daniel has very pale, sensitive skin that begins to burn after only eight minutes in the summer sun. He goes to the beach and takes a tube of SPF 6 sunscreen with him.
   a. If he doesn't go swimming, how long would he be able to sit in the sun before getting burnt, assuming that he applies his sunscreen correctly?
   b. If he used SPF 30+ sunscreen instead, would he be safe sitting in the sun all day? Give a reason for your answer.
9. Discuss the validity of the following statements.
   a. Cancer can be considered as a disease of mitosis.
   b. Melanomas are less dangerous than carcinomas.
10. Tissues are grouped together to form organs to help you function effectively. Describe how the following are important to your survival.
   a. Muscles   b. Bones   c. Skin

Evaluate and create

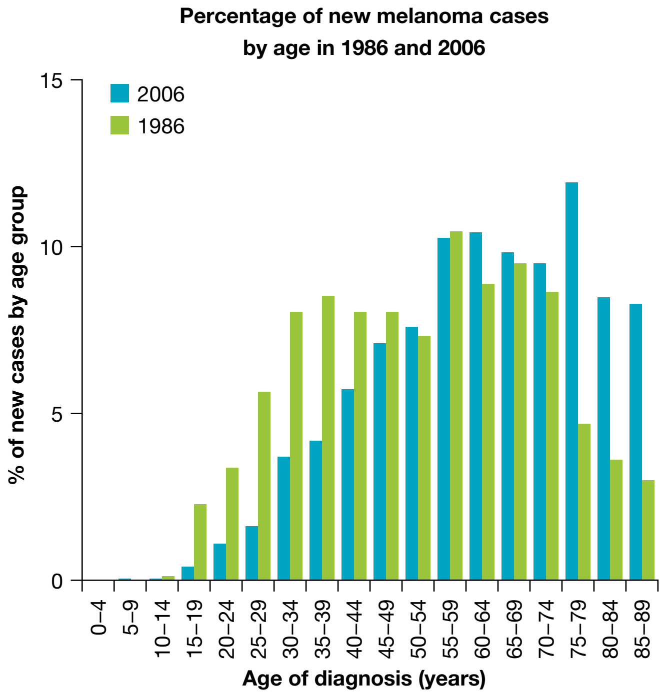
11. SIS Use the 2006 melanoma incidence in Victoria graphs to complete the following.
   a. Describe the pattern of melanoma incidence in Victoria in 2006.
   b. Suggest reasons for this pattern.





c. Identify the age group that has the highest number of new cases of melanomas:
   i. for males
   ii. for females.
d. Do the data suggest that there is a higher incidence of melanomas in males or females?
e. Suggest possible reasons for these data.

12. **SIS** Use the 1986 and 2006 melanoma incidence in Victoria graph to complete the following.
a. State the age group and year with the highest incidence of melanoma cancer.
b. State the age group and year with the lowest incidence of melanoma cancer.
c. Discuss your responses to parts (a) and (b) and suggest possible reasons for your findings.
d. Describe differences in the patterns of melanoma incidence in Victoria between 1986 and 2006.
e. Discuss your observations and suggest reasons for this difference.



13. Design and construct a model that shows details of the three layers of skin.

14. **SIS** Design and construct a multipurpose hat that shades the head and has at least one other purpose. Give your multipurpose hat a name. Prepare an advertising brochure and instruction manual for your hat.
15. **SIS** Design and carry out a survey (consisting of a series of questions) to find out whether people of different age groups protect themselves from the danger of skin cancer by wearing hats, shirts and sunscreens. By sharing your data with other members of your class, you may be able to form a sound conclusion.
16. A number of schools describe themselves as being 'sunsmart'. Find out what the criteria are and who decides whether they are 'sunsmart'.
17. Design your own 'sunsmart' advertising campaign. Present your advertisement as a video clip with music.
18. **SIS** Investigate the correct treatment for burns. Create a poster to be displayed in your laboratory.
19. **SIS** Obtain a selection of at least five different sunscreens. Identify criteria that could be used to determine their similarities and differences. Construct a matrix table with these criteria and record details for each sunscreen. Determine which sunscreen you would use. Which criteria did you use? Give reasons for your criteria. If you were to invent the 'ideal' sunscreen, what features would it have and why? Design an advertising brochure or advertisement for your 'ideal' sunscreen.

Fully worked solutions and sample responses are available in your digital formats.

3.11 Tiny size, big trouble

LEARNING INTENTION

At the end of this subtopic you will be able to explain that microbes are microscopic organisms that can cause disease. You will be able to describe that some microbes can indicate the health of an organism by their presence or absence or extreme numbers.

Science as a human endeavour

3.11.1 'Down the hatch'

Just because you are tiny, doesn't mean that you can't cause trouble — think about how annoying mosquitoes can be! Sometimes it's the small things in life that make the biggest difference. The presence, absence or extreme levels of particular microbes can reflect the health of their habitat, whether it be an organism or an entire ecosystem.

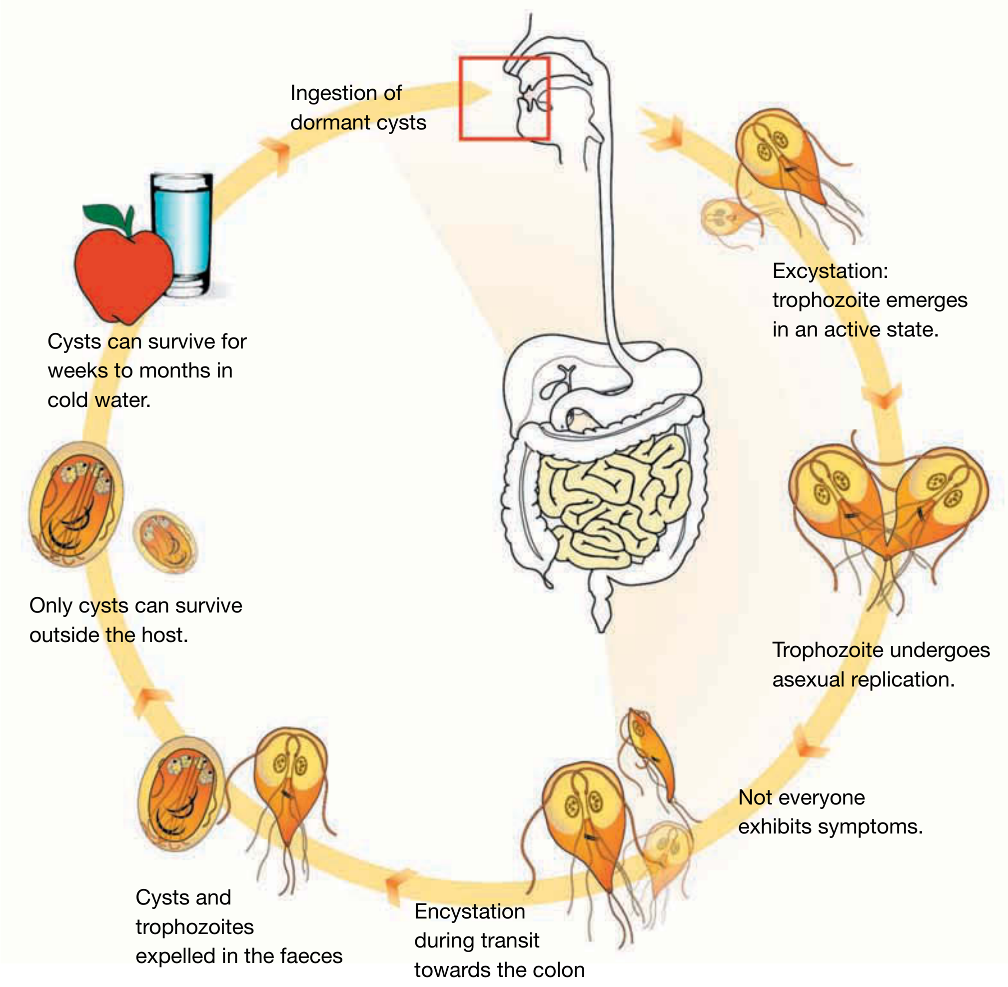
What's in that gulp of water? You may have swallowed a little more than you thought! As well as water, you may have also 'invited in' viruses, bacteria, protozoans, phytoplankton and zooplankton.

FIGURE 3.51 *Giardia lamblia* are pear-shaped and quite large, usually more than 6 μm in size.

A protoctistan (protozoan) by the name of *Giardia lamblia* has become quite well known for 'hitching a ride' in drinking water. These parasites are the cause of one of the most common parasitic gastrointestinal infections in humans worldwide. *Giardia lamblia* made newspaper headlines in 1998, along with another protozoan, *Cryptosporidium parvum*, when high levels of both were reported to be contaminating Sydney's drinking water supply.

Giardia lamblia use their flagella to move around, and they have a complex life cycle. The parasite can survive for a long period outside the body in an inactive form called a cyst. Once swallowed, the cyst is activated by your stomach acid and develops into the disease-causing stage. Using a huge sucker, they then attach themselves to the lining of your intestine, sucking your blood as their food source. After about ten days of infection you could have a million of them living off your blood supply and causing symptoms associated with gastrointestinal complaints. Some of their reproductive cysts pass through your digestive system and are excreted, so that another host can become infected.

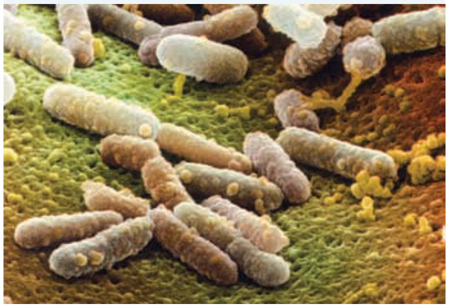
FIGURE 3.52 Where do you fit into the life cycle of *Giardia lamblia?*



3.11.2 Water wise

Living things need water to survive. Some living things also need to live in water to survive. In these ecosystems, there are links between the inhabitants to keep them balanced and healthy. Sometimes, however, these links can be broken or disrupted. This is when problems can occur that may result not only in an unbalanced ecosystem, but also in death.

FIGURE 3.53 Electron micrograph of *E. coli*



Take a swim with me

Escherichia coli (*E. coli*) is a type of bacterium found in our intestine. It usually causes us no harm and passes through our digestive system to be excreted. This enables it to be used as an indicator of sewage contamination in water. Contaminated sewage may contain dangerous or even deadly micro-organisms. It is for this reason that *E. coli* levels are tested and reported at various beaches and swimming locations.

FIGURE 3.54 Warning signs at a waterway in Sydney

WHAT DOES IT MEAN?

The word pathogen comes from the Greek terms *pathos*, meaning 'disease', and *gen*, meaning 'birth'.

CASE STUDY: Aquatic botanist

Professor Gustaaf Hallegraeff is a scientist at the University of Tasmania. In his research he uses light, scanning and transmission electron microscopes to help him classify tiny marine organisms called phytoplankton. On the basis of his findings, he has produced publications to communicate information about harmful Australian microalgae.

FIGURE 3.55 Professor Gustaaf Hallegraeff

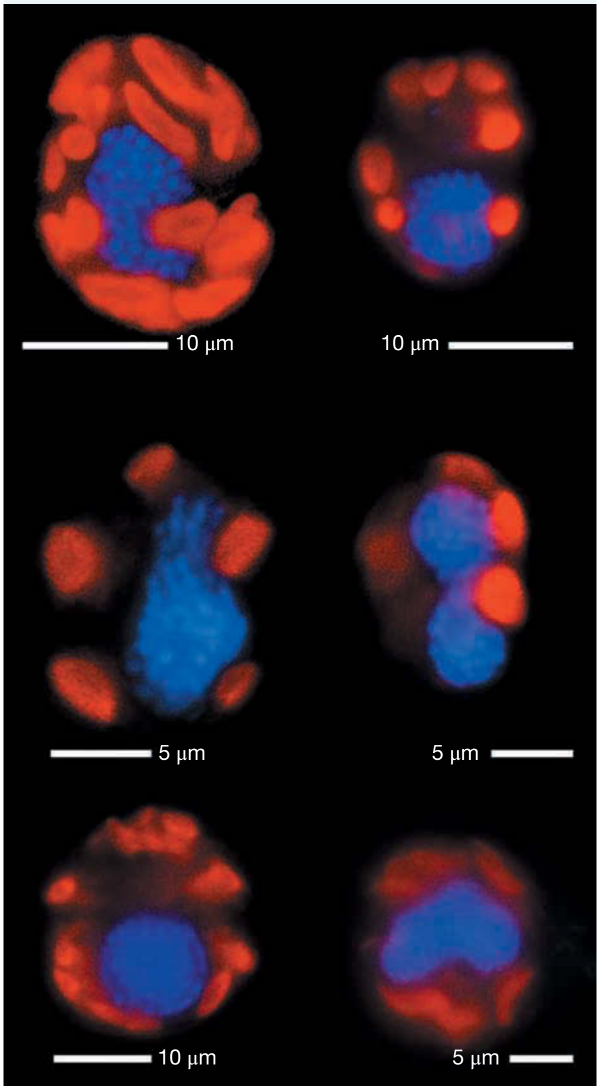
Algal blooms

Algal blooms occur naturally and provide food for many aquatic organisms. Sometimes, however, they can cause harm. Algal blooms can cause large fluctuations in the levels of oxygen and pH (acidity) of the water and block sunlight penetrating through it. The species that cause these blooms may also be toxic to some of the aquatic organisms or even toxic or a skin irritant to humans. The presence of algal blooms can have economic as well as biological consequences.

FIGURE 3.56 *Microcystis* is an example of blue-green algae.

FIGURE 3.57 Algal bloom at Warragamba Dam, Sydney, New South Wales

FIGURE 3.58 Fluorescence microscopy can be used to identify the species that a cell belongs to, and can therefore help determine whether the cell may be of a dangerous type. In this image, the position of the chloroplasts shows as red and the nucleus as blue.



EXTENSION: Snap frozen

Australian Antarctic Division scientists are using a new field emission scanning electron microscope that magnifies specimens by up to 650 000 times. This allows them to observe features two million times smaller than the head of a pin. Snap-freezing technology is used, with the specimen being snap-frozen in super-cooled liquid nitrogen in temperatures of –210 °C! The snap-freeze process allows scientists to study more delicate specimens than were previously able to be observed.

Red tide of death

Scientists at the University of Tasmania have discovered that two new types of algae are killing fish in the Southern Ocean. These algae have been found in abundance and, when in full bloom, produce a distinctive red-coloured tide. The university's scientists are working with the Australian Antarctic Division to try to establish the number of fish that are suffocating from the algae. This will enable sustainable fishing levels to be maintained.

elog-0401

INVESTIGATION 3.12

Teeming with tiny …

Aim

To observe micro-organisms found in water on a microscope slide

Materials

- light microscope
- microscope slides (well slides work best for this observation)
- coverslips
- pipette
- toothpick
- water from a variety of sources (e.g. sea water, pond water, stagnant water, fish tank water)

Method

1. Use a pipette to put a drop of sample water on a clean microscope slide.
2. Gently place a coverslip over the drop of water by putting one edge down first. Use a toothpick.
3. Observe the slide under a microscope.
4. Remove the coverslip, rinse and dry the slide, and then prepare a new slide specimen and repeat the previous steps.

Results

Draw detailed sketches of what you see. Remember to include a title, the magnifications used and as many comments as you can.

Discussion

1. Construct a matrix to show the similarities and differences between the specimens.
2. Suggest reasons for these differences.
3. Research common micro-organisms found in water to identify your specimens.
4. Which kingdoms do you think each specimen may belong to? Provide reasons for your classification.
5. Identify two structures observed in the investigation and find out more about their function (that is, what their 'job' is).
6. Formulate three research questions that could be used for further investigation.

Conclusion

Write a conclusion for this investigation.

on Resources

assesson Additional automatically marked question sets

3.11 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 4	Questions 3, 5, 6	Questions 7, 8

Remember and understand

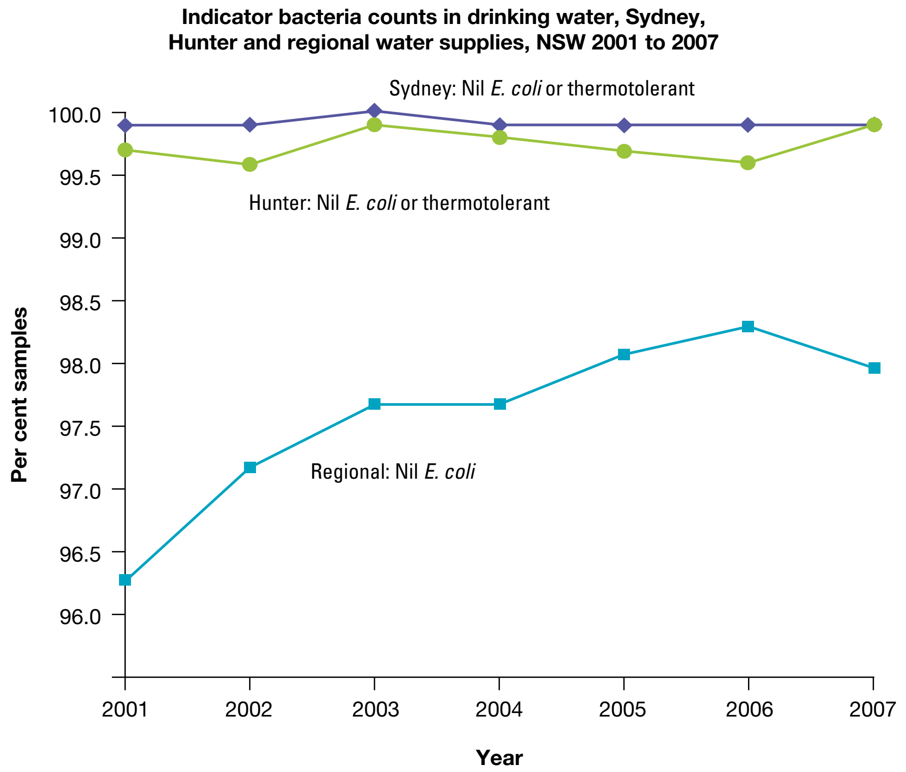
1. Explain why levels of *E. coli* are measured in water.
2. Are algal blooms always harmful? Explain.
3. Outline problems associated with harmful algal blooms.
4. Identify the type of organism that is responsible for causing red tides and killing fish in Australia.

Apply and analyse

5. Explain why scientists are trying to determine the actual numbers of fish being killed by the effects of red tides.
6. State a function of fluorescence microscopy.

Evaluate and create

7. SIS Use the graph shown to answer the following questions.
   a. Describe the pattern of indicator bacteria in each location between 2001 and 2007.
   b. Identify which location has the highest bacterial counts. Suggest a reason for this observation.
   c. Identify which location has the lowest bacterial counts. Suggest a reason for this observation.
   d. Find examples of *E. coli* counts in your local community waters.
   e. Graph your findings and discuss patterns in your class data.
   f. Suggest reasons for the patterns that you have observed.



8. SIS Do microbes reflect marine health? Investigate this question by researching online and justify your response.

Fully worked solutions and sample responses are available in your digital formats.

3.12 Thinking tools — Target maps and single bubble maps

3.12.1 Tell me

What is a target map?

A target map is used to help identify (target) what is part of (relevant to) the topic and what is not part of the topic. They are sometimes called circle maps. Target maps are similar to single bubble maps, in that they both identify and describe the range of the content. However, single bubble maps do not identify the non-relevant material.

For example, you might use a target map to show:
- the characteristics of cells
- the relevant features of an animal cell
- the relevant features of a plant cell.

Why use a target map instead of a single bubble map?

Target maps are a good tool to use for distinguishing what is relevant in a topic, and what is not relevant.

FIGURE 3.59 Target map

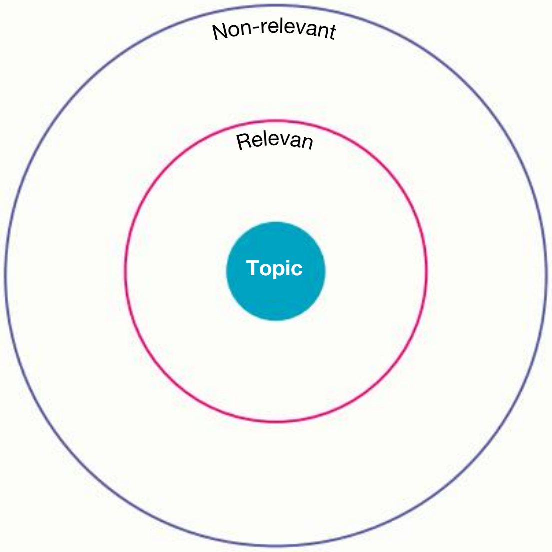
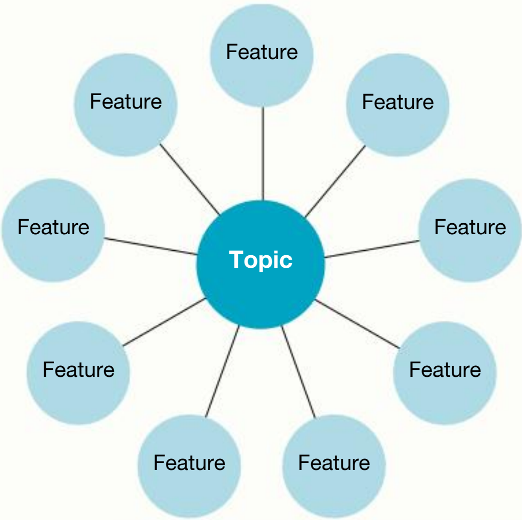


FIGURE 3.60 Single bubble map

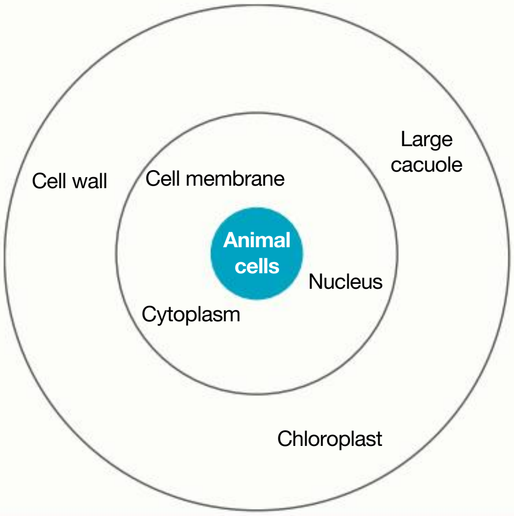


3.12.2 Show me

To create a target map:
1. Draw three concentric circles on a sheet of paper.
2. Write the topic in the centre circle.
3. In the next circle, write words and phrases that are relevant to the topic.
4. In the outer circle, write words and phrases that are not relevant to the topic.

The example in figure 3.61 shows a target map of animal cells.

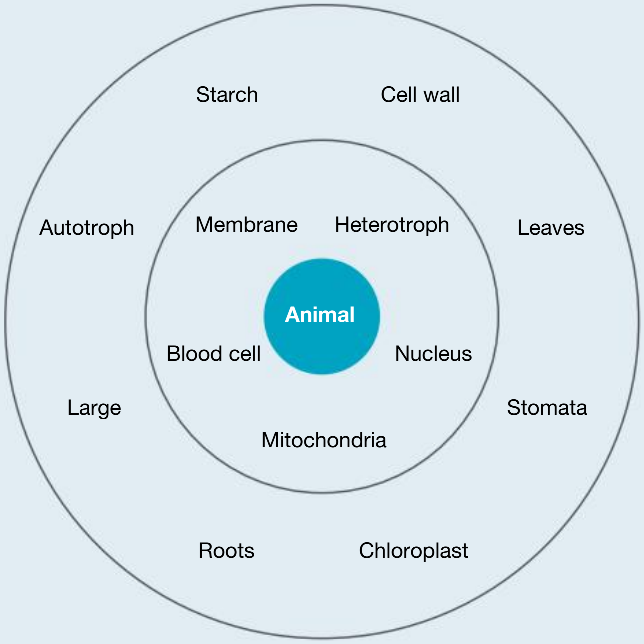
FIGURE 3.61 Target map of animal cells



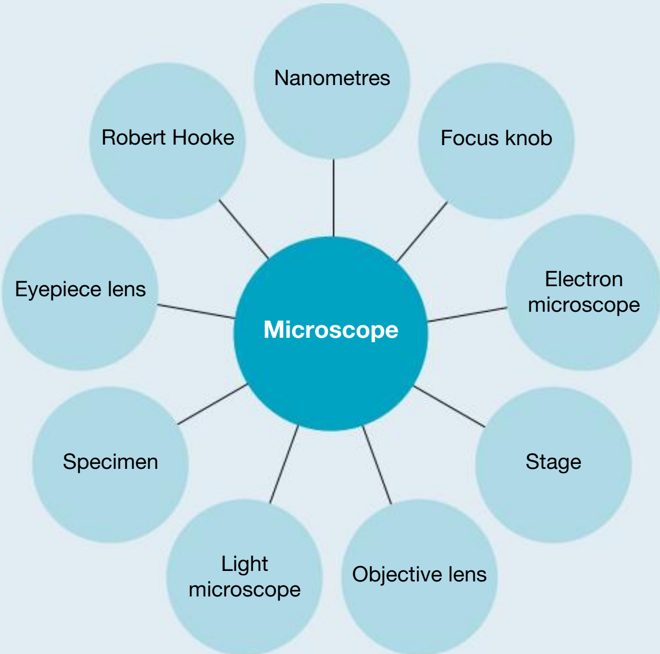
3.12.3 Let me do it

3.12 ACTIVITIES

1. Use the target map to answer the following questions.
   a. List the content that is relevant to animal cells.
   b. List the content that is not relevant to animal cells.
   c. Using the words in the target map, construct a target map that is relevant to plant cells.
   d. Identify which words are relevant to both plant cells and animal cells.
   e. Suggest why plant and animal cells both have these features in common.



2. Use the information in the single bubble map to construct a target map of the parts of a light microscope.



3. a. Use the internet to find images of at least five different types of zooplankton.
   b. Carefully observe your zooplankton images, recording key features of each in single bubble maps.
   c. Construct target maps for each of your zooplankton to show how they are different from the other zooplankton.

Fully worked solutions and sample responses are available in your digital formats.

3.13 Review

Access your topic review eWorkbooks

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-4075	ewbk-4076	ewbk-4077

on Resources

3.13.1 Summary

A whole new world

- The work of many scientists leads to creation of scientific theories such as the cell theory.
- From the initial microscope developed by Robert Hooke in the seventeenth century, microscopes have improved greatly and allow for the observation of smaller scales such as microns and nanometres.

Focusing on a small world

- Two main types of microscopes (light and electron microscopes) are used for different purposes. They differ in terms of their illumination source, magnification, use of living or dead cells and expense.
- Light microscopes are commonly used in school science laboratories and include a stage to place a slide (with a specimen to be viewed), an eyepiece lens, objective lenses, an in-built light source and focus knobs.
- Magnification is determined by multiplying the magnification of the eyepiece lens with the magnification of the objective lens.

Form and function — Cell make up

- All organisms are made of cells; some are made of only one cell (unicellular) and others are made of many cells (multicellular).
- Prokaryotes, such as bacteria, are organisms that are made up of cells that do not contain membrane-bound organelles such as a nucleus.
- Eukaryotes, such as plants, animals, fungi and protoctistans, are made up of cells that contain membrane-bound organelles such as a nucleus.
- Nearly all cells possess a cytoplasm (where hundreds of chemical reactions occur), cell membrane and ribosomes.
- Living things can be divided into five main kingdoms on the basis of cellular differences — Animalia, Plantae, Fungi, Protoctista and Prokaryotae.
- Cells have different structures within them called organelles; their different structures may be due to their different functions.
- Three examples of organelles are the nucleus, which is the control centre of the cell, the mitochondria, which are involved in cellular respiration and the conversion of energy into a form that the cells can use and chloroplasts, which are involved in photosynthesis and the conversion of light energy into chemical energy.

Zooming in on life

- When preparing specimens for viewing under a microscope, dyes allow for different structures to be more visible.
- When sketching microscope specimens, it is important to include the magnification, title and clear labels, and use pencil to sketch the image.

Focus on animal cells

- There are various cell types in animals that differ in shape, size and function.
- Some examples of different animal cells include muscle cells, nerve cells, red blood cells and skin cells.

Focus on plant cells

- All plant cells contain a cell wall and a large central vacuole filled with cell sap.
- Some examples of different plant cells include guard cells (on the surface of leaves), root hair cells and epidermal cells.

Plant cells — holding, carrying and guarding

- Phloem are tissues that transport sugar through a plant through translocation.
- Xylem are tissues that transport water up through plants (from the roots) through a process called transpiration.
- Stomata are tiny pores on the surface of leaves where gas is moved and water is lost. They are surrounded by guard cells, which can allow the stomata to open and close.

Cell division

- Cell division allows cells to divide and produce new cells.
- Mitosis is the division of the nuclear material in eukaryotes. This is followed by cytokinesis, where the replicated cell is divided into two.
- Another common type of cell division is binary fission (occurring more commonly in prokaryotes), which allows bacteria to replicate very quickly.

Skin 'n' stuff

- Skin is the largest organ in the body; its main role is in the protection against invaders (microbes).
- The skin has three main layers: the epidermis, the dermis and the underlying tissue, which includes muscles and nerves.
- Burns, including sunburn, is any damage to the skin. When ultraviolet rays damages DNA in a cell, uncontrolled cell growth can occur.
- Cancer is due to uncontrolled cell division, leading to the formation of tumours.

Tiny size, big trouble

- Microbes are microscopic organisms that can cause disease in other organisms.

3.13.2 Key terms

Animalia the kingdom of organisms that have cells with a membrane-bound nucleus, but no cell wall, large vacuole or chloroplasts (e.g. animals)
antibiotics a substance derived from a micro-organism and used to kill bacteria in the body
antiseptics a mild disinfectant used on body tissue to kill microbes
bactericidal an antiseptic that kills bacteria
bacteriostatic an antiseptic that stops bacteria from growing or dividing but doesn't kill them
benign a tumour that does not spread to other parts of the body
binary fission reproduction by the division of an organism (usually a single cell) into two new organisms
binocular microscope a microscope with two eyepieces through which the specimen is seen using both eyes
burn any damage to the skin; combustion of a substance with oxygen in a flame
cancer a disease resulting in the uncontrolled growth of body cells, forming tumours
cell the smallest unit of life. Cells are the building blocks of living things. There are many different sizes and shapes of cells.
cell membrane the structure that encloses the contents of a cell and allows the movement of some materials in and out
cell sap the mixture inside a plant's vacuoles
cell theory a theory that states that all living things are made up of cells and that all cells come from pre-existing cells
cellular respiration a series of chemical reactions in which the chemical energy in molecules such as glucose is transferred into ATP molecules, which is a form of energy that the cells can use
cellulose a natural substance that keeps the cell wall of plants rigid

chlorophyll the green-coloured chemical in plants that absorbs light energy so that it can be used in the process of photosynthesis
chloroplasts oval-shaped organelles that are involved in the process of photosynthesis that results in the conversion of light energy into chemical energy
chromosomes the tiny, thread-like structures inside the nucleus of a cell. Chromosomes contain the DNA that carries genetic information.
clone an identical copy
cytokinesis the division of the cytoplasm at the end of the cell division process so that one cell divides to form two
cytosol the fluid found inside cells
cytoplasm the jelly-like material inside a cell. It contains many organelles such as the nucleus and vacuoles
deoxyribonucleic acid (DNA) the chemical substance found in all living things that encodes the genetic information of an organism
dermis the medical name for the deeper part of the skin
diffusion movement of one substance through another due to a movement of particles, for example from a region of higher concentration to lower concentration
disinfectants a chemical used to kill bacteria on surfaces and non-living objects
electron microscopes instrument for viewing very small objects. An electron microscope is much more powerful than a light microscope and can magnify things up to a million times.
epidermis the outermost layer of the skin
eukaryote any cells or organisms with a membrane-bound nucleus (e.g. plants, animals, fungi and protists)
evaporates changes state from a liquid to a gas. Evaporation occurs only from the surface of a liquid.
flaccid cells that are not firm due to loss of water
Fungi the kingdom of organisms made up of cells that possess a membrane-bound nucleus and cell wall, but no chloroplasts (e.g. mushrooms). Some fungi can help to decompose dead and decaying matter.
guard cells cells on either side of a stoma that work together to control the opening and closing of the stoma
infectious diseases diseases that can be transferred from one organism to another
light microscopes instrument for viewing very small objects. A light microscope can magnify things up to 1500 times.
lignin a hard substance in the walls of dead xylem cells that make up the tubes carrying water up plant stems. Lignin forms up to 30 per cent of the wood of trees.
magnification the number of times the image of an object has been enlarged using a lens or lens system. For example, a magnification of two means the object has been enlarged to twice its actual size.
malignant a type of tumour that damages cells and can spread to other parts of the body
metabolism the chemical reactions occurring within an organism that enable the organism to use energy and grow and repair cells
micrometre one millionth of a metre
microscope an instrument for viewing small objects
mitochondria small rod-shaped organelles that are involved in the process of cellular respiration that results in the conversion of energy into a form that the cells can use. Singular = mitochondrion.
mitosis the cell division process that results in new cells, which are genetically identical to each other and to the original cell
monocular microscope a microscope with a single eyepiece through which the specimen is seen using only one eye
multicellular made up of many cells
nanometre one billionth of a metre
nanotechnology a science and technology that focuses on manipulating the structure of matter at an atomic and molecular level
non-infectious diseases diseases that cannot be transferred from one organism to another
nucleus (in biology) roundish structure inside a cell that acts as the control centre for the cell; (in chemistry) the central part of an atom, made up of protons and neutrons. Plural = nuclei.
organelles any specialised structure in a cell that performs a specific function
osmosis the movement of water across a semipermeable membrane from where it is in a high concentration to where it is in a low concentration
phloem a type of tissue that transports sugars made in the leaves to other parts of a plant

photosynthesis a series of chemical reactions that occur within chloroplasts in which the light energy is converted into chemical energy. The process also requires carbon dioxide and water, and produces oxygen, water and sugars — which the plant can use as 'food'.
Plantae the kingdom of organisms that have cells with a membrane-bound nucleus, cell wall, large vacuole and chloroplasts (e.g. plants)
pores small openings in the skin. Perspiration reaches the surface of the skin through pores
Prokaryotae the kingdom of unicellular organisms made up of a single cell that does not possess a membrane-bound nucleus or other membrane-bound organelles (e.g. bacteria). Also called *Monera*
prokaryote any cells or organisms without a membrane-bound nucleus (e.g. bacteria)
Protoctista the kingdom of organisms made up of cells that possess a membrane-bound nucleus but vary in other features and do not fit into other groups (e.g. protozoans). Also called *Protista*
receptors specialised structures that sense or receive stimuli
ribosomes small structures within a cell in which proteins such as enzymes are made
stereo microscope a type of binocular microscope through which the detail of larger specimens can be observed
stomata small openings mainly on the lower surface of leaves. These pores are opened and closed by guard cells. Singular = stoma.
sweat gland a tiny, coiled tube in the skin through which water and salt are removed from the body, helping to control body temperature
translocation process in which sugars and amino acids are transported within the plant by phloem tissue in plants
transpiration the loss of water from plant leaves through their stomata
transpiration stream the movement of water through a plant as a result of loss of water from the leaves
tumour an abnormal growth
turgid something that is firm
unicellular made up of only one cell
vacuoles sacs within a cell used to store food and wastes. Plant cells usually have one large vacuole. Animal cells have several small vacuoles or none at all.
vascular bundles groups of xylem and phloem vessels within plant stems
wilt plant stems and leaves droop due to insufficient water in their cells
xylem vessels pipelines for the flow of water up plants. They are made up of the remains of dead xylem cells fitted end to end with the joining walls broken down. Lignin in the cell walls gives them strength.

on Resources

Digital document	Key terms glossary (doc-26465)
eWorkbooks	Study checklist (ewbk-4069) Literacy builder (ewbk-4070) Crossword (ewbk-4072) Word search (ewbk-4073)
Practical investigation eLogbook	Topic 3 Practical investigation eLogbook (elog-4031)

3.13 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 3, 4, 7, 8, 11	Questions 2, 5, 9, 12, 13	Questions 6, 10, 14, 15, 16

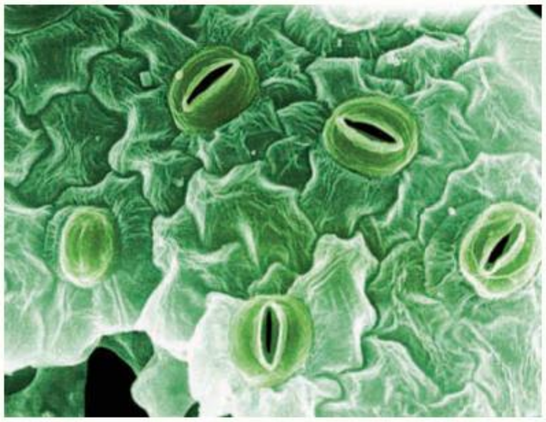
Remember and understand

1. Copy and complete the table provided.

Cell feature	Plant cells	Animal cells	Fungal cells
Cell wall	✓	X	
Cytoplasm			
Cell membrane			
Chloroplast			
Nucleus			
Large vacuole			

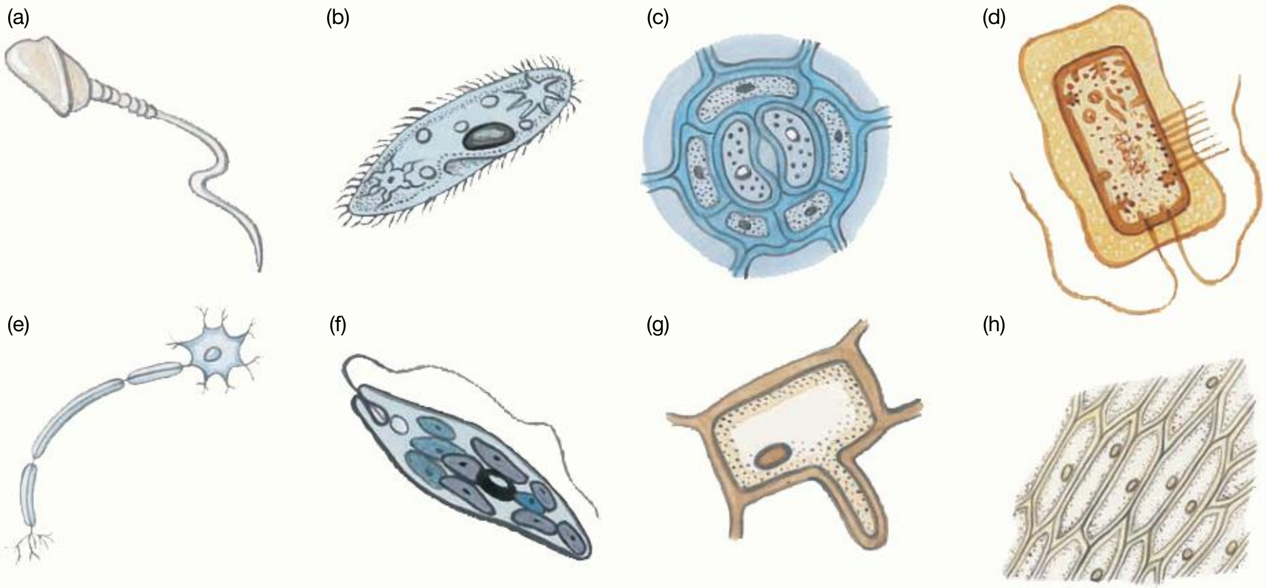
2. Draw and label a typical plant cell and a typical animal cell.
3. Which of the following types of microscopes were used to take the photos shown?
   - Scanning electron microscope
   - Light microscope

   Give reasons for your answers.

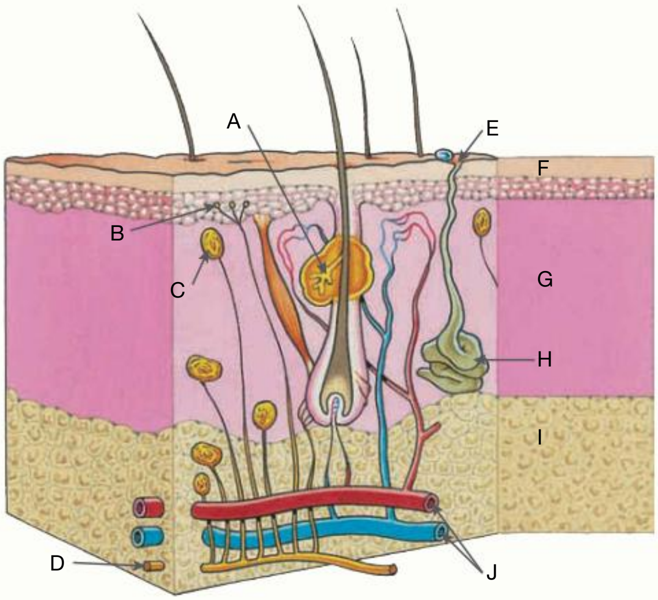


4. Make a sketch of these human cheek cells.

5. a. Match the following cell names to the diagrams provided.
Euglena
Paramecium
onion epidermal cells
nerve cell
sperm cell
guard cells
root hair cell
bacterium
b. To which kingdom does each of these cells belong?



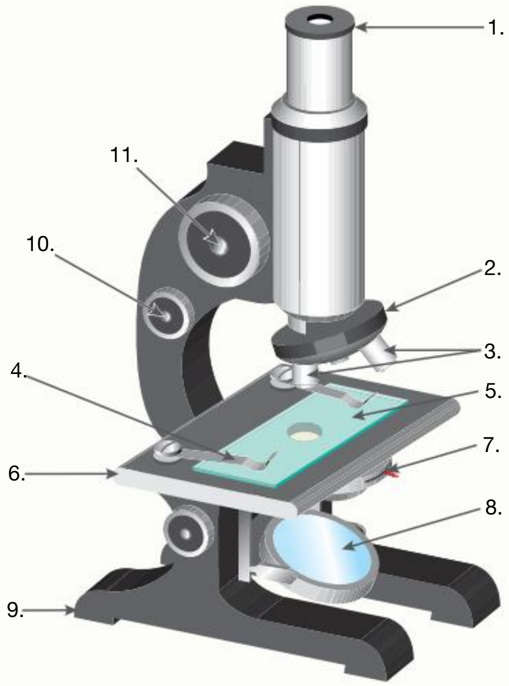
6. Carefully observe the diagram of the skin given. Match the letters on the diagram with the following labels: epidermis, dermis, fatty layer, light receptor, sweat gland, blood vessels, sebaceous gland, pain receptor, nerve, pore.



Apply and analyse

7. a. Brainstorm as many 'cell'-related words as you can, writing them on a piece of paper.
b. Pair up with another class member and add any of their words that you missed. Ask your partner what these words mean if you are unsure.
c. On a new piece of paper, work with your partner to group or link words to make a concept, cluster or mind map.
d. Compare your map with that of another pair in the class, adding as many more bits and pieces as you can.
8. Construct a Venn diagram to show the similarities and differences between light microscopes and electron microscopes.
9. Explain the significance of the invention of the microscope in terms of how we see the world.
10. Suggest why the invention of microscopes led to the development of new scientific language and classifications.

11. Unscramble the words using the clues provided.
   a. Control centre of the cell SEUNCLU
   b. Surrounds the cell ERAMMBNE
   c. Contains cell sap OCVAUEL
   d. Part of the cell between the cell membrane and the nucleus CATOPLMYS
   e. Building blocks of all living things LELSC
   f. Living things ASMOGNIRS
12. What's green and eats porridge? Identify the parts of the microscope shown and use the code provided to find out the answer to this riddle.
   Code:
   O = revolving nose piece; U = objective lenses; S = coarse focus knob; K = fine focus knob; D = microscope slide; L = stage slide clip; C = base; O = mirror; L = iris adjustment; I = stage; M = eyepiece lens



1	2	3	4	5	6	7	8	9	10	11

13. Use the terms in the box provided to construct target maps that are relevant to:
   a. plants
   b. animals
   c. fungi
   d. protoctistans
   e. prokaryotes (monera).

multicellular	chloroplast	*Euglena*
prokaryote	bacteria	mushroom
eukaryote	fern	yeast
nucleus	alga	lizard
cell wall	*Paramecium*	sponge
large vacuole	unicellular	moss
xylem	cell membrane	blood cells
possum	stomata	phloem

14. Construct a single bubble map to identify:
   a. types of plant cells
   b. types of animal cells
   c. scientists who have contributed to our knowledge of cells
   d. examples of body systems
   e. functions of skin
   f. issues related to stem cells.

Evaluate and create

15. a. Why do you think that cells have been described as 'living factories'?
   b. Think of a typical plant or animal cell. Make a list of all of the different parts and organelles. If the cell was a living factory, what might be the job of each listed part?
   c. Write a play to act out what happens in cells and perform it with others in your class. What sorts of things were easy to show? What sorts of things were hard to show? If you were to rewrite the play, what might you change and why?
   d. Convert the classroom into a giant cell! Take photos and then add information to them on a poster.

16. **SIS** Students are exploring the use of biological stains on cells. They have access to some bacterial cells, some plant cells and animal cells as well as the three biological stains listed.

TABLE Biological stains and the organelle they stain

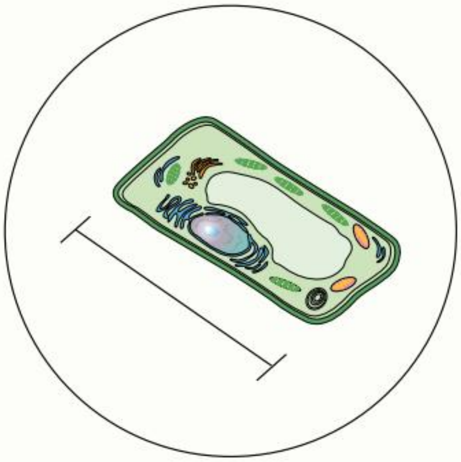
Stain	Organelle stained
Crystal violet	Stains cell walls purple
Methylene blue	Stains nuclei blue
Eosin	Stains cell membranes pink

a. What organelle is present in a plant cell but not in an animal cell?
b. What organelle is present in a plant cell but not in a bacterial cell?
Unfortunately, the containers containing the cells are unlabelled and have been mixed up. No one can determine which is which.
c. Outline an experimental design that would allow you to determine which sample is which so that the correct labels can be applied.
The following observations were recorded.

TABLE Results obtained using different stains on three samples

Stain	Sample A	Sample B	Sample C
Crystal violet	Nothing was stained	Purple structure around outer of cell	Purple structure around outer of cell
Methylene blue	Blue organelle present in middle of cell	Nothing was stained	Blue organelle present in middle of cell
Eosin	Pink line outlining cell	Pink line outlining cell	Pink line outlining cell

d. From these results which do you think is:
   i. Sample A
   ii. Sample B
   iii. Sample C
This diagram is a drawing of one of the cells taken during the experiment. They forgot to add the scale (although they remembered to put in a scale bar).
e. If the field of view was 45 μm in diameter, approximately how big is this cell?
f. What type of cell is it most likely to be plant, animal or bacteria based on it's structure? Give evidence to support your conclusion.



Fully worked solutions and sample responses are available in your digital formats.

on Resources

eWorkbook Reflection (ewbk-3038)

teachon

Test maker
Create customised assessments from our extensive range of questions, including teacher-quarantined questions.
Access the assignments section in learnON to begin creating and assigning assessments to students.

RESOURCE SUMMARY

on Resources

Below is a full list of **rich resources** available online for this topic. These resources are designed to bring ideas to life, to promote deep and lasting learning and to support the different learning needs of each individual.

3.1 Overview

eWorkbooks
- Topic 3 eWorkbook (ewbk-4065)
- Student learning matrix (ewbk-4088)
- Starter activity (ewbk-4067)

Practical investigation eLogbook
- Topic 3 Practical investigation eLogbook (elog-0431)

Video eLesson
- Robert Hooke and cells (eles-1780)

3.2 A whole new world

eWorkbook
- History of the light microscope (ewbk-4053)

Video eLesson
- Historic bacteriologists Van Leeuwenhoek, Pasteur and Koch (eles-2026)

Interactivity
- Development of microscopes and cell theory (int-3392)

3.3 Focusing on a small world

eWorkbook
- In focus (ewbk-4055)

Practical investigation eLogbook
- Investigation 3.1: Getting in focus with an 'e' (elog-0390)

Interactivities
- The monocular light microscope (int-3390)
- Field of view (int-5702)

3.4 Form and function — Cell make-up

Video eLesson
- Inside cells (eles-0054)

Interactivity
- Animal and plant cells (int-3393)

3.5 Zooming in on life

eWorkbook
- Preparing a stained wet mount (ewbk-4057)

Practical investigation eLogbooks
- Investigation 3.2: Preparing a wet mount (elog-0391)
- Investigation 3.3: Preparing stained wet mounts (elog-0392)

3.6 Focus on animal cells

Interactivity
- Body cells (int-3395)

Practical investigation eLogbook
- Investigation 3.4: Animal cells — what's the difference? (elog-0393)

3.7 Focus on plant cells

eWorkbook
- Plant transport highways (ewbk-4059)

Interactivity
- Plant cells (int-3396)

Practical investigation eLogbook
- Investigation 3.5: Plant cells in view (elog-0394)

3.8 Plant cells — holding, carrying and guarding

eWorkbooks
- Leafy exchanges (ewbk-4061)
- Photosynthesis (ewbk-4063)

Practical investigation eLogbooks
- Investigation 3.6: Stem transport systems (elog-0395)
- Investigation 3.7: Observing leaf epidermal cells (elog-0396)
- Investigations 3.8: Looking at chloroplasts under a microscope (elog-0397)
- Investigation 3.9: Moving in or out? (elog-0398)

3.9 Cell division

Practical investigation eLogbooks

- Investigation 3.10: Mitosis: Patterns of order (elog-0399)
- Investigation 3.11: Where are those germs? (elog-0400)

Video eLesson

- Binary fission (eles-2028)

3.10 Skin 'n' stuff

Video eLesson

- A cure? (eles-0070)

3.11 Tiny size, big trouble

Practical investigation eLogbook

- Investigation 3.12: Teeming with tiny... (elog-0401)

3.13 Review

eWorkbooks

- Topic review Level 1 (ewbk-4075)
- Topic review Level 2 (ewbk-4076)
- Topic review Level 3 (ewbk-4077)
- Study checklist (ewbk-4069)
- Literacy builder (ewbk-4070)
- Crossword (ewbk-4072)
- Word search (ewbk-4073)
- Reflection (ewbk-3038)

Practical investigation eLogbook

- Topic 3 Practical investigation eLogbook (elog-0431)

Digital document

- Key terms glossary (doc-26465)

To access these online resources, log on to **www.jacplus.com.au**.

4 Systems — living connections

LEARNING SEQUENCE

4.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

4.1.1 Introduction

Throughout history, humans have asked questions about our bodies and how they work. Our current knowledge has resulted from their curiosity, imagination, and persistence. Their findings have shown that your body, like that of many other multicellular organisms, is very complex. It consists of **body systems** that work together to keep you alive. Each of your systems is made up of **organs**, which are made up of **tissues**, which are made up of **cells** — which cannot survive independently of each other. Differences in the structure of the cells, tissues and organs within these body systems well suit them to their specific functions. What questions do you have about your body and how it works?

body system groups of organs, within our bodies that carry out specific functions

organs structures, composed of tissue, that perform specific functions

tissue group of cells of similar structure that perform a specific function

cell the smallest unit of life. Cells are the building blocks of living things. There are many different sizes and shapes of cells.

FIGURE 4.1 Body systems work together to keep them alive.

on Resources

Video eLesson The human body and internal organs (eles-2040)

This animation shows the major human body systems. How many can you recognise?

4.1.2 Think about the human body

1. Why is it unusual for herbivores to have canine teeth?
2. Which human blood group is the most common?
3. What do intestinal villi in humans have in common with root hairs in plants?
4. How can burping give you heartburn?
5. What causes asthma?
6. What causes vomit to be green?
7. Why are red blood cells red?
8. What causes the 'lub dub' sound that your heart makes?
9. What is special about cardiac muscle?
10. Why aren't all of your teeth the same shape?

4.1.3 Science inquiry

Getting below the surface

Have a look at the other students in your classroom. How different from one another are you? Which features do you all have in common? Perhaps there are differences on the outside, but inside you are made up of all of the same bits and pieces organised in the same way.

Think and create

Some of the things that you have in common with your classmates are your body systems.

1. Use a mind map to summarise all that you know about human body systems.
2. Compare your mind map with those of at least three team members.
3. Create a new team mind map that combines all your ideas and compare that with the mind map of another team. Add any comments that you think help you learn more about human body systems.

Think and investigate

4. In your team, make a list of ten questions about human body systems. Select four questions and place these on the class noticeboard with those of other teams to make a 'class question gallery'. Arrange these questions into groups or themes.
5. Browse the class question gallery and select one question that interests you most. Research your selected question and report back to the class on your findings in an interesting and creative way.

on Resources

eWorkbooks	Topic 4 eWorkbook (ewbk-4734) Student learning matrix (ewbk-4736) Starter activity (ewbk-4737)
Practical investigation eLogbook	Topic 4 Practical investigation eLogbook (elog-0520)
learnon	Access and answer an online Pre-test and receive **immediate corrective feedback** and **fully worked solutions** for all questions.

4.2 Driven by curiosity?

LEARNING INTENTION

At the end of this subtopic you will learn that scientific knowledge and understanding of the world changes as new evidence becomes available. You will also be able to provide examples of how our knowledge and understanding of the human body has changed over time.

Science as a human endeavour

4.2.1 Intensely curious …

… in the medical faculty he learned to dissect the cadavers of criminals under inhuman, disgusting conditions… because he wanted [to examine and] to draw the different deflections and reflections of limbs and their dependence upon the nerves and the joints. This is why he paid attention to the forms of even very small organs, capillaries and hidden parts of the skeleton.

Paolo (the first biographer of Leonardo da Vinci), 1520

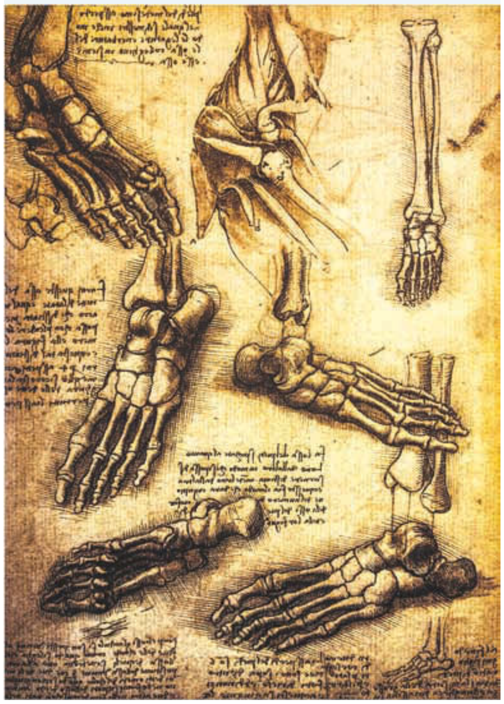
on Resources

Video eLesson Leonardo's sketches and anatomy (eles-1769)

Leonardo da Vinci was one of the best scientific minds of his time. He was intensely curious and painstaking in his observations. He used close observation, repeated testing and precise illustrations with explanatory notes. Using pen, chalk and brush, his scientific illustrations offered visual answers to mysteries that had escaped others for centuries. His volumes of amazing notes of scientific and technical observations in his handwritten scripts led to the birth of a new systematic and descriptive method of scientific study.

Leonardo da Vinci questioned everything. He may have been the most relentlessly curious man in history. He asked questions such as: Why do birds fly? Why can seashells be found in mountains? What is the origin of the wind and clouds? Why do people die? Where is the human soul found?

FIGURE 4.2 Leonardo da Vinci spent hours amid rotting corpses to draw amazingly detailed observations of body structures.



4.2.2 Dissecting, details and drawing

Leonardo's anatomical studies of human muscles and bones began around 1490. His exploration of embryology and cardiology came later, with his astonishingly detailed image of a fetus within the womb (around 1505) providing details for obstetric surgery hundreds of years later. His observations were not just of bodies — later generations have been in awe of his sketches of inventions that were centuries ahead of their time.

FIGURE 4.3 Is this a self-portrait of a young Leonardo da Vinci (1452–1519)? 'Hidden' under handwriting on a page of his *Codex on the flight of birds* for about 500 years, a combination of scientific techniques were used to 'unveil' it.

4.2.3 Challenging 'knowledge'

Knowledge of the human body was very different in Leonardo's day from what we accept today. The heart was thought to be made up of two chambers and its function to warm the blood, which was thought to be made in the liver. It was also thought that sperm were produced in the marrow of the spinal column and that the human soul may be located in the spine. Leonardo had questions he wanted to answer. He wanted to find out more. His investigations challenged the accepted knowledge of his day.

FIGURE 4.4 Leonardo's sketches of a fetus in the womb were completed between 1510 and 1513.

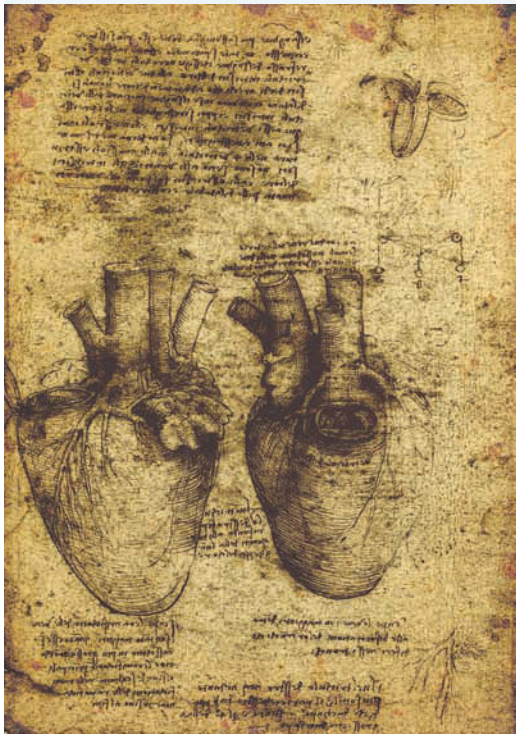
4.2.4 Visions and models

Leonardo also emphasised the significance of visual observations and model making — he believed that reality needed to be reconstructed before it could be represented. His models of hands or legs were used to reveal the structural relationships between different layers of arteries, muscles and bones. Leonardo also made a glass model of the heart and used water with different coloured dyes to trace its flow through the heart. His investigations linked anatomy (structure) and physiology (function).

Analogies are sometimes used to help people to connect new learning to previous knowledge. Leonardo used analogies to compare arteries in human bodies to 'underground rivers in the earth' and described the bursting of blood from a vein like 'water rushing out a burst vein of the earth'.

FIGURE 4.5 Leonardo drew this diagram around 1510. Can you see his secretive, reversed form of handwriting?

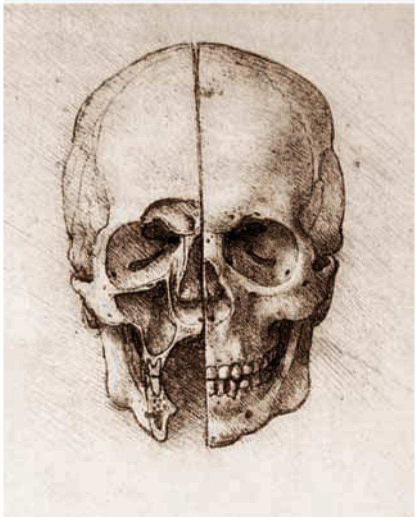
FIGURE 4.6 Leonardo da Vinci was a master of detail with his sketches of body parts.



Leonardo's dissections led to changes in the knowledge and understanding of the structure and function of the heart, including that:

- the heart was a muscle
- the heart did not warm the blood
- the heart had four chambers
- left ventricle contractions were connected to the pulse in the wrist.

FIGURE 4.7 Leonardo sketched this skull in 1489.



To locate cavities around the brain and cranium, Leonardo used innovative techniques, such as injecting molten wax into them. Although Leonardo did not find the location of the human soul, his studies led him to the discovery that the brain and spine were connected.

Leonardo's curiosity, determination, creativity and persistence did more than make an amazing contribution to our current scientific knowledge of our bodies. These features also helped mould the way in which scientific frameworks were developed to structure our investigations to explore our questions.

on Resources

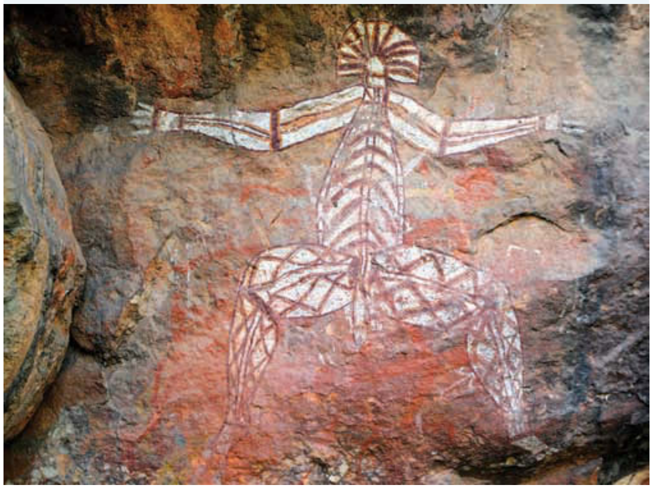
Weblink Leonardo da Vinci's inventions turned into models

4.2.5 Curiosity throughout time and space

Curiosity is one of the features of humans that has contributed to our survival. Some of this curiosity has been about the structure and function of our own bodies. Evidence of this curiosity is woven throughout history and is often found in art. While Leonardo da Vinci provides one example of curiosity driving a search to find out more, he is not the only example. Nor is human curiosity limited to the place or time in which you live.

Knowledge of the internal biology and physiological process in art appears in rock paintings in caves in Australia that are thousands of years old. Examples of Aboriginal x-ray art provide evidence that this type of knowledge dates back more than 6000 years.

FIGURE 4.8 Aboriginal 'x-ray style' rock painting figure from Kakadu National Park, Northern Territory, Australia

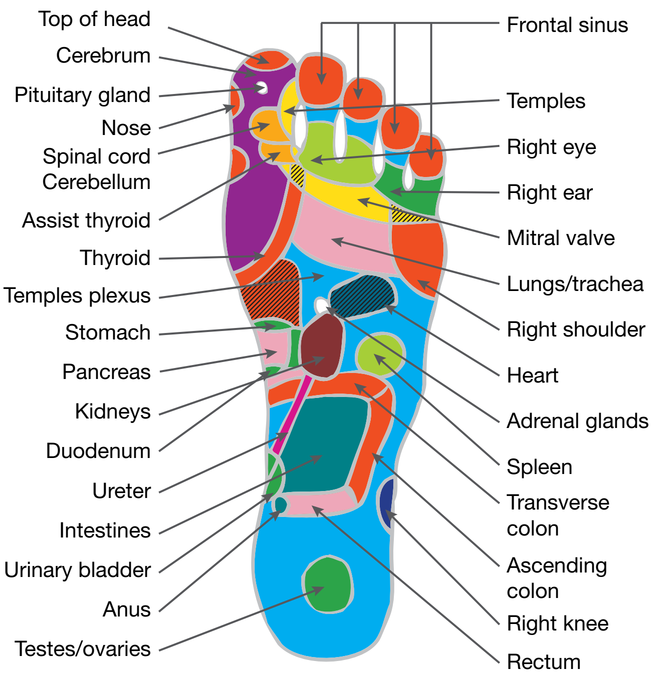


The culture and scientific knowledge of the times often determines the types of treatment given for various diseases of the human body. In medieval times, astrology played a key role in medicine and medical prognosis. It was believed that the 'movement of the heavens' could influence human physiology, with each part of the body being associated with a different astrological sign. An image of the 'Zodiac Man' in the medical texts of the time was used to assist practitioners in their medical treatments.

Chinese traditional medicine is an ancient medical system that has been practised for over 5000 years and applies understanding of the laws and patterns of nature to the human body. It views health as the changing flow throughout the body of vital energy (*qi*) that, if hindered, can lead to illness. Acupressure is an application of this theory that aims to release blocked energy by stimulating specific points along the body's energy channels.

FIGURE 4.9 The 'Zodiac Man' chart was based on astrology and provided advice on when, for example, to 'bloodlet' (a medical treatment involving bleeding the patient), regulated by the position of the moon.

FIGURE 4.10 An example of an acupressure reflexology chart



Scientists are curious

Scientists are also often driven by the thirst to find answers to their questions. With increased technology and knowledge, the answers to these questions often result in even more questions.

Compared with the situation in Leonardo's day, there are now an amazing number of different types of careers that involve investigations, explorations and applications of science to the human body. Australian scientists are involved in medical research and intervention. They are also involved in the invention and development of medical equipment that assists our understanding of our body systems.

4.2.6 Australian scientists: creative inventors and explorers

Australian scientists have made significant contributions to medical discoveries and inventions. Howard Florey and his team discovered how penicillin could be extracted, purified and produced to be used as an antibiotic to help fight bacterial infections. Barry Marshall and Robin Warren showed that a certain type of bacteria caused stomach ulcers that could be treated with antibiotics. Professor Graeme Clark and his team were involved in the invention of an effective 'bionic ear'. Dr Fiona Wood pioneered a new treatment for burns in her development of spray-on skin that used the patient's own skin cells. Professor Ian Frazer developed the world's first vaccine against cervical cancer.

SCIENCE AS A HUMAN ENDEAVOUR: David Unaipon

David Unaipon (1872–1967) has been described as 'Australia's Leonardo'. He was born in South Australia, the fourth of nine children of James Ngunaitponi and his wife Nymbulda. Both his parents were of the Yaraldi group of the lower Murray region. 'Unaipon' is an Anglicisation of Ngunaitponi.

Obsessed with discovering the secret of perpetual motion, David made ten patent applications between 1909 and 1944 for inventions including a modified handpiece for shearing, a centrifugal motor, a multiradial wheel and a mechanical propulsion device.

Interested in Aboriginal mythology, philosophy and science, David was a preacher, author and inventor. He compiled his own versions of Aboriginal legends such as *Hungarrda* (1927), *Kinie Ger — The Native Cat* (1928) and *Native Legends* (1929). David's published poetry and legends pre-dated the work of other Aboriginal writers by over 30 years.

FIGURE 4.11 David Unaipon

DISCUSSION

The Warlpiri are one of the largest Aboriginal groups in the Northern Territory. Research and report on their traditional health system and the involvement of ngangkayikirili (or ngangkari or ngangkayi) and Yawulyu ceremonies of the Warlpiri.

SCIENCE AS A HUMAN ENDEAVOUR: The bionic ear

The cochlear implant, also known as the bionic ear, has allowed some people with inner-ear problems to hear sound for the first time. When deafness results from serious inner-ear damage, no sounds are heard at all. Normal hearing aids, which make sound louder, do not help in these cases because the cochlea cannot detect the vibrations. However, the cochlear implant can often help by changing sound energy from outside the ear into electrical signals that can be sent to the brain.

FIGURE 4.12 An enlarged x-ray of the cochlea showing the experimental electrode array inside

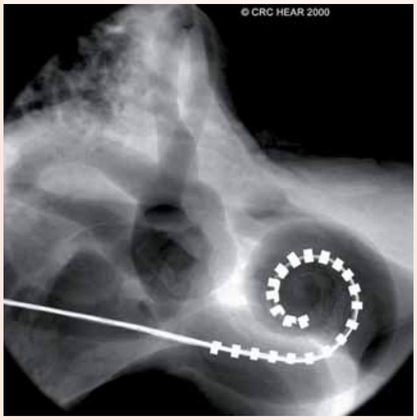
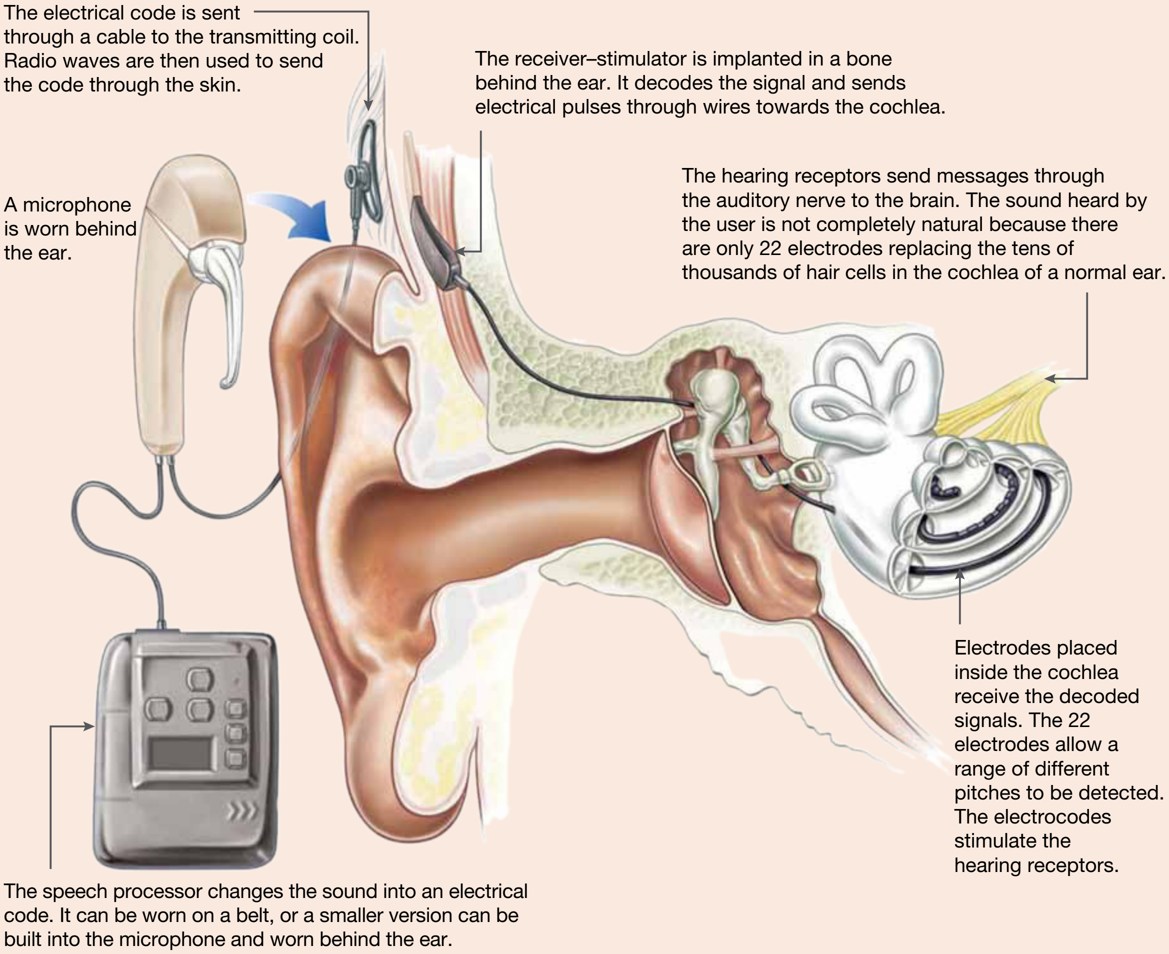


FIGURE 4.13 How a cochlear implant works



Resources

assessON Additional automatically marked question sets

4.2 Exercise

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To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3, 11	Questions 4, 6, 7, 12	Questions 5, 8, 9, 10

Remember and understand

1. State whether the following statements are true or false. If false, justify your response.
   Leonardo da Vinci's dissections led to changes in the knowledge and understanding:
   a. of the structure and function of the heart
   b. in that the heart was a muscle with three chambers that warmed the blood
   c. in that the heart's left ventricle contractions were connected to the pulse in the wrist
   d. in that the location of the human soul was in the spine.
2. Match the Australian scientist with their scientific contribution.

Australian scientist	Scientific contribution
a. Barry Marshall	A. I developed the world's first vaccine against cervical cancer.
b. David Unaipon	B. I was involved in discovering how penicillin could be extracted, purified and produced to be used as an antibiotic to help fight bacterial infections.
c. Fiona Wood	C. I pioneered a new treatment for burns using spray-on skin that used the patient's own skin cells.
d. Graeme Clark	D. I have been described as 'Australia's Leonardo' and was interested in Aboriginal mythology, philosophy and science.
e. Howard Florey	E. I was involved in the invention of an effective 'bionic ear'.
f. Ian Frazer	F. Robin Warren and I showed that a certain type of bacteria caused stomach ulcers that could be treated with antibiotics.

3. Distinguish between anatomy and physiology.

Apply and analyse

4. Imagine you were alive in the medieval times. Suggest why astrology played a key role in medicine and medical prognosis.
5. Suggest how scientific understanding of human body systems can detemine how we respond to public health issues such as the 2009 swine flu pandemic and the 2020 coronavirus outbreak.
6. Research and report on one of the following:
   a. *Codex* on the flight of birds
   b. The history behind *Treatise on painting* and how it relates to science
   c. The *da Vinci® Mitral Valve Repair* and why it was named after Leonardo da Vinci
   d. Aboriginal x-ray art with a focus on examples of Aboriginal knowledge of the internal biology and physiological processes of animals

e. The processes involved in the preparation of mummies in ancient Egypt. Include what happened to specific body organs and why.
f. Traditional Chinese medicine with a focus on the knowledge of the structure and function of human body systems.
7. Research three Australian scientists involved in medical research and intervention, and present your findings as a curriculum vitae.
8. Find an example of how Australian scientists have been involved in the development of medical equipment. Produce a brochure to advertise this equipment to prospective buyers.

Evaluate and create

9. SIS
   a. Do you believe that acupressure should be available as a medical treatment? Justify your response.
   b. Does scientific knowledge support your stance? Explain.
10. SIS Evaluate the analogies used by Leonardo da Vinci to describe arteries and the bursting of blood from a vein. Incorporate current scientific knowledge into your evaluation.
11. SIS Research Leonardo da Vinci's sketches and then select one of the following creative tasks:
   a. Construct a tree diagram to show how one of da Vinci's inventions is related to something that we use today.
   b. Construct a model of one of Leonardo's inventions.
12. SIS
   a. Research Leonardo da Vinci's sketches of some of his inventions.
   b. Create your own variation of one of Leonardo's inventions, presenting it as a series of annotated sketches.
   c. Construct your own PMI (Plus, Minus, Interesting) chart to evaluate your invention.
   d. Share and discuss your sketches with two other students and add any relevant comments to your invention PMI.
   e. If you were to create another variation of Leonardo's inventions, what would you do differently to improve your final outcome.

Fully worked solutions and sample responses are available in your digital formats.

4.3 Working together?

LEARNING INTENTION

At the end of this subtopic you will be able to provide examples of how the different body systems — made up of specialised organs, tissues and cells — work together to keep multicellular organisms alive.

4.3.1 The building blocks of life

Like all matter in the universe, you are made up of atoms. Collections of atoms make up **molecules**, molecules make up organelles, which make up cells, which make up tissues, which make up organs, which make up systems, which make up you. This progression is shown in figure 4.14.

molecule two or more atoms joined (bonded) together

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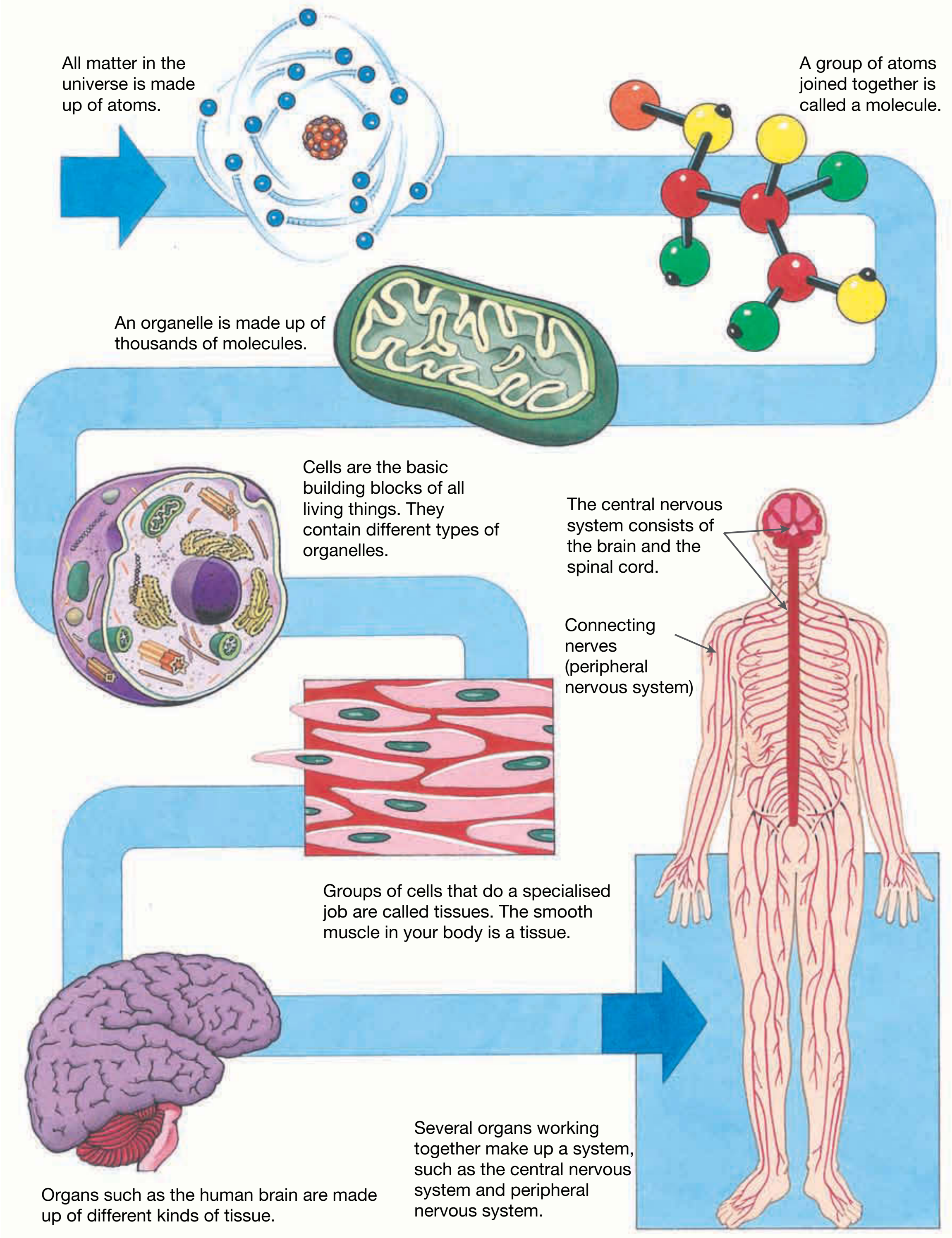
FIGURE 4.14 The building blocks of life



4.3.2 All alone? Independent!

Unicellular organisms are made up of only one cell that must do all of the jobs that are required to keep the organism alive. These single-celled organisms are small enough that essential substances (e.g. oxygen) and wastes (e.g. carbon dioxide) can be exchanged with their environment through simple diffusion.

4.3.3 One of many? Better get organised!

Like other multicellular organisms, you are made up of many cells. These cells cannot survive independently of each other. They depend on each other and work together. Working together requires organisation.

Pattern, order and organisation

Multicellular organisms are made up of a number of body systems that work together to keep them alive. Body systems are made up of organs, which are made up of tissues, which are made up of particular types of cells.

FIGURE 4.15 Useful substances (e.g. oxygen) can move into cells and wastes (e.g. carbon dioxide) can move out through a process called diffusion.

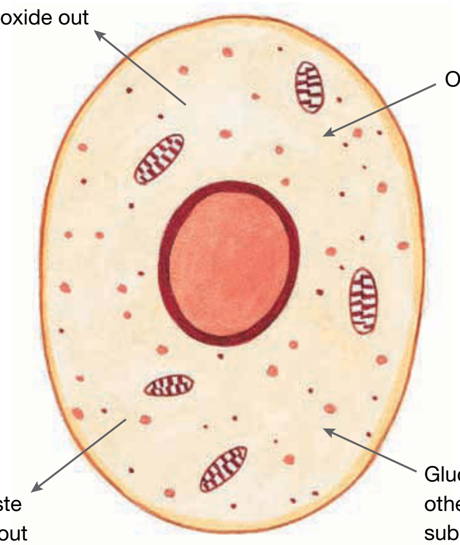
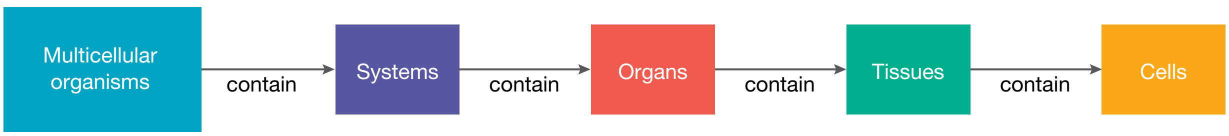


FIGURE 4.16 Organisation of systems



Cells

Within each cell there are structures called **organelles**. Each organelle has a particular job to do. Mitochondria, for example, are organelles in which the chemical energy in glucose is transformed into energy that our cells can use.

Multicellular organisms are made up of many different types of cells, each with a different job to do. Although these cells may have similar basic structures, they differ in size, shape, and in the number and types of organelles they contain. The different make-up of different types of cells and structures within them makes them well suited to their function.

Tissues

Groups of similar cells that perform a specialised job are called tissues. Muscle tissue contains cells with many mitochondria so that the energy requirements of the tissue can be met. Nerve tissue consists of a network of nerve cells with extensions to help carry messages throughout your body. Table 4.1 shows some examples of tissues that make up your body, what they look like and what their main functions are.

multicellular organisms living things comprised of specialised cells that perform specific functions

organelle any specialised structure in a cell that performs a specific function

TABLE 4.1 Examples of tissues and their main functions

Name of tissue	Structural feature	Main functions
Epithelial tissue	Sheets of cells	To line tubes and spaces, and form the skin
Connective tissue	Tough flexible fibres	To bind and connect tissues together
Skeletal tissue	Hard material	To support and protect the body, and permit movement
Blood tissue	Runny fluid containing loose cells	To carry oxygen and food substances around the body
Nerve tissue	Network of threads with long extensions	To conduct and coordinate messages
Muscle tissue	Bundles of elongated cells	To bring about movement

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FIGURE 4.17 There are different types of tissues, each with structural features that suit them to their function.

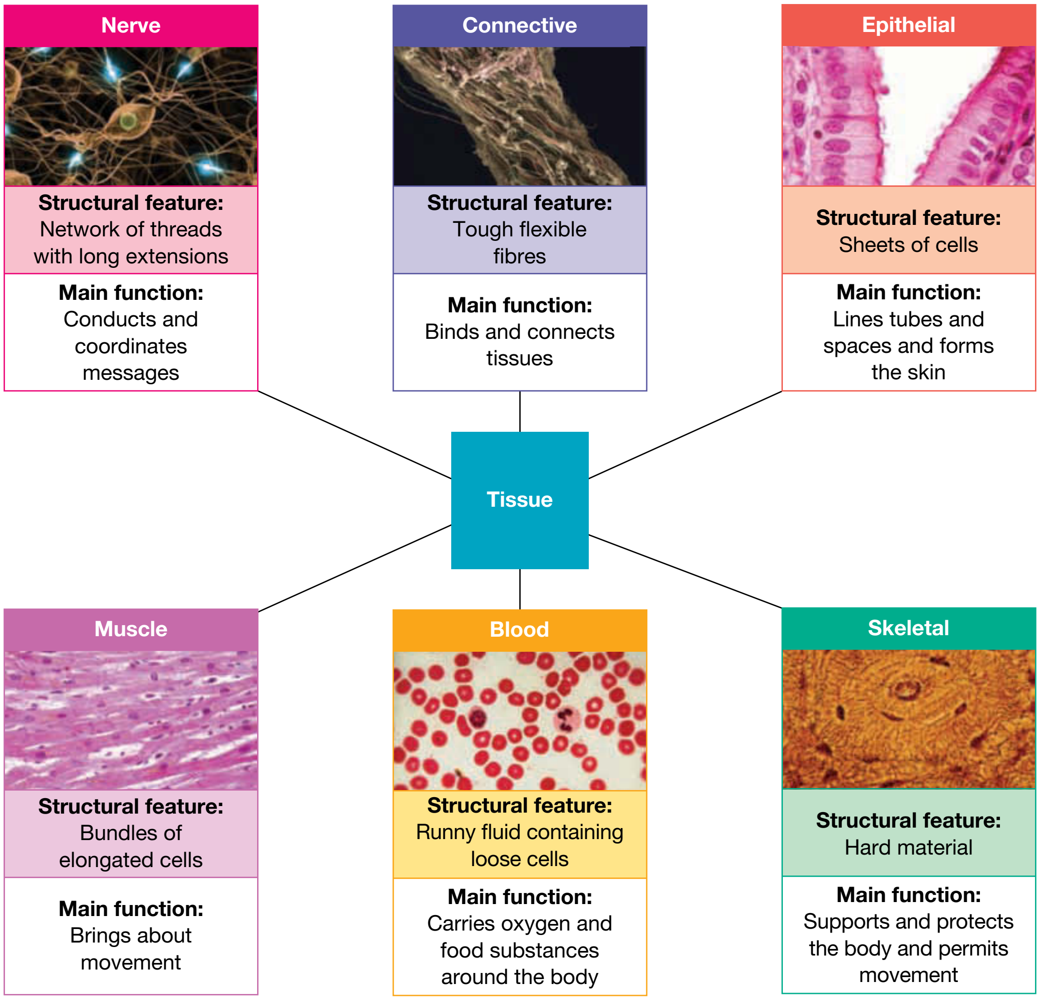

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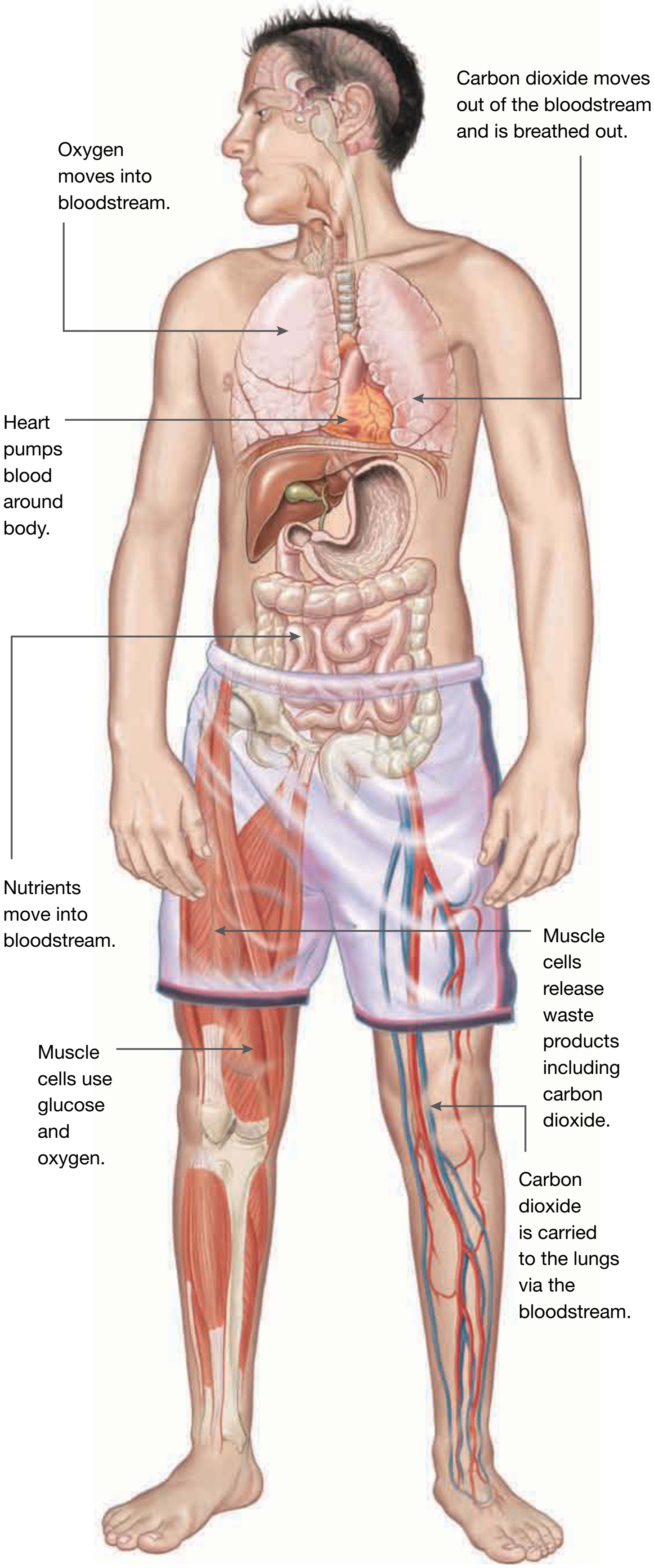
FIGURE 4.18 You are made up of many different body systems that contain organs that work together to keep you alive.



Organs

Organs are made up of one or more different kinds of tissue and perform one (or sometimes more) main function or job. Examples of your organs include:

- brain
- stomach
- lungs
- heart
- skin
- kidneys.

Systems

Multicellular organisms contain organised systems of organs that work together to perform specialised functions. Table 4.2 provides examples of some of your systems, some organs within them and their main functions.

TABLE 4.2 Examples of systems and their main functions

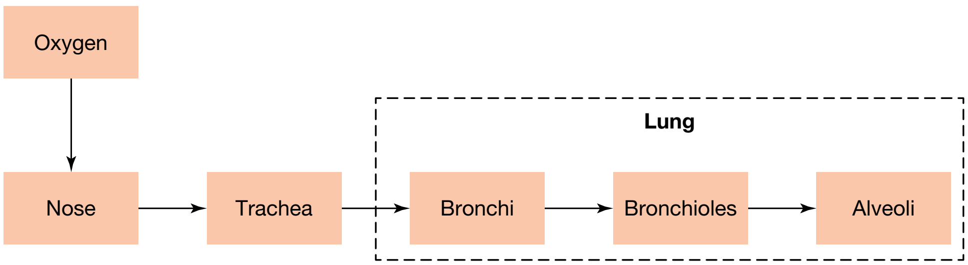
Name of system	Organs in system	Main functions
Digestive system	Stomach, intestine, liver, pancreas, gall bladder	To digest and absorb food
Respiratory system	Trachea and lungs	To take in oxygen and get rid of carbon dioxide
Circulatory system	Heart and blood vessels	To carry oxygen and food around the body
Excretory system	Kidneys, bladder, liver	To get rid of poisonous waste substances
Sensory system	Eyes, ears, nose	To detect stimuli
Nervous system	Brain and spinal cord	To conduct messages between body parts
Musculoskeletal system	Muscles and skeleton	To support and move the body
Reproductive system	Testes and ovaries	To produce offspring

4.3.4 Systems need to work together

Body systems within multicellular organisms work together to keep them alive. For example, cells need energy to survive. A process called **cellular respiration** breaks down glucose to release energy in a form that your cells can then use. This process also requires oxygen and produces carbon dioxide, a waste product. Your digestive, circulatory, respiratory and excretory systems work together to provide your cells with nutrients and oxygen, and to remove wastes such as carbon dioxide.

cellular respiration a series of chemical reactions in which the chemical energy in molecules such as glucose is transferred into ATP molecules, which is a form of energy that the cells can use

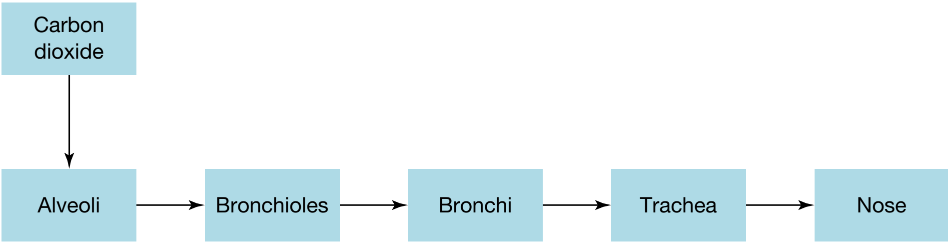
FIGURE 4.19 Your respiratory system is involved in getting oxygen into your body.



Respiratory system

Your **respiratory system** is responsible for getting oxygen into your body and carbon dioxide out. This occurs when you inhale (breathe in) and exhale (breathe out).

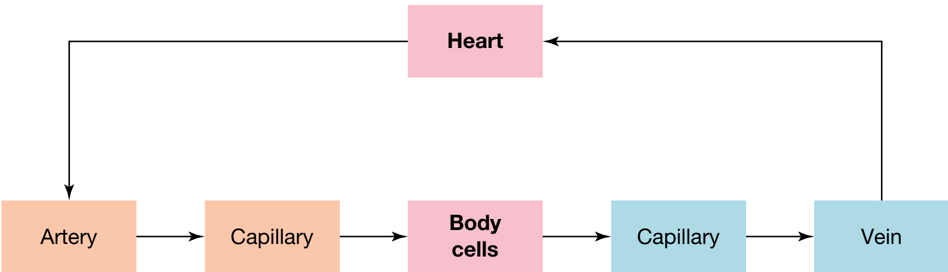
FIGURE 4.20 Your respiratory system is involved in getting carbon dioxide out of your body.



Circulatory system

Your **circulatory system** is responsible for transporting oxygen and nutrients to your body's cells, and wastes such as carbon dioxide away from them. This involves **blood cells** that are transported in your **blood vessels** and **heart**. The major types of blood vessels are **arteries**, which transport blood from your heart; **capillaries**, through which materials are exchanged with cells; and **veins**, which transport blood back to the heart.

FIGURE 4.21 Your circulatory system is involved in transporting blood cells in blood vessels to and from your body cells and your heart.



Digestive and excretory systems

Your **digestive system** plays a key role in supplying your body with the nutrients it requires to function effectively. You ingest food, digest it, then egest it. Your digestive system is involved in breaking food down, so nutrients are small enough to be transported to, and used by, your cells.

Your **excretory system** removes waste products from a variety of chemical reactions that your body needs to stay alive. The main organs of your excretory system are your skin, lungs, liver and kidneys. Your skin excretes salts and water as sweat, and your lungs excrete carbon dioxide when you breathe out. Your liver is involved in breaking down toxins for excretion and your kidneys are involved in excreting the used waste products of chemical reactions (e.g. urea) and any other chemicals that may be in excess (including water), so that a balance within your blood is maintained. Some of the organs of the excretory system are shown in the flowchart in figure 4.22.

respiratory system the lungs and associated structures that are responsible for getting oxygen into your body and carbon dioxide out

circulatory system the heart, blood and blood vessels which are responsible for circulating oxygen and nutrients to your body cells and carbon dioxide and other wastes away from them

blood cells living cells in the blood

blood vessels the veins, arteries and capillaries through which the blood flows around the body

heart a muscular organ that pumps deoxygenated blood to the lungs to be oxygenated and then pumps the oxygenated blood to the body

arteries hollow tubes (vessels) with thick walls carrying blood pumped from the heart to other body parts

capillaries numerous tiny blood vessels, that are only a single cell thick to allow exchange of materials to and from body cells. Every cell of the body is supplied with blood through capillaries.

veins blood vessels that carry blood back to the heart. They have valves and thinner walls than arteries.

digestive system a complex series of organs and glands that processes food to supply the body with the nutrients it needs to function effectively

excretory system the body system that removes waste substances from the body

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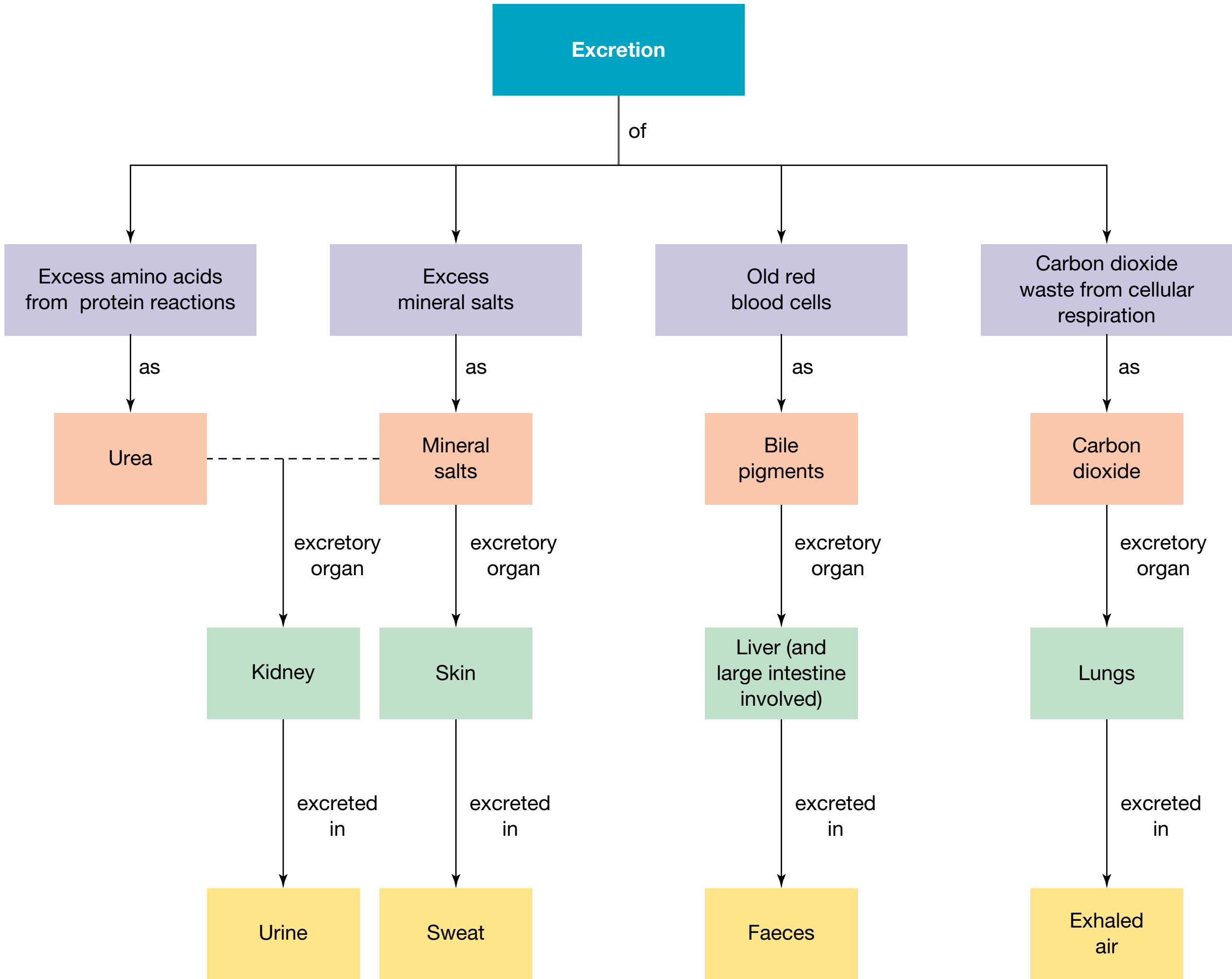
FIGURE 4.22 Different organs in your excretory system are involved in the removal of different types of wastes.



Other body systems

Your **musculoskeletal system** consists of both your bones and various types of muscles throughout your body. Bones and muscles provide both support and protection for your organs. While the **reproductive systems** of males and females contain different organs in each gender, they both play a key role in continuation of our species. Other systems such as your **nervous system** and **endocrine system** are also involved in coordinating and regulating processes in your body. You will find out more about these later in your studies.

musculoskeletal system consists of the skeletal system (bones and joints) and the skeletal muscle system (voluntary or striated muscle). Working together, these two systems protect the internal organs, maintain posture, produce blood cells, store minerals and enable the body to move.

reproductive system body system in which human males and females possess different reproductive organs with the overall aim of reproducing the offspring of the next generation

nervous system neurons, nerves and the brain, which are responsible for detecting and responding to both internal and external stimuli to keep us alive

endocrine system the body system of glands that produce and secrete hormones into the bloodstream to regulate processes in various organs

elog-0522

INVESTIGATION 4.1

Mapping your organs

Aim

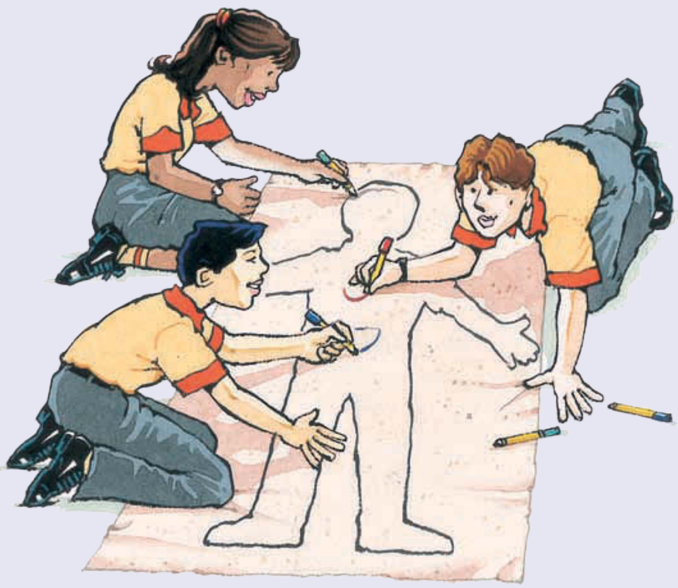
To draw a diagram to map out the positions and shapes of some human body organs

Materials

- large sheets of paper (e.g. butcher paper)
- pencils and marker pens
- sticky tape
- scissors
- optional: light coloured material, sewing thread and needle (or stapler or craft glue), 'stuffing', various other bright coloured materials

Method

1. Use the sticky tape to join the paper together so that it is the size of a student's body outline.
2. One member of the team lies down on the paper with their arms away from their body.
3. Another team member carefully draws (about 5 cm away from their body) an outline of their partner's body.
   - Once the outline is drawn, the person on the paper can join the rest of the team for the remainder of the activity.
   - As a team, decide where in the body outline the following organs are located: heart, lungs, small intestine, nose, oesophagus, liver, stomach, ears, kidney, large intestine, pancreas, eyes, bladder, brain, trachea, mouth.
   - Once the location of each organ has been agreed upon, discuss their shape and size.
4. Once consensus is reached within the group, draw each of these organs onto the paper body outline.
   - Compare your diagram to reference materials to judge its accuracy.



5. Using these references as a guide, use different coloured pens to draw in more accurate organ shapes, sizes or locations onto your paper body outline.
   Optional: Use the final version of your organ body outline as a pattern to make human body organ stuffed toys or a human body organ blanket.

Results

How accurate was your team's first attempt at drawing the body organ outline?

a. Which organs were located correctly and which were not?

b. How closely did your team's estimate of shape and size compare to that referenced for each organ?

Discussion

1. Identify the system to which each of the organs on your outline belong.
2. As an individual learner, identify which organs had a size, shape and location that you expected and which did not.

Conclusion

Summarise what you have learned about human body organs in this investigation.

DISCUSSION

Did you take a particular role in this team? Assess how well you supported other members of your team.

In pairs, apply your understanding of the structure and function of two different body systems by writing ten trivial pursuit questions (with answers) for each of your selected systems.

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4.3 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3, 4, 10, 11, 12, 13, 14	Questions 5, 6, 7, 8, 9, 17	Questions 15, 16, 18, 19

Remember and understand

1. Identify whether the following statements are true or false. Justify any false responses.

Statement	True or false
a. All living things consist of at least one cell.	
b. Unicellular organisms are made up of only one cell that must do all of the jobs that are required to keep the organism alive.	
c. Multicellular organisms are made up of different types of cells that cannot survive independently of each other so need to work together.	
d. Multicellular organisms are made up of different types of cells, each with different jobs to do.	
e. The differences in the size and shape of different types of cells and structures within them make them well suited to their specific function.	

f. Cellular respiration involves production of glucose.	
g. The respiratory system takes oxygen into your body and removes carbon dioxide from your body.	
h. The circulatory system transports carbon dioxide and nutrients to your body cells, and transports wastes such as oxygen away from them.	
i. Arteries transport blood to your heart and veins transport blood away from your heart.	
j. Your kidneys, skin, liver and lungs all play a role in removing wastes from your body.	

2. Recall a feature that organisms have in common with other matter in the universe.
3. Order the following from most complex to least complex: Molecules, Organelles, Organs, Multicellular organisms, Systems, Tissues, Atoms, Cells.
4. What am I? Identify the most appropriate term, by matching it to the corresponding description.

Term	Description
a. Tissue	**A.** A structure within a cell with a specific job to do
b. Organ	**B.** A collection of similar cells that perform a specific function
c. System	**C.** Different types of tissues grouped together to perform a specific function
d. Organelle	**D.** Different organs working together to perform a specialised function to keep an organism alive

5. List six:
   a. types of tissues **b.** examples of organs **c.** types of systems.
6. Name two organs in the:
   a. respiratory system **b.** circulatory system **c.** digestive system.
7. Name an example of an organelle and state its function.
8. Match the type of tissue with its function in the table shown.

Tissue	Function
a. Blood	**A.** Conducts and coordinates messages
b. Connective tissue	**B.** Brings about movement
c. Muscle tissue	**C.** Binds and connects tissues
d. Nervous tissue	**D.** Lines tubes and spaces and forms skin
e. Skeletal tissue	**E.** Carries oxygen and food substances around the body

9. Match the system with its organs in the table shown.

System	Organs
a. Circulatory system	**A.** Liver, kidney, skin, lungs
b. Digestive system	**B.** Lungs, trachea
c. Excretory system	**C.** Stomach, liver, gall bladder, intestines, pancreas
d. Nervous system	**D.** Heart, blood vessels
e. Respiratory system	**E.** Brain, spinal cord

10. Describe two ways in which unicellular organisms differ from multicellular organisms.
11. Suggest why different types of cells within a multicellular organism may differ in their size and shape.
12. Explain why cells in muscle tissue contain many mitochondria.
13. Describe the relationship between:
    a. atoms, molecules, organelles and cells
    b. cells, tissues, organs and systems.

14. Outline the overall function of the:
  a. digestive system
  b. respiratory system
  c. circulatory system.

Apply and analyse

15. Suggest how scientific understanding of human body systems can help us to diagnose and treat a variety of illnesses.
16. Construct Venn diagrams to compare the:
  a. digestive system and respiratory system
  b. respiratory system and circulatory system
  c. excretory system and reproductive system
  d. circulatory system and excretory system.

Evaluate and create

17. SIS
  a. Select a body system and construct a PMI chart on how its structural features assist it in achieving its function.
  b. Propose ways in which the body system could be improved.
  c. Justify your proposed improvements.
18. SIS
  a. Design and construct a model of one of the following human body systems: respiratory, excretory, digestive or circulatory.
  b. Share your model with your team.
  c. With your team, construct a PMI chart on the accuracy of your model in effectively describing the structure and function of your selected body system.
  d. Identify three ways in which it could be improved.
19. SIS Select one of the following research questions to investigate and present your findings as a labelled model(s), informative animation, picture story book or interesting class presentation. For each question, select animal (i), (ii) or (iii) to compare it with a human.
  a. In which ways are the respiratory systems of (i) a fish, (ii) an earthworm OR (iii) an insect and a human similar, and how are they different?
  b. In which ways are the digestive systems of (i) a starfish, (ii) a snake OR (iii) a bird and a human similar, and how are they different?
  c. In which ways are the circulatory systems of (i) an insect, (ii) a frog OR (iii) a snake and a human similar, and how are they different?

Fully worked solutions and sample responses are available in your digital formats.

4.4 Digestive system — break it down

LEARNING INTENTION

At the end of this subtopic you will be able to describe the structure and function of the digestive system.

4.4.1 Digestion

Digestion involves the breaking down of food so that the nutrients it contains can be absorbed into your blood and carried to each cell in your body.

Five key processes are important in supplying nutrients to your cells. These are:
- ingestion — taking food into your body
- mechanical digestion
- chemical digestion
- absorption of the broken-down food into your cells
- assimilation — converting the broken-down food into chemicals in your cells.

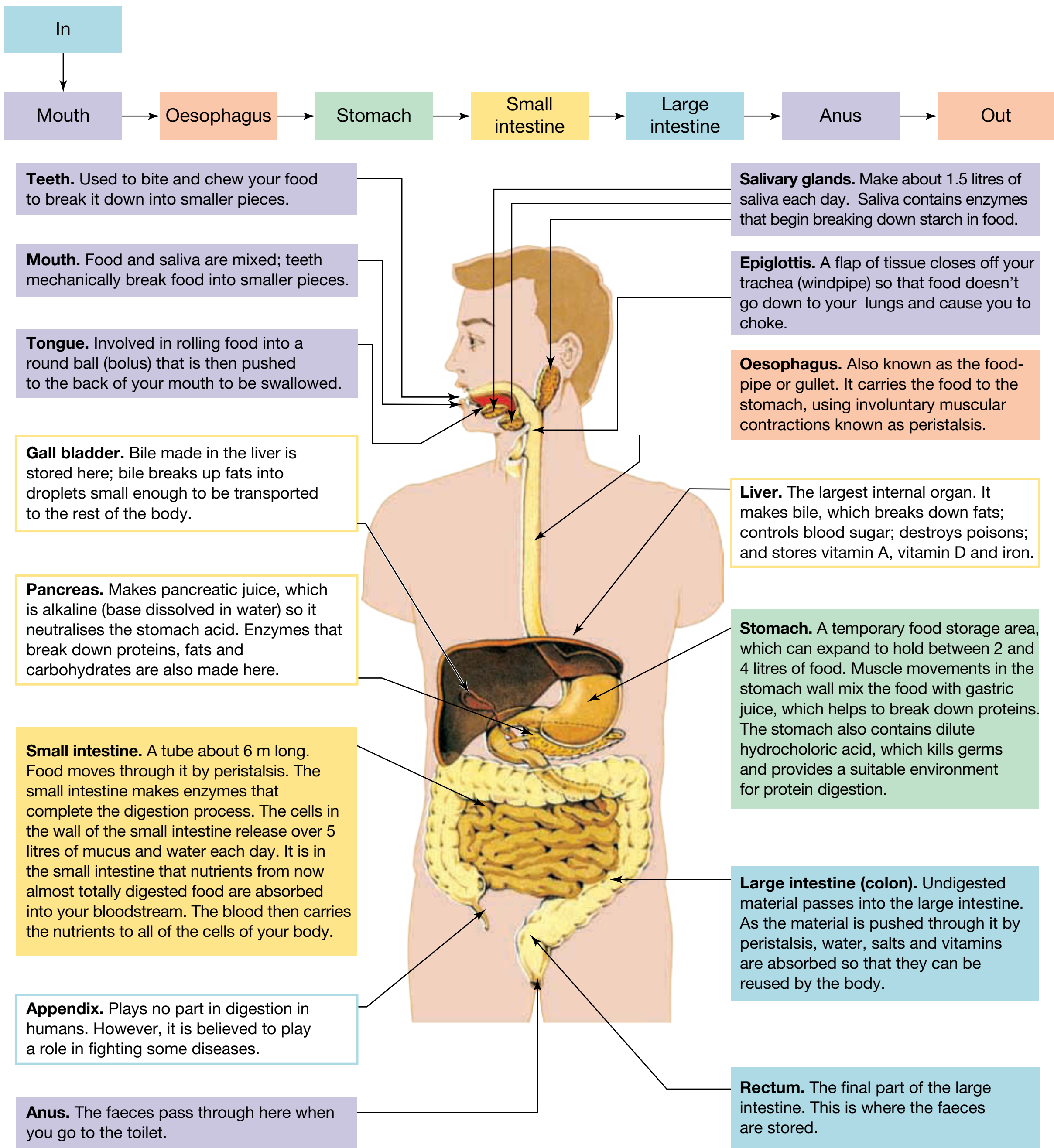
digestion breakdown of food into a form that can be used by an animal. It includes both mechanical digestion and chemical digestion.

eles-2041

int-3398

ewbk-4719

FIGURE 4.23 The human digestive system



4.4.2 Mechanical and chemical digestion

Mechanical digestion (also known as physical digestion) involves physically breaking down the food into smaller pieces. Most of this process takes place in your **mouth** when your teeth bite, tear, crush and grind food. **Chemical digestion** involves the use of chemicals called enzymes to break down food into small molecules. These molecules can then pass through the walls of the small intestine and into the bloodstream.

mechanical digestion digestion that uses physical factors such as chewing with the teeth

mouth the opening of the alimentary canal through which food is taken into the body

chemical digestion the chemical reactions changing food into simpler substances that are absorbed into the bloodstream for use in other parts of the body

Gastrointestinal tract

The key role of your digestive system is to supply your body with the nutrients it requires to function effectively. Your **gastrointestinal tract** (or digestive tract) may be considered as your main digestive highway. It consists of a long tube with coils, large caverns and thin passageways. Other organs that provide chemicals to break down the food or absorb nutrients are attached to the alimentary canal. The alimentary canal begins at the mouth and ends at the anus, where waste products are removed. Excretion of waste products produced by the body's cells can also involve other organs, such as the skin, lungs and kidneys.

Mouth

You ingest food, digest it, then egest it. The whole process of digestion starts with you taking food into your mouth. **Enzymes** (such as amylases) in your **saliva** are secreted by your **salivary glands** and begin the process of chemical digestion of some carbohydrates. Your teeth physically break down food in a process called mechanical digestion, then your tongue rolls the food into a slimy, slippery ball-shape called a **bolus**.

gastrointestinal tract also called the digestive tract and the alimentary canal, tubular passage that starts with the mouth and ends with the anus; it intakes and digests food (absorbing energy and nutrients) and expels waste

enzymes special chemicals that speed up reactions but are themselves not used up in the reaction

saliva watery substance in the mouth that contains enzymes involved in the digestion of food

salivary glands glands in the mouth that produce saliva

bolus round, chewed-up ball of food made in the mouth that makes swallowing easier

teeth hard structures within the mouth that allow chewing

on Resources

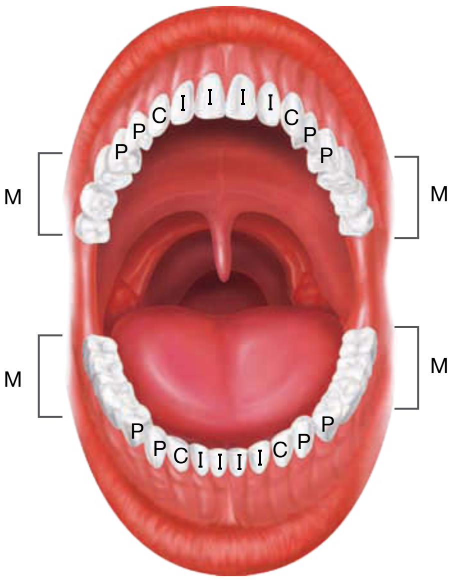
Video eLesson Swallowing (eles-2042)

Look at those teeth!

In many vertebrates, mechanical digestion begins with the teeth. There are four main types of **teeth** in humans, each type with a different function and position in your mouth as shown in figure 4.24. Your teeth are your very own set of cutlery.

int-5335

FIGURE 4.24 Four different types of human teeth

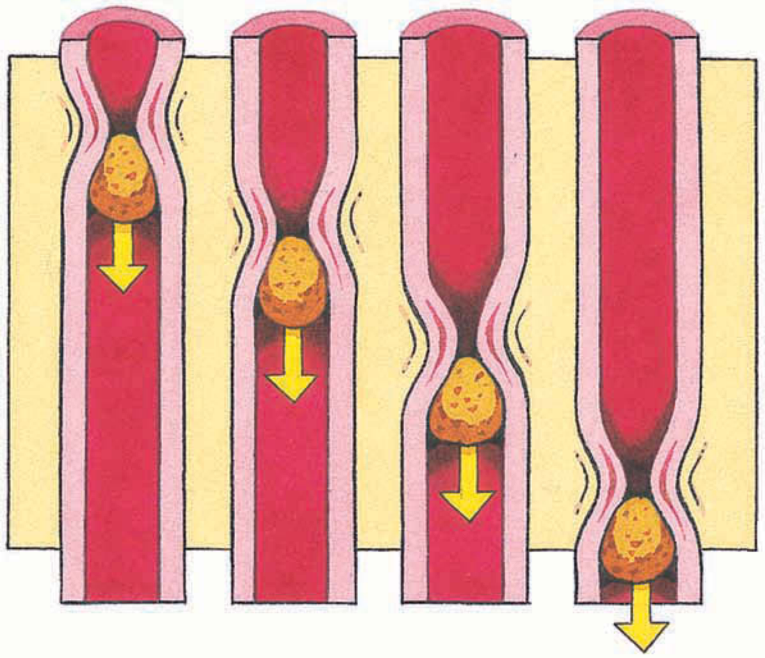


Type of teeth	Structure	Description
Incisors (I)		Shape: Spade-shaped with straight, sharp edge Function: Cutting and biting food Location: Found at the front of your mouth
Canines (C)		Shape: Sharp points and fang-like Function: Shearing and tearing through food Location: Found on each side of incisors
Premolars (P)		Shape: Generally two pointed cusps Function: Roll, grind and crush food Location: Found between the canines and molars
Molars (M)		Shape: Have between three and five cusps that fit together with those in the upper and lower jaws Function: Grind food Location: Found at the back of your mouth

Oesophagus to stomach

The bolus is then pushed through your **oesophagus** by muscular contractions known as **peristalsis**. From here it is transported to your **stomach** for temporary storage and further digestion.

FIGURE 4.25 Partly digested food is forced along the oesophagus by peristalsis — a wave of involuntary muscular contractions.



oesophagus part of the digestive system composed of a tube connecting the mouth with the stomach

peristalsis the process of pushing food along the oesophagus or small intestine by the action of muscles

stomach a large muscular organ that churns and mixes food with gastric juice to start to break down protein

small intestine the part of the digestive system between the stomach and large intestine, where much of the digestion of food and absorption of nutrients takes place

absorption the taking in of a substance, for example from the intestine to the surrounding capillaries

villi tiny finger-like projections from the wall of the intestine that maximise the surface area of the structure to increase the efficiency of nutrient absorption. Singular = villus.

nutrients substances that provide energy and chemicals that living things need to stay alive, grow and reproduce

bile a substance produced by the liver that helps digest fats and oils

gall bladder a small organ that stores and concentrates bile within the body

lipids type of nutrients that include fats and oils

Stomach to small intestine

Once the food gets from your stomach to your **small intestine**, more enzymes (including amylases, proteases and lipases) break it down into molecules that can be absorbed into your body. The **absorption** of these nutrient molecules occurs through finger-shaped **villi** in the small intestine (figure 4.26). Villi are shaped like fingers to maximise surface area, which increases the efficiency of **nutrient** absorption into the surrounding capillaries. Capillaries are tiny blood vessels that transport the nutrients from the villi into your bloodstream. Once absorbed into the capillaries (of your circulatory system), these nutrients are transported to cells in the body that need them.

on Resources

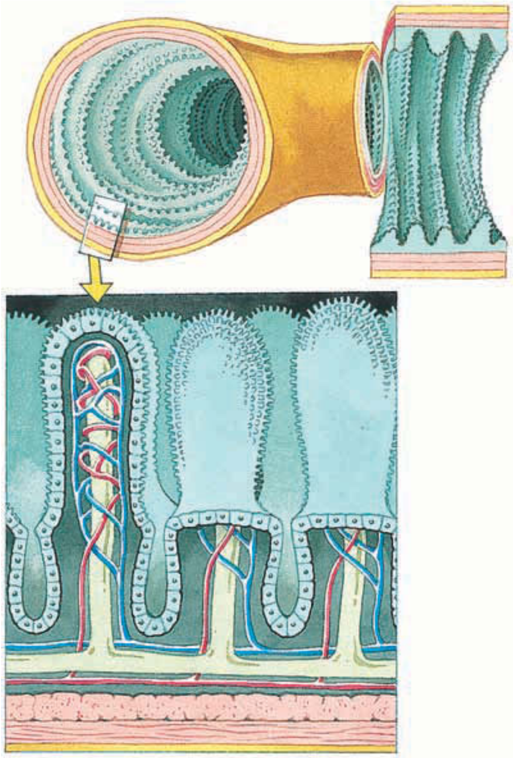
Weblink Observing villi 1

4.4.4 The liver, pancreas and large intestine

Liver

Your liver is an extremely important organ with many key roles. One of these is the production of **bile**, which is transported to your **gall bladder** via the bile ducts to be stored until it is needed. Bile is transported from the gall bladder to the small intestine where it is involved in the emulsification of **lipids** such as fats and oils.

FIGURE 4.26 The absorption of most nutrients into your body occurs in the ileum, the last section of the small intestine. The finger-like villi on its walls give it a large surface area that speeds up nutrient absorption. Undigested material continues on to the large intestine where water and vitamins may be removed, and then the remainder is pushed out through the anus as faeces.



Pancreas

Enzymes, such as **lipases**, **amylases** and **proteases**, which break down lipids, carbohydrates and proteins respectively, are made by the **pancreas** and secreted into the small intestine to chemically digest these components of food.

Large intestine

On its way through the digestive tract (alimentary canal), undigested food moves from the small intestine to the **colon** of the **large intestine**. It is here that water and any other required essential nutrients still remaining in the food mass may be absorbed into your body. **Vitamin D** manufactured by bacteria living within this part of the digestive system is also absorbed. Any undigested food, such as the **cellulose** cell walls of plants (which we refer to as fibre), also accumulates here and adds bulk to the undigested food mass.

The **rectum** is the final part of the large intestine where the faeces is stored before being excreted through the **anus** as waste.

Fat stuff

Breaking down lipids, such as fats and oils, is hard work! Because lipids are insoluble in water, they tend to clump together into large blobs. Bile helps solve this problem. As half of the bile molecule is attracted to water and the other half attracted to lipids, it helps to **emulsify** or separate the lipids so the lipase enzymes can gain access to them and do their job. This is an example of bile and lipase working together to get the job done.

lipases enzymes that break fats and oils down into fatty acids and glycerol

amylases an enzyme in saliva that breaks starch down into sugar

proteases enzymes that break proteins down into amino acids

pancreas a large gland in the body that produces and secretes the hormone insulin and an important digestive fluid containing enzymes

colon the part of the large intestine where food mass passes from the small intestine, and where water and other remaining essential nutrients are absorbed into the body

large intestine the penultimate part of the digestive system, where water is absorbed from the waste before it is transported out of the body

vitamin D a nutrient that regulates the concentration of calcium and phosphate in the bloodstream and promotes the healthy growth and remodelling of bone

cellulose a natural substance that keeps the cell wall of plants rigid

rectum the final section of the digestive system, where waste food matter is stored as faeces before being excreted through the anus

anus the final part of the digestive system, through which faeces are passed as waste

emulsify combine two liquids that do not normally mix easily

4.4.5 Enzymes

Chemical digestion is usually assisted by compounds called enzymes that increase the rate of the chemical reactions. Without enzymes, a single meal could take many years to break down. Mechanical digestion increases the rate of chemical digestion because it increases the surface area of the food particles. This exposes more of the food surface to the digestive chemicals and enzymes.

Chemical digestion begins in your mouth where enzymes in saliva begin to break down some of the carbohydrates in the food that you eat.

FIGURE 4.27 Bile emulsifies fat so that lipases can break it down.

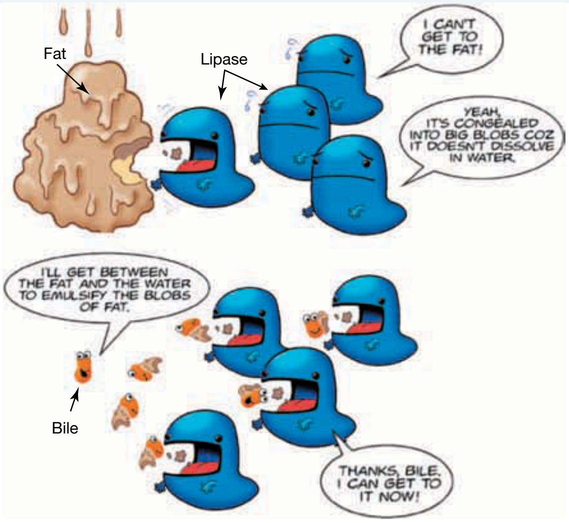


FIGURE 4.28 Types of digestive enzymes

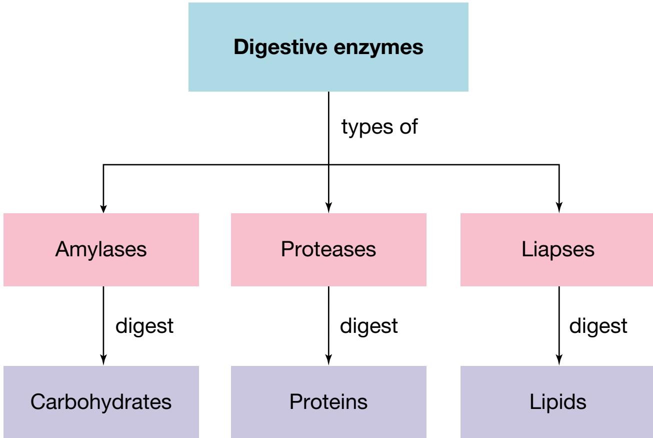
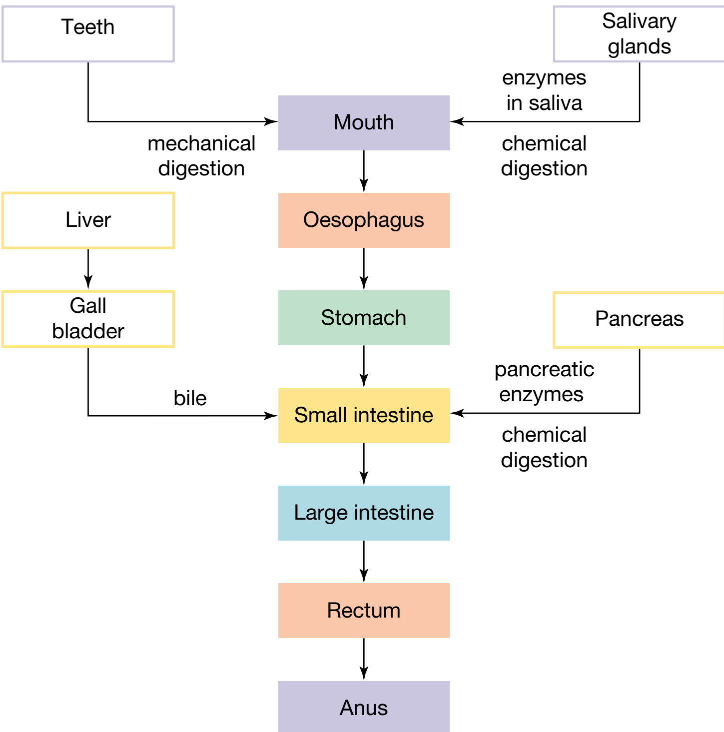


FIGURE 4.29 Digestion occurs within your digestive system in a systematic and organised manner.



Not too hot!

Enzymes are made of protein. That is why it is important that they are not overheated. If they are too hot, they can become **denatured**. It's the same as cooking an egg — once they are denatured, they can't go back to how they were before, so they can't work as enzymes anymore. Different enzymes operate best within specific temperature ranges.

denatured describes the condition of proteins after they have been overheated

elog-0523

INVESTIGATION 4.2

Does temperature affect enzymes?

Aim

To investigate the effect of temperature on enzyme activity

Materials

- 4 beakers
- 8 test tubes
- milk
- 4 thermometers
- fresh pineapple puree (Fresh pineapple can be pureed using a food processor. If fresh pineapple is not available, use junket powder or a junket tablet dissolved in 10 mL water.)

Method

1. Add water to the beakers so that they are two-thirds full. Use cold tap water and ice for beaker 1, cold tap water for beaker 2, hot tap water for beaker 3 and boiling water (from a kettle) for beaker 4. These are the 'water baths'.
2. Half-fill four test tubes with milk and put one test tube in each water bath.
3. Place one teaspoon of fresh pineapple puree (or 1 mL junket solution dissolved in 10 mL water) in the other four test tubes. Put one of these test tubes in each water bath.
4. Allow the test tubes to stand in the water baths for at least 5 minutes.
5. For each water bath, pour the fresh pineapple puree into the milk and stir briefly.

Results

1. Copy the table provided and complete it with your results. Remember to include a title for your table.

Water bath	Temp. of milk and pineapple mix (°C)	Time taken to set (minutes)

2. Quickly record the temperature of the milk and pineapple mixture and then allow it to stand undisturbed. The mixture will eventually set. Record the time taken to set. If the milk has not set after 15 minutes, record the time as 15+.

Discussion

1. Pineapple juice and junket contain an enzyme that causes a protein in milk (casein) to undergo a chemical reaction and change texture; that is why the milk sets. At what temperature did the enzyme work best? Explain.
2. Did the enzyme work well at very high temperatures? Explain your answer.
3. Which variables were controlled in this experiment?
4. Do you think that the same results would be obtained if tinned pineapple puree was used instead of fresh pineapple puree? Explain your answer.
5. Identify the strengths and limitations of this investigation, and suggest ways to improve it.
6. Propose a research question about enzymes that could be investigated.

Conclusion

Write a conclusion for this investigation.

4.4.6 'Ase' endings

There are specific enzymes for specific tasks. The substance that they break down is called a **substrate**. The resulting substance is referred to as the **product**. As figure 4.30 shows, the enzyme remains unchanged at the end of the process.

Enzymes that break down carbohydrates, such as starch, into glucose are called amylases (see figure 4.31). Those that break down fats and oils into fatty acids and glycerol are called lipases. Proteases are enzymes that break down proteins into amino acids.

Each enzyme has specific conditions in which it works. For example, amylases that break down carbohydrates in the stomach work in acidic environments, while those in the small intestine work best in alkaline conditions.

FIGURE 4.30 Enzymes speed up chemical reactions in the body, but are not changed so can be reused again and again.

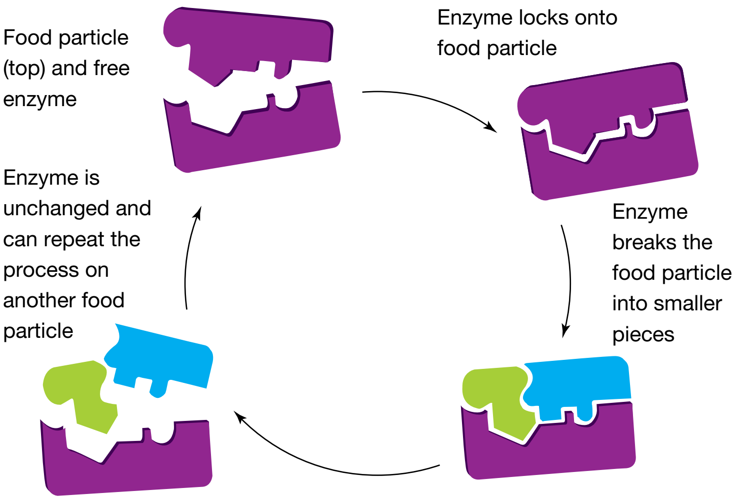
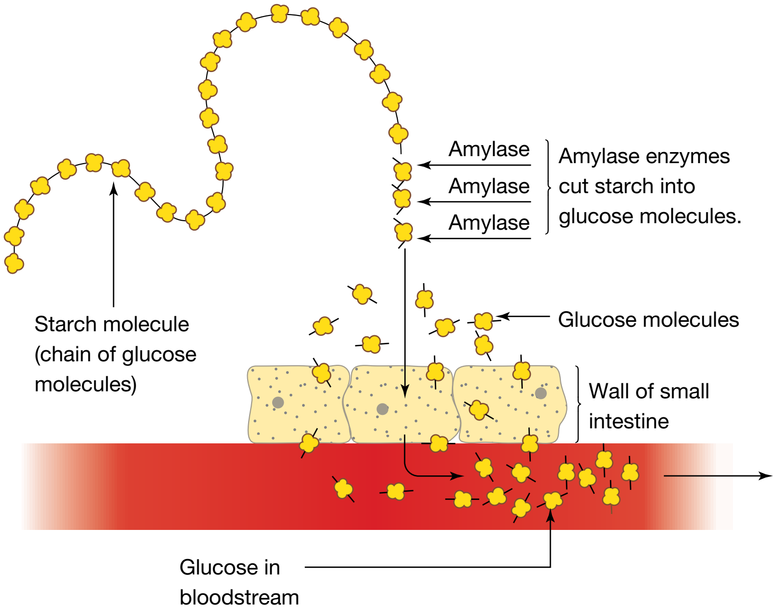


FIGURE 4.31 Amylases in the saliva and stomach break starch down into glucose molecules.



4.4.7 Personal explosions

Well, excuse me! Have you burped or passed wind recently? Have you had diarrhoea or vomited? These 'personal explosions' are related to the processing of nutrients by your body.

Burping, or belching, occurs when air is swallowed or sucked in. This may happen when you talk while you eat, eat or drink too quickly, or drink fizzy drinks (such as those with carbon dioxide gas dissolved in them). When you eat too fast and don't chew your food enough, more acid can be produced in your stomach. When you burp, some of this acid can rise up into your oesophagus, resulting in a burning sensation called **heartburn**.

substrate substance acted upon by an enzyme

product new chemical substance that results from a chemical reaction

burping release of swallowed gas through the mouth

heartburn burning sensation caused by stomach acid rising into the oesophagus

Resources

Video eLesson Stomach acid reflux, heartburn (eles-2531)

Flatulence refers to the release of gases when you 'pass wind' through your anus. These gases are produced by bacteria in your large intestine. The odour and composition of the gases depend on the foods you have eaten and the amount of air you have swallowed.

Diarrhoea is the excessive discharge of watery faeces. It occurs when the muscles of the large intestine contract more quickly than normal, usually in an effort to rid your body of an infection. As a result, the undigested food moves through too rapidly for enough water to be absorbed into your body.

Green vomit? Messages from your stomach wall travel to the 'vomiting centre' of your brain, resulting in forceful ejection of your stomach contents (and occasionally also contents from your small intestine). **Vomiting** can be caused by eating or drinking too much, anxiety, infections or chemicals that irritate your stomach wall. If the vomit is green, it may be due to the colour of food ingested or the presence of bile, which is produced by your liver to help digest food in your small intestine.

flatulence release of gas through the anus. This gas is produced by bacteria in the large intestine.

diarrhoea excessive discharge of watery faeces

vomiting the forceful ejection of matter from the stomach through the mouth

elog-0524

INVESTIGATION 4.3

Making a burp model

Aim

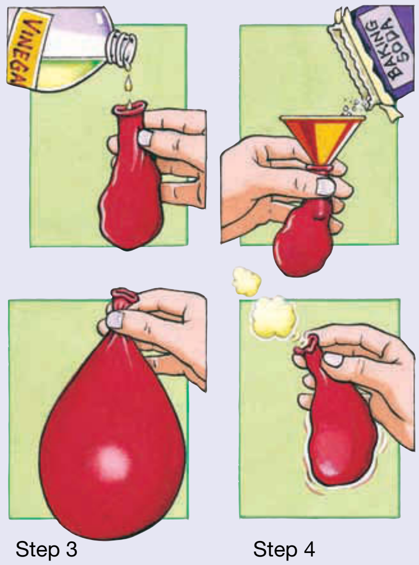
To construct a burp model and to design and construct a model that demonstrates the functioning of a process related to the digestive system

Materials

- vinegar
- baking soda
- medium/large balloon
- funnel

Method

1. Pour a small amount of vinegar into the bottom of the balloon 'stomach'.
2. Add some baking soda to the balloon 'stomach' using a funnel.
3. Using your fingers, pinch the balloon closed at its neck.
4. Watch as your 'stomach' expands with gas.
5. Unpinch the top of the balloon (or 'oesophagus / food tube') to release the gas (or burp).
6. Try to make your model sound like the real thing!



Results

1. Summarise your observations in a flowchart that includes labelled diagrams or digital/photographic images.
2. Select an organ belonging to an animal of your choice. Find out more about the structure and function of your selected organ and how it does its job. Summarise your findings.
   - Design and make a simple model (such as the one used for this experiment) to show how your selected organ achieves its function, or what happens when something goes wrong.
3. Summarise your design plans and labelled diagrams or digital images into an advertising brochure or digital multimedia advertisement.

Discussion

Comment on the challenges you experienced during the design and construction of your model, and suggest ways that you could overcome these if you were to do it again.

Conclusion

Write a conclusion for this investigation.

on Resources

eWorkbooks	Mechanical and chemical digestion (ewbk-4720) The digestive system (ewbk-4722)
assess on	Additional automatically marked question sets

4.4 Exercise

learn on

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 6, 7, 10, 11, 12, 13, 15	Questions 3, 4, 5, 8, 16, 18, 21	Questions 9, 14, 17, 19, 20, 22

Remember and understand

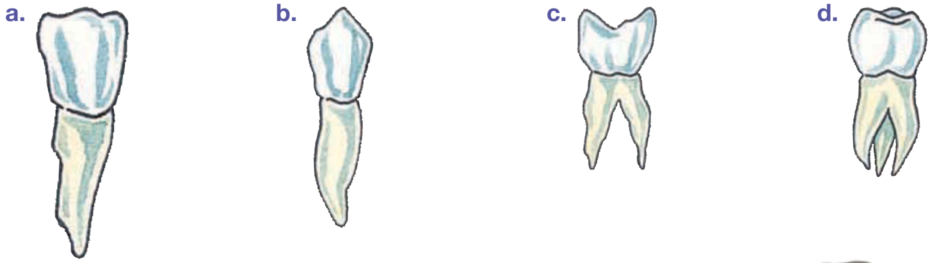
1. State whether the following statements are true or false. Justify any false responses.

Statement	True or false
a. Mechanical digestion occurs when chemicals in your body react with food to break it down.	
b. Ingestion involves taking food into your body, whereas digestion involves breaking food down.	
c. Many enzymes have names that end with the suffix ‘ase’.	
d. ‘Bolus’ is the term used to describe the muscular contractions that push food down your oesphagus to your stomach.	
e. Plant cell walls make up much of the fibre that accumulates in our large intestines.	
f. The process of denaturing enzymes kills them.	
g. Proteases are enzymes that breakdown carbohydrates.	
h. Heartburn can be caused by acid from your stomach rising up your oesphagus.	
i. Flatulence refers to the release of gases when you ‘pass wind’ through your anus.	
j. The green colour of vomit may suggest the presence of bile, which has been produced by the gall bladder.	

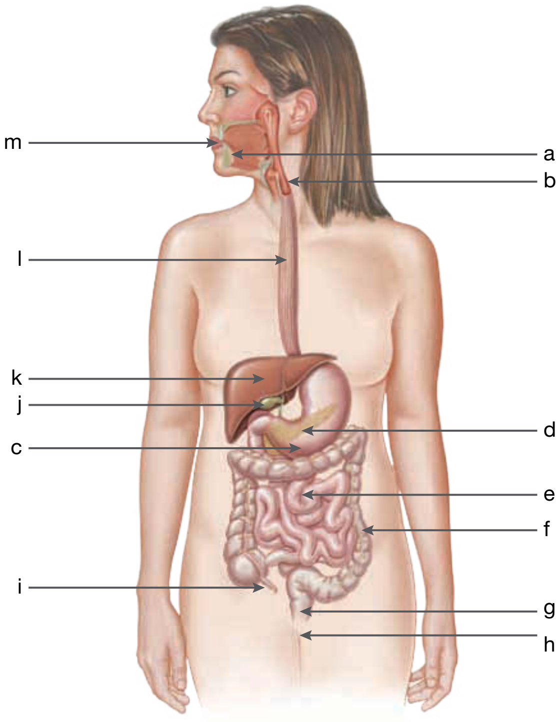
2. Match the types of teeth with their specific function.

Types of teeth	Function
a. Canines	A. Biting and cutting food
b. Incisors	B. Grinding and crushing food
c. Molars and premolars	C. Tearing and grasping food

3. Identify the different types of teeth as being one of the following: incisors, canines, premolars or molars.



4. Identify the organs (a–m) in the figure given.
5. State the name of the:
   a. organ in which the digestive process begins
   b. type of digestion in which enzymes secreted by your salivary glands are involved in
   c. slimy, slippery ball-shape in which your tongue rolls food
   d. muscular contractions that push the bolus through the oesophagus to the stomach
   e. organ in which most of the absorption of nutrients occurs
   f. finger-shaped structures through which nutrients are absorbed in the small intestine.
6. Order the following organs into the correct sequence: stomach, large intestine, oesophagus, anus, mouth, small intestine.



7. Match the organ with its function in the table shown.

Organ	Function
a. Gall bladder	A. Where the breakdown of starch and protein is finished and fat breakdown occurs
b. Large intestine	B. Temporary storage of food and where protein digestion begins
c. Liver	C. Tube that takes food from mouth to stomach
d. Oesophagus	D. Stores undigested food and waste while bacteria make some vitamins
e. Pancreas	E. Stores faeces
f. Rectum	F. Makes enzymes used in the small intestine
g. Small intestine	G. Makes bile, stores glycogen and breaks down toxins
h. Stomach	H. Stores bile made in the liver until needed in the small intestine

8. State the name of the:
   a. type of digestion that involves enzymes
   b. enzymes that break down fats
   c. enzymes that break down proteins
   d. substances that enzymes act on.
9. List the five key processes that are important in the supply of nutients to your cells.
10. Explain why it is important to break down food that we eat.
11. Describe what happens to enzymes when they get too hot.
12. Describe the process of peristalsis and suggest why it occurs.
13. Suggest why it is necessary to drink fluids when you suffer from diarrhoea.
14. Describe the relationship between:
   a. teeth and mechanical digestion
   b. the pancreas and the small intestine
   c. the liver, gall bladder and the small intestine
   d. the villi, small intestine and capillaries
   e. bile, lipase and fats.

Apply and analyse

15. Which teeth are used to:
   a. bite into a pear
   b. crush and grind nuts?
16. Suggest how you can still swallow food if you were positioned upside down.
17. Take a small piece of bread into your mouth. Although at first you don't taste much, after a while, it may taste sweet. Suggest why.
18. Create Venn diagrams to compare:
   a. mechanical and chemical digestion
   b. lipases and proteases
   c. small intestine and large intestine.
19. Use information in this subtopic and other resources to relate structural features to the functions of the following parts of the digestive system.

TABLE Parts of the digestive system and their functions

Part of system	Structural features	Function
Oesophagus		
Stomach		
Small intestine		
Villi		
Large intestine		

Evaluate and create

20. **SIS** When cows burp, they release methane gas into the air. This gas is believed to be one of the major causes of global warming. It has been suggested that cows could be responsible for about 20 per cent of the methane in the atmosphere. Research these claims.
   a. On the basis of your findings, do you agree? Justify your response.
   b. Design an experiment that could be used to test the claim that cows contribute to increased methane gas in the atmosphere.
21. **SIS** Design an investigation to test the following hypotheses:
   - Fresh pineapple results in a faster enzyme reaction than canned pineapple.
   - The length of time that pineapple puree is kept in ice affects the rate of enzyme reaction.
   - Different coloured junket tablets result in different rates of enzyme reaction.
22. **SIS**
   a. Imagine that you are either a cheese and tomato sandwich or a hamburger.
   b. List the ingredients of the food you chose in part (a).
   c. Research what happens (and where) to each of these ingredients when eaten.
   d. Construct a flowchart to show the process of digestion in the human body, including events and locations.

e. Use this information to write a story in either a cartoon or picture book format.
f. Convert your story into a play.
g. Perform your play to the class using animations, team members or puppets.

Fully worked solutions and sample responses are available in your digital formats.

4.5 Digestive endeavours

LEARNING INTENTION

At the end of this subtopic you will be able to give examples of ways in which science and technology have contributed to scientific knowledge and understanding of your digestive system and have led to related improved medical treatments.

Science as a human endeavour

4.5.1 The digestive system as a scientific human endeavour

When your digestive system is healthy, it actively works along, busily doing its job without you even having to think about it. But sometimes, things can go wrong. For example, tooth decay, gum disease, intestinal polyps and a variety of digestive system diseases may result in some form of intervention. Research and developments in science and technology have not only increased our understanding and knowledge about our digestive system but have also led to improved medical treatments to help us when things go wrong.

4.5.2 Do you look after your teeth?

It is very important to look after your teeth. Damaged or missing teeth can make it difficult for you to chew your food properly and therefore may affect digestion of foods.

Ouch! Does your tooth hurt?

Your teeth can decay when bacteria in your mouth turn sugar from your food into acid. This acid can 'eat' a hole in your tooth enamel and dentine. Once this hole reaches a nerve, you get a toothache. Figure 4.32 shows the structure of a tooth and where decay usually occurs — at the top of large back teeth and at the side where one tooth touches another.

How many times do you clean your teeth each day?

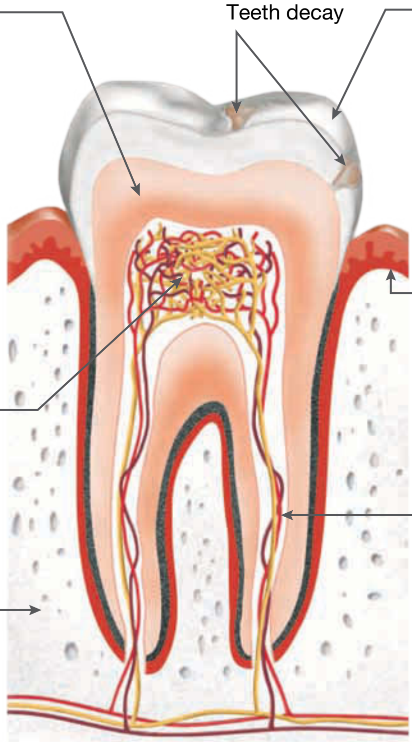
If you don't clean your teeth regularly (at least once a day), they can become covered with a thin film of food, saliva and bacteria. This is called plaque. As this plaque rots, it causes your gums to swell and bleed. This is known as gum disease.

Do you drink tap or bottled water?

Our water supply and toothpaste often contain fluoride, which helps prevent tooth decay. Fluoride protects the enamel and helps repair or rebuild the enamel in your teeth. If you have replaced drinking tap water with bottled water, read the label and find out if it has fluoride in it. In which other ways is bottled water different from tap water? Can drinking bottled water instead of tap water affect the health of your teeth?

eles-2532

FIGURE 4.32 Structure of a tooth showing where tooth decay occurs



4.5.3 A future in teeth?

Dentistry is only one example of many different 'tooth pathway' careers that you may be aware of. Examples of other dental specialities include oral and maxillofacial surgeons, dental–maxillofacial radiologists, endodontists, oral physicians, oral pathologists, orthodontists, paediatric dentists, periodontists, prosthodontists, public health dentists and special needs dentists.

FIGURE 4.33 Oral surgery is one of the many tooth-related careers you can choose from.

FIGURE 4.34 Missing a tooth? A synthetic replacement for a tooth root is used in a tooth implant.

4.5.4 Do you have the stomach for it?

In the early 1800s, Dr William Beaumont made discoveries about how the stomach worked by dangling food on a silk thread into the wounded stomach of Alexis St Martin. Almost 200 years later, Australian scientists, Dr Barry J Marshall and Dr Robin Warren made the discovery that linked *Helicobacter pylori* bacteria to gastroduodenal disease and, as a result, radically improved how peptic ulcer disease is treated.

FIGURE 4.35 In 1822, Alexis St Martin was shot in the stomach at close range. His wound healed, but left an open hole that showed the inside of his stomach. By dangling food suspended on a silk thread, his doctor William Beaumont made some breakthrough discoveries on how our stomachs work.

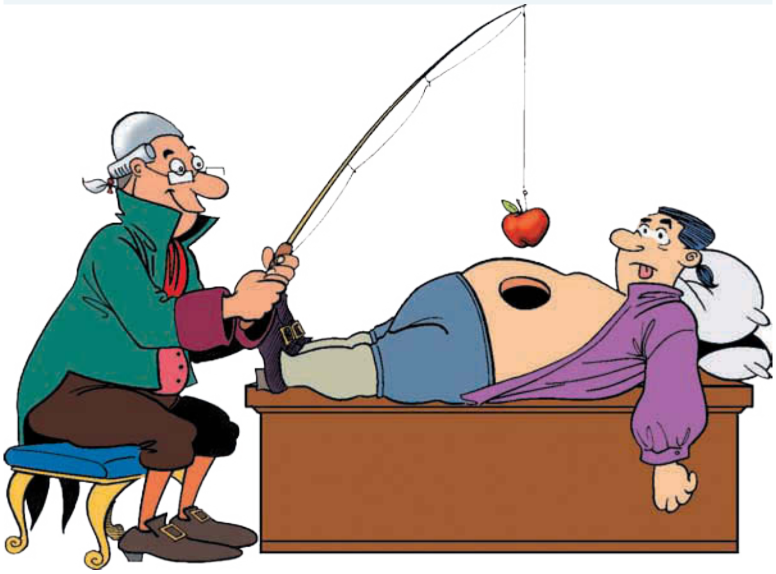


FIGURE 4.36 Australian scientists Dr Barry J. Marshall and Dr Robin Warren received the 2005 Nobel Prize in Medicine for their discovery that linked *Helicobacter pylori* bacteria to gastroduodenal disease.

4.5.5 Going up or down?

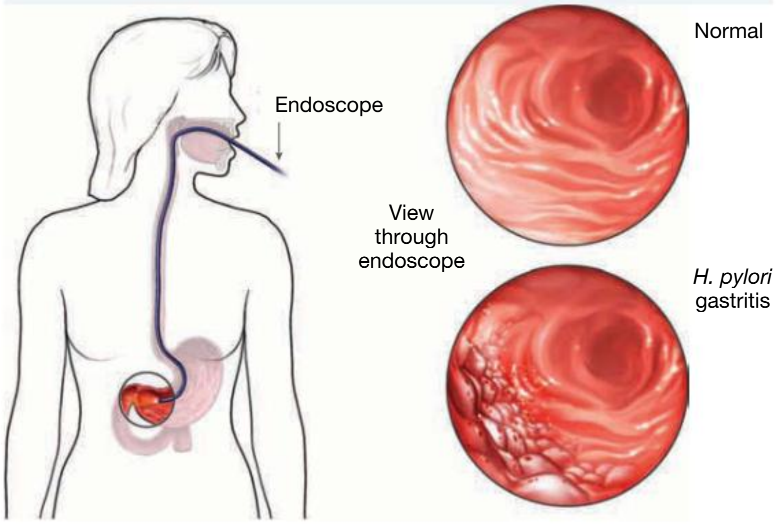
Gastroscopy and colonoscopy involve the use of endoscopes (from the Greek words meaning to 'see within').

A major advantage of these techniques is that they gather important information without needing to cut into the body.

Gastroscopy

Gastroscopy involves passing a long flexible endoscope through your mouth, down your oesophagus and into your stomach and duodenum. Although it takes only about five minutes, a lot of information can be gathered about the health of this part of your digestive system.

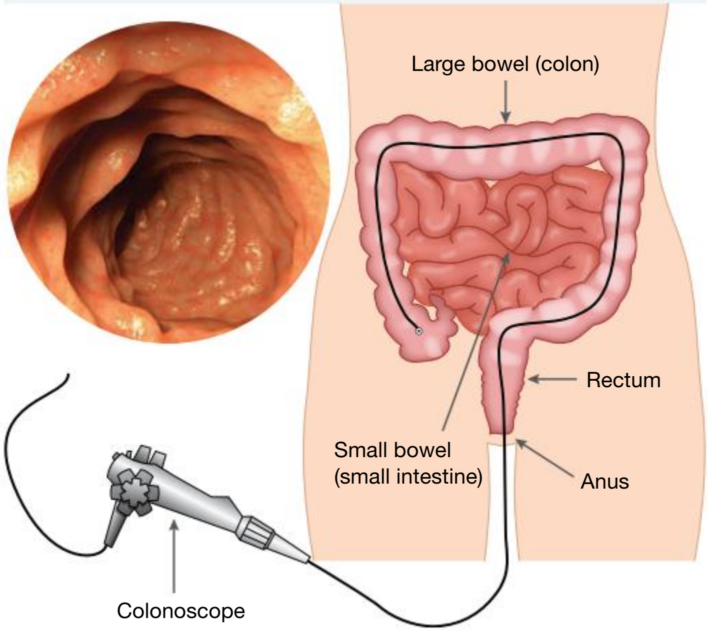
FIGURE 4.37 Gastroscopy procedure



Colonoscopy

A colonoscopy enables the doctor to look directly at the lining of your colon or bowel. In this case the endoscope is inserted through your rectum. This procedure may take about thirty minutes. The results may be used to investigate abnormalities or detect the presence of colon polyps, which in some cases may turn into cancer. A colonoscopy can enable small polyps to be removed or a biopsy to be taken for further testing.

FIGURE 4.38 Colonoscopy procedure



on Resources

Video eLessons Colon biopsy tool (eles-2533)
Colonoscopy procedure (eles-2534)

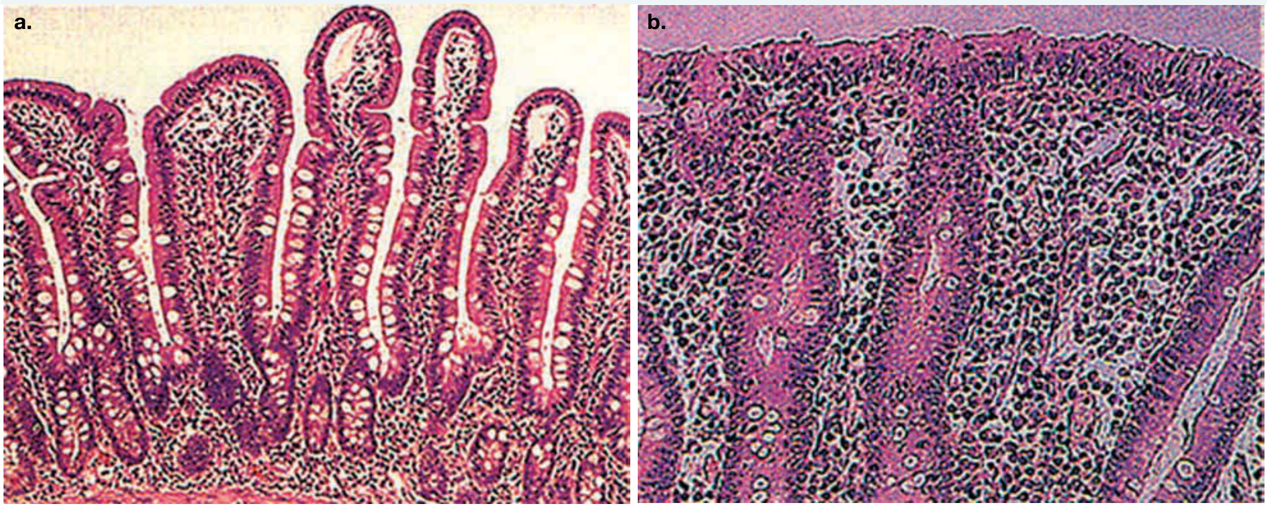
4.5.6 Villi alert!

The last section of your small intestine is lined with finger-like projections called villi. Their shape increases the surface area available for nutrients to diffuse through them into tiny blood vessels called capillaries. Once in the bloodstream, the nutrients are transported to other parts of your body.

Coeliac disease

Coeliac disease is an auto-immune disease — that is, one in which your body produces antibodies to attack your own tissues. In this case, the immune system reacts abnormally to gluten. As a result, the villi of the small intestine become inflamed and flattened. This reduces the surface area available for the absorption of nutrients.

FIGURE 4.39 Biopsies of **a.** normal intestine and **b.** coeliac intestine



Coeliac Australia refers to coeliac disease as a 'hidden epidemic'. Although about 1 in 70 people in Australia have been diagnosed with the condition, many (about 80 per cent) do not know that they have it. If left undiagnosed, more severe consequences, such as a variety of nutritional deficiencies, bowel cancer and osteoporosis, may result.

SCIENCE AS A HUMAN ENDEAVOUR: Coeliac disease under focus

People with coeliac disease are intolerant to gluten. This protein is found in wheat, rye, barley and oats.

In 2019, within hours of eating gluten, distinct markers were discovered in the blood of people affected by coeliac disease. This discovery involved an international collaboration of the world's leading coeliac disease experts. The team included Associate Professor Jason Tye-Din, Head of coeliac research at Australia's Walter and Eliza Hall Institute of Medical Research. Although there are already blood tests available for diagnosis, this discovery has triggered research with a focus of developing a simple blood test to diagnose coeliac disease.

In 2009, the world's first trials of a coeliac disease vaccine developed by Australian researchers began. Ten years later, the phase 2 trials for Nexvax2® were discontinued. Although the quest to discover and develop an effective medical treatment for Coeliac disease continues, a strict, gluten-free diet is still the only way to manage it.

FIGURE 4.40 Associate Professor Jason Tye-Din, Head of coeliac research at Australia's Walter and Eliza Hall Institute of Medical Research and a gastroenterologist at The Royal Melbourne Hospital

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INVESTIGATION 4.4

Observing villi

Aim

To investigate the internal structure of the lining of the small intestine

Materials

- prepared slides of the walls of the small intestine
- monocular light microscope

Method

Use a light microscope to observe the prepared slide of the walls of the small intestine.

Results

Draw a diagram of your observations. Record the magnification used, label a villus and use descriptive labels to record your detailed observations.

Discussion

1. Describe the function of a villus. (Read through the information previously given in this subtopic if you are unsure.)
2. With reference to your observations, suggest how the shape of a villus suits its function.

Conclusion

Write a conclusion for this investigation.

on Resources

assesson Additional automatically marked question sets

4.5 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3, 4, 5, 7	Questions 6, 8, 9, 10, 11, 12	Questions 13, 14, 15

Remember and understand

1. State whether the following statements are true or false. Justify any false responses.

Statement	True or false
a. Acid produced from sugar in food may 'eat' a hole in your tooth enamel and dentine.	
b. Plaque refers to a thin film of food, saliva and bacteria that may cover your teeth.	
c. Rotting plaque can cause your gums to swell and bleed.	
d. Fluoride may be added to the water supply or toothpaste to increase tooth decay.	

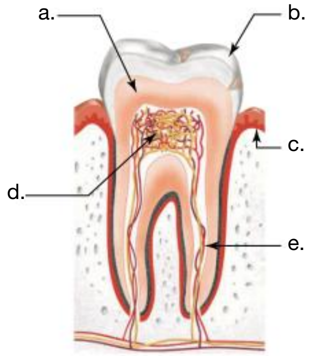
(continued)

(continued)

Statement	True or false
e. Gastroscopy and colonoscopy both involve the use of endoscopes.	
f. A colonoscopy procedure involves passing a long flexible endoscope through your mouth, down your oesophagus and into your stomach and duodenum.	
g. The results from a colonoscopy may be used to investigate abnormalities or detect colon polyps, which in some cases may turn into cancer.	
h. It is in the last section of your large intestine where most of the nutrients are absorbed into your bloodstream.	
i. The shape of the villi in the small intestine increases the surface area available for absorption of nutrients into capillaries.	
j. People with coeliac disease can eat foods containing gluten.	

2. Label the structures (a–e) in the diagram of the tooth using the following terms: Enamel, Dentine, Gum, Pulp, Root canal.

Structure of the tooth



3. Match the tooth part to its description.

Tooth part	Description
a. Dentine	**A.** The name of the channel where the nerves and blood vessels go down into the jawbone
b. Enamel	**B.** The bone-like material that gives the tooth its shape and makes up most of the tooth but, if exposed, wears away
c. Pulp	**C.** This forms a coating over the exposed surface of the tooth and is the hardest substance in your body.
d. Root canal	**D.** This part of the tooth contains most of the nerves and blood vessels.

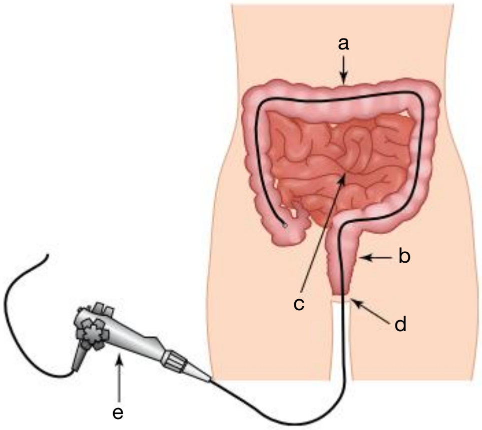
4. Identify the missing labels (a–e) for the diagram of the colonoscopy procedure shown.

5. Describe the discovery that led to two Australian scientists winning the 2005 Nobel Prize in Medicine.

6. Outline the relationship between diet, coeliac disease and the digestive system.

7. Approximately how many people in Australia are affected by coeliac disease?

Colonscopy procedure



Apply and analyse

8. Imagine that you have invited two friends over for a sleepover. One of them has coeliac disease and the other is lactose intolerant.
   a. Find out the cause and symptoms associated with each of these conditions.
   b. Find out what sorts of foods you could offer your friends.
   c. Design a dinner and breakfast menu that includes foods that each of your friends would be able to eat.
   d. Share and discuss your menus with those of other class members.
9. Use a Venn diagram to compare gastroscopy and colonoscopy.
10. Select one of the 'tooth pathway' careers in the text 4.5.3 'A future in teeth'. Find out details of the training required and what a career in this pathway would entail. Present your findings in a brochure and include a section that describes what 'a day in the life of a …' would be like.
11. Research one of the following digestion-related diseases and report on the cause, symptoms, treatment or cure, possible consequences and current research.
    - Heartburn
    - Inflammatory bowel disease
    - Irritable bowel syndrome
    - Appendicitis
    - Constipation
    - Crohn's disease
    - Diverticulosis
    - Gallstones
    - Haemorrhoids
    - Pancreatitis
    - Peptic ulcer
    - Colonic polyps
12. Find out more about one of the following digestion-related scientific careers and report your findings as a journal entry.
    - Gastroenterologist
    - Endoscopist
    - Colorectal surgeon

Evaluate and create

13. SIS Recently scientists have suggested a link between the presence of bacteria *Helicobacter pylori* and cancer protection. Find out more about this research and suggest possible implications that it may have.
14. SIS
    a. Identify claims made about the coeliac vaccines such as Nexvax2®
    b. Do you think that the Nexvax2® clinical trials should have been discontinued? Justify your response.
15. SIS Design an investigation to test the following hypotheses:
    - Drinking fluoridated water reduces tooth decay.
    - Mouthwash prevents the growth of bacteria that cause tooth decay.
    - Drinking bottled water rather than tap water increases tooth decay.

Fully worked solutions and sample responses are available in your digital formats.

4.6 Circulatory system — blood highways

LEARNING INTENTION

At the end of this subtopic you will be able to describe the structure and function of the circulatory system.

4.6.1 What's in blood?

An average-sized human has about five litres of blood; that's about a bucketful. Blood is made up of red blood cells (**erythrocytes**), white blood cells (**leucocytes**), blood platelets and the straw-coloured fluid they all float in, called **plasma**.

erythrocytes red blood cells
leucocytes white blood cells
plasma the yellowish liquid part of blood that contains water, minerals, food and wastes from cells

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FIGURE 4.41 You have all of this in your blood.

Blood in mammals consists of:

- **Plasma** (about 55% of blood)
  - **Serum**
    Contains:
    - water (about 90%)
    - proteins
    - gases (e.g. carbon dioxide)
    - nutrients
    - waste minerals and other substances
  - **Fibrinogen**
    Function: clotting of blood
- **Cells**
  - **Red blood cells**
    (about 45% of blood)
    - 5–6 million per mm^3
    - No nucleus
    - Cytoplasm with haemoglobin
    - Function: carries oxygen and carbon dioxide
  - **White blood cells**
    (less than 0.1% of blood)
    - 7000 per mm^3
    - Nucleus present
    - Colourless cytoplasm
    - Function: defence against disease
- **Platelets**
  (less than 0.01% of blood)
  - 250 000 per mm^3
  - Function: aids in clotting of blood

Ready to carry!

Each drop of blood contains about 300 million red blood cells with the important job of carrying oxygen around your body. Red blood cells are red because they contain an iron-containing pigment called haemoglobin. Oxygen reacts with haemoglobin in red blood cells to form oxyhaemoglobin, which makes the blood an even brighter red. This change in colour intensity can indicate the amount of oxygen being transported in blood at a particular time.

The shape and size of red blood cells make them well suited to their function. Their small size allows them to fit inside tiny capillaries. When mature, red blood cells lack a nucleus, increasing space available to carry haemoglobin and hence oxygen. Their biconcave shape means that they have a large surface area for their size, which also assists in their important oxygen transporting role.

FIGURE 4.42 These red blood cells (erythrocytes) travel around the body up to 300 000 times (or for about 120 days). After this they literally wear out and die. Fortunately, each second, you are manufacturing about 1.7 million replacement red blood cells in your bone marrow.

EXTENSION: The effect of altitude on oxygen levels in blood

The amount of oxygen carried by haemoglobin varies with altitude. At sea level, about 100 per cent of haemoglobin combines with oxygen. At an altitude of 13 000 metres above sea level, however, only about 50–60 per cent of the haemoglobin combines with oxygen.

Fit to fight!

White blood cells contain a nucleus, and are larger and fewer in number than red blood cells. They are often referred to as the 'soldiers' in the blood as they are involved in fighting disease. Some white blood cells produce chemicals called antibodies; others engulf and 'eat' bacteria and other foreign matter. When you are ill or fighting an infection, the number of white blood cells in your blood increases for this reason.

Clot and cover ...

If you cut yourself, you bleed. This is because a blood vessel has been cut. **Platelets** in the blood help it to clot and plug the damaged blood vessel. This seal prevents germs getting in.

on Resources

Video eLesson Bleeding (eles-2535)

EXTENSION: Blood pigments

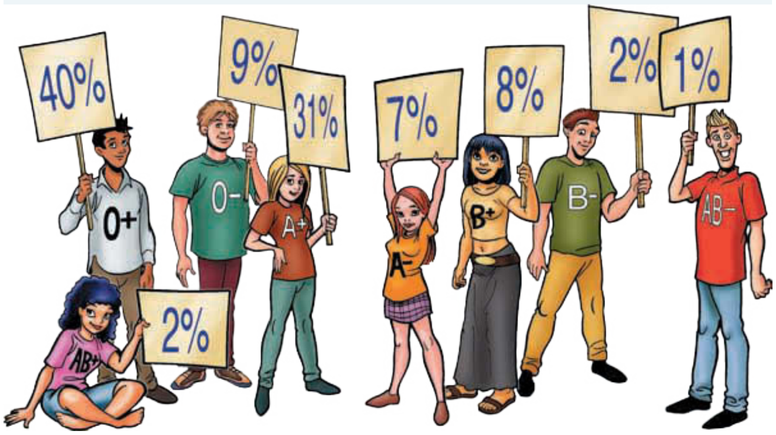
Insect blood looks a little like raw egg white, because it contains no pigment. The blood of crabs and crayfish, however, contains the pigment haemocyanin. This pigment has copper in it and is blue when combined with oxygen. This differs from haemoglobin in humans, which is red when combined with oxygen.

4.6.2 Mix and match?

How much do you know about the red stuff that flows throughout your body? Did you know that your blood might not mix too well with that of your friends? Blood can be grouped into eight types using the ABO system and the Rhesus (Rh) system. Your blood type is inherited from your parents.

These classification systems are based on whether particular chemicals (antigens) are present or absent on your red blood cells. If you are Rh-negative, you do not have the Rhesus factor on your red blood cells; if you do, you are Rh-positive.

FIGURE 4.43 How common is your blood?



The ABO system divides blood into groups A, B, AB and O. If you need a blood transfusion, it is very important to know your blood type and that of the donor because some blood types cannot be mixed. If the wrong types are mixed, the blood cells may clump together and cause fatal blockages in blood vessels.

4.6.3 Connected pathways

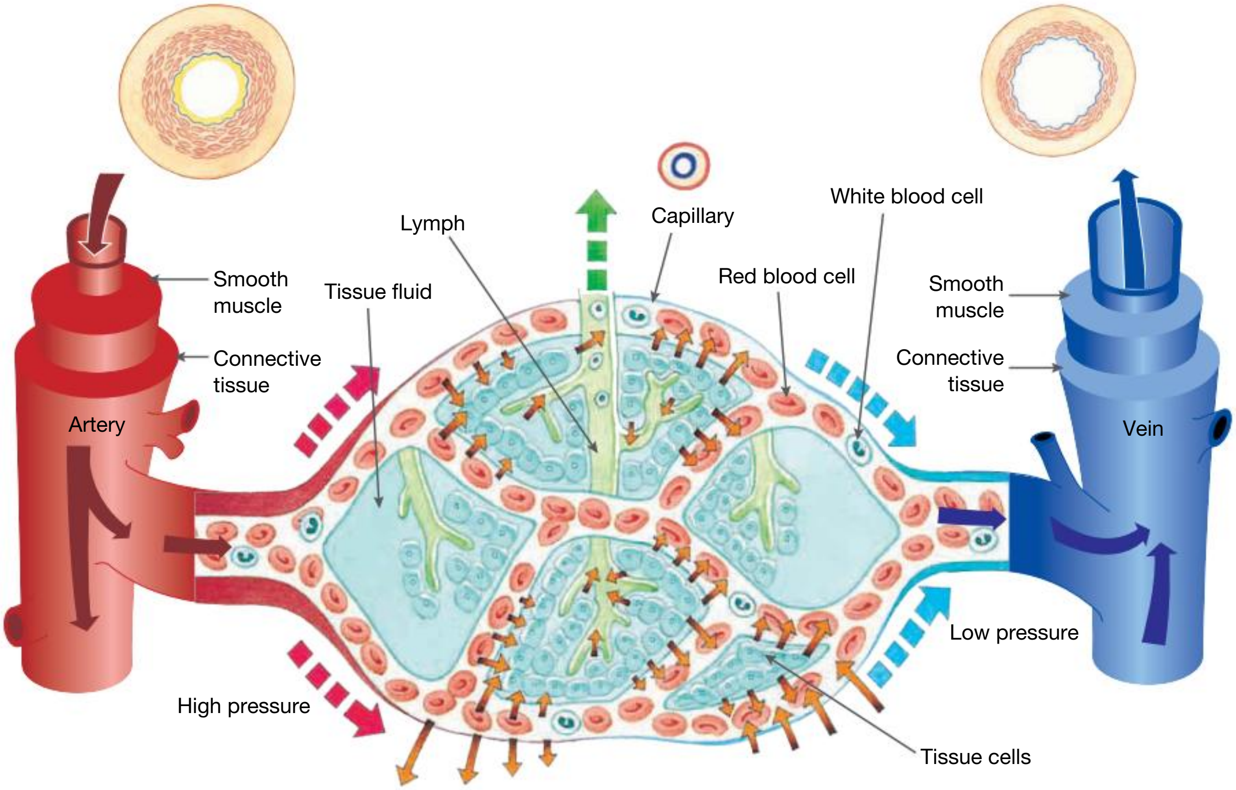
Your circulatory system is responsible for transporting oxygen and nutrients to your body's cells, and wastes such as carbon dioxide away from them. This involves interactions between blood cells, blood vessels and your heart.

white blood cells living cells that fight bacteria and viruses as part of the human body's immune system

platelets small bodies involved in blood clotting. They are responsible for healing by clumping together around a wound.

Blood vessels called arteries transport blood from your heart, whereas others, called veins, transport blood back to the heart. Materials are exchanged between blood and cells through tiny blood vessels called capillaries that are located between arteries and veins.

FIGURE 4.44 Your circulatory system consists of your heart, blood vessels and blood. Arteries, capillaries and veins are the major types of blood vessels through which your blood travels.



Arteries, veins and capillaries

Arteries have thick, elastic, muscular walls and carry blood under high pressure away from your heart. Veins have thinner walls and possess valves that prevent the blood from flowing backwards as they take blood to your heart.

FIGURE 4.45 The circulatory system

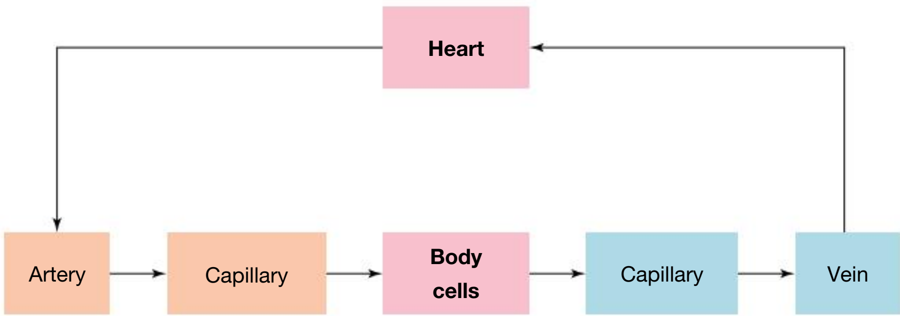


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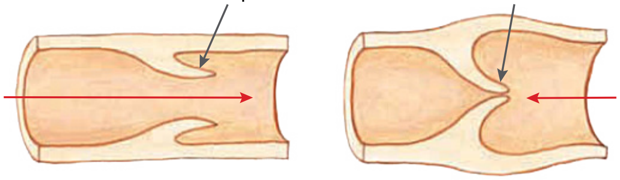
FIGURE 4.46 Veins have valves to ensure that blood flows in only one direction.



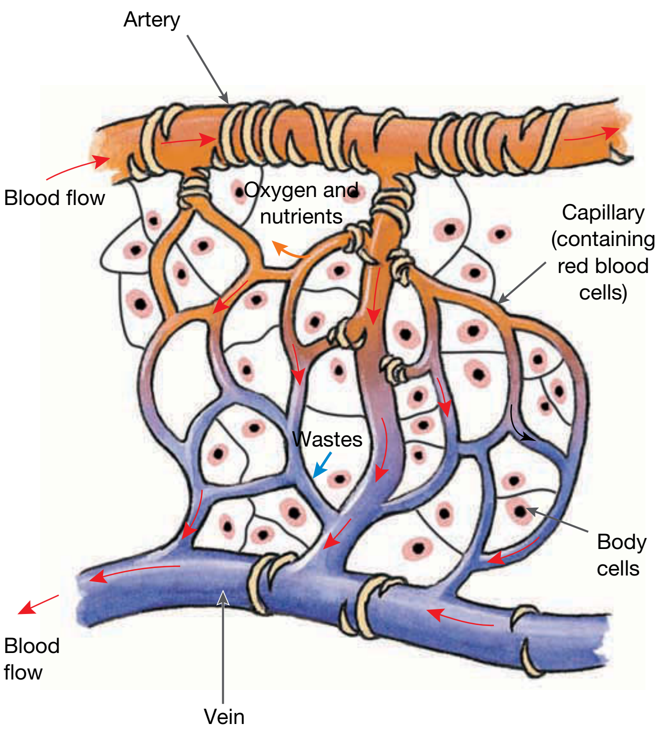
Capillaries are the most numerous and smallest blood vessels. Your body contains about 100 000 km of capillaries, which penetrate almost every tissue, so no cell is very far away from one. Capillaries are very important because they transport substances such as oxygen and nutrients to cells and remove wastes such as carbon dioxide.

CASE STUDY: Bruising

If you bump yourself but haven't cut your skin, a bruise may form. Bruises are caused by burst blood capillaries under your skin. The bruise changes from black to purple to yellow as the blood clears away.

FIGURE 4.47 As the blood clears away from a bruise the colour changes.

FIGURE 4.48 In the capillaries, oxygen diffuses out of the blood and waste produced by cells diffuses into the bloodstream.



4.6.4 Have a heart

Often linked with emotions, love and courage, the heart has a special meaning for most of us. In a clinical sense, however, it is merely a pump about the size of your clenched fist.

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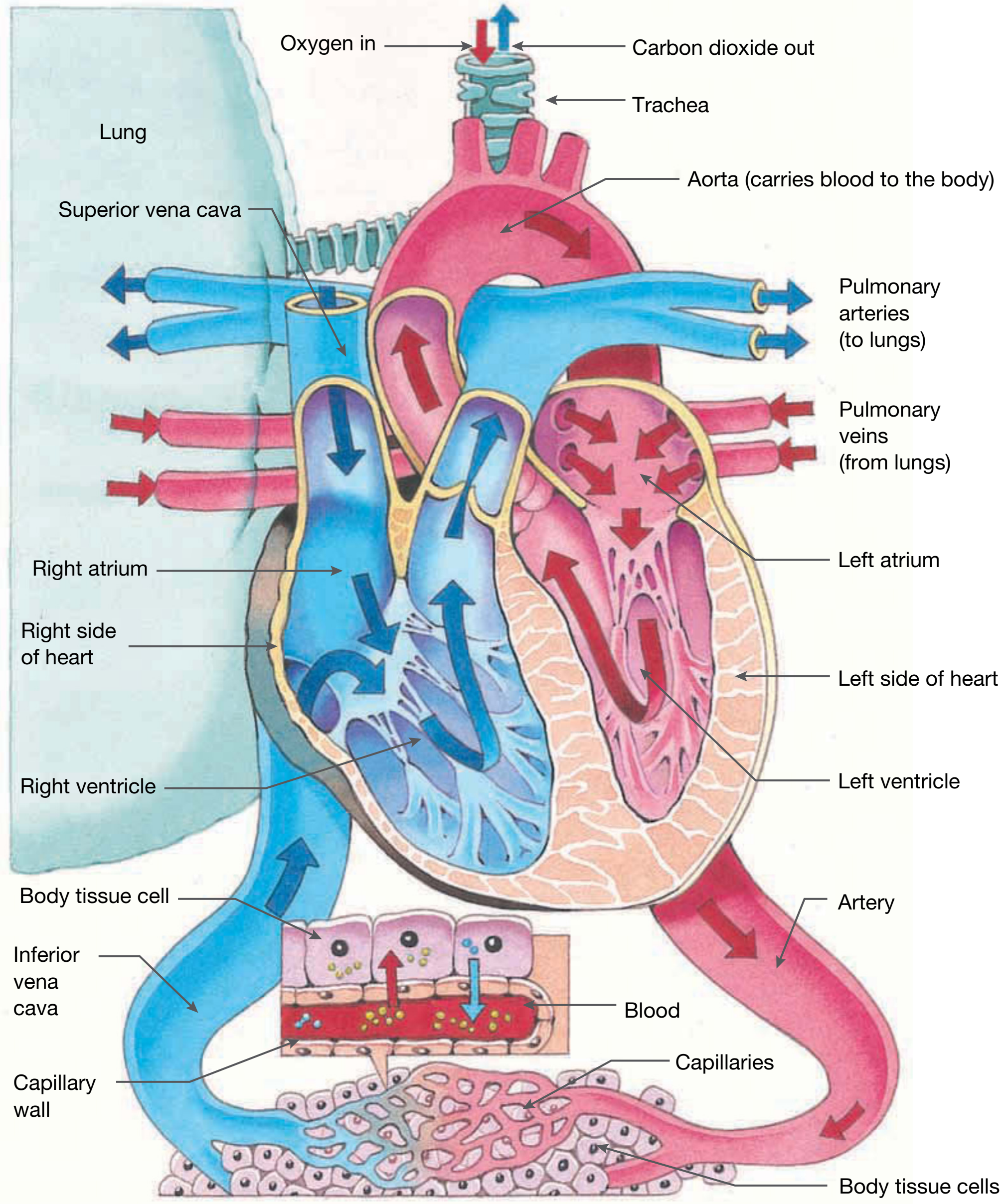
FIGURE 4.49 The movement of blood through the heart



Two pumps in one

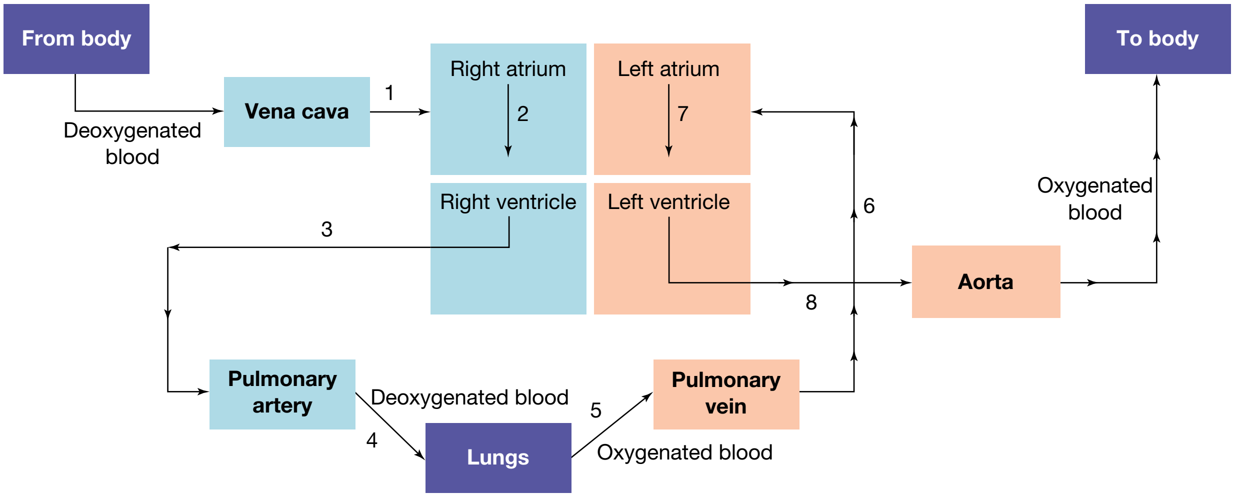
To be more precise, the human heart is actually *two* pumps. One side contains **oxygenated blood** and the other deoxygenated. Veins bring 'used' **deoxygenated blood** (stripped of oxygen and bluish in colour) from cells in your body back to your heart. All of these veins join up into a larger vein called the **vena cava**. Entering the top right chamber of your heart, blood is pumped into the bottom right chamber. It is then pumped out to your lungs where it picks up oxygen and becomes oxygenated and more reddish in colour. It also loses some of its carbon dioxide. The oxygenated blood then returns via a vein from your lungs to the left-hand side of your heart to be pumped out through arteries to your body tissues, where it delivers oxygen and nutrients. The deoxygenated blood then returns to the right-hand side of the heart for the cycle to be repeated.

oxygenated blood the bright red blood that has been supplied with oxygen in the lungs

deoxygenated blood blood from which some oxygen has been removed

vena cava large vein leading into the top right chamber of the heart

FIGURE 4.50 The heart is actually two pumps. One side pumps oxygenated blood and the other deoxygenated blood.

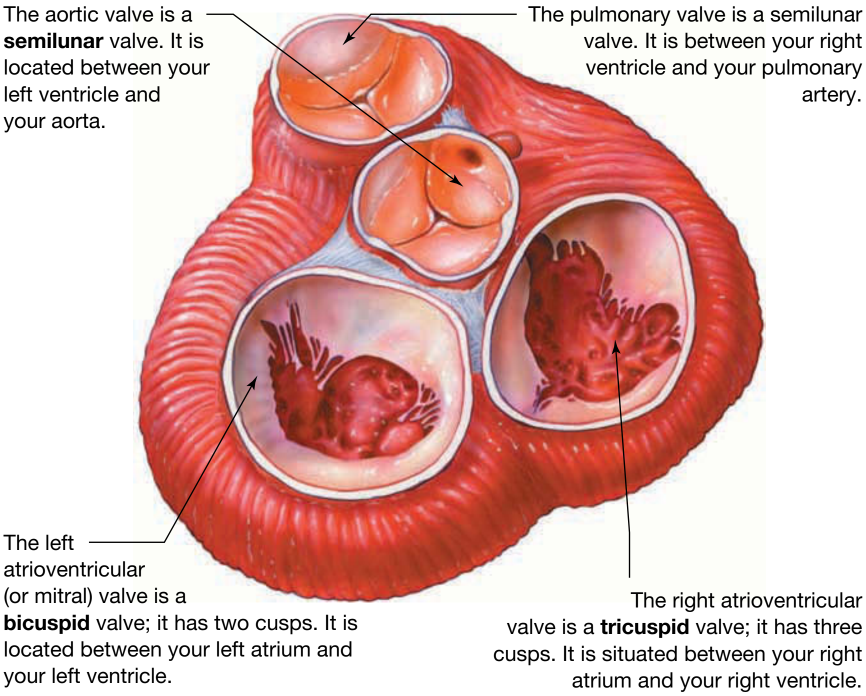


Four chambers

The human heart has four chambers. The upper two chambers are called the **left atrium** and **right atrium** (plural = atria), and the lower two chambers are the **left ventricle** and **right ventricle**. The two sides of the heart are different. The walls of the left side are thicker and more muscular because they need to have the power to force the blood from the heart to the rest of the body.

Flap-like structures attached to the heart walls, called **valves**, prevent the blood from flowing backwards and keep it going in one direction. If you listen to your heart beating, you will hear a **'lub dub'** sound. The 'lub' sound is due to the valves between the ventricles and atria shutting. The 'dub' sound is due to the closing of the valves that separate the heart from the big blood vessels that lead to the lungs and the rest of the body.

FIGURE 4.51 The valves of the heart



left atrium upper left section of the heart where oxygenated blood from the lungs enters the heart

right atrium upper right section of the heart where deoxygenated blood from the body enters

left ventricle lower left section of the heart, which pumps oxygenated blood to all parts of the body

right ventricle lower right section of the heart, which pumps deoxygenated blood to the lungs

valves flap-like folds in the lining of a blood vessel or other hollow organ that allow a liquid, such as blood, to flow in one direction only

'lub dub' the sound made by the heart valves as they close

4.6.5 Blood pressure

The heart's pumping action and the narrow size of the blood vessels result in a build-up of considerable pressure in the arteries. The force with which blood flows through the arteries is called **blood pressure**. It is affected by different activities and moods. It also goes up and down as the heart beats, being highest when the heart contracts (**systolic pressure**) and lowest when the heart relaxes (**diastolic pressure**). A person's blood pressure is expressed as a fraction. This fraction is the systolic pressure over the diastolic pressure, such as 120/70.

blood pressure measures how strongly the blood is pumped through the body's main arteries

systolic pressure the higher blood pressure reading during contraction of the heart muscles

diastolic pressure the lower blood pressure reading during relaxation of the heart muscles

heartbeat contraction of the heart muscle occurring about 60–100 times per minute

pulse alternating contraction and expansion of arteries due to the pumping of blood by the heart

pacemaker electronic device inserted in the chest to keep the heart beating regularly at the correct rate. It works by stimulating the heart with tiny electrical impulses.

cardiac muscle special kind of muscle in the heart that never tires. It is involved in pumping blood through the heart.

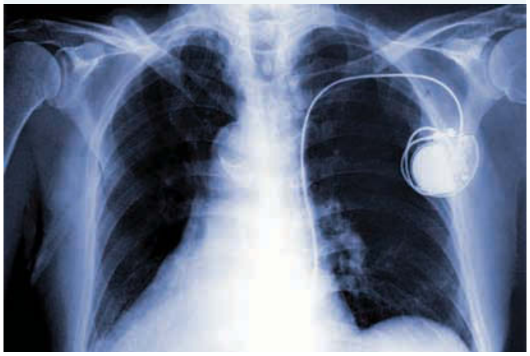
4.6.6 Keeping the pace

During each minute that you are sitting and reading this, about 5–7 litres of blood completes the entire circuit around your body and lungs. In a single day, your heart may beat about 100 000 times and pump about 7000 litres of blood around your body.

A normal human heart beats about 60–100 times a minute, this rate increasing during exercise or stress. With each **heartbeat**, a wave of pressure travels along the main arteries. If you put your finger on your skin just above the artery in your wrist, you can feel this **pulse** wave as a slight throb. Your pulse rate immediately after exercise can be used as a guide to your physical fitness. The fitter you are, the less elevated your heart rate will be after vigorous exercise.

The regular rhythmic beating of the heart is maintained by electrical impulses from the heart's **pacemaker**, which is located in the wall of the right atrium. Some people with irregular heartbeats are fitted with artificial, electronic pacemakers to regulate the heart's actions and correct abnormal patterns.

FIGURE 4.52 Person fitted with a pacemaker



Try clenching your fist every second for five minutes. Getting a little tired? The heart is made up of special muscle called **cardiac muscle**, which never tires. Imagine having a 'cramp' or 'stitch' in your heart after running to catch the bus! Owing to its unique electrical properties, heart muscle will continue to beat even if it is removed from the body. Scientists have shown that even tiny pieces of this muscle cut from the heart will continue to beat when they are placed in a test tube of warm salty solution.

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INVESTIGATION 4.5

Viewing blood cells

Aim

To observe blood cells under a light microscope

Materials

- prepared slide of blood smear
- microscope

Method

1. Place the prepared slide onto the microscope stage.
2. Use low power to focus, then carefully adjust to high power.
3. Find examples of red blood cells and white blood cells on the slide.

Results

1. Draw diagrams of representative red blood cells and white blood cells. On your diagram, include descriptive labels and the magnification used.
2. Estimate (a) how many red blood cells could fit inside a white blood cell and (b) how many of each cell type could fit across the field of view.

Discussion

1. Summarise the similarities and differences between the structures of red blood cells and white blood cells.
2. Suggest reasons for the differences.
3. Find out more about the structural differences between red blood cells and white blood cells.
4. Describe how the structure of each type of blood cell well suits it to its function.

Conclusion

Summarise your findings.

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INVESTIGATION 4.6

Heart dissection

Aim

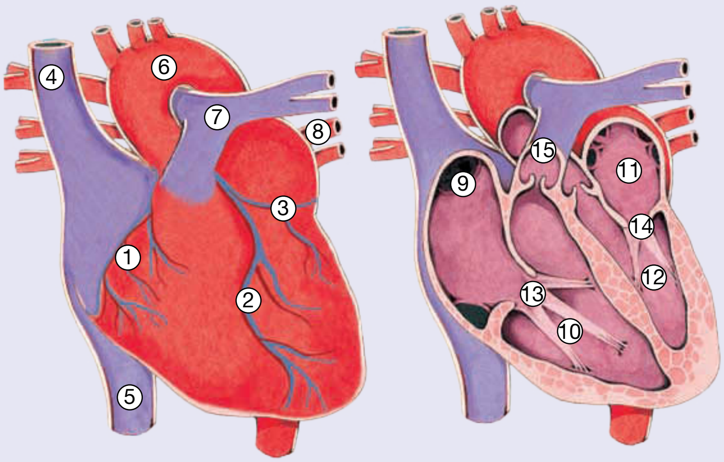
To observe the structure of a mammalian heart

Materials

- sheep's heart preferably with the blood
- vessels still attached
- dissecting instruments
- newspaper or paper to cover
- dissection board

Method

1. Place newspaper on the dissection board, then place the heart on top of the paper.
2. Use the diagram shown to identify the parts of the heart.
3. Try to locate where blood enters and leaves the heart:
   a. to and from the lungs
   b. to and from the rest of the body.
4. Cut the heart in two so that both halves show the two sides of the heart (similar to the illustration in figure 4.49).



1. Right coronary artery
2. Left anterior descending coronary artery
3. Circumflex coronary artery
4. Superior vena cava
5. Inferior vena cava
6. Aorta
7. Pulmonary artery
8. Pulmonary vein
9. Right atrium
10. Right ventricle
11. Left atrium
12. Left ventricle
13. Tricuspid valve
14. Mitral valve
15. Pulmonary valve

Results

1. Sketch and label the heart and use arrows to show the direction of blood flow.
2. In a diagram, record your observations of the thickness of the walls on the left side of the heart compared with the right side.
3. Suggest reasons for the differences observed.
4. Try to locate the valves in the heart.

Discussion

1. Describe the valves and suggest their function.
2. Write a summary paragraph about the structure and function of the heart.

Conclusion

Write a conclusion for this investigation.

on Resources

eWorkbook — Blood and blood highways (ewbk-4724)

assess on — Additional automatically marked question sets

4.6 Exercise

learn on

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 3, 4, 9, 10, 11, 16, 21	Questions 2, 5, 6, 12, 13, 15, 17, 22, 24	Questions 7, 8, 14, 18, 19, 20, 23, 25

Remember and understand

1. State whether the following statements are true or false. Justify any false responses.

Statement	True or false
a. The human heart is made up of three chambers.	
b. Valves in the heart prevent blood from flowing backwards and keep it going in one direction.	
c. The walls on the left side of the human heart are thicker and more muscular than those on the right.	
d. The ‘dub’ sound is due to the closing of the valves between the ventricles and atria shutting.	
e. Arteries take blood to and from the heart.	
f. The force with which blood flows through the arteries is called blood pressure.	
g. Systolic pressure results when the heart relaxes.	
h. You are considered to be Rh-negative if you have the Rh antigen in your red blood cells.	
i. The right side of the human heart pumps deoxygenated blood to the lungs.	

2. What am I? State another name for each of the following.
   a. Red blood cell
   b. Leucocyte
   c. Straw-coloured fluid in which blood cells float in
   d. A cell fragment involved in clotting of the blood
   e. The iron-containing pigment that gives red blood cells their colour
3. Match the circulatory system term with its description in the table shown.

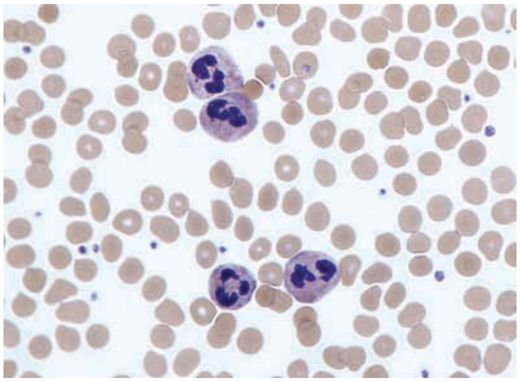
Term	Description
a. Artery	A. The bottom two chambers of the heart
b. Atria	B. Cell involved in transporting oxygen around the body
c. Capillary	C. Blood vessel that takes blood to the heart
d. Heart	D. Cell involved in protection against infection
e. Red blood cell	E. Blood vessel that takes blood away from the heart
f. Vein	F. The top two chambers of the heart
g. Ventricles	G. Organ that pumps blood around the body
h. White blood cell	H. Blood vessel that exchanges substances with cells

4. List the following in the order that a red blood cell would travel after leaving the aorta: pulmonary artery, left ventricle, right atrium, intestine, lung, pulmonary vein, left atrium, liver, right ventricle.
5. Outline what blood is and what blood does.
6. Name and describe the types of blood vessels in which blood travels around your body.
7. Describe the relationship between arteries, capillaries and veins.
8. a. Describe what is unusual about cardiac muscle.
   b. Describe what blood pressure is caused by.
   c. Explain why there are valves in the heart.
9. a. How many times does a normal human heart beat each minute?
   b. Suggest what may cause the heart rate to increase.
   c. Explain how the rhythmic beating of the heart is maintained.

Apply and analyse

10. Carefully examine figure 4.43. Which blood type is the most common? Which is the least common?
11. **SIS** Construct a bar graph to show the proportions of the different parts of blood.
12. The higher the altitude, the less oxygen there is in the air. Propose a reason people living at high altitudes usually have more red blood cells than people living at low altitudes.
13. Think of other ways that information about the components of blood could be organised visually. Organise the material in one of these ways.
14. a. Copy figure 4.44 into your workbook.
    b. Use red and blue coloured pencils to show the path taken for a red blood cell to travel from the vena cava to the aorta. Use a red coloured pencil to indicate oxygenated blood and a blue coloured pencil to show deoxygenated blood.
    c. In your diagram which two blood vessels transport:
       i. deoxygenated blood
       ii. oxygenated blood
    d. Use an 'X' to indicate which blood vessel you would expect to have the highest blood pressure.
15. Find out more about how blood circulates in insects and lobsters.
16. Find out what happens when people donate their blood at a blood bank. How often can you donate blood, how long does it take and how much blood do they take? Prepare a brochure, storyboard, PowerPoint presentation or cartoon to share your findings.

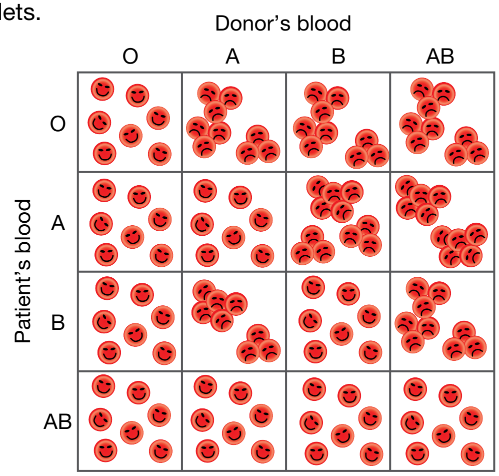
17. Observe the image of human blood cells.
    a. Identify which are white blood cells and which are red blood cells.
    b. Describe how you distinguished between the two types of blood cells.
    c. Which are in the greatest abundance? Suggest a reason for this.



18. What is the difference between:
    a. the blood in the two sides of the heart
    b. the structure of the two sides of the heart
    c. systolic and diastolic pressure?

Evaluate and create

19. Compare red blood cells, white blood cells and blood platelets.
20. Carefully examine the figure which shows which blood group combinations may be compatible for a blood transfusion.
    a. Which blood group(s), A, B, AB or O, can be accepted by:
        i. all blood groups
        ii. blood group AB
        iii. blood group A?
    b. Which blood group, A, B, AB or O, can receive transfusions from all blood types?



21. a. Use information in this subtopic and other resources to relate structural features to the functions of the following parts of the circulatory system.

TABLE Parts of the circulatory system and their functions

Part of system	Structural features	Function
Arteries		
Veins		
Capillaries		
Red blood cells		
White blood cells		

    b. Convert the information in the table above into a Venn diagram, target map or another visual thinking tool.
22. a. Some people have religious grounds for disagreeing with the use of blood transfusions. Imagine a four-year-old child with a life-threatening condition. Her parents will not allow her to have the blood transfusion that she needs. What should the doctors do? Discuss this with your team and report your decision to the class. If there are any differences of opinion, organise a class debate on the issue.
    b. Would your response be different if the child was 18 years old and wanted the blood transfusion, but her parents would not allow it?
23. A day after donating blood, a person finds that they have an infectious disease that can be transmitted by blood. What should they do? Discuss this with your team, giving reasons for your opinions.
24. With a partner, construct a PMI chart for a law that makes it compulsory for everyone over 16 to donate blood at least once a year.
25. Imagine that you have a friend who is anaemic. They are constantly tired and very pale.
    a. Using the internet and other resources, find out what you could do to help your friend improve their health.

b. Report back to your team, sharing your ideas and any other relevant information. Have your team summarise your ideas in a cluster map or mind map.
c. As a team, decide on a strategy for helping your anaemic friend.
d. Share your strategy with other teams as a mind map, flowchart, concept map or another visual tool.
e. Reflect on what you have learned during this activity. How might it influence your future behaviour or thinking? Could any of the strategies designed by the groups be used to solve any other problems? If so, which ones?

Fully worked solutions and sample responses are available in your digital formats.

4.7 Transport technology

LEARNING INTENTION

At the end of this subtopic you will be able to provide examples of how — due to discoveries made using new and improved technologies — our understanding of the circulatory system has changed over time.

Science as a human endeavour

4.7.1 Scientific theories can change over time

Our understanding of the circulatory system has been built by scientists and physicians throughout human history. With new observations and evidence, some theories have been discarded and others developed or modified. New technologies have enabled new observations to be made, which have resulted in new ways of thinking about the structure and functioning of the human body.

Claudius Galen (*c*.129–*c*.199 AD)

For over a thousand years, the key training books used for doctors were based on the ideas of the Greek physician Claudius Galen. Galen's ideas were based on his observations of dissections of animals (other than humans). Galen described the human heart as being made up of two chambers and also being the source of the body's heat. He believed that blood was made by the liver and travelled to the right chamber of the heart and that the left chamber made 'vital spirits' which were then transported by arteries to body organs. He was the first to use the pulse as a diagnostic aid.

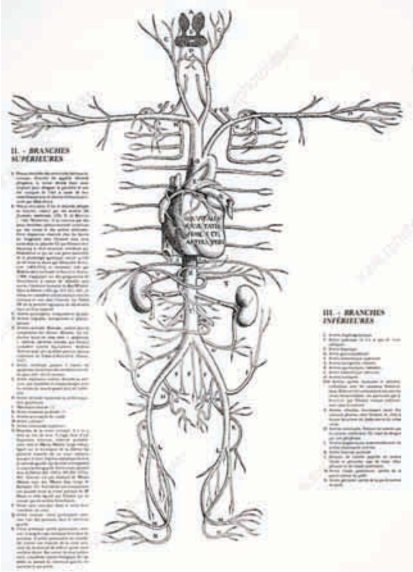
FIGURE 4.53 Claudius Galen (*c*.129–*c*.199 AD)

Andreas Vesalius (1514–1564)

Hundreds of years later another physician, Andreas Vesalius, began to transform medical knowledge — by questioning all previous theories. He believed that it was necessary to dissect bodies to find out how they worked. As the Church did not allow this, he took bones from graves and even stole a body from the gallows. His drawings showed the position and working of the muscles and organs in the body. Vesalius's observations proved that some of Galen's theories were wrong and he discovered anatomical structures previously unknown. His findings helped establish surgery as a separate medical profession.

FIGURE 4.54 Andreas Vesalius (1514–1564), Belgian anatomist, dissecting a cadaver. Vesalius was made professor of anatomy and surgery at Padua University, Italy, in 1537.

FIGURE 4.55 A sixteenth-century artwork showing the circulatory system, drawn by Andreas Vesalius



William Harvey (1578–1657)

Although Vesalius had assisted in revising the structure of the human heart, there was still confusion about its function. About 100 years later, William Harvey, an English physician, conducted a series of circulation experiments (figure 4.57) that showed the way valves in the veins control the flow of blood back to the heart. The publication of this work in *On the Motion of the Heart and Blood in Animals* (1628) published his work on blood circulation led to another change in how we think about the heart and our circulatory system.

FIGURE 4.56 English physician, William Harvey (1578–1657)

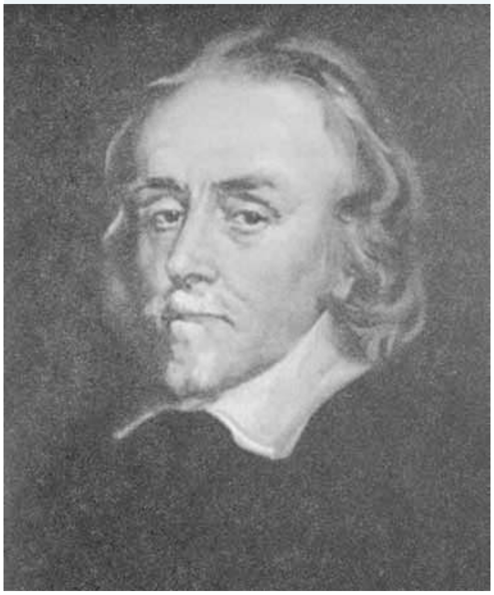
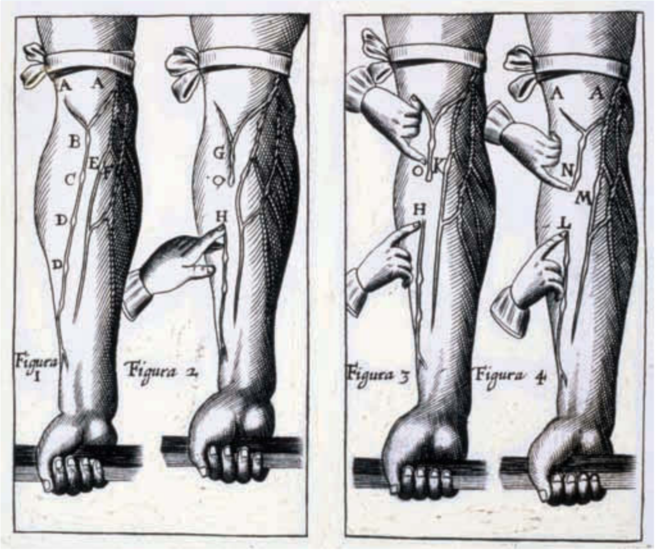


FIGURE 4.57 William Harvey's artwork of an arm with a tourniquet shows the way the valves in the veins control the flow of blood back to the heart.



4.7.2 Heart technology

Heart and blood vessel diseases are a key cause of death for many Australians. Medical research and new technologies strive to minimise the effects of diseases and disorders of the circulatory system.

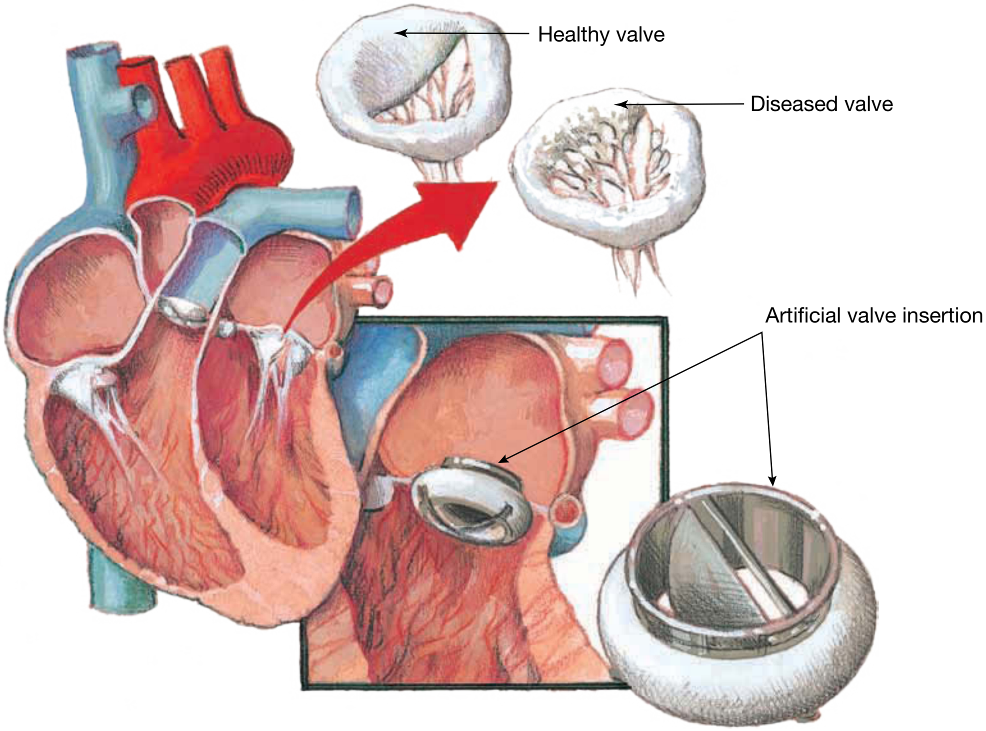
Faulty heart and vein valves

The heart, like many other pumps, depends on a series of valves to work properly. These valves open and close to receive and discharge blood to and from the chambers of the heart. They also stop the blood from flowing backwards. If any of the four heart valves becomes faulty, the function of the heart may be impaired.

Veins throughout the body may also contain valves that keep the blood flowing in one direction. Defective valves in leg veins can cause blood to drain backwards, and to pool in the veins closest to the skin surface. These veins can become swollen, twisted and painful, and are called **varicose veins**.

varicose veins expanded or knotted blood vessels close to the skin, usually in the legs. They are caused by weak valves that do not prevent blood from flowing backwards.

FIGURE 4.58 A faulty heart valve may be replaced by an artificial valve. Why are the heart valves so important to the functioning of the heart?



on Resources

Video eLesson Heart valve (eles-0858)

4.7.3 'If I only had a heart …'

The tin man from *The Wizard of Oz* would have been very happy with the development of an artificial heart. This mechanical device is made of titanium and plastic. Surgeons also implant a small electronic device in the abdominal wall to monitor and control the pumping speed of the heart. An external battery is strapped around the waist and can supply about 4–5 hours of power. An internal rechargeable battery is also implanted inside the wearer's abdomen. This is so they can be disconnected from the main battery for about 30–40 minutes for activities such as showering.

FIGURE 4.59 An artificial heart

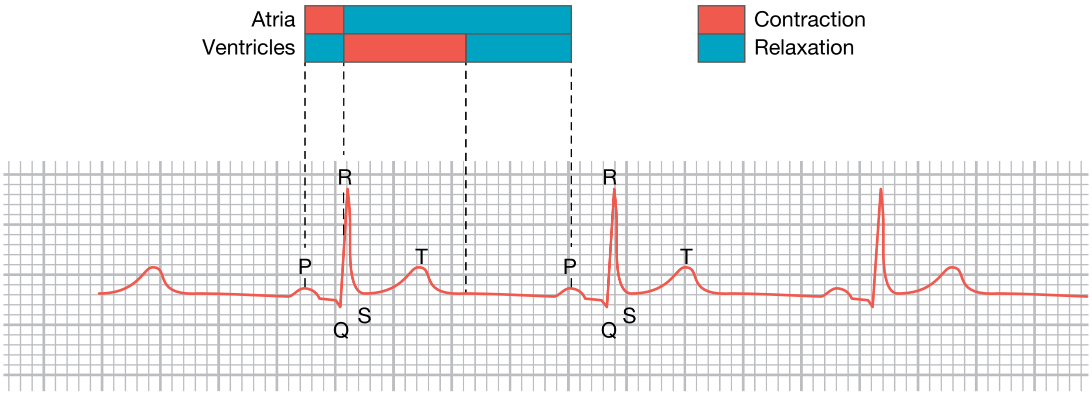
4.7.4 A heart — but no pulse?

If only the left ventricle is damaged, and the rest of the heart is in good working order, a backup pump may be implanted alongside the heart. One model of these devices results in its wearers having a gentle whirr rather than a pulse. This is the sound of the propeller spun by a magnetic field to force a continuous stream of blood into the aorta.

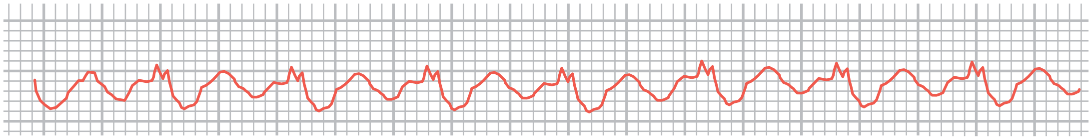
Getting the beat!

An **electrocardiogram (ECG)** shows the electrical activity of a person's heart. ECG patterns are valuable in diagnosing heart disease and abnormalities.

FIGURE 4.60 Electrocardiograms



(a) Normal electrocardiogram



(b) Abnormal electrocardiogram

on Resources

Video eLesson Beating heart with ECG (eles-2050)

4.7.5 Artificial blood

A current wave of interest in vampire movies and books has brought with it discussion about the merits of artificial blood sources. The interest in artificial blood, however, is not new; people have thought about its use in blood transfusions for hundreds of years. William Harvey's description in 1628 of how blood circulated through the body prompted a variety of unsuccessful investigations into the use of alternative fluid substitutes. Shortage of blood supplies during war and disease epidemics has fired up the quest for an artificial blood substitute. Currently, the two most promising red blood cell substitutes are haemoglobin-based oxygen carriers (HBOCs) and perfluorocarbon-based oxygen carriers (PFCs).

electrocardiogram (ECG) graph made using the tiny electrical impulses generated in the heart muscle, giving information about the health of the heart

PFCs are usually white, whereas HBOCs are a very dark red. Although PFCs are entirely synthetic, HBOCs are made from sterilised haemoglobin. The haemoglobin may be from human or cow blood, human placentas or bacteria that have been genetically engineered to produce haemoglobin. As the haemoglobin doesn't have a cell membrane to protect it, various techniques such as cross-linking and polymerisation are used to make it less fragile. Some scientists are even investigating the idea of wrapping it in an artificial membrane.

FIGURE 4.61 Human red blood cells are much larger than HBOCs and PFCs.

CASE STUDY: Transplant pioneer

If your heart or lungs were not working properly and you had needed a heart or lung transplant in the 1980s, the doctor to see was Victor Chang.

Victor Chang was an Australian doctor who was awarded a Companion of the Order of Australia for his contribution to medicine. Dr Chang played an important role in establishing the heart transplant unit at St Vincent's Hospital in Sydney. He set up a team of 40 health professionals who were the finest in their field and developed new procedures and techniques that led to an improved rate of success. Of his patients, 92 per cent were still alive one year after their heart or lung transplant operation and 85 per cent were still alive five years later.

FIGURE 4.62 The late Dr Victor Chang, pioneering heart transplant surgeon

The first heart transplant operation that Victor Chang carried out at St Vincent's Hospital was in 1984 on a young girl called Fiona Coote. Fiona is now an adult and, although she has since needed a second heart transplant, she owes her life to Dr Chang.

Dr Victor Chang also developed an artificial heart valve, called the St Vincent heart valve, and was working on developing an artificial heart. Unfortunately, his life was tragically cut short in 1991 when he was murdered by gunshot.

Artificial blood vessels?

Will the artificial blood vessels of the future be made by bacteria? Molecular biologist Helen Fink, working in Sweden, has suggested this may be the case. The cellulose produced by *Acetobacter xylinum* bacteria is strong enough to cope with blood pressure and function within our bodies, and could be used for artificial blood vessels in heart bypass operations in the future (figure 4.63).

FIGURE 4.63 In the future, will artificial blood vessels like this one be made by bacteria?

elog-0528

INVESTIGATION 4.7

Check your heart

Aim

To investigate the short-term effects of exercise on heart rate and blood pressure

Materials

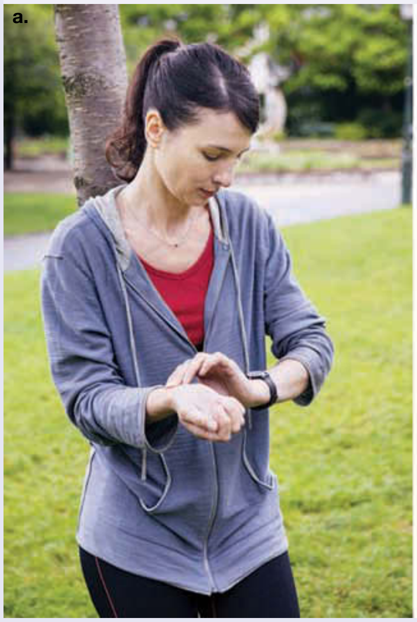
- stopwatch
- blood pressure monitor
- optional: data logging or digital measuring devices

Method

1. Find your pulse, either on the inside of your wrist or in your neck (see the illustrations). Make sure you use two fingers, not your thumb, to find your pulse.

Two places where your pulse should be easy to find: **a.** radial location (wrist) **b.** carotid location (neck)

a.



b.

2. Measure and record your heart rate in beats per minute (bpm) by counting the number of times your heart beats in 15 seconds and then multiplying this number by 4.
3. Measure and record your blood pressure using the blood pressure monitor.
4. Go for a walk in the playground or around the school oval. Measure and record your heart rate and blood pressure again.
5. Run up and down a flight of stairs. Measure and record your heart rate and blood pressure again.

Results

Record your answers in the table provided.

TABLE Heart rate and blood pressure at rest and during exercise

Test	Heart rate (bpm)	Blood pressure (mm Hg)
Before exercise		
After walking		
After running up stairs		

Discussion

1. What effect does exercise have on heart rate and blood pressure?
2. Identify strengths and limitations of this investigation and suggest improvements.
3. Design and carry out an experiment to test the following hypothesis: 'There is a link between a person's resting heart rate and the number of hours the person spends exercising each week'.

Conclusion

Write a conclusion for this investigation.

on Resources

assess on Additional automatically marked question sets

4.7 Exercise

learn on

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3, 7, 13	Questions 4, 5, 8, 10, 14	Questions 6, 9, 11, 12, 15, 16, 17

Remember and understand

1. State whether the following statements are true or false. Justify any false responses.

Statement	True or false
a. Over 1700 years ago, Andreas Vesalius described the human heart as being made up of two chambers and the source of the body's heat.	
b. Over 350 years ago, William Harvey published his findings on blood circulation, which contributed to our present-day understanding of the heart and the circulatory system.	

(continued)

(continued)

Statement	True or false
c. Over 30 years ago, Victor Chang developed an artificial heart.	
d. An electrocardiogram (ECG) shows the electrical activity of a person's heart.	
e. Defective valves in leg arteries can cause varicose veins.	

2. What are varicose veins and what causes them?
3. What is an electrocardiogram and when is it useful?
4. **a.** Explain why valves are important to the functioning of the heart.
   b. Outline how heart valves are similar to the valves in veins.
5. Describe how an electrocardiogram is used to detect heart abnormalities.

Apply and analyse

6. **SIS** Look at the electrocardiograms in figure 4.60.
   a. At 'P', are the muscle cells of the atria contracted or relaxed?
   b. After the 'QRS' wave, is the ventricle relaxed or contracted?
   c. How does the normal electrocardiogram differ from the abnormal electrocardiogram?
   d. Suggest what might be wrong with the heart activity shown on the abnormal electrocardiogram.
7. **SIS** Construct a matrix table to show the differences between red blood cells, HBOCs and PFCs.
8. **a.** Which organs are most successfully transplanted into humans?
   b. List sources of the organs for transplant and identify associated issues.
   c. Describe how donors and organ recipients are matched.
   d. Organ recipients can require specific treatment after the operation. Outline what this involves and why it is needed.
9. Dr Mary Kavurma and Dr Seana Gall are Tall Poppy Science Award winners. This award recognises young scientists who excel at research, leadership and communication. Dr Kavurma is a scientist at the University of New South Wales involved in research into atherosclerosis and cardiovascular disease. Dr Gall is based at the Menzies Research Institute, University of Tasmania, and her research field is cardiovascular epidemiology.
   a. Find out more about their research and that of other scientists in this field of science.
   b. Find out more about Australia's Tall Poppy Science Awards and other winners.

Evaluate and create

10. **SIS**
   a. Identify issues associated with organ transplantation.
   b. As a team, select one of these issues and find out why it is an issue.
   c. What is your opinion on the issue?
   d. Share your opinion and reasons for it with other members of your team.
   e. Construct a team PMI chart on the organ transplant issue.
11. **SIS**
   a. If you required a new heart, would you prefer an artificial one or one from a human or other natural source? Provide reasons for your response.
   b. Outline your opinion on being an organ donor yourself.
   c. Find out issues related to organ transplants and construct a PMI summary.
12. **SIS** There are a number of issues surrounding the development and use of artificial blood. Find out what these are and then construct a PMI chart as a summary. What is your opinion about artificial blood? Provide reasons for your opinion.
13. **SIS** Find articles in the media that advertise foods or drinks that can reduce heart disease. As a team, research the claims and summarise your findings in a SWOT diagram. As a class, be involved in a debate that includes members from different interest groups or with different perspectives or biases.
14. **SIS** Doctors use a stethoscope to listen to heartbeats. Make and test your own stethoscope using rubber tubing and a plastic funnel.
15. **SIS**
   a. Use the internet to identify problems relating to the circulatory system.
   b. Select one of these problems and construct a model or animation to demonstrate its effect on normal body function.

16. SIS In your team, design and perform an experiment to investigate the effect of different types of activities on your heart rate.
17. Find out more about Galen, Vesalius and Harvey and their work and discoveries. Suggest how they were influenced by the times in which they lived. Why didn't they just accept the ideas of their times? Why did they ask questions? Propose a question or hypothesis that you may have asked if you lived in each of their times.

Fully worked solutions and sample responses are available in your digital formats.

4.8 Respiratory system — breathe in, breathe out

LEARNING INTENTION

At the end of this subtopic you will be able to describe the structure and function of the respiratory system.

4.8.1 Cells need energy!

Breathe in deeply … now breathe out. You have exchanged gases with your environment. You have supplied your body with some essential oxygen and removed some unwanted carbon dioxide. You do this about 15–20 times a minute without even having to think about it. Where does this oxygen go and where did the carbon dioxide come from?

Your cells need **oxygen** as it is essential for cellular respiration. This process involves breaking down **glucose** so that energy is released in a form that your cells can use. This reaction produces **carbon dioxide** as a waste product that needs to be removed.

Cellular respiration

glucose + oxygen → carbon dioxide + water + energy

on Resources

Video eLesson The human bronchiole (eles-2044)

Respiratory system

The main role of your respiratory system is to get oxygen into your body and carbon dioxide out. This occurs when you inhale (breathe in) and exhale (breathe out). The respiratory system is made up of your **trachea** (or windpipe) and your **lungs**.

EXTENSION: Epiglottis

Wrong way, turn back! There is a flap of tissue at the top of the trachea called the **epiglottis**. This tissue's job is to stop food 'going down the wrong way'. If food does go the wrong way, a cough moves the food back up, to either be removed or travel its correct pathway — down your oesophagus to your stomach.

oxygen atom that forms molecules (O_2) of tasteless and colourless gas; it is essential for cellular respiration for most organisms and is a product of photosynthesis

glucose a six-carbon sugar (monosaccharide) that acts as a primary energy supply for many organisms

carbon dioxide a colourless gas in which molecules (CO_2) are made up of one carbon and two oxygen atoms; essential for photosynthesis and a waste product cellular respiration. The burning of fossil fuels also releases carbon dioxide.

trachea narrow tube from the mouth to the lungs through which air moves

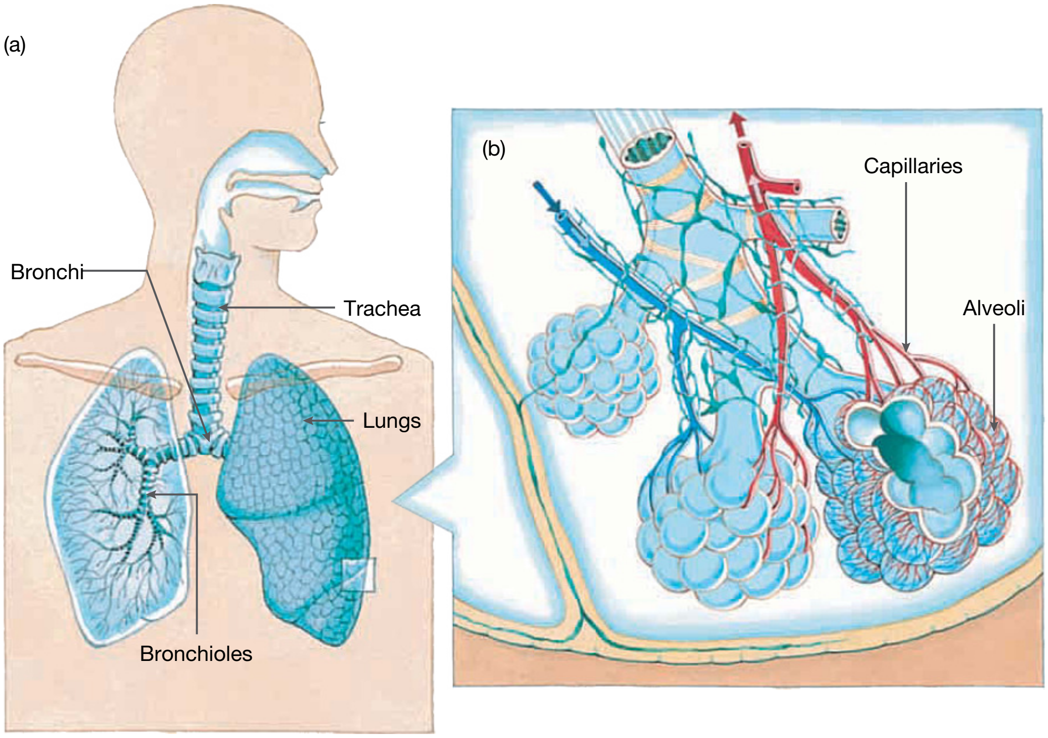
lungs the organ for breathing air. Gas exchange occurs in the lungs.

epiglottis leaf-like flap of cartilage behind the tongue that closes the air passage during swallowing

ewbk-7082

int-8233

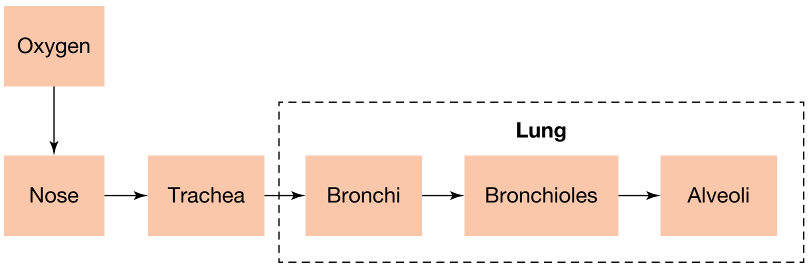
FIGURE 4.64 a. Organs of the respiratory system with **b.** a portion of the lung expanded to show details



Getting oxygen to your lungs

When you breathe in, air moves down your trachea, then down into one of two narrower tubes called **bronchi** (bronchus). After that, the air moves into smaller branching tubes called **bronchioles**, which end in tiny air sacs called **alveoli** (alveolus). It is at the alveoli that gases (such as oxygen and carbon dioxide) are exchanged between the respiratory system and the circulatory system.

FIGURE 4.65 The pathway oxygen travels to your lungs when you inhale



bronchi the narrow tubes through which air passes from the trachea to the smaller bronchioles and alveoli in the respiratory system. Singular = bronchus.

bronchioles small branching tubes in the lungs leading from the two larger bronchi to the alveoli

alveoli tiny air sacs in the lungs at the ends of the narrowest tubes. Oxygen moves from alveoli into the surrounding blood vessels, in exchange for carbon dioxide. Singular = alveolus.

4.8.2 Working together to get oxygen from lungs to cells

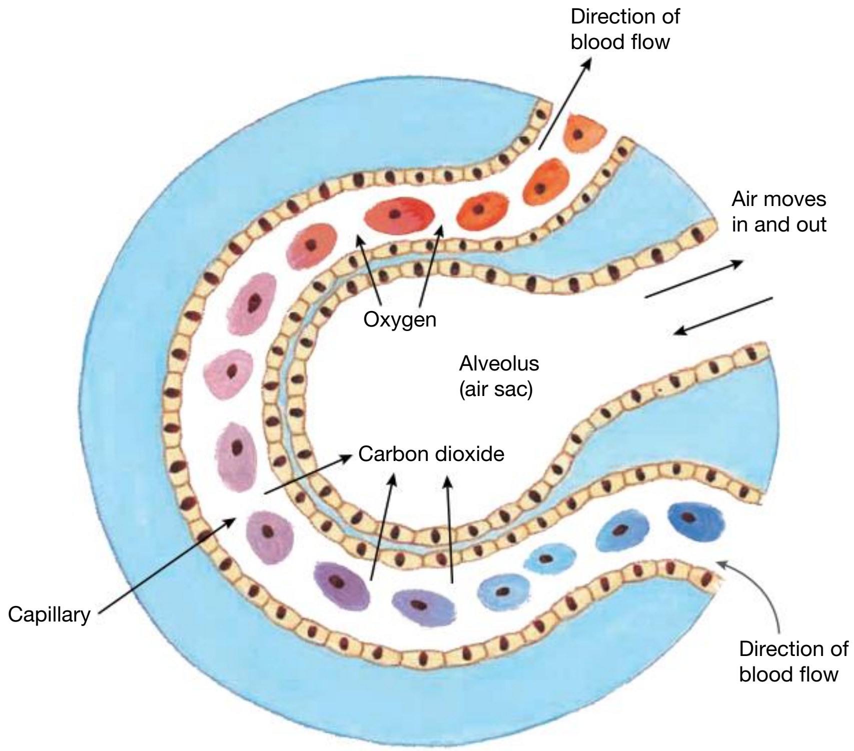
Your circulatory and respiratory systems work together to get oxygen to your cells. Once you have breathed in and oxygen has reached your alveoli, oxygen diffuses into red blood cells in capillaries that surround the alveoli.

The oxygen diffuses into the red blood cells because there is a higher concentration of oxygen inside the alveoli than inside the blood cells. Once inside the red blood cells, oxygen binds to haemoglobin to form oxyhaemoglobin. It is in this form that oxygen travels throughout your body. The blood that it travels in is referred to as oxygenated blood.

FIGURE 4.66 The pathway oxygen travels from your lungs to your body cells

Oxygenated blood
↓
Pulmonary vein → Left artrium of heart → Left ventricle of heart → Aorta → Arterioles → Capillary → Body cell

FIGURE 4.67 In an alveolus, oxygen diffuses into the blood and carbon dioxide diffuses out of the blood.



The oxygenated blood travels from your lungs via the **pulmonary vein** to the left atrium of your heart. From here, it travels to the left ventricle where it is pumped under high pressure to your body through a large artery called the **aorta**. The oxygenated blood is then transported to smaller vessels (**arterioles**) and finally to capillaries through which it diffuses into body cells for use in cellular respiration.

pulmonary vein the vessel through which oxygenated blood travels from your lungs to the heart

aorta a large artery through which oxygenated blood is pumped at high pressure from the left ventricle of the heart to the body

arterioles vessels that transport oxygenated blood from the arteries to the capillaries

CASE STUDY: Garlic breath

Phew … garlic breath! Have you ever heard someone say this? Garlic or onion breath comes from further down than your mouth! It has travelled through a number of your body systems. After you have eaten food containing either of these, and it has been digested, it is absorbed through the walls of your intestines and then into your blood. When the smelly onion or garlic blood reaches your lungs through your circulatory system, you breathe out the smelly gas.

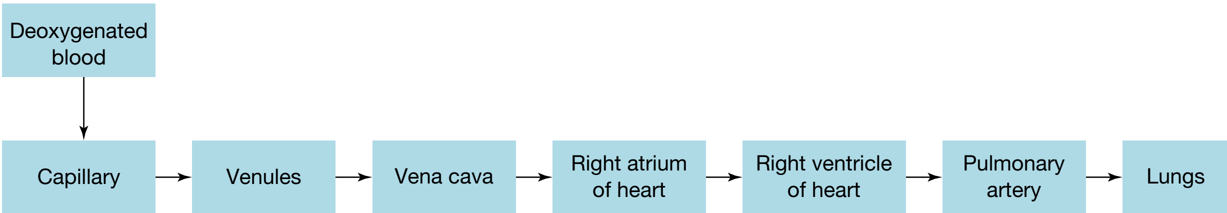
4.8.3 Working together to get carbon dioxide from cells

Carbon dioxide is a waste product of cellular respiration and needs to be removed from the cell. When carbon dioxide has diffused out of the cell into the capillary, the blood in the capillary is referred to as deoxygenated blood. This waste-carrying blood is transported from the capillaries to small veins (**venules**) to large veins called vena cava, then to the right atrium of your heart. From here it travels to the right ventricle where it is pumped to your lungs through the **pulmonary artery** (the only artery that does not contain oxygenated blood). This process is shown in figure 4.66.

venules small veins

pulmonary artery the vessel through which deoxygenated blood, carrying wastes from respiration, travels from the heart to the lungs

FIGURE 4.68 The pathway carbon dioxide travels from your body cells to your lungs



Exhaling carbon dioxide from lungs

Once the deoxygenated blood reaches the alveoli of the lungs, carbon dioxide diffuses out of the capillaries. This occurs because there is a higher concentration of carbon dioxide inside the capillaries than in the alveoli. Carbon dioxide is then transported into the bronchiole, then bronchi and trachea, until it finally exits through your nose (or mouth) when you exhale.

FIGURE 4.69 The pathway carbon dioxide travels from your lungs to be exhaled

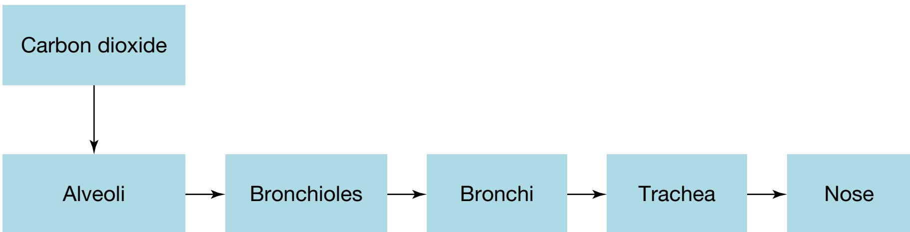
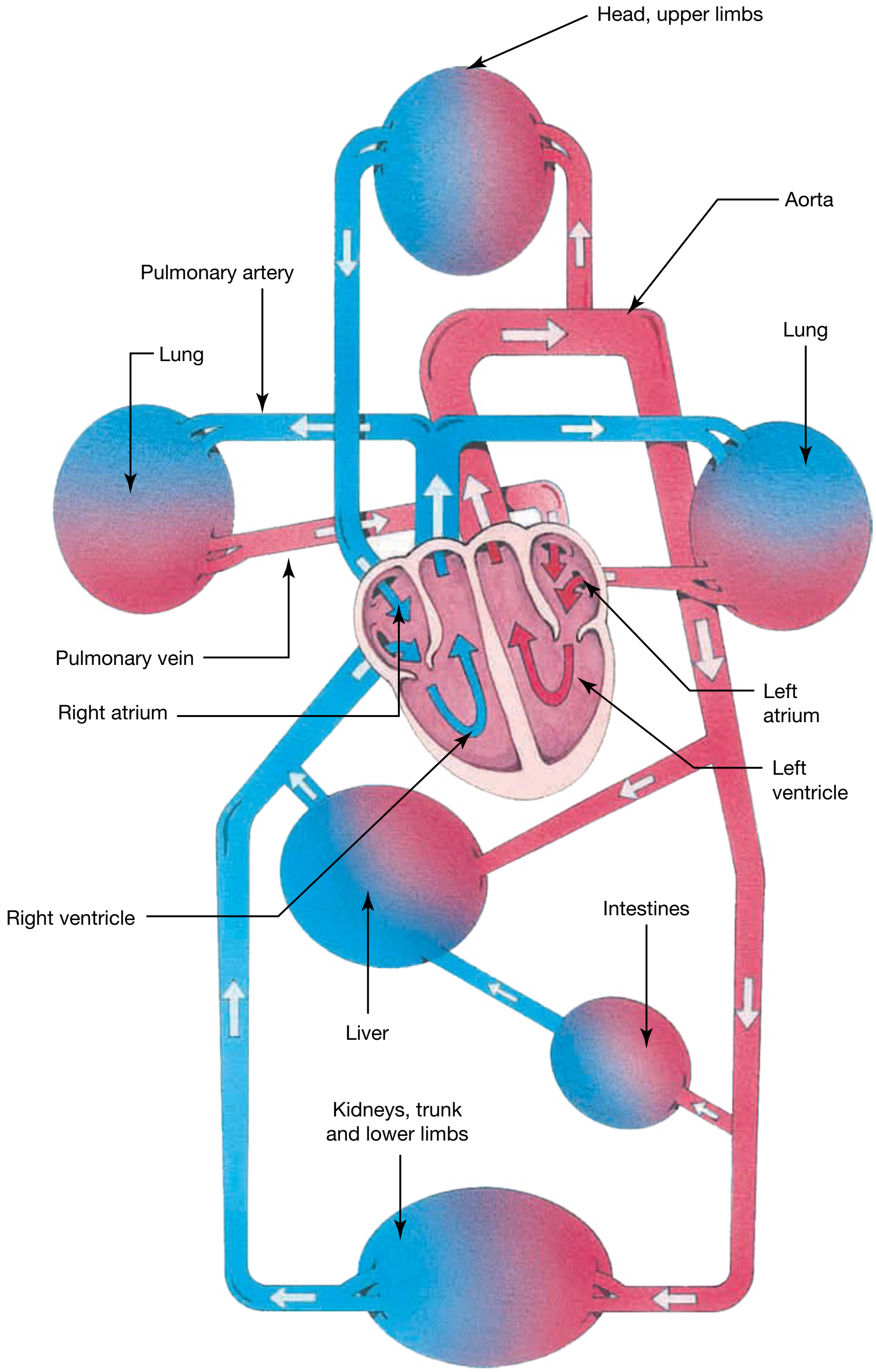


FIGURE 4.70 Your respiratory and circulatory systems form connected highways that provide your cells with what they need and remove what they don't.



4.8.4 Brain AND muscle?

The respiratory system also relies on organs from other systems. When you breathe in, a muscle beneath your rib cage called the **diaphragm** tightens. This allows the lungs to expand and air to be pulled into them. When you breathe out, the diaphragm relaxes, which reduces the size of the lungs and pushes air out. The largest volume of air that you can breathe in or out at one time is called your **vital capacity**.

diaphragm flexible, dome-shaped, muscular layer separating the chest and the abdomen. It is involved in breathing.

vital capacity the largest volume of air that can be breathed in or out at one time

Breathing involves muscle movements that are automatic and controlled by the respiratory centre in the brain.

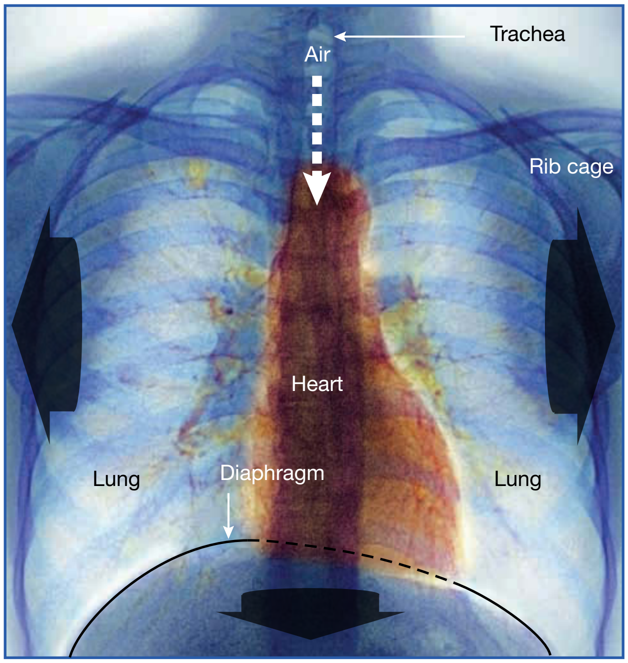
breathing movement of muscles in the chest causing air to enter the lungs and the altered air in the lungs to leave. The air entering the lungs contains more oxygen and less carbon dioxide than the air leaving the lungs.

on Resources

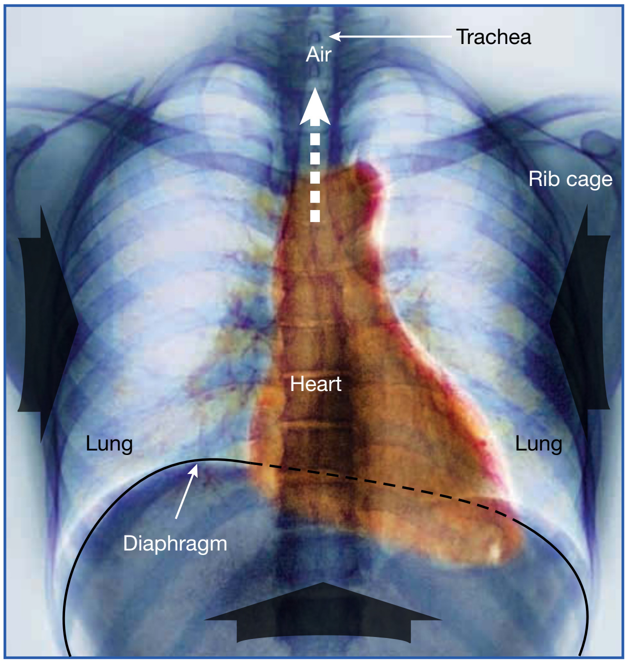
Video eLesson The action of the diaphragm and lungs (eles-2045)

FIGURE 4.71 When you breathe in, your diaphragm tightens; when you breathe out, it relaxes.

(a) Breathing in



(b) Breathing out



elog-0529

INVESTIGATION 4.8

Hands on pluck

Aim

To investigate the trachea, lungs, heart and liver of a mammal

Materials

- sheep's pluck (heart and lungs) with part of the liver and trachea attached
- newspaper and tray to place the pluck on
- plastic disposable gloves
- balloon pump and rubber tubing

Method

1. Carefully observe and record the shape, size, colour and texture of the sheep's trachea, lungs, heart and liver. Include notes on how they are connected. Can you see any blood vessels?
2. Push a piece of rubber tubing down the trachea to the lungs and use a balloon pump to blow some air into the trachea.

CAUTION

For hygiene reasons, do not use your mouth to blow into the tube inserted in the trachea.

3. Cut through the lung, heart and liver tissue. Make a record of your observations describing how they are similar and how they are different. Discuss possible reasons for the differences with your team members.
4. Using a scalpel or scissors, cut off a small piece of heart, lung and liver. Place each piece into a beaker of water and observe what happens. Discuss possible reasons for your observations with your team members.

Results

Record observations in the table provided.

TABLE Observations of dissection of a mammal's pluck

Organ	Shape (sketch)	Approx. size (cm)	Colour	Texture	Other comments	System to which the organ belongs
Trachea						
Lung						
Heart						
Liver						

Discussion

1. Could you see any blood vessels? Try to find out their names and what sort of blood they carry.
2. Suggest why there are rings of cartilage around the trachea.
3. Suggest reasons for the differences in texture between the heart and lungs.
4. Suggest reasons for the differences in the shapes of the organs that you observed.
5. Comment on something that you learned or found particularly interesting from this investigation. Share your comment with others.
6. Research and report on the following points for each of the organs in this investigation:
   - its function and how it carries this out
   - the system to which it belongs
   - a disease relevant to it.

Conclusion

Write a conclusion for this investigation.

elog-0530

INVESTIGATION 4.9

Measuring your vital capacity

Aim

To investigate the vital capacity of lungs

Materials

- balloon
- ruler

Method

1. Blow up a balloon to about 20 cm in diameter two or three times to stretch it. Release the air each time.
2. Take the biggest breath you can, then blow out all the air into the balloon. Tie up the end of the balloon to hold in your 'blown out' air.
3. Use a ruler to measure and record the diameter of the balloon as shown on the opposite page.
4. Use the table below to determine your approximate vital capacity in litres.
5. Release the air from the balloon and repeat your measurement of vital capacity three more times. Average your results to get your best estimate of the maximum 'blow-out' of your lungs.

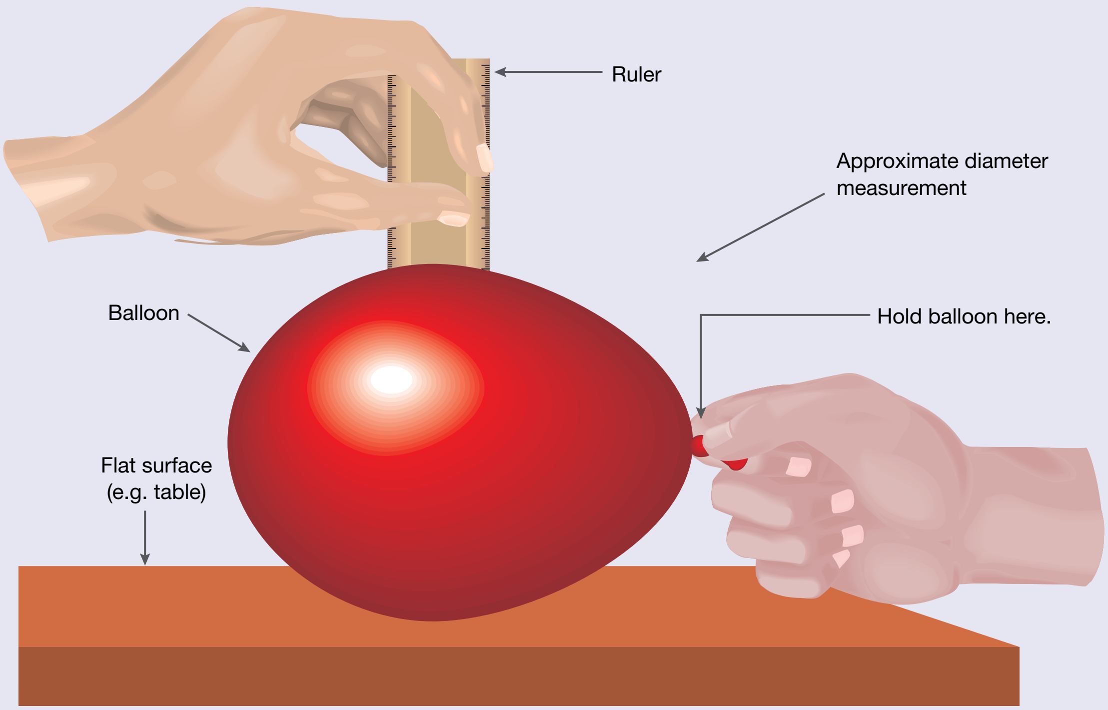


TABLE How to measure the diameter of the balloon

Balloon diameter (cm)	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Approx. vital capacity (litres)	0.3	0.4	0.5	0.7	0.9	1.2	1.4	1.8	2.1	2.6	3.0	3.6	4.2	4.8

Results

1. Draw a table with the following headings.

TABLE Vital capacity results

Name	Male or female?	Does this student play a wind instrument?	Lung capacity (L)

2. Collect results from all the students in your class and complete the table.
3. Calculate the average lung capacity for all the females and for all of the males in your class.
4. Calculate the average lung capacity for all students in your class who play a wind instrument.

Discussion

1. Suggest why you were asked to stretch the balloon first.
2. Suggest why you measured your vital capacity four times.
3. With reference to your results, do females have a bigger or smaller lung capacity than males in your class?
4. Compare the average lung capacity for students who play a wind instrument with the average value for students who do not. Do your results suggest that playing a wind instrument has an effect on lung capacity? Explain.
5. Reflect on the method used to investigate vital capacity and identify improvements that could be made if you were to do the investigation again.

Conclusion

Summarise your findings, and write a conclusion for this investigation.

on Resources

eWorkbook Breathing — constructing a report (ewbk-4726)

assess on Additional automatically marked question sets

4.8 Exercise

learn on

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 4, 5, 9, 12	Questions 2, 6, 8, 10, 13	Questions 3, 7, 11, 14

Remember and understand

1. State whether the following statements are true or false. Justify any false responses.

Statement	True or false
a. Body cells need oxygen for the process of cellular respiration.	
b. The process of cellular respiration produces energy in a form that the cell can use and oxygen is a waste product.	
c. The role of the respiratory system is to get carbon dioxide into your body and oxygen out.	
d. The respiratory system is made up of your oesophagus and your lungs.	
e. Oxygen diffuses from the alveoli into red blood cells in capillaries that surround them.	

2. Match the terms associated with the respiratory system with their description in the table provided.

Term	Description
a. Alveoli	A. Blood vessel that carries deoxygenated blood from the heart to the lungs
b. Bronchiole	B. One of two narrower tubes that leads off the trachea
c. Bronchus	C. A muscle that allows the lungs to expand so that air can be pulled in
d. Diaphragm	D. A red pigment that binds to oxygen
e. Haemoglobin	E. Blood vessel that carries oxygenated blood from the lungs to the heart
f. Pulmonary artery	F. Tube through which air moves from your mouth to your lungs
g. Pulmonary vein	G. Tiny air sac through which oxygen diffuses into capillaries
h. Trachea	H. Small branching tube with alveoli at its end

3. Use flowcharts to identify the pathway that:
   a. oxygen travels to get from the air outside your body to the alveoli of your lungs
   b. oxygen travels to get from your lungs to your body cells
   c. carbon dioxide travels to get from your body cells to the alveoli of your lungs
   d. carbon dioxide travels to get from your lungs to the air outside your body.
4. Describe how oxygen gets from the alveoli of your lungs into blood cells in your capillaries.
5. Differentiate between the terms ‘cellular respiration’, ‘respiratory system’ and ‘breathing’.

Apply and analyse

6. Some people describe the structure of the lungs as an upside-down hollowed-out tree. To which parts of the lungs might the following be referring?
   a. Trunk
   b. Branches
   c. Twigs
   d. Leaves
7. Give reasons for the following pieces of advice.
   a. It is better to breathe through your nose than your mouth.
   b. You should blow your nose when you have a cold rather than sniff it back.
   c. You should not talk while you are eating or drinking.
8. SIS This table shows approximate percentages of various gases breathed in and breathed out.

TABLE Composition of air inhaled and exhaled

Gas	Oxygen (%)	Carbon dioxide (%)	Water vapour (%)	Nitrogen (%)
Air breathed in	21	0.04	1	78
Air breathed out	15	4	5	76

   a. i. Compare the percentage of oxygen breathed in to that breathed out.
      ii. Suggest a reason for this pattern.
   b. i. Compare the percentage of carbon dioxide breathed in to that breathed out.
      ii. Suggest a reason for this pattern.
   c. The percentages in the table can vary in different weather conditions and at different heights above sea level. Research these variations and the possible implications this may have on humans.
9. Find out what a spirometer is.
10. Some singers can hold a musical note for a very long time. Investigate what muscles and techniques they use to be able to do this.
11. Did you know that mountain climbers often find it difficult to breathe? Some wear oxygen tanks to allow them to climb very high mountains. Research the effects of high altitude on breathing and report your findings.

Evaluate and create

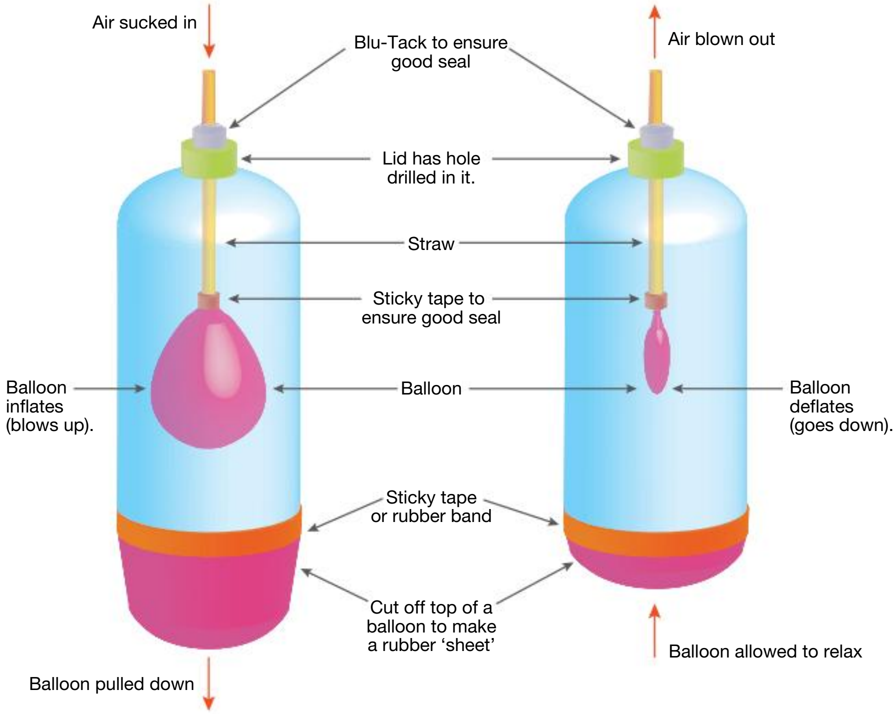
12. Use information in this subtopic and other resources to relate structural features to the functions of the following parts of the respiratory system.

TABLE Parts of the respiratory system and their functions

Part of system	Structural features	Function
Trachea		
Alveoli		
Lungs		
Capillaries		

13. **SIS** Carefully observe the model lung shown.

A model lung. When the rubber sheet at the bottom is pulled down, the pressure inside the jar drops and air is sucked into the balloon. The balloon inflates (blows up).



a. Identify which body parts are represented in the model lung by the:
   i. straw
   ii. rubber sheet at the bottom of the bottle
   iii. balloon connected to the straw
   iv. plastic bottle.

b. Pull the rubber sheet at the bottom of your model downwards. Record your observations. Release the rubber sheet. Record your observations. Discuss how your observations relate to how a lung works. Suggest how the model could be improved.

14. **SIS** Construct a model lung as shown in the diagram. You can use the following items:
- two clear 1-litre plastic bottles with tops
- four balloons
- two plastic drinking straws
- rubber bands or very sticky tape
- plasticine or Blu-Tack
- scissors.

Fully worked solutions and sample responses are available in your digital formats.

4.9 Short of breath?

LEARNING INTENTION

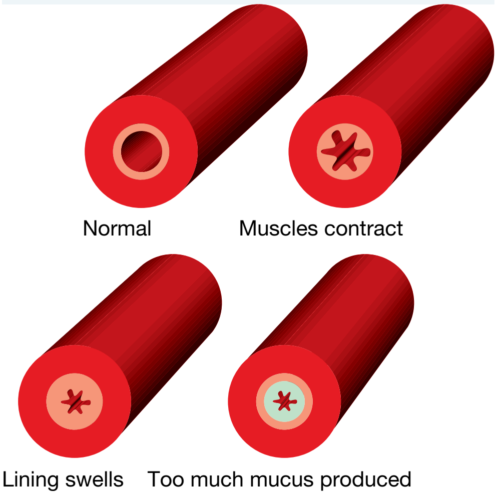
At the end of this subtopic you will be able to describe examples of illnesses and problems associated with the respiratory system.

4.9.1 Asthma

int-5351

If you do not suffer from **asthma**, it is very likely that you know someone who does. Asthma is a very common condition and the number of people who suffer from it has increased over the years.

FIGURE 4.72 Asthma is a narrowing of the air pipes.



What is asthma?

Asthma is a narrowing of the air pipes that join the mouth and nose to the lungs. The pipes most affected are the bronchi. They become narrower as:

- the muscle wall of the air pipes contracts
- the lining of the air pipes swells
- too much mucus is produced.

The narrow pipes make breathing difficult and can result in wheezing, coughing and a tight feeling in the chest. The coughing is usually worse at night.

What causes asthma?

It is not known why some people get asthma and others do not. It seems that it can be inherited, but many people from families without a history of asthma are affected. Asthma is certainly the result of sensitive airways. An asthma attack occurs when those sensitive airways are 'triggered'. If the sufferer has a cold, the airways are already inflamed and are more likely to be triggered.

Some of the common triggers of an asthma attack are:

- vigorous exercise
- cold weather
- cigarette smoke
- dust and dust mites
- moulds
- pollen
- air pollution
- some foods and food additives
- some animals.

Not all asthma sufferers are affected by the same triggers. Some people suffer attacks only as a result of exercise. Others might be affected by any one or more of the triggers. It is important that those who get asthma try to find out what triggers the attacks. Many of the triggers can be avoided.

asthma narrowing of the air pipes that join the mouth and nose to the lungs

4.9.2 Controlling the triggers

The best way to control asthma is to avoid the triggers. While this is not always possible, it is worthwhile to recognise the triggers so that you can minimise them.

Pollen and moulds

Pollen from some grasses and trees is very light and becomes airborne on even slightly windy days. The inhaling of pollen can be reduced by avoiding outdoor activities and keeping windows and doors closed on breezy spring days. Moulds live in warm, humid conditions and thrive in bathrooms, kitchens and bedrooms. Their spores are easily breathed in, triggering attacks in some asthma sufferers. Moulds can be reduced by airing the house regularly.

Air pollution

Those asthma sufferers whose attacks are triggered by air pollution are warned to remain indoors as much as possible and avoid vigorous activity on smoggy days. If tobacco smoke is a trigger, the cigarette smoke of others needs to be avoided.

Dust mites

Dust mites are a common trigger of asthma attacks. Dust mites are microscopic animals that live in their thousands in warm, moist and dark places like doonas, sheets, pillows, carpets and curtains. Dust mite droppings float in the air and are easily inhaled.

Since you share so much of yourself and where you live with this fellow Australian, you should probably know its name. It is the most common dust mite (a relative of spiders and ticks) in Australia, *Dermatophagoides pteronyssinus*. The good news is that it is half a millimetre long and doesn't bite. The bad news is that there may be thousands of them living in your pillow, each defecating about 20 faecal pellets a day, reproducing (each female laying about 30 eggs in her lifetime), dying and decomposing. The fact that dust mites mate for 24 hours at a time (perhaps because their penis is only about as wide as their sperm) may make this particularly disturbing!

FIGURE 4.73 A house dust mite

Our skin scales are the main food source for these dust mites, so wherever we are, they are. Dr Janet Rimmer (a respiratory physician and Director of the National Asthma Council Australia) also suggests that, of the 45 per cent of Australians who are affected by allergies, about 80 per cent are allergic to dust mites. But not all researchers have bad news about dust mites. Dr Matthew Colloff, a CSIRO researcher, has found them so interesting that he wrote a book (called *Dust mites*) about them.

Even the cleanest house has dust mites, but their numbers can be reduced by:
- exposing your mattress to the sun, because dust mites are susceptible to drying out
- washing bedding materials and bedclothes with tea-tree or eucalyptus oil or in hot water (above 55 °C)
- removing soft toys that collect dust or hot washing them weekly
- regularly vacuuming curtains and carpets
- airing the bedroom by keeping doors and windows open
- replacing carpets with hard flooring.

EXTENSION: Shedding our skin

Dust mites thrive best in bedding and carpets because these contain plenty of dead human skin cells. Humans shed a complete layer of dead skin cells every month. That amounts to about 1 kilogram of skin cells each year. In fact, most of the dust in your house consists of dead skin cells.

4.9.3 Asthma medication

Asthma medications can be divided into two main groups: preventers and relievers. Preventers make the lining of the airways less sensitive and therefore less likely to be triggered. Relievers open up the airways once an attack has commenced. Most asthma medications are applied with inhalers or 'puffers', which direct the medication straight into the air tubes for fast action. Severe attacks of asthma require other drugs and sometimes extra oxygen needs to be supplied.

FIGURE 4.74 Asthma medication is usually delivered through an inhaler.

4.9.4 Up in smoke

Asthma is not the only condition that can interfere with your lungs functioning as they should. Some human activities can damage not only your lungs, but also those of others around you. Smoking is one example of such an activity. About 15 000 Australians die each year as a result of diseases caused by smoking. Smoking is actually the largest preventable cause of death and disease in Australia.

4.9.5 Just one cigarette

There are clearly many long-term effects of smoking. However, figure 4.76 shows what happens to you after smoking just one cigarette.

There are some more obvious effects such as bad breath, body odour and watery eyes. After several cigarettes, your teeth and fingers become stained. Your sense of taste is reduced. Even your stomach is affected as acid levels increase.

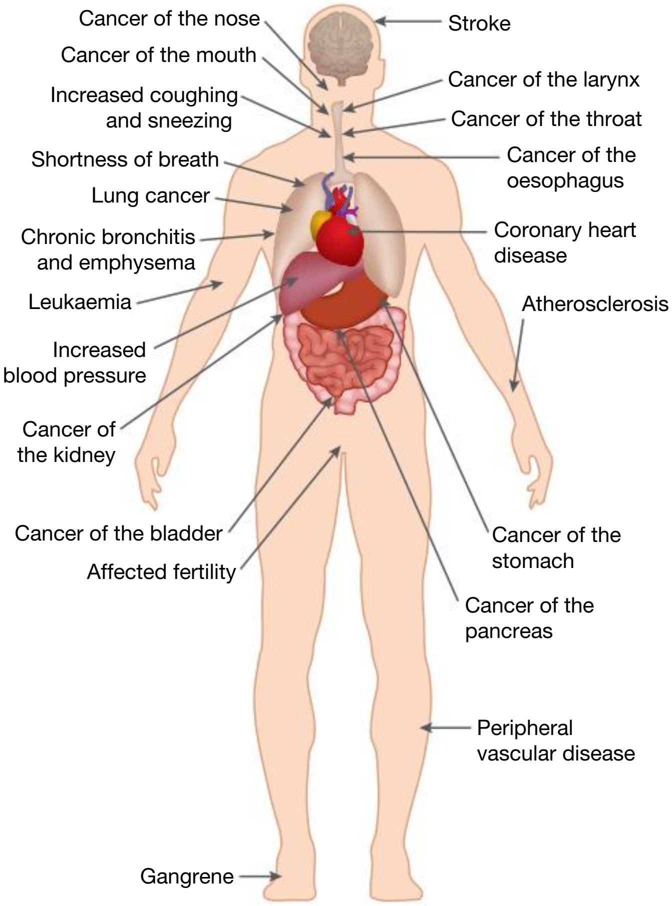
Smoking and your lungs

Lung cancer is the most well-known disease caused by smoking. Chemicals that cause cancer are called **carcinogens**. Cigarette tobacco contains a number of carcinogens. The chemicals in cigarettes also clog up the fine hairs in your air tubes with a mixture of mucus and foreign chemicals.

Cough it up

Coughing is the body's way of trying to clear the air tubes. However, not all of the clogging can be cleared by coughing. A dirty mixture remains in the air tubes, causing swelling, making them sensitive and slowing down the passage of air. Eventually, the sticky mixture sinks down into the lungs, where it blocks some of the pathways to the alveoli, where freshly breathed air should deliver oxygen to the blood.

FIGURE 4.75 With over 4000 chemicals in each cigarette, smoking can lead to any of these conditions and effects.

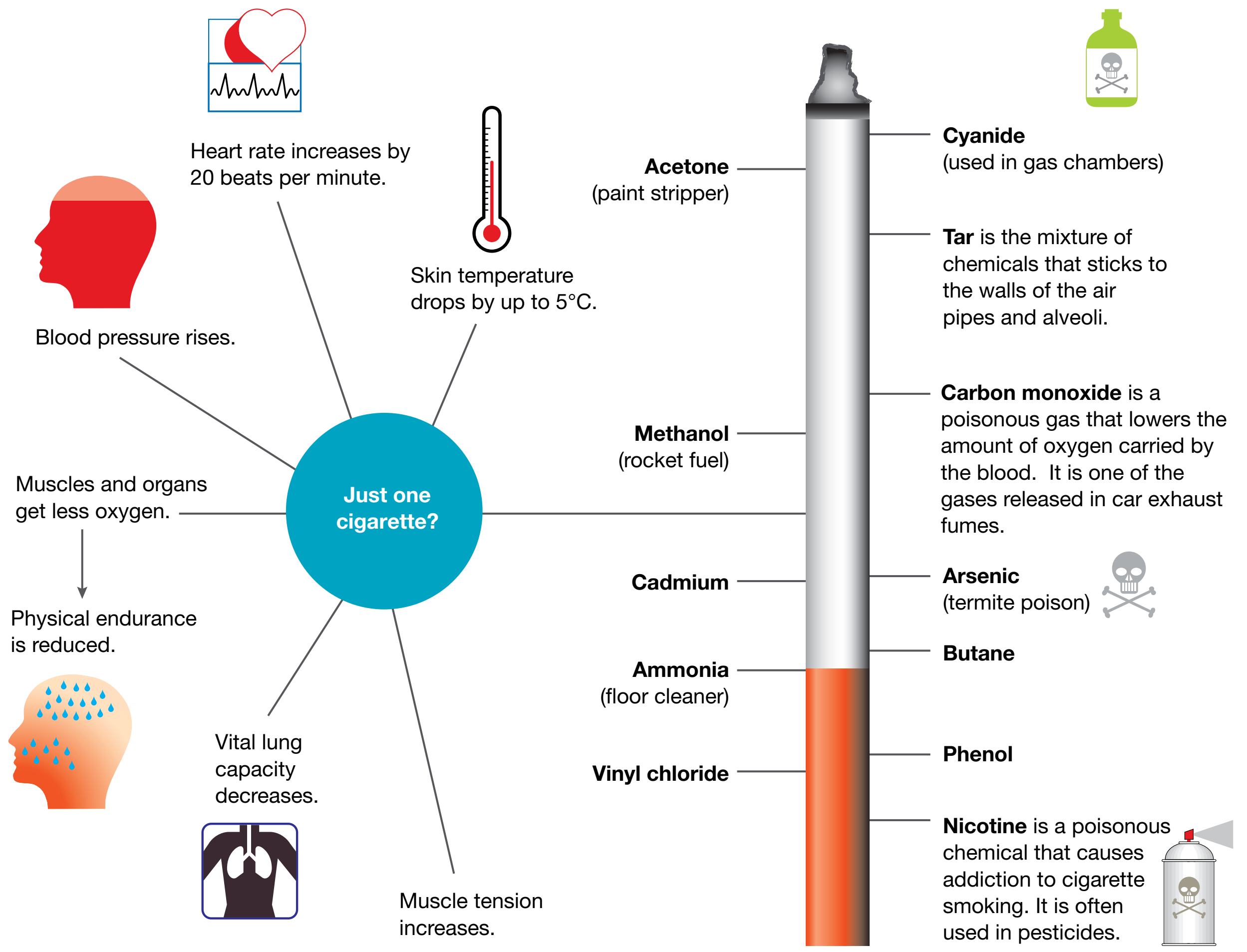


carcinogens chemicals that cause cancer

The diseases caused by this blocking process are called chronic obstructive pulmonary diseases, or COPD. **Emphysema** is the worst of these diseases and results in the eventual destruction of the alveoli.

emphysema condition in which the air sacs in the lungs break open and join together, reducing the amount of oxygen taken in and carbon dioxide removed

FIGURE 4.76 The results of just one cigarette



SCIENCE AS A HUMAN ENDEAVOUR: Professor Robyn O'Hehir BSc, MBBS (Hons I), FRACP, PhD, FRCP, FRCPath

1. **What is your current science-related title?**
   I am a Professor of Medicine, with particular responsibilities for allergy, clinical immunology and respiratory medicine, at Monash University, Melbourne. I am also the Director of the Department of Allergy, Immunology and Respiratory Medicine at the Alfred Hospital in Melbourne.
2. **What field of science are you in?**
   Allergy, cellular immunology and respiratory medicine. I was appointed to the first Chair in Allergy and Clinical Immunology in Australia.
3. **Describe some science that you are involved in at the moment.**
   Millions of people around the world suffer from allergies. I am sure you know several friends who have asthma or hay fever, or you may even have them yourself. Asthma and hay fever are usually triggered by proteins called allergens, from house dust mites or grass pollens. Allergies to peanuts and shellfish are less common but often more serious, because they can trigger life-threatening allergic reactions called anaphylaxis. Allergies are caused by

reactions between white blood cells ('T cells') and environmental proteins that are usually harmless. My research group is trying to find ways to damp down the allergic T-cell responses.

Allergen immunotherapy (allergy shots) is the only treatment that can prevent allergic diseases, but currently it can't be used for peanut allergies, even though this is one of the most serious allergens. To develop a safe and effective vaccine against peanut allergies, we are identifying parts of critical peanut proteins that can build up tolerance in allergic patients without risking anaphylaxis.

4. **What do you enjoy about being a scientist?**
   I enjoy the fact that my research not only is laboratory-based, exploring novel methods for switching off allergic responses, but also lets me see patients and train other doctors in how to do research from bench to bedside to the community. I head an active clinical department, still carry out clinics with patients, and am actively engaged in national and international tests of new preventions and treatments for allergies. My combined research and clinical duties allow translation of our research findings into better clinical practice.
5. **What triggered your interest in science?**
   I decided to specialise in allergy and respiratory medicine, focusing on asthma, following my experiences as a young trainee physician at the Alfred Hospital in Melbourne. Asthma was a huge problem in Australia at that time, and many times I resuscitated young adults in the hospital emergency room — and I watched them return, with appropriate medication and careful education, to confident, full lives. Some remain my patients today. The ability to dissect underlying mechanisms of disease and then work towards new therapeutics and practices to benefit patients is a great excitement and honour. The diversity of patients and their needs ensures that every day is quite different.
6. **Do you have any other comments that may be of interest to Year 8 Science students?**
   A career in science combined with medicine may take a bit longer in terms of training, but it gives you a fantastic ability to do interesting work that is intellectually demanding and also involves working with lots of people who need your help. I am very glad that I chose a career in science and medicine.

on Resources

eWorkbook Smoking and diseases (ewbk-4728)

assess on Additional automatically marked question sets

4.9 Exercise

learn on

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 3, 6, 9	Questions 2, 4, 7, 10, 11	Questions 5, 8, 12, 13, 14

Remember and understand

1. State whether the following statements are true or false. Justify any false responses.

Statement	True or false
a. Asthma is a rare condition and the number of people suffering from it has decreased in the past 50 years.	
b. Asthma is a narrowing of the air pipes that join the mouth and nose to the lungs.	

c. The tubes most affected by asthma are the bronchi.	
d. Breathing can be restricted during an asthma attack due to swelling of the bronchi.	
e. All asthma sufferers are affected by the same triggers.	
f. Fungal spores from moulds can be a trigger for asthma attacks.	
g. Fewer asthma attacks are likely to occur on a windy day than on a day without wind.	
h. Dust mites are a common trigger for asthma attacks.	
i. Asthma medications may be classified as being preventers if they make the lining of the airways more sensitive.	
j. Asthma medications may be classified as being relievers if they open up the airways once an attack has commenced.	
k. Smoking just one cigarette may increase your blood pressure.	
l. There is no link between smoking and lung cancer.	
m. Chemicals in cigarettes can block some of the pathways to the alveoli in your lungs, which can reduce the amount of oxygen delivered to your cells.	

2. a. What happens to the air pipes during an asthma attack to make breathing difficult?
   b. Why is an asthma attack more likely to be triggered in a person with a cold?
   c. What is an asthma trigger?
   d. What are the two major types of asthma medication and how are they different from each other?

Apply and analyse

3. Create a poster that sends one single important message about smoking.
4. a. Find out more about Allergy & Anaphylaxis Australia.
   b. Outline the topics covered in a first aid course for management of anaphylaxis.
   c. What is an EpiPen and how is it used?
5. **SIS**
   a. In your team, brainstorm ideas about the common triggers of asthma that can be controlled. Summarise your discussion in a bubble map.
   b. Construct a table similar to the one provided.
   c. Again, as a team, add suggestions to your table of ways that the trigger could be controlled.

TABLE Asthma triggers and controls

Trigger	How the trigger can be controlled?
Moulds	Air the house regularly.

6. **SIS**
   a. If you suffer from asthma, prepare a talk for the rest of your class explaining:
      i. what it is
      ii. how it affects you
      iii. how you control it or try to prevent attacks.
   b. If you do not suffer from asthma, write a set of at least five questions that you could ask an asthma sufferer in an interview. If possible, conduct the interview and record the answers in writing, or as audio or video.

7. **SIS** Propose a series of questions to find out more about each of the areas listed. Investigate them, and then share your findings with others in your class.
   a. Allergies
   b. Asthma
   c. Anaphylaxis
   d. Allergen immunotherapy
   e. Clinical immunology and respiratory medicine
8. a. Describe the structure and function of an alveolus.
   b. Suggest how the structure of an alveolus is related to its function.
   c. Suggest how smoking affects the ability of an alveolus to perform its function.

Evaluate and create

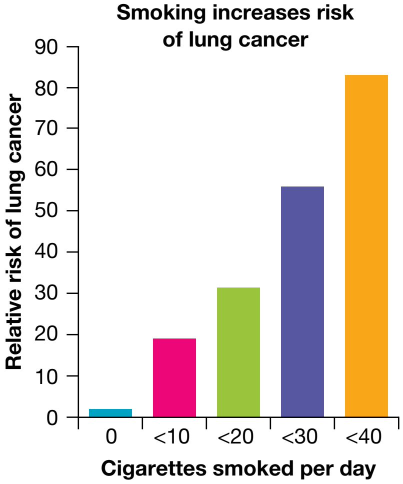
9. **SIS** Draw up a two-column table. The first column should be headed 'Reasons for smoking'; the second column should be headed 'Reasons for not smoking'. With at least one other person, complete the table. Then compare your table with others. You might be able to construct a large table for the whole class.
10. **SIS** Smoking-related diseases cost taxpayers many millions of dollars because hospitals are mostly paid for by governments. Write down your opinion of each of the proposals given. Give reasons for your opinion.
   a. The cost of hospital treatment for diseases caused by smoking should be paid for by the patient because it was their fault that they got sick.
   b. Cigarettes should cost more. The extra money made from them could then be given to hospitals to help pay for treating smoking-related diseases.
   c. Cigarette companies who make profits from smoking should be made to pay for hospital treatment of patients with diseases caused by smoking.
11. **SIS** The table shows how the popularity of smoking has changed over the past 70 years or so.

TABLE Percentage of adult Australians who smoke

Year	1945	1964	1969	1974	1976	1980	1983	1986	1989	1992	1998	2001	2004
Males (%)	72	58	45	41	40	40	37	33	30	28	29	28	26
Females (%)	26	28	28	29	31	31	30	28	27	24	24	21	20

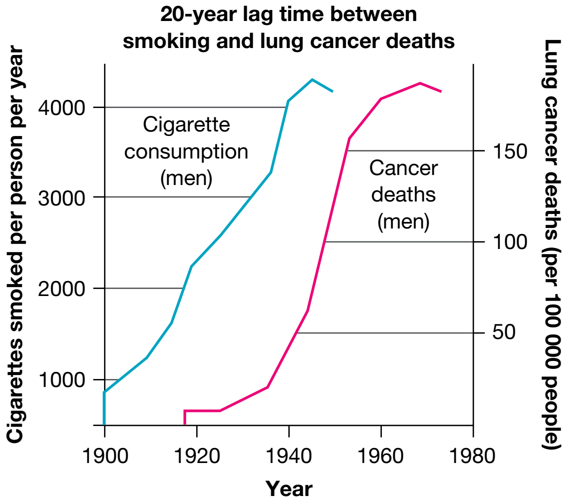
   a. Draw a line graph of the data in the table. Use 'Year' on the *x*-axis and '% of adult Australians who smoke' on the *y*-axis. Draw lines for males and females in different colours.
   b. Why do you think that the percentage of females who smoke has changed little while the percentage of males who smoke has declined greatly?
   c. Use dotted lines to show your prediction of the trends up to the year 2020. What percentage of males and females do you predict will be smoking in 2020?
12. **SIS** Study the graph in figure 4.77.
   a. Copy and complete the following statements.
      i. People who smoke 10 cigarettes a day are ____________ times more likely to develop lung cancer than non-smokers.
      ii. People who smoke 30 cigarettes a day are ____________ times more likely to develop lung cancer than people who smoke 10 cigarettes a day.
   b. If a packet of 20 cigarettes costs $30 calculate how much a person smoking 40 cigarettes a day spends on smoking:
      i. each day
      ii. each week
      iii. each year.

FIGURE 4.77 The risk of getting lung cancer increases with the number of cigarettes smoked daily.



13. **SIS** Study the graph in figure 4.78.
   a. Describe how the incidence of lung cancer deaths changed between 1900 and 1980.
   b. Identify when the number of male smokers peaked.
   c. Identify when the number of deaths from lung cancer peaked.
   d. Explain why there is a 20-year gap between the two numbers.
   e. The graph shows data for male smokers only. Predict when the number of cases of lung cancer deaths in women peaked (use the graph you drew for question 11 to answer this).
14. **SIS** Design an experiment that would investigate the effect of passive smoking on heart rates. Investigate whether any relevant research has been performed in this area. If so, share it with others in your class.

FIGURE 4.78 The number of deaths from lung cancer has risen as cigarette consumption has increased but there is a 20-year lag time because lung cancer takes years to develop.



Fully worked solutions and sample responses are available in your digital formats.

4.10 The excretory system

LEARNING INTENTION

At the end of this subtopic you will be able to describe the structure and function of the excretory system and provide examples of problems associated with it.

Being alive requires energy and nutrients. It also results in the production of wastes that need to be removed.

4.10.1 Excretory system

Excretion is any process that gets rid of unwanted products or waste from the body. The main organs involved in human excretion are your **skin**, lungs, **liver** and **kidneys**. Your skin excretes salts and water as sweat, and your lungs excrete carbon dioxide (produced by cellular respiration) when you breathe out. Your liver is involved in breaking down toxins for excretion, and your kidneys are involved in excreting the unused waste products of chemical reactions (e.g. urea) and any other chemicals that may be in excess (including water) so that a balance within our blood is maintained.

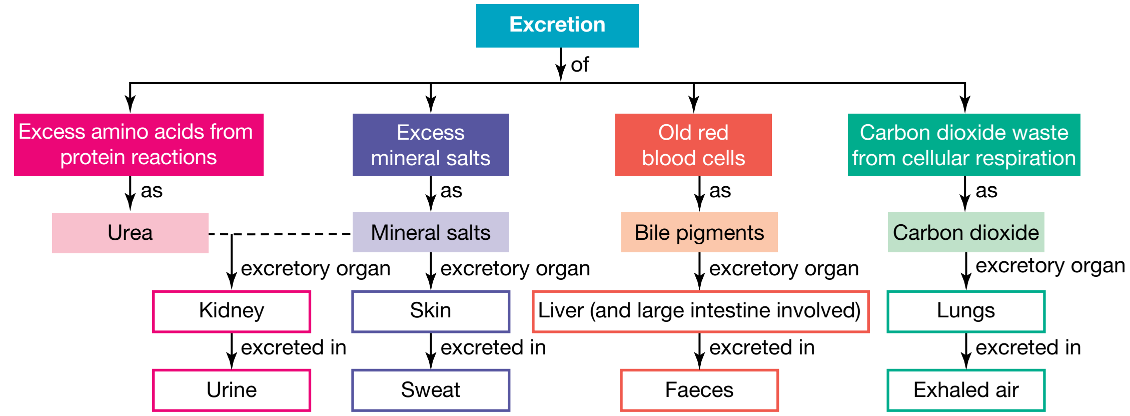
excretion removal of wastes from the body

skin external covering of a vertebrate's body

liver largest gland in the body. The liver secretes bile for digestion of fats, builds proteins from amino acids, breaks down many substances harmful to the body and has many other essential functions.

kidneys body organs that filter the blood, removing urea and other wastes

FIGURE 4.79 The four main organs involved in human excretion are kidneys, skin, liver and lungs.



4.10.2 Kidneys

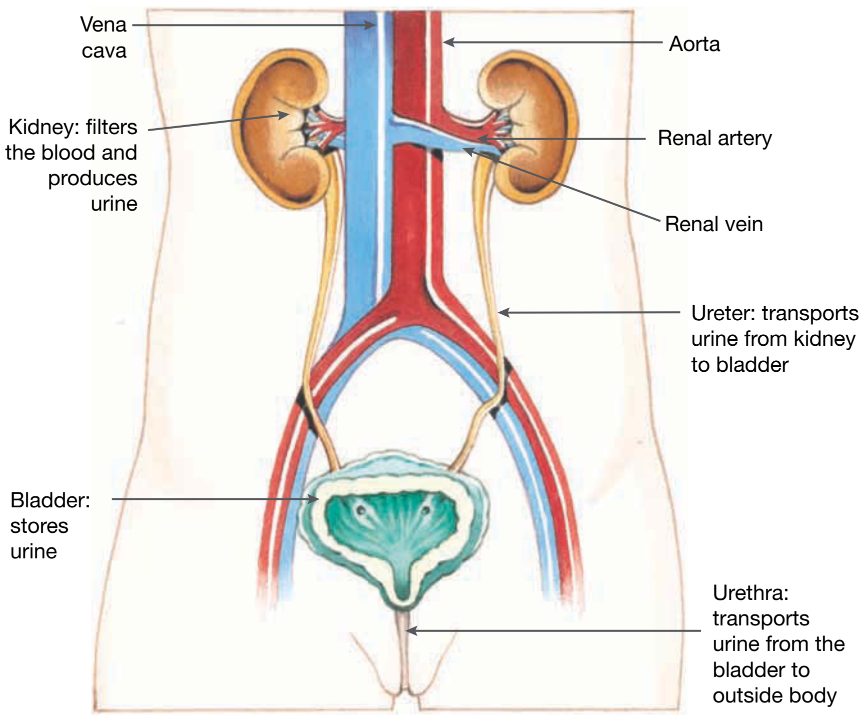
If you put your hands on your hips, your kidneys are close to where your thumbs are. You have two of these reddish-brown, bean-shaped organs. Without them you would survive only a few days.

Organs, tubes and urine

Your kidneys play a key role in filtering your blood and keeping the concentration of various chemicals and water within appropriate levels. Each of your kidneys is made up of about one million **nephrons**. These tiny structures filter your blood, removing waste products and chemicals that may be in excess. Chemicals that your body needs are reabsorbed into capillaries. The fluid remaining in your nephrons travels through tubes called **ureters** to your **bladder** for temporary storage. As it fills, your bladder expands like a balloon. It can hold about 400 mL of this watery fluid which contains unwanted substances called **urine**. **Urination** occurs when urine moves from your bladder through a tube called the **urethra** and out of your body.

eles-2051
ewbk-7084
int-8234

FIGURE 4.80 Your kidneys have an important role in the excretion of wastes from your body.



nephrons the filtration and excretory units of the kidney

ureters tubes from each kidney that carry urine to the bladder

bladder sac that stores urine

urine yellowish liquid, produced in the kidneys. It is mostly water and contains waste products from the blood such as urea, ammonia and uric acid.

urination passing of urine from the bladder to the outside of the body

urethra tube through which urine is emptied from the bladder to the outside of the body

Nephrons — How their structure suits their function

Each nephron is made up of a long tubule (very fine tube) that forms a cuplike structure at one end called the **Bowman's capsule**. This structure surrounds a cluster of capillaries called the **glomerulus** (from an ancient Greek word meaning 'filter').

Blood containing wastes travels to the glomerulus within each nephron in your kidneys, where the blood is filtered. Wastes and excess water move into the surrounding Bowman's capsule. As this 'waste' fluid moves along the tubules, any useful substances are reabsorbed back into capillaries that are 'twisted' around the tubules, and hence back into circulation. The remaining fluid becomes urine, which eventually travels in your ureters to your bladder prior to urination.

Bowman's capsule a cup-like structure at one end of a nephron within the kidney, surrounding the glomerulus. It serves as a filter to remove wastes and excess water.

glomerulus a cluster of capillaries in the kidney that acts as a filter to remove wastes and excess water

FIGURE 4.81 Each of your kidneys is made up of about a million nephrons.

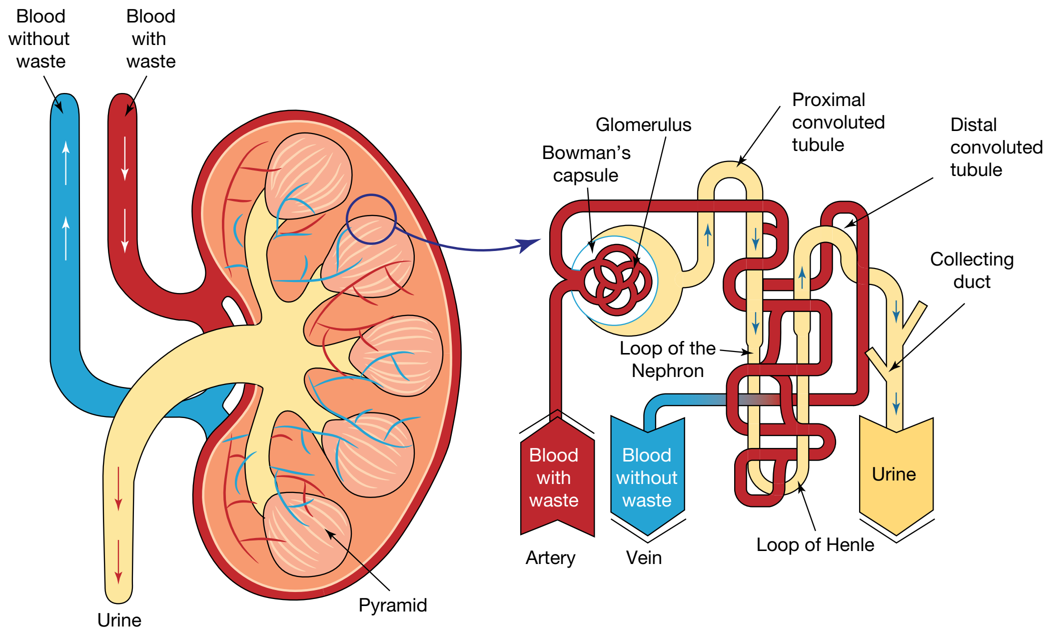
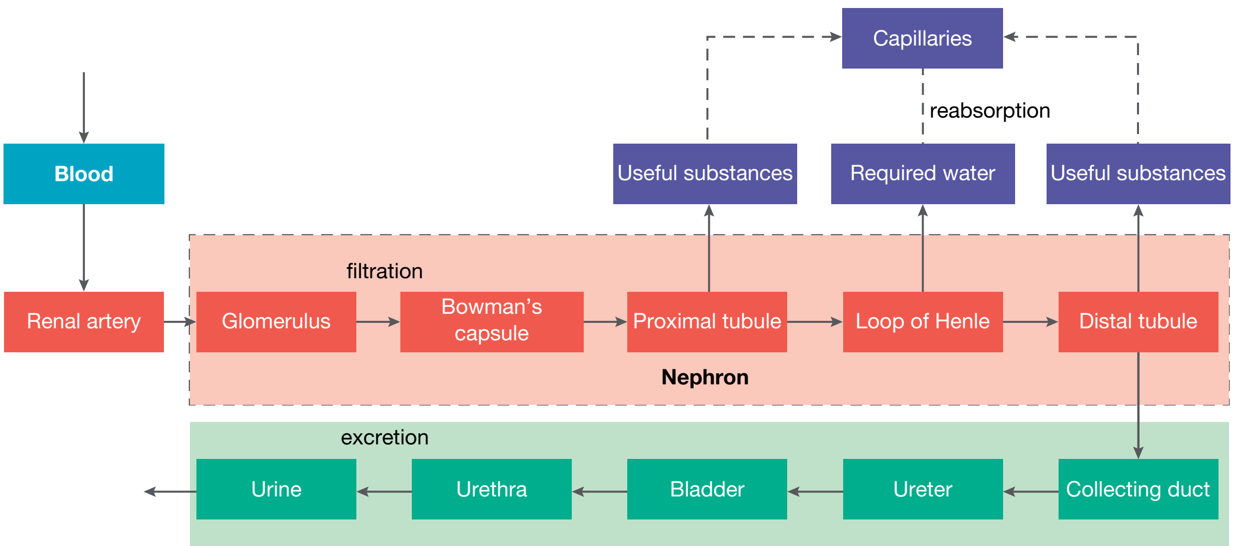


FIGURE 4.82 An organised approach is required for your excretory systems to work effectively. Although each structure has its own specific job to do, it is also dependent on other structures doing their jobs as well.



4.10.3 Have a drink!

Both blood and urine are mostly made up of water. Water is very important because it assists in the transportation of nutrients within and between the cells of the body. The concentration of substances in blood is also influenced by the amount of water in it.

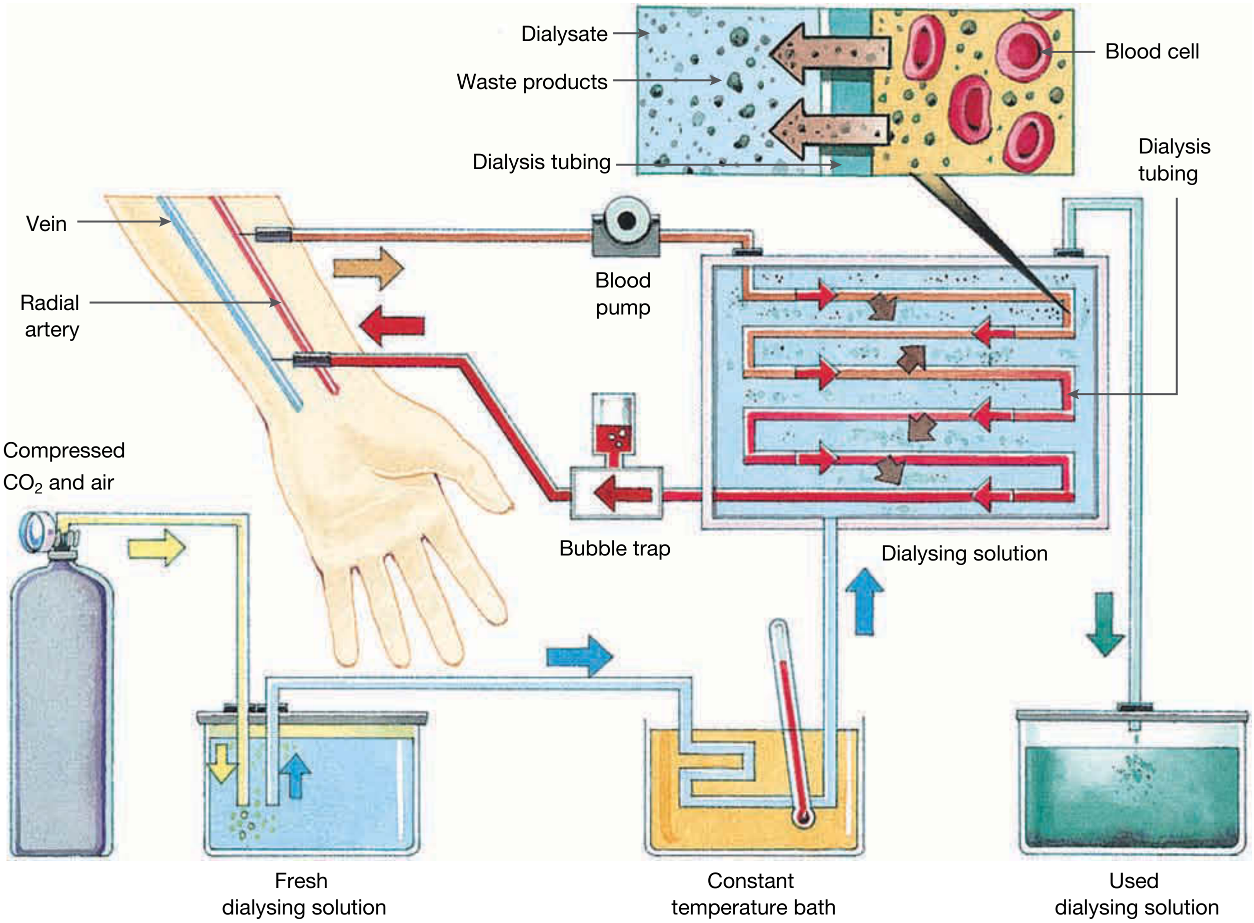
Water helps the kidneys do their job because it dilutes toxic substances and absorbs waste products so that they can be transported out of the body. If you drink a lot of water, more will be absorbed from your large intestines and your kidneys will produce a greater volume of dilute urine. If you do not consume enough liquid, you will urinate less and produce more concentrated urine.

4.10.4 Haemodialysis

People with kidney disease may not be able to remove the waste materials from their blood effectively. They may need to be linked up to a machine that does this job for them; their blood is passed along a tube that lets wastes, such as urea, pass out of it. However, useful substances, such as glucose, proteins and red blood cells, stay in the tube and are kept in the blood. This process is called **haemodialysis**.

haemodialysis the process of passing blood through a machine to remove wastes

FIGURE 4.83 Haemodialysis



4.10.5 Liver

Livers are busy places!

Over a litre of blood passes through your liver each minute. Your liver is like a chemical factory, with more than 500 different functions. Some of these include sorting, storing and changing digested food. The liver removes fats and oils from the blood and modifies them before they are sent to the body's fat deposits for storage. It also helps get rid of excess protein, which can form toxic compounds dangerous to the body. The liver converts these waste products of protein reactions into urea, which travels in the blood to the kidneys for excretion. It also changes other dangerous or poisonous substances so that they are no longer harmful to the body. Your liver is an organ that you cannot live without.

FIGURE 4.84 The liver performs over 500 different functions.

Too much alcohol?

The liver is also involved in breaking down alcohol. Alcohol is converted into a substance called acetaldehyde, which is then converted to acetate and finally into carbon dioxide and water. The carbon dioxide is transported from the liver to the lungs and then exhaled out of the body. The water may be removed as vapour in breath, sweat on skin or as urine.

Alcohol can also affect the amount of urine produced by the kidneys. Reabsorption of water may be reduced in the kidneys, resulting in the production of more urine. Increased urination can result in dehydration and consequently impair other body functions.

on Resources

Video eLesson The liver (eles-2536)

EXTENSION: Removing excess salt

The human kidneys remove excess salt from the blood to help keep levels constant. Different types of animals have other ways of removing excess salt from their bodies. Turtles, for example, have salt-secreting glands behind their eyes. Hence you may see a turtle 'shedding tears'. On the other hand, penguins and some other seabirds, such as the southern giant petrel, may appear to have runny noses because that is where their salt-secreting glands are located.

on Resources

eWorkbook Removing waste from blood (ewbk-4773)

assess on Additional automatically marked question sets

4.10 Exercise

learn on

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Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 4, 5, 6, 7, 11	Questions 2, 8, 9, 12, 14	Questions 3, 10, 13, 15

Remember and understand

1. State whether the following statements are true or false. Justify any false responses.

Statement	True or false
a. Excretion involves getting rid of unwanted products or wastes from the body.	
b. Skin, lungs, liver and kidneys are the main organs involved in human excretion.	
c. Human skin is involved in the excretion of carbon dioxide.	
d. Human lungs excrete urea.	
e. Human kidneys remove excess salt from the blood to help keep levels constant.	
f. The liver converts waste products of protein into urea, which is then excreted via the kidney.	
g. Blood and urine are mostly made up of water.	
h. If you drink a lot of water, less will be absorbed from your large intestines and your kidneys, which will result in a greater volume of dilute urine.	
i. The filtering of blood in each nephron of your kidney occurs in the glomerulus.	
j. Blood in your renal artery contains less 'waste' than blood in your renal vein.	

2. Match the terms associated with the excretory system with their description in the table provided.

Term	Description
a. Bladder	A. Watery fluid produced by kidneys that contains unwanted substances
b. Kidney	B. Transports urine from the bladder to outside the body
c. Ureter	C. Stores urine
d. Urethra	D. When urine moves from the bladder, through the urethra and out of the body
e. Urination	E. Transports urine from kidneys to bladder
f. Urine	F. Filters the blood and produces urine

3. Define the term excretion.
4. Draw and label a diagram of the kidneys showing the following attachments: renal arteries, renal veins, ureters, bladder.
5. Outline what happens when you drink a lot of water.

6. Describe one way in which excess salt is removed from your body.
7. Explain how haemodialysis assists people with kidney disease.
8. Describe the relationship between:
   a. a kidney and a nephron
   b. kidneys and urine
   c. alcohol, lungs and kidneys.

Apply and analyse

9. SIS
   a. Carefully observe the haemodialysis diagram in figure 4.81. Suggest reasons the following are included in the process.
      i. Blood pump
      ii. Bubble trap
      iii. Constant temperature bath
   b. Suggest what you would expect to find in used dialysis solution.
   c. Suggest why red blood cells don't pass through the dialysis tubing.
   d. Use a Venn diagram to compare haemodialysis with real kidneys.
10. Distinguish between:
    a. the ureter and the urethra
    b. a Bowman's capsule and a glomerulus
    c. the bladder and the kidney.
11. Research and report on one of these conditions: urinary incontinence, kidney stones, kidney transplants, cystitis, blood in urine, proteinuria, nephritis.
12. Find out and report on:
    a. the differences between the urethra in human males and human females
    b. why pregnant women often need to urinate more frequently
    c. how the prostate gland in males may affect urination in later life
    d. which foods can change the colour or volume of urine
    e. which tests use urine in the medical diagnosis of diseases.

Evaluate and create

13. Research the nephrons of animals that live in different environments (e.g. deserts, oceans and rivers). Comment on similarities and differences in their structure. Suggest reasons for the differences.
14. SIS Use the table provided and the other information in this subtopic to answer the following questions.

TABLE Substances in blood and urine

	Quantity (%)	
Substance	**In blood**	**In urine**
Water	92	95
Proteins	7	0
Glucose	0.1	0
Chloride (salt)	0.37	0.6
Urea	0.03	2

    a. Draw two bar graphs to show the quantity of water, proteins, glucose, salt and urea in blood and in urine.
    b. Which substance is in the greatest quantity? Suggest a reason for this.
    c. Which substances are found only in blood?
    d. Which substances are found in urine in a greater quantity than in blood? Suggest a reason for this.
    e. When would the amount of these substances in the urine become greater or less than in the blood?
15. SIS Find out more about nephrons and how they work. Construct a model of a nephron that shows how it is linked to blood vessels and how urine gets to your bladder from it.

Fully worked solutions and sample responses are available in your digital formats.

4.11 Musculoskeletal system — keeping in shape

LEARNING INTENTION

At the end of this subtopic you will be able to describe the structure and function of the musculoskeletal system.

4.11.1 Bones

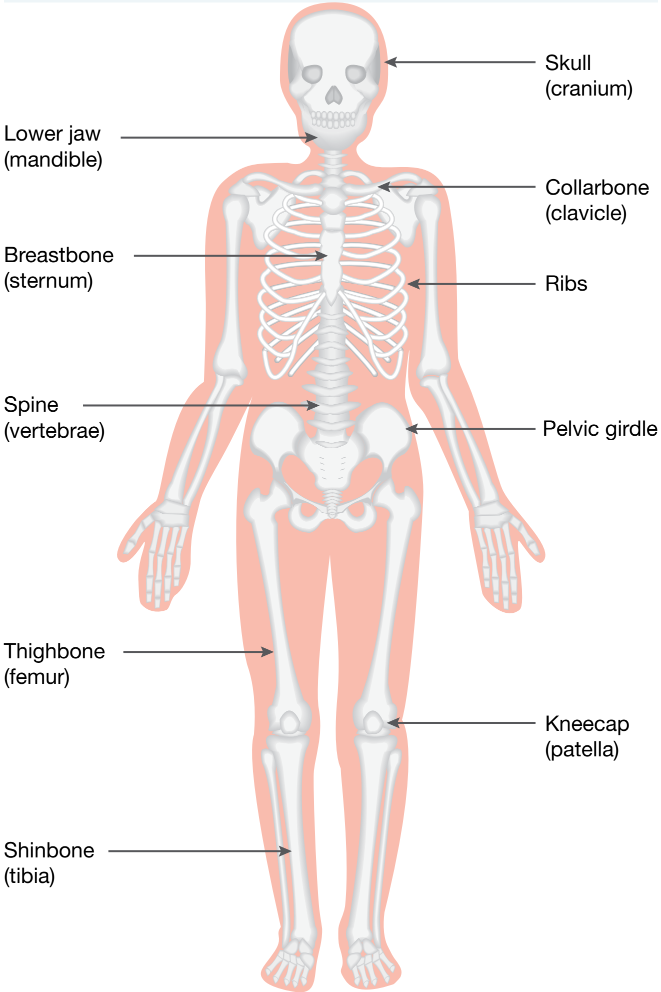
Your musculoskeletal system consists of your **skeletal system** (bones and joints) and your **skeletal muscle system**. Working together, these two systems protect your internal organs, maintain posture, produce blood cells, store minerals and enable your body to move.

Did you know that an adult human **skeleton** contains over 200 separate **bones**? Without a skeleton we may resemble jelly-like blobs! Not only does it provide a structure for our muscles to attach to, allowing us to move, but it also provides support, protects vital organs (e.g. brain and heart) and forms a frame that gives our body shape.

eles-2537

ewbk-7086

FIGURE 4.85 An adult human skeleton contains over 200 separate bones.



Your bones are many different shapes and sizes, depending on the job that they have to do. They can be short, thick, round or flat. The longest bone in your body is the femur, or thigh bone. A feature that all bones have in common, however, is that they are all light and strong. Why do you think they share this feature?

skeletal system consists of the bones and joints

skeletal muscle system voluntary or striated muscle

skeleton the bones or shell of an animal that support and protect it as well as allowing movement

bones the pieces of hard tissue that make up the skeleton of a vertebrate

It's hard being a bone

Bones are alive. If bones were not alive, how would you grow taller? How would a broken arm or leg mend? Bones contain living cells and need a blood supply to provide them with oxygen and other nutrients.

Not only are bones busy providing you with support and movement, they are also busy inside. Bones contain soft tissue called **bone marrow**. This is very important because it is where blood cells are made.

Throughout the first 20 years of your life, most of the soft and rubbery **cartilage** that made up your skeleton is gradually replaced with bone. Your trachea, nose and ears, however, are made mostly of cartilage and the ends of your bones remain covered in cartilage.

Compact bones, such as the long bone of your femur, have a strong and hard outer layer that contains **calcium** and **phosphorus**. This is why you need an adequate supply of these minerals. Investigation 4.10 shows what could happen to your bones without a supply of these important **minerals**.

The hardening of your bones as you get older is called **ossification**. After ossification, the bone is made up of about 70 per cent non-living matter and 30 per cent living matter. As you get even older, your bones may get dry and **brittle**, which is why older people break their bones more easily.

bone marrow a substance inside bones in which blood cells are made

cartilage a waxy, whitish, flexible substance that lines or connects bone joints or, in some animals such as sharks, replaces bone as the supporting skeletal tissue. The ears and tips of noses of people are shaped by cartilage.

calcium an element occurring in limestone, chalk, also present in vertebrates and other animals as a component of bone, shell etc. It is necessary for nerve conduction, heartbeat, muscle contraction and many other physiological functions.

phosphorus a substance that plays an important role in almost every chemical reaction in the body. Together with calcium, it is required by the body to maintain healthy bones and teeth.

minerals substances that make up rocks. Each mineral has its own chemical make-up.

ossification hardening of bones

brittle breaks easily into many pieces

elog-0531

INVESTIGATION 4.10

Rubbery bones

Aim

To investigate the effect of calcium and phosphorus deficiency on bone

Background information

Vinegar is an acid that dissolves minerals such as calcium and phosphorus, removing them from bones.

Materials

- 2 chicken or turkey bones
- water
- 2 jars (or beakers)
- vinegar

Method

1. Clean the two chicken or turkey bones and leave them to dry overnight.
2. Observe the bones and then place one bone in a jar of vinegar and the other in a jar of water.
3. Allow the bones to soak for at least three days. Then remove the bones and observe any changes.
4. Return the bones to their previous jars for another week, then remove and observe any further changes in the bones. Can you tie either bone into a knot?

Results

1. Construct a table to record your observations.
2. Record your observations of the bone:
   a. before placing them in the solutions
   b. after soaking for three days
   c. a week after your observation in part (b).

Discussion

1. Suggest a reason for the inclusion of the jar of water in the investigation.
2. Describe changes that you observed for each bone.
3. Provide reasons for the changes that you observed.
4. Relate this investigation to your bones and your diet.

Conclusion

Propose a conclusion for your findings.

4.11.2 Joints

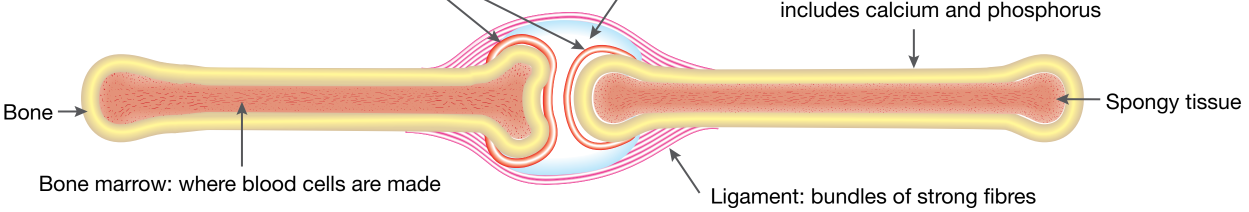
A **joint** is the region where two bones meet. Your knees and elbows are examples of joints. Bones at a joint are held together by bundles of strong fibres called **ligaments**. The cartilage that covers the end of each bone is itself covered with a liquid called **synovial fluid**. The cartilage and synovial fluid work together to stop bones from scraping against each other.

joints region where two bones meet

ligament band of tough tissue that connects the ends of bones or keeps an organ in place

synovial fluid the liquid inside the cavity surrounding a joint that helps bones to slide freely over each other

FIGURE 4.86 The region where bones meet is called a joint. Cartilage and synovial fluid stop bones scraping against each other.



Most joints allow your bones to move. The amount and direction of movement allowed depends on the type of joint. Twist your neck. The joint between your skull and spine is a **pivot joint**, which allows this twisting type of movement (figure 4.87a). Bend your elbow. Your elbows and knees are **hinge joints**, like those of a door. They allow movement in only one direction (figure 4.87b). Roll your shoulder. Your hip and shoulder joints are **ball and socket joints**, allowing movement in many directions (figure 4.87c).

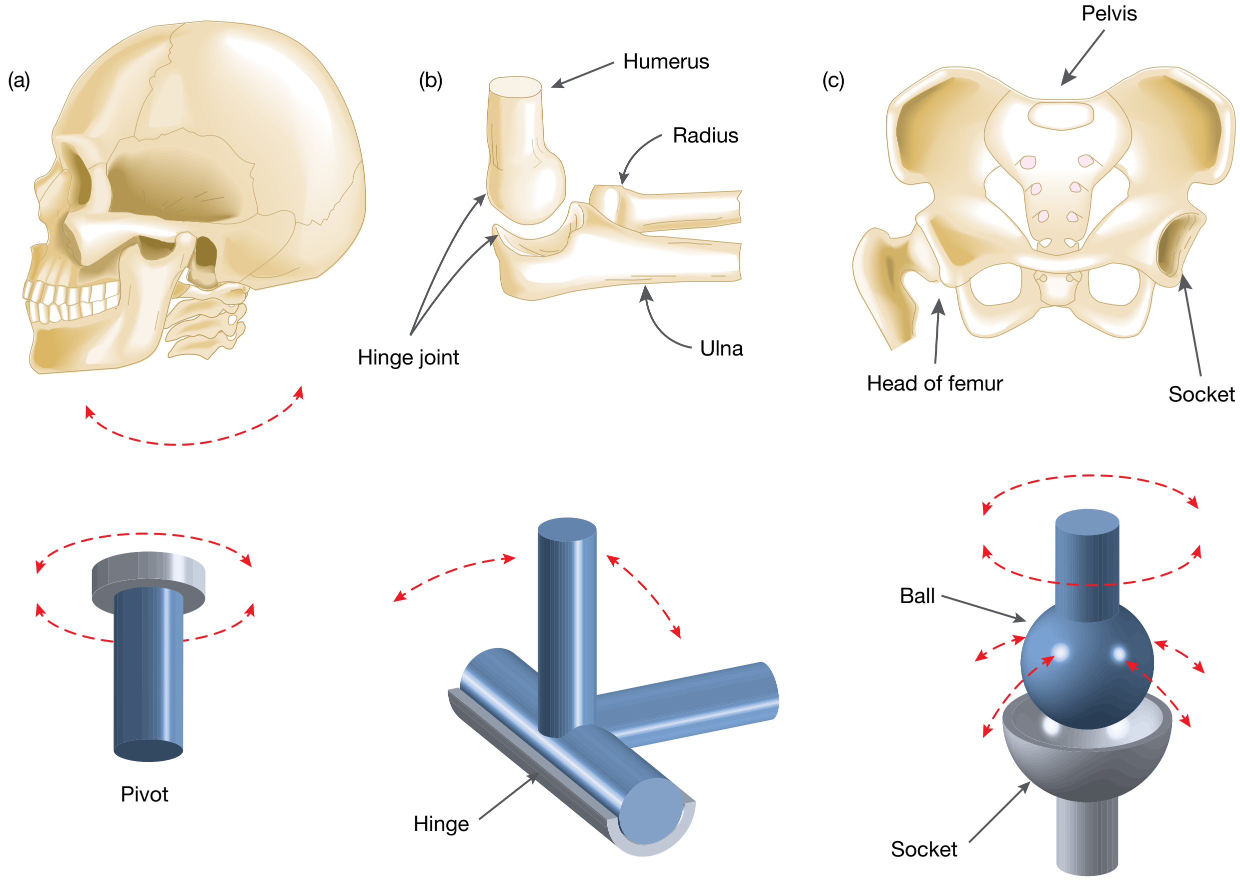
pivot joint joint that allows a twisting movement

hinge joints joints in which two bones are connected so that movement occurs in one plane only

ball and socket joints joints where the rounded end of one bone fits into the hollow end of another

eles-2052

FIGURE 4.87 Different types of joints: **a.** pivot joint **b.** hinge joint **c.** ball and socket joint



Some joints, such as those that join the plates in your skull, do not move. These are called **immovable joints**. While not allowing movement, these joints provide a thin layer of soft tissue between bones. Their job is to absorb enough energy from a severe knock to prevent the bone from breaking.

FIGURE 4.88 The plates of the skull are immovable joints.

immovable joints joints that allow no movement except when absorbing a hard blow

4.11.3 Muscles

Muscles are tough and elastic fibres. The movement of muscles is controlled by the brain, which sends signals through your nerves. Muscles such as those that make your heart pump and those that control your breathing rate are called **involuntary muscles** — they work without you having to think about it. The muscles that are connected to bones are called **voluntary muscles** because you have to choose to use them.

All pull, no push!

Muscles are connected to the bones of your skeleton by bundles of tough figures called **tendons**. Muscles pull on bones by contracting or shortening. Muscles never push.

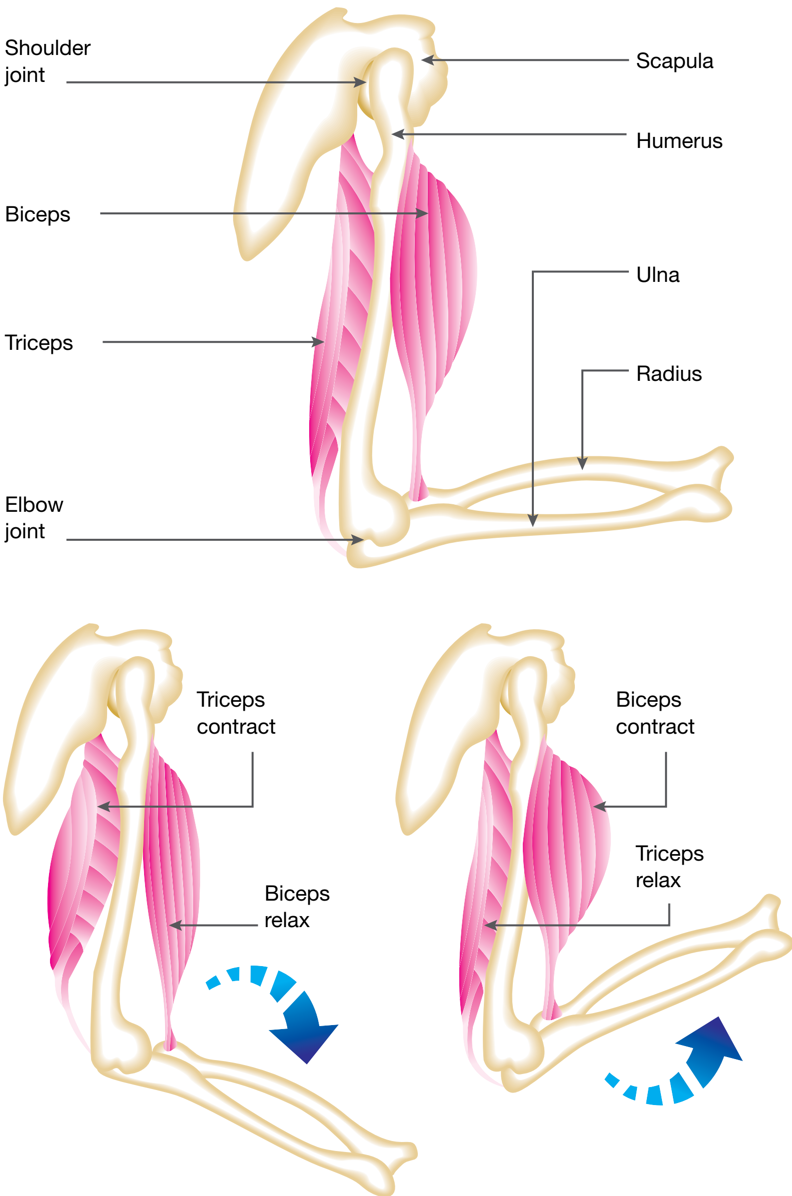
muscles tissue consisting of cells that can shorten

involuntary muscles muscles not under the control of the will; they contract slowly and rhythmically. These muscles are at work in the heart, intestines and lungs.

voluntary muscle muscle attached to bones; it moves the bones by contracting and is controlled by an animal's thoughts

tendons tough rope-like tissue connecting a muscle to a bone

FIGURE 4.89 When your biceps contract, your arm bends upwards. When your triceps contract, your arm straightens.



4.11.4 Broken bones

Breaks and fractures

When a bone breaks, the ends of the bone may need to be put back into place (set) so that they can grow together. If a bone is shattered into several pieces, it is sometimes possible to use pins or wire to hold the pieces in place while the bone heals. A **greenstick fracture** occurs when the bone cracks but does not break. This type of **fracture** is common in children because their bones are more flexible.

On the mend?

New technologies are being researched and developed to help fix broken bones. Some of these involve special cells called **stem cells**, while others involve the use of special 'glues' that hold bones together and aid the healing process. Scientists at CSIRO are currently working on a liquid gel called NovoSorb that glues the fractured bone together so that it is supported while it heals. As this gel degrades naturally, it does not require follow-up surgery to remove pins as is needed with older technologies.

Osteoporosis

Osteoporosis is a loss of bone mass that causes bones to become lighter, more fragile and easily broken. In Australia, over one million people are estimated to have osteoporosis and a further six million to have low bone density. Osteoporosis is more common in older age groups. It is also more common in females than males.

In your teenage years, you can help protect yourself from getting osteoporosis later in life by having a healthy diet and exercising. Your diet should include dairy products such as milk, cheese and yoghurt and other foods high in calcium. Such a diet will help ensure that your bone mass is adequate as an adult.

on Resources

Video eLesson Osteoarthritis (eles-2053)

4.11.5 Ouch! Torn or swollen?

Sprains

Sprains occur when ligaments joining bones at a joint are torn or stretched. Sprains usually happen when you fall onto a joint, such as an elbow or an ankle, and twist it.

Arthritis

Arthritis is a swelling of the joints that makes movement difficult. Osteoarthritis occurs mainly in elderly people and is caused by wear and tear of the joints. The cartilage gradually breaks down, thus allowing bare bones to grate against each other instead of sliding or turning smoothly. Rheumatoid arthritis is a swelling of the tissue between the joints. The swelling causes the joints to slip out of place, which then causes great pain and deformities.

Tennis elbow

Tennis elbow can result from repeated grasping and bending back of your wrist. This repeated action can lead to the inflammation of the tendon that connects the muscles of your forearm to the bone in your upper arm. As these muscles are used to bend your wrist backwards, any activity (not just playing tennis or other racquet sports) with repetitive actions (e.g. painting, texting, or using your computer keyboard or mouse) may result in tennis elbow.

greenstick fracture a break that is not completely through the bone, often seen in children

fracture a break in a bone

stem cells undeveloped cells found in blood and bone marrow that can reproduce themselves indefinitely

osteoporosis loss of bone mass that causes bones to become lighter, more fragile and easily broken

sprains injury caused by tearing a ligament

arthritis a condition in which inflammation of the joints causes them to swell and become painful

tennis elbow repeated grasping and bending back of your wrist can lead to the inflammation of the tendon that connects the muscles of your forearm to the bone in your upper arm causing pain

Torn hamstrings

Torn hamstrings are a common sporting injury. The hamstring muscle joins the pelvis to the bottom of the knee joint, running along the back of the thigh. It controls the bending of the knee and straightening of the hips. A sudden start or turn in sport often stretches the hamstring muscle too far. It tears, causing great pain. Cold and unprepared muscles are more likely to tear. Proper warming up before strenuous sporting activity is one way to reduce the chances of tearing a muscle.

FIGURE 4.90 Torn hamstrings are a common but painful sporting injury.

torn hamstring a common sporting injury caused by overstretching the hamstring muscle, which joins the pelvis to the knee joint

elog-0532

INVESTIGATION 4.11

Chicken wing dissection

Aim

To investigate the structure of a chicken wing

CAUTION

Take special care when using scissors and scalpels.

Materials

- chicken wing
- dissection tray or board
- newspaper
- disposable gloves
- scalpel
- scissors

Method

1. Use the scalpel carefully to make a small incision in the middle of the upper part of the wing.
2. Use the scissors to cut through the chicken skin in order to remove it but keep the bones, muscles (meat) and tendons in place. Do not cut the tendons.
3. Observe the wing without its skin.

Results

1. Sketch one of the joints in the chicken wing. Label the bones, the tendons and the muscles. Show clearly where the muscle inserts (attaches to the bones). Use arrows to show how the bones move when the muscle is shortened.
2. Is cartilage harder or softer than bone?

3. Feel the cartilage with a gloved hand. Does the cartilage feel rough or slippery? Why does it need to be slippery?

Discussion

1. Describe differences that you observed between cartilage, tendons, muscles and bones.
2. Relate this investigation to your own joints, muscles, tendons and bones.

Conclusion

Propose a conclusion for your findings.

on Resources

eWorkbook Bones, joints and muscles (ewbk-4732)

assess on Additional automatically marked question sets

4.11 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 4, 6, 10, 15	Questions 2, 5, 7, 8, 11, 12	Questions 3, 8, 9, 13, 14

Remember and understand

1. State whether the following statements true or false. Justify any false responses.

Statement	True or false
a. The musculoskeletal system consists of your skeletal system (bone and joints) and your skeletal muscle system.	
b. Working together, the skeletal system and the skeletal muscle system protect internal organs, maintain posture, produce blood, store minerals and enable your body to move.	
c. Bones contain hard tissue called bone marrow in which blood cells are made.	
d. Your trachea, nose and ears are mostly made up of bone.	
e. The job of immovable joints, such as those in your skull, is to absorb enough energy from a sever knock to prevent the bone from breaking.	
f. Bones at a joint are held together by tendons, whereas muscles are connected to bones by ligaments.	
g. New technologies are being researched and developed to help fix broken bones that include using stem cells and special ‘glues’.	
h. Voluntary muscles are connected to bones and you can choose when and how to use them.	
i. Involuntary muscles only work when you consciously decide to use them.	

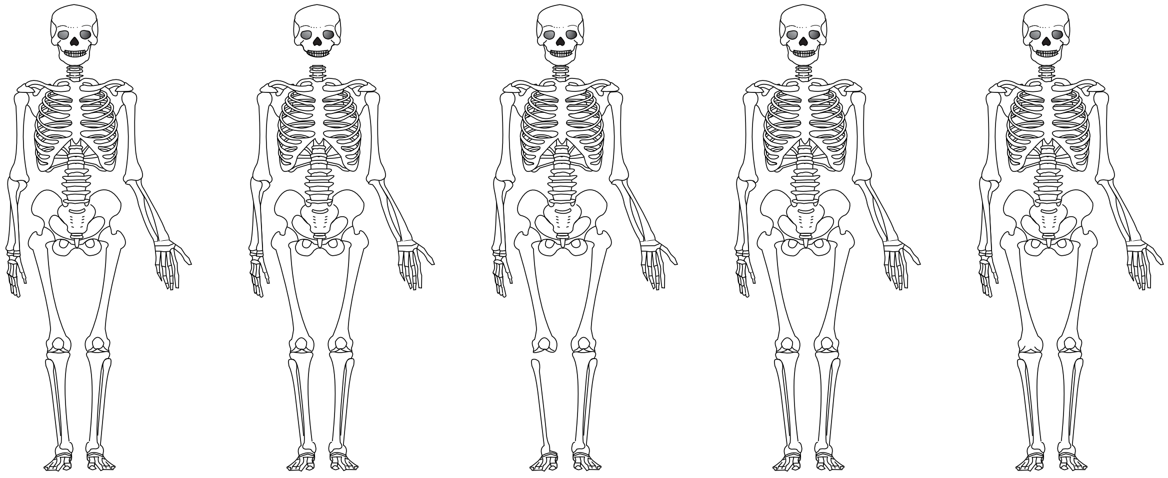
2. Match the common name with scientific term in the table provided.

Common name	Scientific term
a. Breastbone	A. Mandible
b. Kneecap	B. Cranium
c. Lower jaw	C. Vertebrae
d. Shinbone	D. Tibia
e. Skull	E. Sternum
f. Spine	F. Femur
g. Thighbone	G. Patella

3. Some joints are referred to as immovable joints. What is the use of having joints that don't move?
4. Write down an example of each of the following types of joint.
   a. Hinge
   b. Ball and socket
   c. Pivot
   d. Immovable
5. Identify the type of joint (pivot, hinge, ball and socket or immovable) that:
   a. allows movement in many directions such as when you roll your shoulder
   b. does not move, such as those that join the plates in your skull
   c. allows a twisting type of movement like when you twist your neck
   d. allows movement in one direction, such as when you bend your elbows and knees.
6. Ligaments and tendons are bundles of tough fibres. What is the major difference between a ligament and a tendon?
7. Describe the action of the biceps and triceps muscles as you bend your elbow to raise your forearm.
8. Describe the job done by each of the following parts of a joint.
   a. Ligament
   b. Cartilage
   c. Synovial fluid

Apply and analyse

9. Look carefully at each of the skeletons shown. Three of them are incomplete. Identify the incomplete skeletons and name the missing parts.



(a) (b) (c) (d) (e)

10. Apart from warming up just before a game, how do the best basketball and netball players reduce the likelihood of torn muscles and tendons?
11. What would happen if the cartilage in your knee joint wore out?
12. Research and report on one of the following science careers: orthopaedic surgeon, physiologist, physiotherapist, occupational therapist, rheumatologist, fitness trainer.

13. Find out more about the structure and function of skeletal, smooth and cardiac muscle tissue.
14. What is dietary rickets and how is it caused?
15. Your musculoskeletal system consists of your skeletal system (bones and joints) and your skeletal muscle system (voluntary or striated muscle). Working together, these two systems protect your internal organs, maintain posture, produce blood cells, store minerals and enable your body to move. Use information in this subtopic and other resources to relate structural features to the functions of the following parts.

TABLE Parts of the musculoskeletal system and their functions

Part of system	Structural features	Function
Bones		
Cartilage		
Joints		
Skeletal muscles		

Fully worked solutions and sample responses are available in your digital formats.

4.12 Same job, different path

LEARNING INTENTION

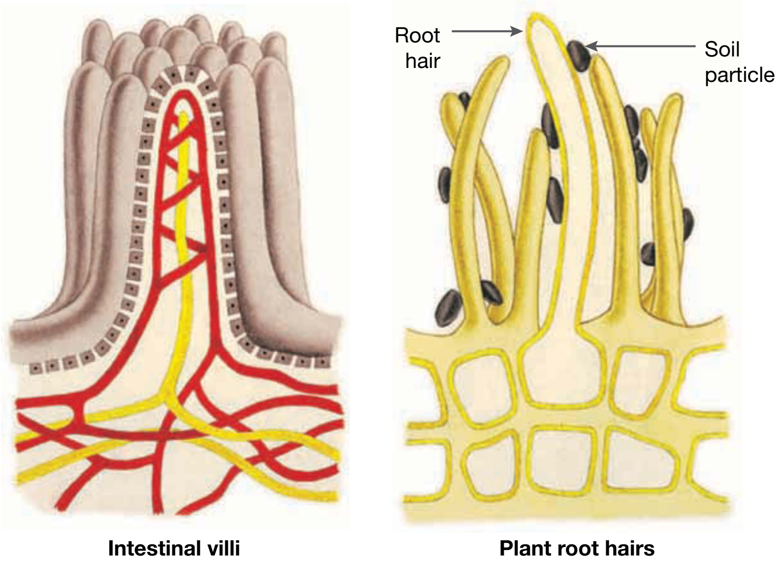
At the end of this subtopic you will be able to provide examples of how variations in the structures of the organs in the respiratory and digestive systems make them well suited to perform their specific tasks.

4.12.1 Patterns, order and organisation

Similar, but different? While organisms can have different solutions to life's challenges, these differences share similar patterns, order and organisation.

Organisms possess a variety of structures that help them to obtain the resources that they need to survive. While there are similarities and patterns in some of these structures, there are also differences. These differences provide examples of wonderful and creative solutions to the continual challenge of staying alive.

FIGURE 4.91 Similar structures? What might their function be?



Shaping clues

The structures of cells and tissues often provide clues to their function. For example, structures that are involved in absorption often have shapes that increase their surface area to volume ratio. Intestinal villi in humans and plant root hairs are examples of this. Can you see the similarities in figure 4.91? Can you think of other cells or tissues that also share this pattern?

4.12.2 Respiratory routes

Cellular respiration

glucose + oxygen → carbon dioxide + water + energy

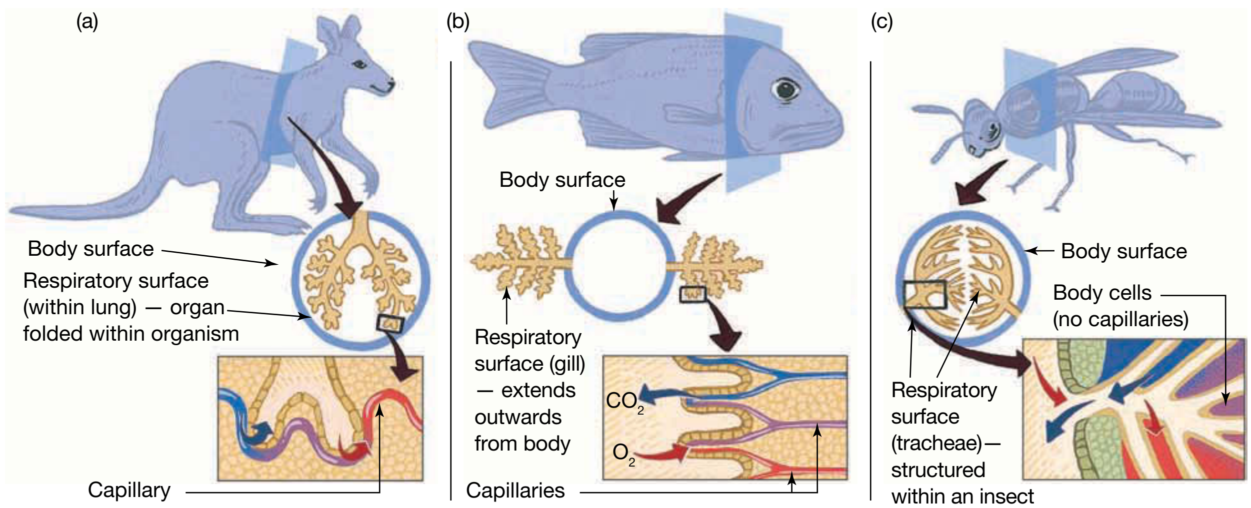
Cellular respiration is essential for life. Organisms require a supply of oxygen and a way to remove the carbon dioxide that is produced as waste. Although this gaseous exchange is essential, different types of organisms achieve it in different ways.

FIGURE 4.92 Flatworm

Unicellular organisms are small enough that gases such as oxygen and carbon dioxide can simply diffuse in and out of their cell. Likewise, some very thin multicellular organisms have many of their cells in direct contact with their environment. These organisms rely simply on diffusion for their exchange of gases. Flatworms, for example, do not need a respiratory system, as they use their whole body surface to obtain the oxygen they require from the water in which they live. Some other small animals, such as worms living on land, can exchange gases through their mucus-covered skin. Oxygen from the air dissolves in the mucus, while carbon dioxide seeps out. Tiny blood vessels in their skin transport the gases to and from the rest of the worm's body.

Other animals may have specialised gas exchange organs. Three main kinds of these organs are lungs in mammals and amphibians, gills in fish, and tracheae in insects. Examine figure 4.93 to compare the structure of these organs. How are they similar? How are they different?

FIGURE 4.93 Notice any similarities or differences in these gas exchange surfaces?



4.12.3 What do they eat?

Animals can be classified on the basis of their diet. **Herbivores** eat plants; **carnivores** eat other animals; **omnivores** eat both plants and animals. An animal's teeth can provide hints to the types of food that it eats. Observe the teeth in the skulls of the vertebrates shown in figure 4.94. Based on your observations, predict the types of food that they may eat.

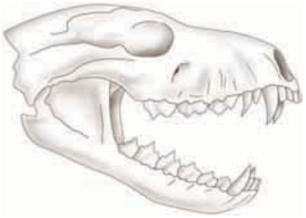
herbivore animal that eats only plants

carnivore animal that eats other animals

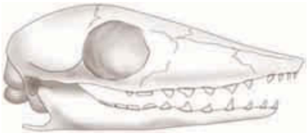
omnivore animal that eats plants and other animals

FIGURE 4.94 Skulls of vertebrates

(a) Wombat



(b) Tasmanian devil



(c) Numbat

(d) Human

Wombats are herbivores. They have large incisors for biting and cutting, but no canines. They also have large premolars and molars because the fibrous plant materials they eat need a lot of grinding. Tasmanian devils are carnivores. Because their prey is alive and moving, they possess large canines for stabbing and holding on to it. Their incisors are used for tearing meat. The molars and premolars in carnivores have cutting edges. Insectivores are carnivores that eat only insects. Their teeth are small and pointed so that they can crush the exoskeleton of the insect, which they then swallow whole. Even if you are a vegetarian, as a species, humans are considered to be omnivores. We possess all of the different types of teeth needed to break down both meat (from animal tissue) and plants.

4.12.4 Digestive differences

Although most vertebrates possess a digestive system that has a similar pattern, order and organisation, there may be differences that are related to nutritional needs and diet. Consider, for example, differences in the digestive systems of herbivores with diets that are high in plant material with lots of cellulose compared with those of carnivores with lots of animal flesh, high in protein. How would these compare with the digestive system of an organism that ate only nectar and pollen?

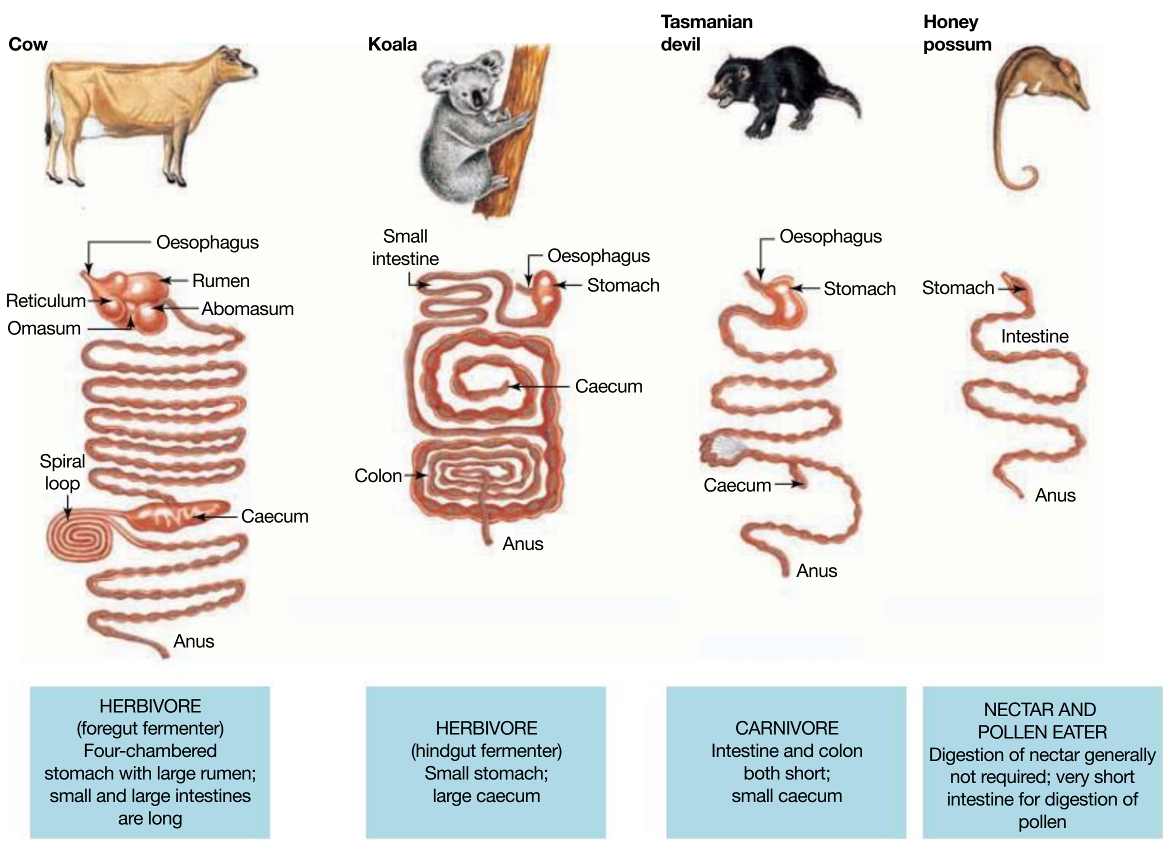
DISCUSSION

Some animals that live in water, such as sea anemones, have a digestive sac that acts as both a mouth and an anus. Find out more about the digestive system of sea anemones.

a. Describe how this digestive system is similar to that of humans and how it is different.

b. Suggest reasons for the differences.

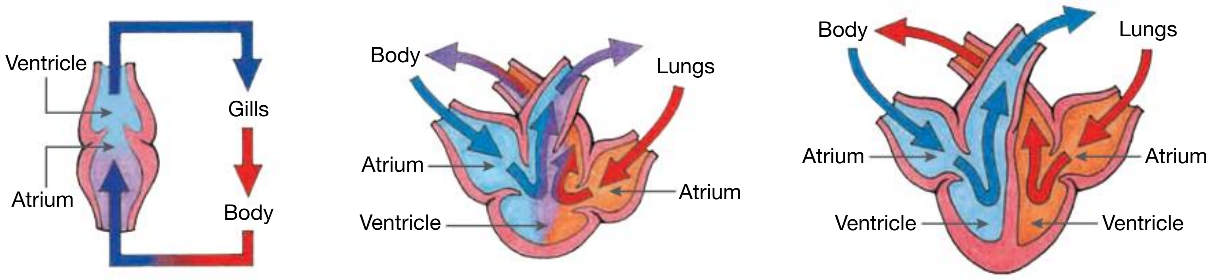
FIGURE 4.95 Notice any similarities or differences in these digestive systems?



4.12.5 Heart count?

Two, three or four? Not all animals have a four-chambered heart like you. Fish have a heart with two chambers and blood passes through the heart only once each time around the body. The hearts of amphibians and most reptiles are three chambered and allow oxygenated and deoxygenated blood to mix. Birds and mammals are similar to amphibians and most reptiles in that blood flows through the heart twice in each circulatory trip, but they possess a heart with four chambers that does not allow the mixing of blood. What do they share? How are they different?

FIGURE 4.96 Around we go … but which route do we take?



(a) A fish heart has two chambers. Note that blood passes through the heart only once for every circulation within the body.

(b) Amphibians and most reptiles have a three-chambered heart. Oxygenated and non-oxygenated bloods mix in the single ventricle as blood flows through the heart twice for every circulation within the body.

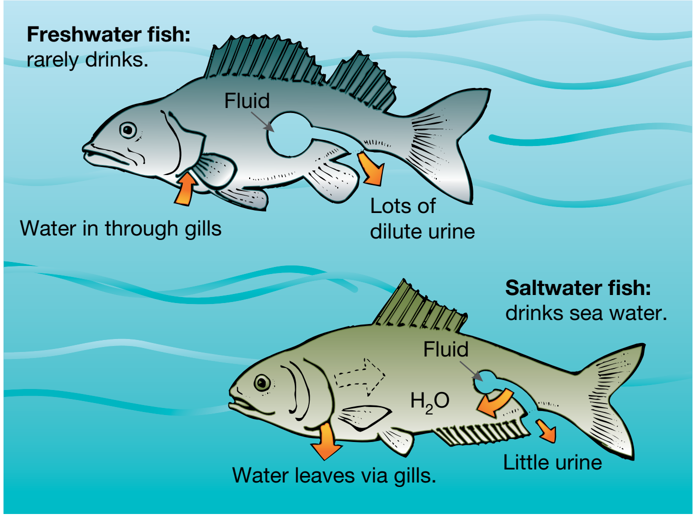
(c) Birds and mammals have a four-chambered heart and blood flows through the heart twice for every circulation within the body.

4.12.6 Throwing out the trash!

Different types of fish, living in different environments, can also differ in how they maintain their salt balance.

Proteins are involved in a variety of different chemical reactions that keep animals alive. **Ammonia** is formed when proteins break down. Ammonia is toxic to cells and requires either lots of water to release it into, or conversion into a less toxic form (such as urea or uric acid). Conversion into other forms costs the animal energy. Whichever form these **nitrogenous wastes** are in, they need to be removed from the animal's body.

FIGURE 4.97 Saltwater fish, such as snapper, drink sea water constantly and produce a small volume of urine. Freshwater fish, such as Murray cod, however, rarely drink, but make lots of urine.



Different types of animals use different strategies to remove nitrogenous wastes. This is linked to the amount of water available in the environments in which they live. Fish, for example, have a ready supply of water, so most fish release their nitrogenous waste as ammonia. The main nitrogenous waste excreted by humans is **urea**. Uric acid requires the least water for excretion. Insects, spiders and birds excrete their wastes as **uric acid**. The uric acid produced by birds is solid; it is stored in their bodies without diluting it with water and is excreted with their faeces. Animals living in dry environments, such as insects and snakes, also excrete their wastes in this form to conserve water.

FIGURE 4.98 Birds produce nitrogenous waste in a form of solid uric acid. What advantage to they gain from this?

protein chemical made up of amino acids needed for growth and repair of cells in living things

ammonia a nitrogenous waste product of protein break down

nitrogenous wastes waste products from protein break down, including ammonia, urea and uric acid

urea a nitrogen-containing substance produced by the breakdown of proteins and removed from the blood by the kidneys

uric acid a nitrogenous waste product of protein break down

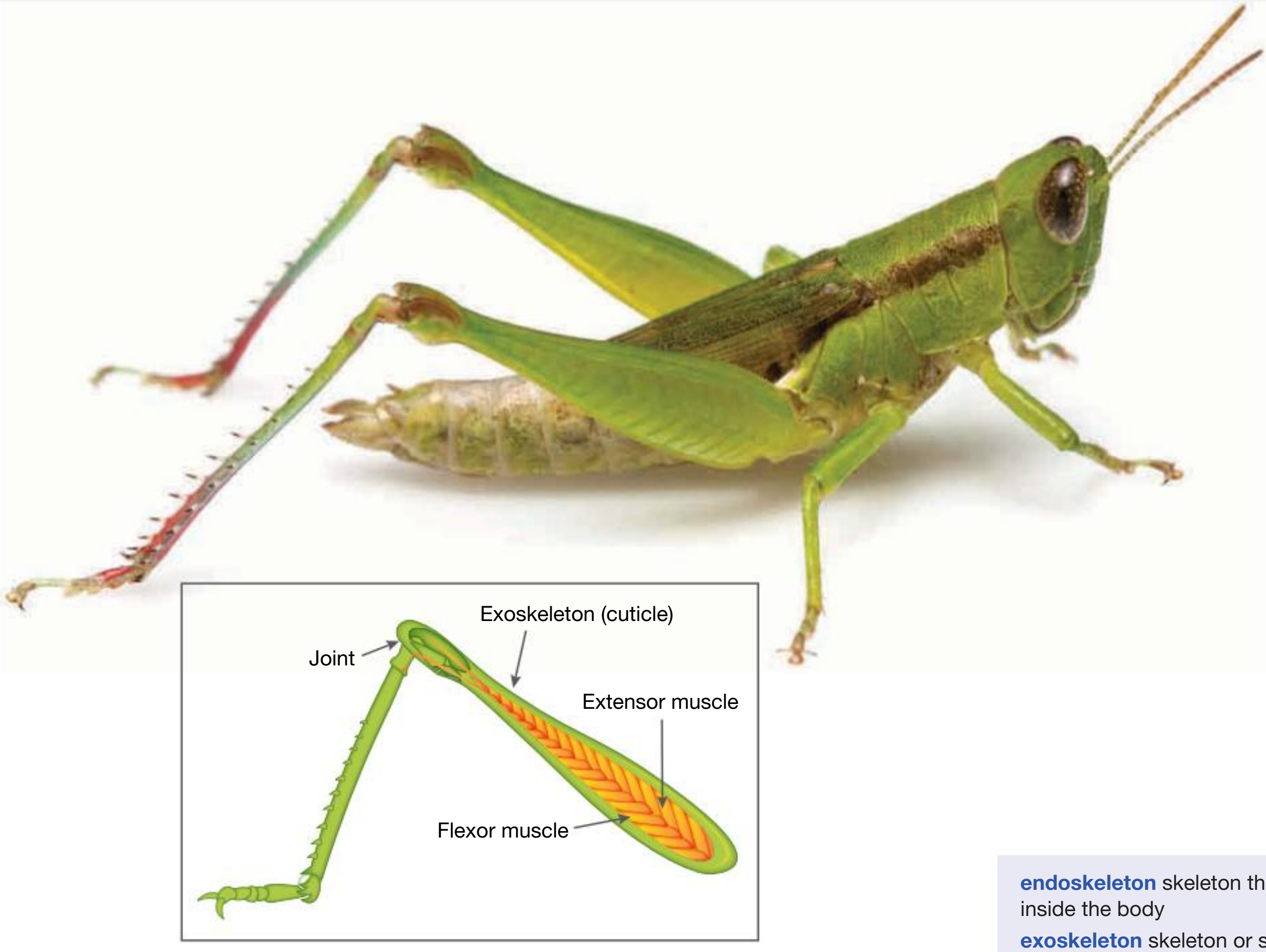
Have you noticed the pattern? The environment in which an organism lives, in this case the amount of water available, can play a role in how different species have evolved different strategies to the same problem of removal of their wastes.

4.12.7 Inside or out?

Are you wearing your skeleton on the inside or outside? Vertebrates (such as humans) have an internal backbone. They also have an internal skeleton called an **endoskeleton**. You can read more about our endoskeleton on the previous pages. Invertebrates, however, do not possess a backbone. Some invertebrates, such as grasshoppers and ants, have their skeleton on the outside of their bodies. Their external skeleton is called an **exoskeleton**. Other invertebrates, such as worms and jellyfish, do not have any skeleton at all.

Due to their different body structures, invertebrates can use their muscles in different ways to achieve movement. Worms and slugs, for example, can stretch and shorten muscles in certain parts of their body to bring about movement. Even though the muscles of jellyfish have no bones or other hard parts to attach to, they propel themselves through water by pumping water into their body cavities and releasing it suddenly. The muscles in insects, such as grasshoppers, are attached to their exoskeleton. They can extend their legs by contracting the extensor muscles and relaxing their flexor muscles.

FIGURE 4.99 The muscles in insects are attached to the exoskeleton, the outer covering of the body. This grasshopper can extend its leg by contracting the extensor muscle and relaxing the flexor muscle.



endoskeleton skeleton that lies inside the body

exoskeleton skeleton or shell that lies outside the body

elog-0533

INVESTIGATION 4.12

Inside or out?

Aim

To use models to investigate the differences between how muscles join to bones in animals with endoskeletons and exoskeletons

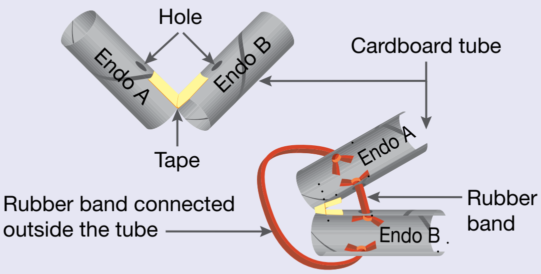
Materials

- 2 cardboard tubes, each at least 30 cm long
- sticky tape
- rubber bands
- large nail or other pointed object

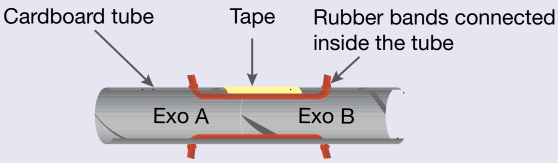
Method

1. Cut each cardboard tube into two pieces about 15 cm long.
2. Using the nail, make two holes on opposite sides of each tube. These should be about 5 cm from one end of each piece.
3. Label two pieces ‘Endo A’ and ‘Endo B’ and the other two pieces ‘Exo A’ and ‘Exo B’.
4. Tape Endo A and Endo B together on one side, so that they form a hinge at the ends with the small holes.
5. Cut two rubber bands and thread the cut ends through the holes from the outside.
6. Tie knots so that the rubber bands can’t pull back through the holes.
7. Tape Exo A and Exo B together in the same way as Endo A and Endo B.
8. Cut another two rubber bands and thread the cut ends through the holes so that they run *inside* the tube.
9. Make sure that they are stretched very tightly, and then tie knots on the outside of the tubes.

The rubber bands are like the muscles in your arm. They are attached to the bones on either side of your elbow. The arm bends at the joint when the muscle contracts.



The rubber bands are like the muscles in an insect’s limb. When a muscle contracts, the joint on which it operates straightens.



Results

1. When one rubber band contracts, what happens to the one on the opposite side?
2. Draw sketches of each tube and record your observations when the joint is moved.

Discussion

1. Describe how the two skeletons are different.
2. Identify the strengths and limitations of the method and how you could improve it.
3. Research and construct models that demonstrate how two different types of organisms have developed different strategies to solve the same ‘problem’ that is related to their survival.

Conclusion

Write a conclusion for this investigation.

on Resources

assess on Additional automatically marked question sets

4.12 Exercise

learnON

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 4, 7, 8, 10, 19	Questions 3, 6, 9, 11, 14, 16, 17, 20	Questions 5, 12, 13, 15, 18, 21, 22

Remember and understand

1. State whether the following statements are true or false. Justify any false responses.

Statement	True or false
a. The structures of cells and tissues often provide clues to their function.	
b. Structures involved in absorption often have shapes that increase their surface area to volume ratio.	
c. Unicellular organisms are small enough that gases such as oxygen and carbon dioxide can simply diffuse in and out of their cell.	
d. Respiratory surfaces in different animals can have shapes that make them efficient at exchanging gases such as oxygen and carbon dioxide.	
e. Intestinal villi in humans and root hairs in plants have shapes that reduce the surface area to volume ratio available for exchange of materials.	
f. Humans excrete their nitrogenous wastes as uric acid whereas birds excrete it as urea.	
g. Amphibians have a four-chambered heart whereas birds have a two chambered heart.	
h. Freshwater fish rarely drink and produce little urine, whereas saltwater fish constantly drink and produce lots of urine.	
i. Ammonia formed when proteins break down is toxic to cells.	
j. The strategies that different types of animals use to remove nitrogenous wastes is not influenced by the amount of water available in the environments in which they live.	

2. Place the following terms in order of simplest to most complex: cell, organ, system, multicellular organism, tissue.
3. Provide an example of how structure can give clues about function.
4. Write the word equation for cellular respiration.
5. Describe two key functions of gaseous exchange.
6. Suggest why there are differences between herbivores and carnivores in the structures of their digestive systems.
7. Name two organs belonging to each of the following systems.
   a. Respiratory system   **b.** Circulatory system   **c.** Excretory system

Apply and analyse

8. Why don't herbivores have canine teeth?
9. How do we know what different types of dinosaurs ate, even though they haven't existed for about 65 million years?

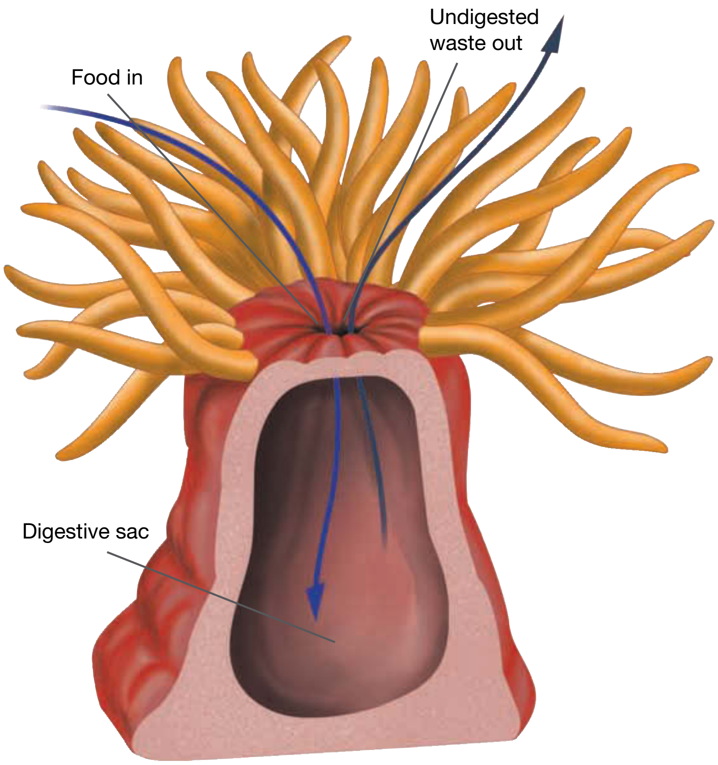
10. Select an organ (e.g. heart, lungs or stomach) and find out the answers to the following questions.
    a. What is the function of the organ?
    b. Which system does it belong to?
    c. What other organs are in the same system?
11. Complete the following table.

TABLE Features of the body systems of mammals and fish

Feature	Mammal	Fish
Number of chambers in the heart		
Times blood travels through the heart in each circulatory trip		
Name of gaseous exchange respiratory organ		

12. a. Outline the key differences between the structures of the digestive systems of a cow, a koala, a Tasmanian devil and a honey possum.
    b. Suggest reasons for the differences.
13. Some animals that live in water, such as sea anemones, have a digestive sac that acts as both a mouth and an anus.
    a. Find out more about the digestive system of sea anemones and construct a model to demonstrate your understanding of how it works.
    b. Describe how this digestive system is similar to that of humans and how it is different.
    c. Suggest reasons for the differences.

Sea anemone



14. SIS Construct a matrix table to compare the diets and teeth of herbivores, carnivores, omnivores and insectivores.
15. SIS Construct a table to summarise similarities and differences between the hearts and circulation of fish, amphibians and mammals.

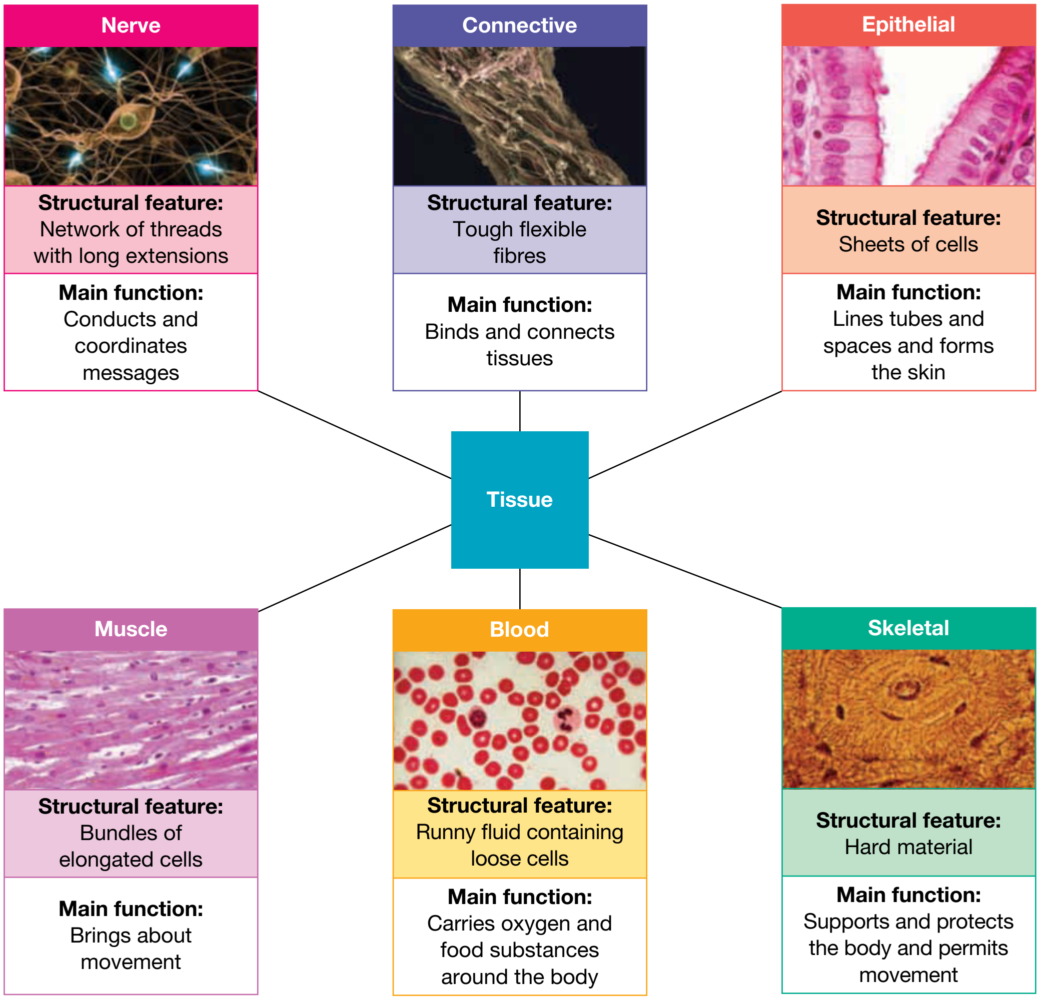
Evaluate and create

16. Research and prepare a poster on the hearts of different types of animals.
17. Find out about the different tissues and systems that exist in plants. Present your information using diagrams and lots of colour, on a poster or PowerPoint presentation. Be as creative as you can.
18. SIS In a small team, formulate scientific questions about how the structure of the heart, kidney or lungs is related to the function of that organ. Research these questions and present your findings to the class.

19. **SIS** Design and construct a model of one of the following systems: respiratory, excretory, reproductive, digestive.

20. a. Select one of the tissues in the mind map shown and find out more about what it does and how it works.

There are different types of tissues, each with structural features that suit them to their function.



b. Use your findings to write a brief play that other students in your class can act out.

21. Select an animal of your choice.
    a. Find out how it:
        i. detects stimuli
        ii. supports itself and moves
        iii. takes in oxygen and removes carbon dioxide
        iv. conducts messages from one part of its body to another.
    b. Construct a model or animation to demonstrate one of the functions listed above.

22. There are differences in the form in which groups of animals excrete nitrogenous wastes. Find out the differences between humans, freshwater fish, saltwater fish and insects. Communicate your findings using models or in a puppet play, documentary or animation.

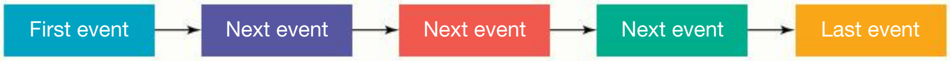
Fully worked solutions and sample responses are available in your digital formats.

4.13 Thinking tools — Flowcharts and cycle maps

4.13.1 Tell me

Flowcharts are a useful thinking tool, that can help to show the order in which events happen. They help you to diagrammatically display the order that stages occur. Sometimes they are called a flow map, a sequence chart or a chain of events.

FIGURE 4.100 Flowchart

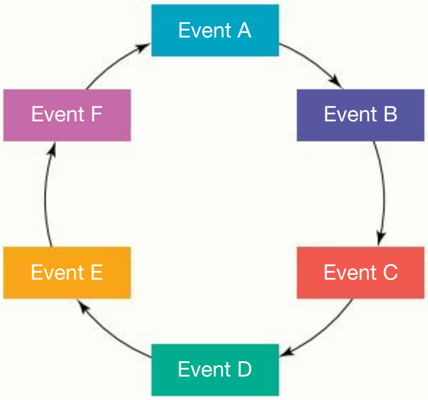


Flowcharts are similar to cycle maps in that the both show a sequence of events. However, cycle maps show the sequence of events repeated in the same order; flowcharts show only a linear sequence.

For example, you might use a flowchart to show:
- the respiratory system
- the excretory system.

But you may choose a cycle map to show:
- the movement of blood through the body.

FIGURE 4.101 Cycle map



4.13.2 Show me

To create a flowchart:
1. Decide in which direction your flowchart will be read — from left to right, from the bottom up or from the top down.
2. Write the first action of the process you are describing inside a box.
3. Write the next event in another box and join this by an arrow to the first box.
4. Repeat until you have reached the final event.

4.13.3 Let me do it

4.13 ACTIVITIES

1. a. Read through the information in subtopic 4.6 to refresh your memory on the structure and function of your heart.
   b. Use a flowchart to show the movement of blood through your body using the following labels: left atrium, right atrium, right ventricle, left ventricle, pulmonary artery, pulmonary vein, lungs, aorta, vena cava, from body, to body.
2. Construct a cycle map to outline the overall movement of blood through the heart.
   a. Use this information to design a working model of a human heart.
   b. Use a flowchart to plan the construction of your heart model.
3. a. Find out more about Leonardo da Vinci's models of the human heart.
   b. Use a flowchart to map changes in scientific ideas about the heart throughout history.

Fully worked solutions and sample responses are available in your digital formats.

4.14 Review

Access your topic review eWorkbooks

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-4746	ewbk-4748	ewbk-4750

on Resources

4.14.1 Summary

Patterns, order and organisation

- Multicellular organisms are made up of body systems that work together to keep them alive.
- Body systems are made up of organs, which are made up of tissues, which are made up of cells, which cannot survive independently of each other.
- Although the cells within a multicellular organism may have similar basic structures, they differ in size, shape, and in the number and types of organelles they contain.
- The variations in different types of cells and structures within them make them well suited to their function.
- The structures of cells and tissues often provide clues to their function. For example:

TABLE Structural features of body parts and their function

Structure	Structural details	Well suited to function
Muscle tissue	Contain cells with many mitochondria	So that the energy requirements of the tissue can be met
Human intestinal villi and plant root hairs	Shapes that increase their surface area to volume ratio	Both involved in absorption

- Body systems within multicellular organisms work together to keep them alive.
- Your digestive, circulatory, respiratory and excretory systems work together to provide your cells with nutrients and oxygen, and to remove wastes such as carbon dioxide.

Digestive system

- Your digestive system plays a key role in supplying your body with the nutrients it requires to function effectively. It is involved in breaking food down, so nutrients are small enough to be transported to, and used by, your cells.
- The main organs in your digestive system are your mouth (including teeth and tongue), oesophagus, stomach, small intestine, large intestine, pancreas, gall bladder and liver.
- Mechanical digestion involves physically breaking down the food into smaller pieces. Most of this process takes place in your mouth when your different types of teeth. For example:

TABLE Structural features of the teeth and their function

Type of teeth	Structure	Well suited to function
Incisors	Chisel edge and thin crown	Biting
Canines	Sharp point and cone-shaped crown	Tearing
Premolars and molars	Points or cusps that fit together in upper and lower jaws	Crushing and grinding

- Chemical digestion involves the use of chemicals called enzymes to break down food into small molecules.
- Most nutrients are absorbed into your bloodstream in the last of your small intestine, which is lined with finger-like projections called villi.
- The shape of villi increases the surface area through which nutrients can diffuse into tiny blood vessels called capillaries, which transport them to other parts of your body.

Circulatory system

- Your circulatory system is responsible for transporting oxygen and nutrients to your body's cells, and wastes such as carbon dioxide away from them.
- The main organs in your circulatory system are your blood, blood vessels and heart.
- Blood is made up of red blood cells (erythrocytes), white blood cells (leucocytes), blood platelets and the plasma that they all float in.
- Red blood cells are red because they contain an iron-containing pigment called haemoglobin, which reacts with oxygen to form oxyhaemoglobin.
- The structure of red blood cells makes them well suited to perform their oxygen-transporting role. For example:

TABLE Structural features of red blood cells and their function

Structural details of red blood cells	Well suited to function
Biconcave shape	Large surface area to volume ratio
Lack of a nucleus	Increases the available space for haemoglobin and hence oxygen
Small size	Enables them to fit inside tiny capillaries

- Involved in fighting disease, white blood cells contain a nucleus and are larger and fewer in number than red blood cells.
- Platelets in the blood help it to clot and plug the damaged blood vessel.
- Blood cells are transported in blood vessels to and from your heart.
- The major types of blood vessels are arteries, veins and capillaries.

TABLE Structural features of the circulatory system and their function

Structure	Structural details	Well suited to function
Arteries	Thick, elastic, muscular walls	Carry blood under high pressure away from the heart
Veins	Valves	Helps prevent the backflow of blood
Capillaries	Only one cell thick	The site of exchange of materials to and from cells

- The structure of your heart is also well suited to its function.

TABLE Structural features of the heart and their function

Structural details of heart	Well suited to function
Two pumps	Right side for deoxygenated blood and left side for oxygenated blood
Left side more muscular than right side	The right side of the heart pumps deoxygenated blood a short distance to the lungs; whereas, the left side pumps oxygenated blood out to the whole body.
Valves	Helps prevent the back flow of blood

Respiratory system

- Your respiratory system is responsible for getting oxygen into your body and carbon dioxide out. This occurs when you inhale and exhale.
- The main organs in your respiratory system are your trachea and lungs (bronchi, bronchioles and alveoli).
- The large surface area to volume ratio of alveoli and their closeness to capillaries, make them well suited to their role in gas exchange.

Excretory system

- The excretory systems removes waste products from a variety of chemical reactions that your body needs to stay alive.
- The main organs of your excretory system are your skin, lungs, liver and kidneys.
- Skin is involved in the excretion of salts and water as sweat; lungs in the excretion of carbon dioxide; the liver in breaking down toxins for excretion, and kidneys in the excretion of the unused waste products of chemical reactions (e.g. urea) and any other chemicals that may be in excess (including water).

Musculoskeletal system

- Your musculoskeletal system consists of both your bones and various types of muscles throughout your body, which provide both support and protection for your organs.

Same job, different path

- Organisms possess a variety of structures that help them to obtain the resources they need to survive. While there are similarities and patterns in some of those structures, there are also differences.
- While unicellular organisms are small enough to use diffusion to obtain their oxygen and remove carbon dioxide waste, multicellular organisms have evolved a variety of specialised structures to achieve this.
- Some animals have developed specialised gas exchange organs that all have a gas exchange surface with high surface area to volume ratios. For example:

TABLE Gas exchange organs of different animals

Animal	Specialised gas exchange organ
Mammals and amphibians	Lungs
Fish	Gills
Insects	Tracheae

- Likewise, variations in the structures within digestive systems make them well suited to perform their task for the diets of different types of animals. For example:
  - the size and types of teeth
  - size of the stomach
  - length of the small intestine
  - and presence of a large caecum.

4.14.2 Key terms

absorption the taking in of a substance, for example from the intestine to the surrounding capillaries
alimentary canal passage from the mouth to the anus. Digestion of food occurs as it moves through the canal.
alveoli tiny air sacs in the lungs at the ends of the narrowest tubes. Oxygen moves from alveoli into the surrounding blood vessels, in exchange for carbon dioxide. Singular = alveolus.
ammonia a nitrogenous waste product of protein break down
amylases an enzyme in saliva that breaks starch down into sugar
anus the final part of the digestive system, through which faeces are passed as waste
aorta a large artery through which oxygenated blood is pumped at high pressure from the left ventricle of the heart to the body
arteries hollow tubes (vessels) with thick walls carrying blood pumped from the heart to other body parts
arterioles vessels that transport oxygenated blood from the arteries to the capillaries
arthritis a condition in which inflammation of the joints causes them to swell and become painful
asthma narrowing of the air pipes that join the mouth and nose to the lungs
atom a very small particle that makes up all things. Atoms have the same properties as the objects they make up.
ball and socket joints joints where the rounded end of one bone fits into the hollow end of another
bicuspid a type of valve with two cusps (points). The valve between the heart's left atrium and left ventricle is a bicuspid valve.

bile a substance produced by the liver that helps digest fats and oils
bladder sac that stores urine
blood cells living cells in the blood
blood pressure measures how strongly the blood is pumped through the body's main arteries
blood vessels the veins, arteries and capillaries through which the blood flows around the body
body system groups of organs, within our bodies that carry out specific functions
bolus round, chewed-up ball of food made in the mouth that makes swallowing easier
bone marrow a substance inside bones in which blood cells are made
bones the pieces of hard tissue that make up the skeleton of a vertebrate
Bowman's capsule a cup-like structure at one end of a nephron within the kidney, surrounding the glomerulus. It serves as a filter to remove wastes and excess water.
breathing movement of muscles in the chest causing air to enter the lungs and the altered air in the lungs to leave. The air entering the lungs contains more oxygen and less carbon dioxide than the air leaving the lungs.
brittle breaks easily into many pieces
bronchi the narrow tubes through which air passes from the trachea to the smaller bronchioles and alveoli in the respiratory system. Singular = bronchus.
bronchioles small branching tubes in the lungs leading from the two larger bronchi to the alveoli
burping release of swallowed gas through the mouth
calcium an element occurring in limestone, chalk, also present in vertebrates and other animals as a component of bone, shell etc. It is necessary for nerve conduction, heartbeat, muscle contraction and many other physiological functions.
capillaries numerous tiny blood vessels, that are only a single cell thick to allow exchange of materials to and from body cells. Every cell of the body is supplied with blood through capillaries.
carbon dioxide a colourless gas in which molecules (CO_2) are made up of one carbon and two oxygen atoms; essential for photosynthesis and a waste product cellular respiration. The burning of fossil fuels also releases carbon dioxide.
carcinogens chemicals that cause cancer
cardiac muscle special kind of muscle in the heart that never tires. It is involved in pumping blood through the heart.
carnivore animal that eats other animals
cartilage a waxy, whitish, flexible substance that lines or connects bone joints or, in some animals such as sharks, replaces bone as the supporting skeletal tissue. The ears and tips of noses of people are shaped by cartilage.
cell the smallest unit of life. Cells are the building blocks of living things. There are many different sizes and shapes of cells.
cellular respiration a series of chemical reactions in which the chemical energy in molecules such as glucose is transferred into ATP molecules, which is a form of energy that the cells can use
cellulose a natural substance that keeps the cell wall of plants rigid
chemical digestion the chemical reactions changing food into simpler substances that are absorbed into the bloodstream for use in other parts of the body
circulatory system the heart, blood and blood vessels which are responsible for circulating oxygen and nutrients to your body cells and carbon dioxide and other wastes away from them
colon the part of the large intestine where food mass passes from the small intestine, and where water and other remaining essential nutrients are absorbed into the body
denatured describes the condition of proteins after they have been overheated
deoxygenated blood blood from which some oxygen has been removed
diaphragm flexible, dome-shaped, muscular layer separating the chest and the abdomen. It is involved in breathing.
diarrhoea excessive discharge of watery faeces
diastolic pressure the lower blood pressure reading during relaxation of the heart muscles
digestion breakdown of food into a form that can be used by an animal. It includes both mechanical digestion and chemical digestion.
digestive system a complex series of organs and glands that processes food to supply the body with the nutrients it needs to function effectively
electrocardiogram (ECG) graph made using the tiny electrical impulses generated in the heart muscle, giving information about the health of the heart

emphysema condition in which the air sacs in the lungs break open and join together, reducing the amount of oxygen taken in and carbon dioxide removed
emulsify combine two liquids that do not normally mix easily
endocrine system the body system of glands that produce and secrete hormones into the bloodstream to regulate processes in various organs
endoskeleton skeleton that lies inside the body
enzymes special chemicals that speed up reactions but are themselves not used up in the reaction
epiglottis leaf-like flap of cartilage behind the tongue that closes the air passage during swallowing
erythrocytes red blood cells
excretion removal of wastes from the body
excretory system the body system that removes waste substances from the body
exoskeleton skeleton or shell that lies outside the body
flatulence release of gas through the anus. This gas is produced by bacteria in the large intestine.
fracture a break in a bone
gall bladder a small organ that stores and concentrates bile within the body
gastrointestinal tract also called the digestive tract and the alimentary canal, tubular passage that starts with the mouth and ends with the anus; it intakes and digests food (absorbing energy and nutrients) and expels waste
glomerulus a cluster of capillaries in the kidney that acts as a filter to remove wastes and excess water
glucose a six-carbon sugar (monosaccharide) that acts as a primary energy supply for many organisms
greenstick fracture a break that is not completely through the bone, often seen in children
haemodialysis the process of passing blood through a machine to remove wastes
haemoglobin the red pigment in red blood cells that carries oxygen
heart a muscular organ that pumps deoxygenated blood to the lungs to be oxygenated and then pumps the oxygenated blood to the body
heartbeat contraction of the heart muscle occurring about 60–100 times per minute
heartburn burning sensation caused by stomach acid rising into the oesophagus
herbivore animal that eats only plants
hinge joints joints in which two bones are connected so that movement occurs in one plane only
immovable joints joints that allow no movement except when absorbing a hard blow
involuntary muscles muscles not under the control of the will; they contract slowly and rhythmically. These muscles are at work in the heart, intestines and lungs.
joints region where two bones meet
kidneys body organs that filter the blood, removing urea and other wastes
'lub dub' the sound made by the heart valves as they close
large intestine the penultimate part of the digestive system, where water is absorbed from the waste before it is transported out of the body
left atrium upper left section of the heart where oxygenated blood from the lungs enters the heart
left ventricle lower left section of the heart, which pumps oxygenated blood to all parts of the body
leucocytes white blood cells
ligament band of tough tissue that connects the ends of bones or keeps an organ in place
lipases enzymes that break fats and oils down into fatty acids and glycerol
lipids type of nutrients that include fats and oils
liver largest gland in the body. The liver secretes bile for digestion of fats, builds proteins from amino acids, breaks down many substances harmful to the body and has many other essential functions.
lungs the organ for breathing air. Gas exchange occurs in the lungs.
mechanical digestion digestion that uses physical factors such as chewing with the teeth
minerals substances that make up rocks. Each mineral has its own chemical make-up.
molecule two or more atoms joined (bonded) together
mouth the opening of the alimentary canal through which food is taken into the body
multicellular organisms living things comprised of specialised cells that perform specific functions
muscles tissue consisting of cells that can shorten
musculoskeletal system consists of the skeletal system (bones and joints) and the skeletal muscle system (voluntary or striated muscle). Working together, these two systems protect the internal organs, maintain posture, produce blood cells, store minerals and enable the body to move.
nephrons the filtration and excretory units of the kidney
nervous system neurons, nerves and the brain, which are responsible for detecting and responding to both internal and external stimuli to keep us alive

nitrogenous wastes waste products from protein break down, including ammonia, urea and uric acid
nutrients substances that provide energy and chemicals that living things need to stay alive, grow and reproduce
oesophagus part of the digestive system composed of a tube connecting the mouth with the stomach
omnivore animal that eats plants and other animals
organelle any specialised structure in a cell that performs a specific function
organs structures, composed of tissue, that perform specific functions
ossification hardening of bones
osteoporosis loss of bone mass that causes bones to become lighter, more fragile and easily broken
oxygen atom that forms molecules (O_2) of tasteless and colourless gas; it is essential for cellular respiration for most organisms and is a product of photosynthesis
oxygenated blood the bright red blood that has been supplied with oxygen in the lungs
pacemaker electronic device inserted in the chest to keep the heart beating regularly at the correct rate. It works by stimulating the heart with tiny electrical impulses.
pancreas a large gland in the body that produces and secretes the hormone insulin and an important digestive fluid containing enzymes
peristalsis the process of pushing food along the oesophagus or small intestine by the action of muscles
phosphorus a substance that plays an important role in almost every chemical reaction in the body. Together with calcium, it is required by the body to maintain healthy bones and teeth.
pivot joint joint that allows a twisting movement
plasma the yellowish liquid part of blood that contains water, minerals, food and wastes from cells
platelets small bodies involved in blood clotting. They are responsible for healing by clumping together around a wound.
product new chemical substance that results from a chemical reaction
proteases enzymes that break proteins down into amino acids
protein chemical made up of amino acids needed for growth and repair of cells in living things
pulmonary artery the vessel through which deoxygenated blood, carrying wastes from respiration, travels from the heart to the lungs
pulmonary vein the vessel through which oxygenated blood travels from your lungs to the heart
pulse alternating contraction and expansion of arteries due to the pumping of blood by the heart
rectum the final section of the digestive system, where waste food matter is stored as faeces before being excreted through the anus
red blood cells living cells in the blood that transport oxygen to all other living cells in the body
reproductive system body system in which human males and females possess different reproductive organs with the overall aim of reproducing the offspring of the next generation
respiratory system the lungs and associated structures that are responsible for getting oxygen into your body and carbon dioxide out
right atrium upper right section of the heart where deoxygenated blood from the body enters
right ventricle lower right section of the heart, which pumps deoxygenated blood to the lungs
saliva watery substance in the mouth that contains enzymes involved in the digestion of food
salivary glands glands in the mouth that produce saliva
semilunar a type of valve that is half-moon shaped. The aortic valve is semilunar and is located between the heart's left ventricle and aorta.
skeletal muscle system voluntary or striated muscle
skeletal system consists of the bones and joints
skeleton the bones or shell of an animal that support and protect it as well as allowing movement
skin external covering of a vertebrate's body
small intestine the part of the digestive system between the stomach and large intestine, where much of the digestion of food and absorption of nutrients takes place
sprains injury caused by tearing a ligament
stem cells undeveloped cells found in blood and bone marrow that can reproduce themselves indefinitely
stomach a large muscular organ that churns and mixes food with gastric juice to start to break down protein
substrate substance acted upon by an enzyme
synovial fluid the liquid inside the cavity surrounding a joint that helps bones to slide freely over each other
systolic pressure the higher blood pressure reading during contraction of the heart muscles
teeth hard structures within the mouth that allow chewing
tendons tough rope-like tissue connecting a muscle to a bone

tennis elbow repeated grasping and bending back of your wrist can lead to the inflammation of the tendon that connects the muscles of your forearm to the bone in your upper arm causing pain
tissue group of cells of similar structure that perform a specific function
torn hamstring a common sporting injury caused by overstretching the hamstring muscle, which joins the pelvis to the knee joint
trachea narrow tube from the mouth to the lungs through which air moves
tricuspid a type of valve with three cusps (points). The valve between the heart's right atrium and right ventricle is a tricuspid valve.
urea a nitrogen-containing substance produced by the breakdown of proteins and removed from the blood by the kidneys
ureters tubes from each kidney that carry urine to the bladder
urethra tube through which urine is emptied from the bladder to the outside of the body
uric acid a nitrogenous waste product of protein break down
urination passing of urine from the bladder to the outside of the body
urine yellowish liquid, produced in the kidneys. It is mostly water and contains waste products from the blood such as urea, ammonia and uric acid.
valves flap-like folds in the lining of a blood vessel or other hollow organ that allow a liquid, such as blood, to flow in one direction only
varicose veins expanded or knotted blood vessels close to the skin, usually in the legs. They are caused by weak valves that do not prevent blood from flowing backwards.
veins blood vessels that carry blood back to the heart. They have valves and thinner walls than arteries.
vena cava large vein leading into the top right chamber of the heart
venules small veins
villi tiny finger-like projections from the wall of the intestine that maximise the surface area of the structure to increase the efficiency of nutrient absorption. Singular = villus.
vital capacity the largest volume of air that can be breathed in or out at one time
vitamin D a nutrient that regulates the concentration of calcium and phosphate in the bloodstream and promotes the healthy growth and remodelling of bone
voluntary muscle muscle attached to bones; it moves the bones by contracting and is controlled by an animal's thoughts
vomiting the forceful ejection of matter from the stomach through the mouth
white blood cells living cells that fight bacteria and viruses as part of the human body's immune system

on Resources

Digital document	Key terms glossary (doc-34916)
eWorkbooks	Study checklist (ewbk-4739) Crossword (ewbk-4742) Word search (ewbk-4744) Literacy builder (ewbk-4740)
Practical investigation eLogbook	Topic 4 Practical investigation eLogbook (elog-0520)

4.14 Exercise

learnON

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3, 4, 5, 6, 7, 23, 24	Questions 8, 10, 11, 12, 14, 15, 18, 20, 21, 25	Questions 9, 13, 16, 17, 19, 22, 26

Remember and understand

1. Identify whether the following statements are true or false. Justify any false responses.

Statement	True or false
a. Multicellular organisms are made up of different types of cells that cannot survive independently of each other so they need to work together.	
b. The cells that make multicellular organisms are all the same.	
c. The shape and size of different types of cells within a multicellular organism, and differences in structures within them, make them well suited to their specific function.	
d. Tissues are structures within cells that have a particular job to do.	
e. Organelles are a collection of similar cells that perform a particular function.	
f. Organs are made up of different types of tissues grouped together to perform a particular function.	
g. Systems are made up of different organs working together to perform a specialised function to keep an organism alive.	
h. The excretory system supplies your body with the nutrients it requires to function effectively.	
i. The stomach, liver, gall bladder, intestines and pancreas are all organs of the respiratory system.	
j. When you burp, some of your stomach acid can rise into your oesophagus and cause heartburn.	

2. Use a flowchart to show the relationship between the following, from most complex, to least complex: cells, systems, multicellular tissues, organisms, organs.
3. Identify which description matches the term.

Term	Description
a. Tissue	**A.** A collection of similar cells that perform a specific function
b. Organ	**B.** Different organs working together to perform a specialised function to keep an organism alive
c. System	**C.** Different types of tissues grouped together to perform a specific function
d. Organelle	**D.** Structures within cells that have a specific function

4. Match the type of tissue with its function.

Tissue	Function
a. Blood tissue	A. To bind and connect tissues together
b. Connective tissue	B. To bring about movement
c. Epithelial tissue	C. To carry oxygen and food substances around the body
d. Muscle tissue	D. To conduct and coordinate messages
e. Nerve tissue	E. To line tubes and spaces, and form the skin
f. Skeletal tissue	F. To support and protect the body and permit movement

5. Match the organs with their system.

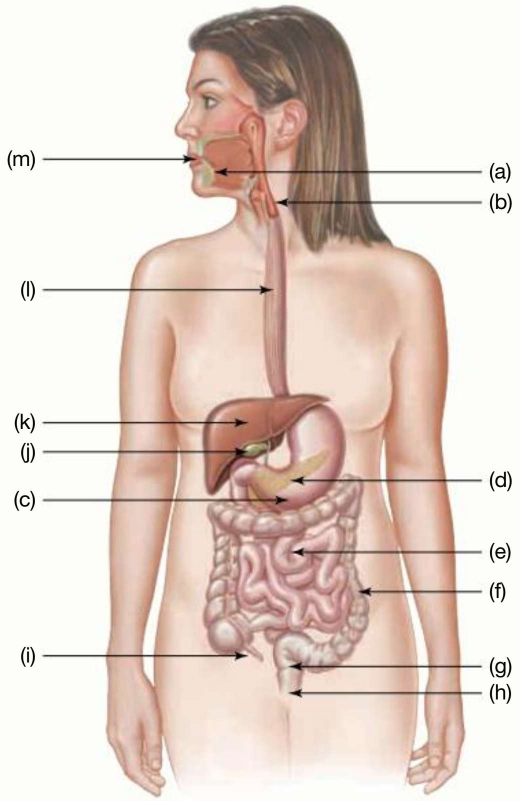
Tissue	System
a. Brain, spinal cord	A. Circulatory system
b. Heart, blood vessels	B. Digestive system
c. Liver, kidneys, skin, lungs	C. Excretory system
d. Lungs, trachea	D. Nervous system
e. Stomach, liver, gall bladder, intestines, pancreas	E. Reproductive system
f. Testes, ovaries	F. Respiratory system

6. Match the system with its function.

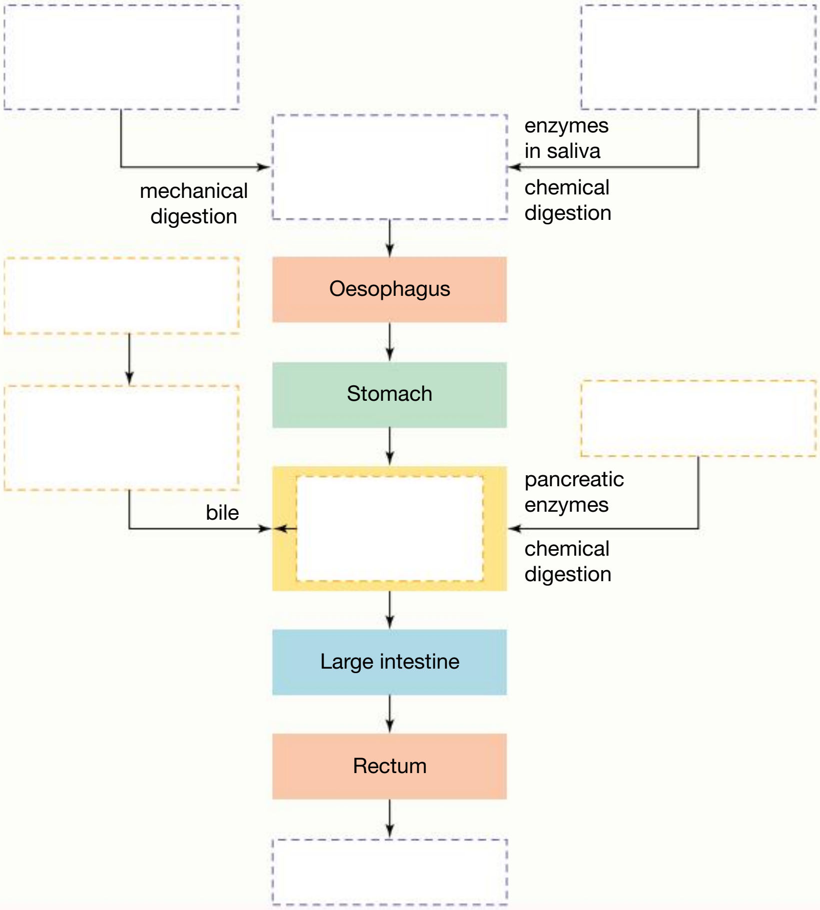
System	Function
a. Circulatory system	A. Removes waste products from your body
b. Digestive system	B. Supplies your body with nutrients it requires to function effectively
c. Excretory system	C. Takes oxygen in and removes carbon dioxide from your body
d. Respiratory system	D. Transports oxygen and nutrients to your body cells and transports wastes such as carbon dioxide from them.

7. Use a flowchart to show the correct sequence for the following parts of the digestive system: anus, mouth, oesophagus, stomach, small intestine, large intestine.

8. Label (a–m) this diagram of the human digestive tract.



9. Match the labels to the digestive system flowchart figure: anus, gall bladder, liver, mouth, pancreas, salivary glands, small intestine, teeth



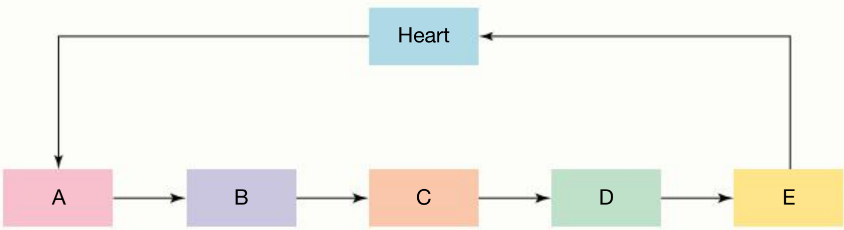
10. Match the description to the process.

Process	Description
a. Absorption of nutrients	A. Physically breaking down food into smaller pieces
b. Assimilation	B. Occurs through villi in the small intestine into capillaries
c. Chemical digestion	C. Taking food into your body
d. Egestion	D. Use of chemicals called enzymes to break down food into small molecules
e. Ingestion	E. Undigested materials and wastes are removed from the body
f. Mechanical digestion	F. Conversion of broken-down food into chemicals in your cells

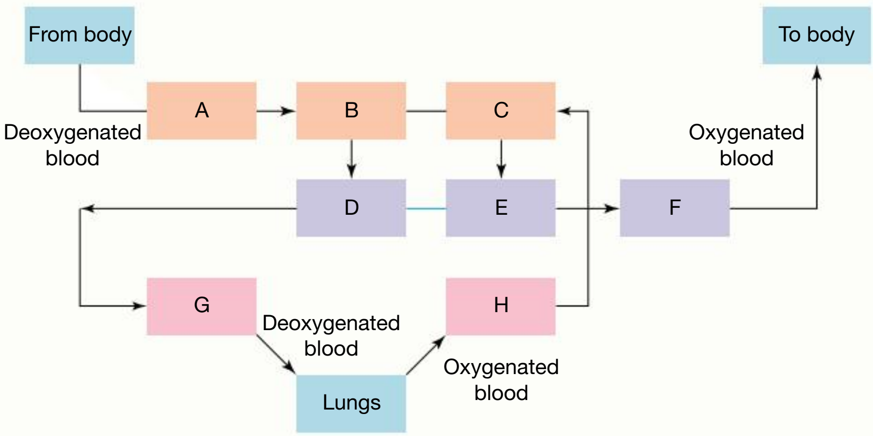
11. Match the organ to its function.

Function	Organ
a. Makes bile, stores glycogen and breaks down toxins	A. Small intestine
b. Makes enzymes used in the small intestine	B. Gall bladder
c. Stores bile made in the liver until needed by the small intestine	C. Large intestine
d. Stores faeces	D. Pancreas
e. Stores undigested food and waste while bacteria make some vitamins	E. Stomach
f. Temporary storage of food and where protein digestion begins	F. Liver
g. Tube that takes food from mouth to stomach	G. Rectum
h. Where the breakdown of starch and protein is finished and fat breakdown occurs	H. Oesophagus

12. Match the labels to its position in the flowchart: artery, body cells, artery capillary, vein capillary, vein.



13. Label the figure provided.



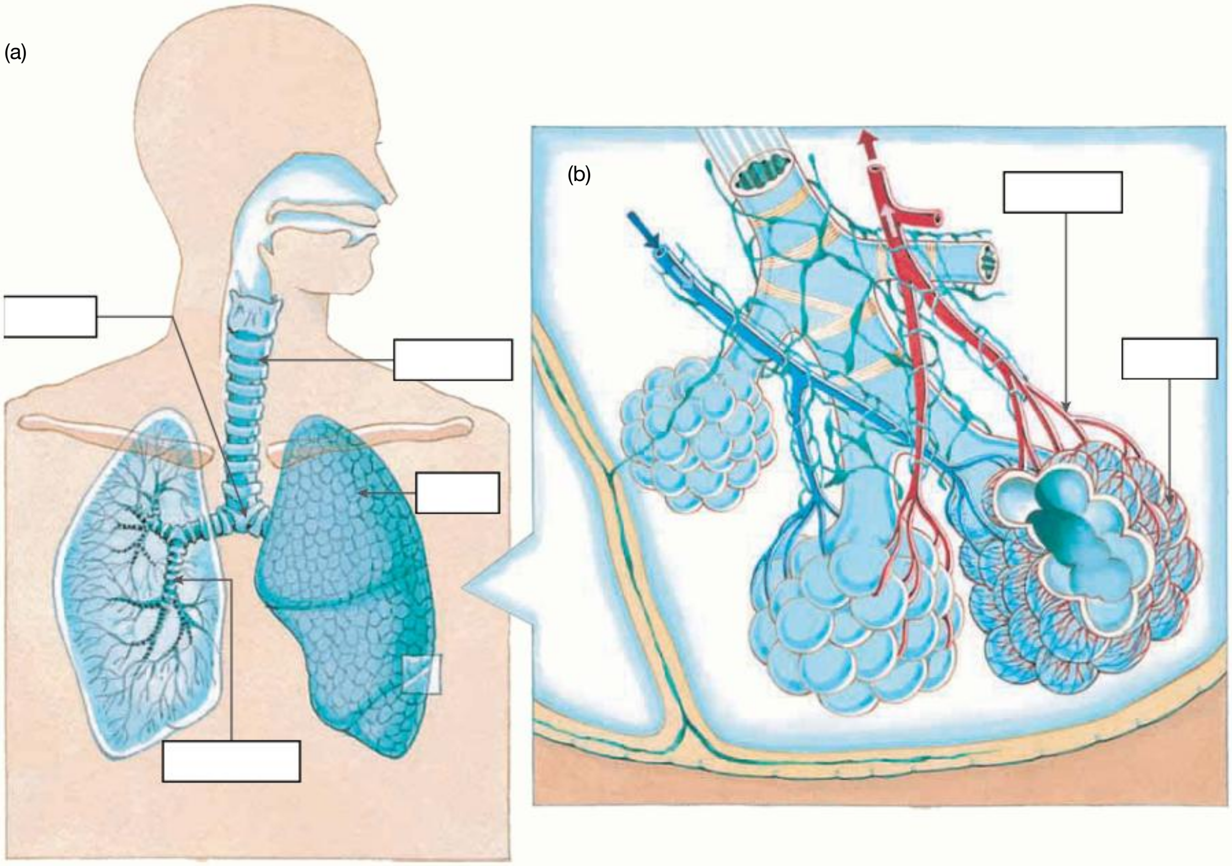
14. Match the term with its most appropriate description.

Term	Description
a. Artery	A. Cells involved in transporting oxygen throughout the body
b. Atrium	B. The bottom two chambers of the heart
c. Capillary	C. The top two chambers of the heart
d. Heart	D. Blood vessel that exchanges substances with cells
e. Red blood cell	E. Cells involved in production against infection
f. Vein	F. Organ that pumps blood around the body
g. Ventricles	G. Blood vessel that takes blood to the heart
h. White blood cells	H. Blood vessel that takes blood away from the heart

15. Match each term with the description of its function.

Term	Description
a. Kidney	A. Transports urine from the kidneys to bladder
b. Bladder	B. When urine moves from the bladder, through the urethra and out of the body
c. Urethra	C. Filters the blood and produces urine
d. Ureter	D. Stores urine
e. Urine	E. Transports urine from bladder to outside body
f. Urination	F. Watery fluid produced by kidneys that contains unwanted substances

16. Suggest labels for the diagrams shown.

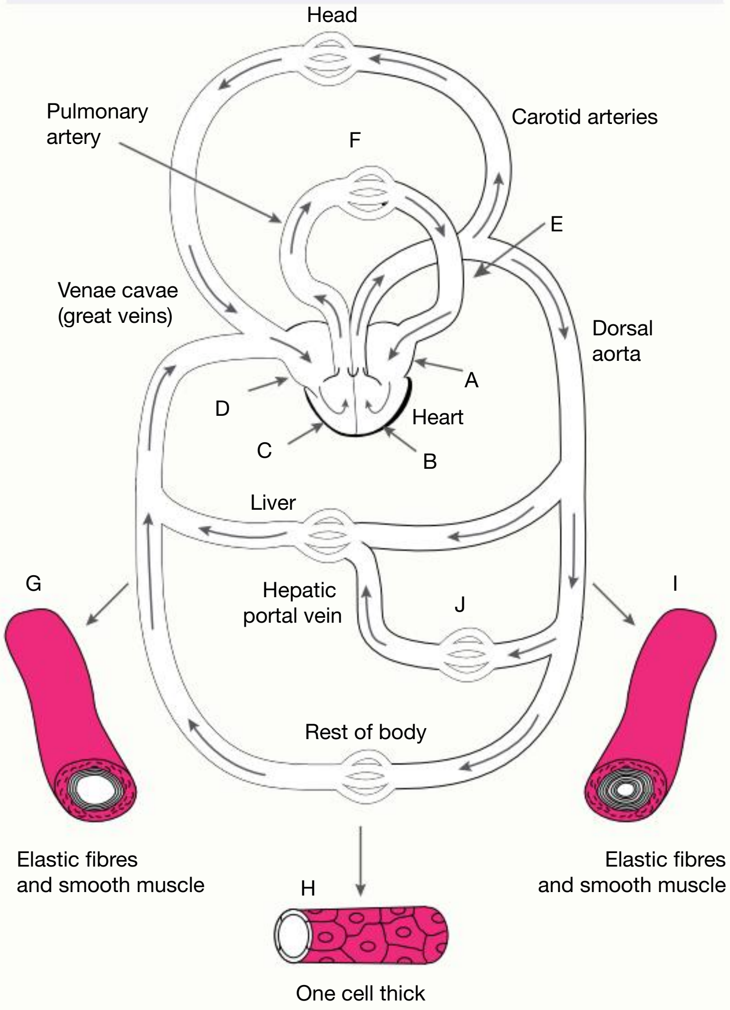


17. Explain how the structure of each of the following makes them well suited to their function.
   a. Red blood cells
   b. Human intestinal villi
   c. Arteries
   d. Capillaries
   e. Alveoli
   f. Molar teeth

Apply and analyse

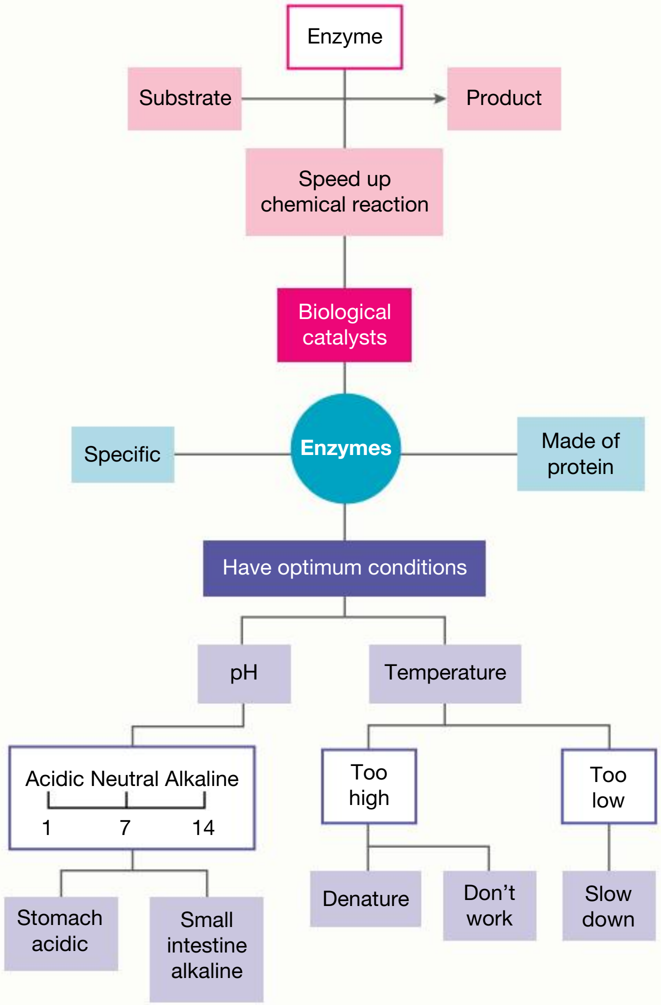
18. Make a copy of the diagram provided in this question in your workbook.
   a. Label the lettered parts (A–J) of the human circulatory system and blood vessels on your diagram.
   b. Use a red pencil to colour in the blood vessels with oxygenated blood, and a blue pencil for those with deoxygenated blood.
   c. State whether the blood in the following blood vessels is deoxygenated or oxygenated.
      i. Aorta
      ii. Pulmonary artery
      iii. Pulmonary vein
      iv. Vena cava
      v. Carotid arteries
   d. Draw a table that shows the differences in structure and function of the arteries, veins and capillaries.

The human circulatory system



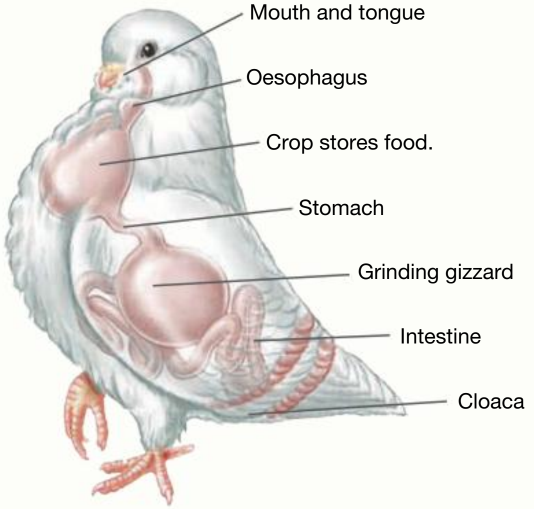
Evaluate and create

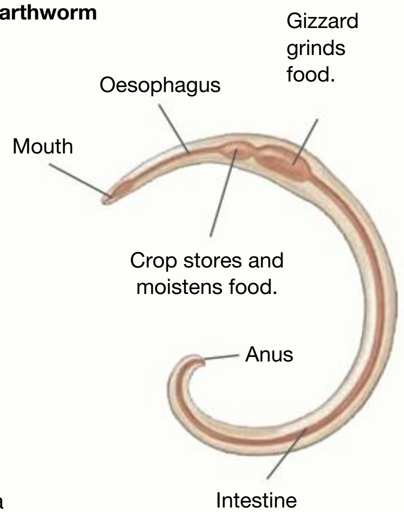
19. The process of replacing oxygen with carbon dioxide is called gas exchange. Some animals exchange gases through lungs or gills. Some other animals exchange gases through their skin, and yet others through rows of air holes along both sides of their bodies.
    Investigate how animals and insects exchange gases to create a mind map and answer the following questions.
    a. Construct a mind map, poster or PowerPoint presentation that summarises your findings on how at least five different animals achieve their exchange of gases.
    b. Why do frogs need lungs when they can exchange gases through their skin?
    c. Why can't fish survive in the air?
    d. Why can't humans breathe under water without air tanks?
    e. How is gas exchange in insects similar to that in humans?
20. Carefully examine the diagram shown. What other points about enzymes could you add to this map? Can you suggest any more links between points already on the map?

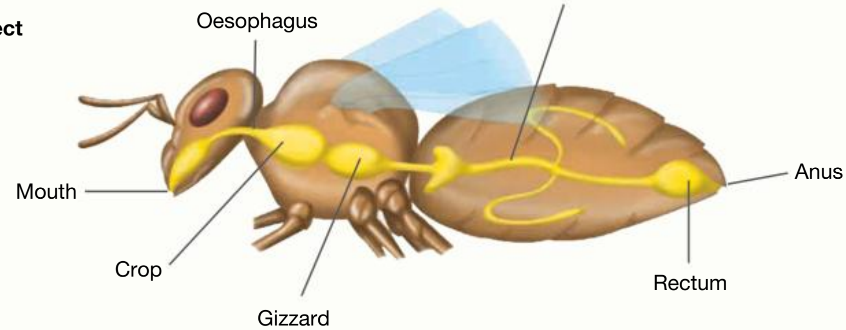


21. Construct Venn diagrams to compare the following:
    a. incisor teeth and canine teeth
    b. intestinal villi and alveoli
    c. red blood cells and white blood cells
    d. trachea and oesophagus
    e. mechanical digestion and chemical digestion.

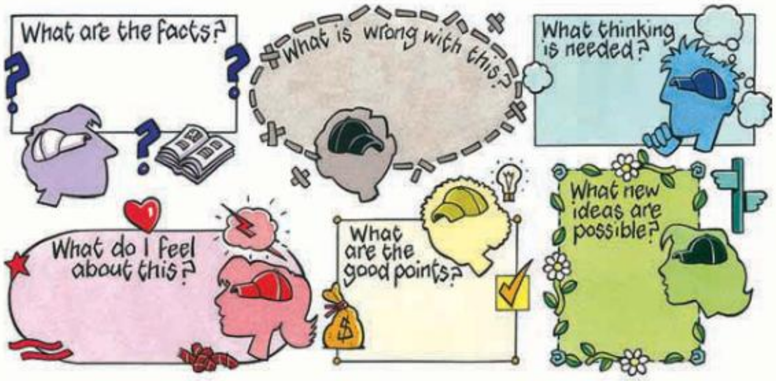
22. Carefully observe the diagrams of the digestive systems of the animals shown. Construct a matrix table that shows the similarities and differences between birds, earthworms, insects and humans.







23. Use your six thinking hats (see subtopic 2.2 in your learnON title at www.jacplus.com.au) for three of the issues or statements provided.



a. Drinking of any alcohol in Australia should be illegal.
b. Smoking in public should be punishable by a 10-year prison sentence.
c. Donating blood at least four times a year should be compulsory for all over the age of 16.
d. Only people under the age of 40 should be allowed to have a heart transplant.

e. Smokers should not be allowed to have surgery.
f. Blood transfusions should be illegal.
g. Everyone should have the right to a blood transfusion.
h. Organ donation should be compulsory.
i. Overweight people should not be allowed to have surgery on their circulatory system.

24. Write a story that tells of the life of a red blood cell.
25. As a team, create a song, poem, cartoon or play about something that you have learned.
26. a. Create a game called 'Nutridigest' that summarises your learning about the digestive system.
b. In a team of four, brainstorm as many questions as you can that could be placed on each of the squares. Creatively write these onto your Nutridigest cards.
c. As a team, discuss the rules for your Nutridigest game. Write down those you agree on.
d. Construct a gameboard for you game.
e. Make a brochure that explains how to play your game.
f. Trial playing the game with your team.
g. Make any alterations to your game that you think would improve it.
h. Play the game that has been created by another team.
i. In a team of eight, discuss the good things (strengths) and not-so-good things (limitations) of each game. Also, suggest ways that they could be improved in the next 'edition'.

Fully worked solutions and sample responses are available in your digital formats.

on Resources

eWorkbook Reflection (ewbk-3038)

teachon

Test maker

Create customised assessments from our extensive range of questions, including teacher-quarantined questions.
Access the assignments section in learnON to begin creating and assigning assessments to students.

RESOURCE SUMMARY

on Resources

Below is a full list of **rich resources** available online for this topic. These resources are designed to bring ideas to life, to promote deep and lasting learning and to support the different learning needs of each individual.

4.1 Overview

eWorkbooks
- Topic 4 eWorkbook (ewbk-4734)
- Student learning matrix (ewbk-4736)
- Starter activity (ewbk-4737)

Practical investigation eLogbook
- Topic 4 Practical investigation eLogbook (elog-0520)

Video eLesson
- The human body and internal organs (eles-2040)

4.2 Driven by curiosity?

Video eLesson
- Leonardo's sketches and anatomy (eles-1769)

Weblink
- Leonardo da Vinci's inventions turned into models

4.3 Working together?

eWorkbook
- Labelling the different body systems (ewbk-4718)

Practical investigation eLogbook
- Investigation 4.1: Mapping your organs (elog-0522)

Interactivities
- Systems (int-6581)
- Types of tissues (int-6582)
- Body systems (int-3397)
- Excretion (int-6583)

4.4 Digestive system — break it down

eWorkbooks
- Labelling the human digestive system (ewbk-4719)
- The digestive system (ewbk-4722)

Practical investigation eLogbooks
- Investigation 4.2: Does temperature affect enzymes (elog-0523)
- Investigation 4.3: Making a burp model (elog-0524)

Video eLessons
- The digestive system (eles-2041)
- Swallowing (eles-2042)
- Stomach acid reflux, heartburn (eles-2531)

Interactivities
- The digestive system (int-3398)
- Types of teeth (int-5335)

Weblink
- Observing villi 1

4.5 Digestive endeavours

Practical investigation eLogbook
- Investigation 4.4: Observing villi (elog-0525)

Video eLessons
- Tooth anatomy and process of decay (eles-2532)
- Colon biopsy tool (eles-2533)
- Colonoscopy procedure (eles-2534)

4.6 Circulatory system — blood highways

eWorkbooks
- Labelling the movement of blood through the heart (ewbk-7088)
- Blood and blood highways (ewbk-4724)

Practical investigation eLogbooks
- Investigation 4.5: Viewing blood cells (elog-0526)
- Investigation 4.6: Heart dissection (elog-0527)

Video eLessons
- Bleeding (eles-2535)
- Veins (eles-2047)
- Blood flow through the heart (eles-2049)

Interactivities
- Components of blood (int-6584)
- Beat it! (int-0210)

4.7 Transport technology

Practical investigation eLogbook
- Investigation 4.7: Check your heart (elog-0528)

Video eLessons
- Heart valve (eles-0858)
- Beating heart with ECG (eles-2050)

4.8 Respiratory system — breathe in, breathe out

eWorkbooks
- Breathing — constructing a report (ewbk-4726)
- Labelling the human respiratory system (ewbk-7082)

Practical investigation eLogbooks
- Investigation 4.8: Hands on pluck (elog-0529)
- Investigation 4.9: Measuring your vital capacity (elog-0530)

Video eLessons
- The human bronchiole (eles-2044)
- The action of the diaphragm and lungs (eles-2045)

Interactivity
- Labelling the human respiratory system (int-8233)

4.9 Short of breath?

eWorkbook
- Smoking and diseases (ewbk-4728)

Interactivity
- Asthma (int-5351)

4.10 The excretory system

eWorkbooks
- Labelling the kidneys (ewbk-7084)
- Removing waste from blood (ewbk-4773)

Video eLessons
- Urinary system (eles-2051)
- The liver (eles-2536)

Interactivity
- Labelling the kidneys (int-8234)

4.11 Musculoskeletal system — keeping in shape

eWorkbooks
- Labelling the major bones of the human skeleton (ewbk-7086)
- Bones, joints and muscles (ewbk-4732)

Practical investigation eLogbooks
- Investigation 4.10: Rubbery bones (elog-0531)
- Investigation 4.11: Chicken wing dissection (elog-0532)

Video eLessons
- Osteoarthritis (eles-2053)
- Skeleton with organs and nervous system (eles-2537)
- Joints in the human body (eles-2052)

Interactivity
- Labelling the major bones of the human skeleton (int-8256)

4.12 Same job, different path

Practical investigation eLogbook
- Investigation 4.12: Inside or out? (elog-0533)

4.14 Review

eWorkbooks
- Topic review Level 1 (ewbk-4746)
- Topic review Level 2 (ewbk-4748)
- Topic review Level 3 (ewbk-4750)
- Study checklist (ewbk-4739)
- Literacy builder (ewbk-4740)
- Crossword (ewbk-4742)
- Word search (ewbk-4744)
- Reflection (ewbk-3038)

Practical investigation eLogbook
- Topic 4 Practical investigation eLogbook (elog-0520)

Digital document
- Key terms glossary (doc-34916)

To access these online resources, log on to **www.jacplus.com.au**.

5 Reproduction

LEARNING SEQUENCE

5.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

5.1.1 Introduction

Reproduction is essential for life on Earth to continue. Living things, or **organisms**, must reproduce to produce **offspring** for their species to survive for future generations. Humans and all animals do it, plants do it, fungi and bacteria do it, but all in different ways. Many animals reproduce sexually, having both male and female individuals just as humans do. However, did you know that many plants have male and female reproductive cells and also reproduce sexually? Some animals, such as the garden snail, have both male and female reproductive organs. In addition, the akoya pearl oyster can change gender many times throughout their life, beginning as a male and then becoming female; they switch genders over and over again to improve their chances of successful reproduction. Although many animals and many plants reproduce sexually there are many others that reproduce by simply dividing into two identical offspring or breaking off part of their body to give rise to the next generation. In this topic you will explore the fascinating area of reproduction in different organisms and develop an ability to discuss reproduction using the correct scientific terminology.

organisms living things
offspring the young born of a living organism

FIGURE 5.1 Dandelions use the wind to help them to disperse their seeds.

on Resources

Video eLesson Medical ultrasound of human fetus at 26 weeks gestation (eles-4234)

Humans have a gestation period of nine months. During this time, starting with a single cell, a human is made. This video is an ultrasound of a 26-week-old fetus — can you see them rubbing their nose?

EXTENSION: Hermaphrodites

Did you know that not all plants or animals have separate sexes? Some invertebrates are both male and female at once. These interesting combinations are called hermaphrodites. This enables an individual to achieve greater reproductive efficiency than if it was just the one sex.

Snails have been around for 600 million years and have developed intriguing methods of reproduction. Each snail has an organ called an ovotestis, which makes both sperm and eggs, and a single tube to carry both the sperm and the eggs.

After a complex courtship in which hermaphrodite snails rear up, each pressing its muscular foot against its partner, and stroking each other with their tentacles, they simultaneously insert their sex organ into the other's body. In this manner, each snail gives sperm to the other and each has its eggs fertilised.

FIGURE 5.2 Garden snail *Cornu aspersum*

5.1.2 Think about reproduction

1. How fast can human sperm swim?
2. Why is a dinner date for a male redback spider a bad idea?
3. How can a discarded arm become a whole new animal?
4. Do flowers have ova and sperm cells?
5. Why are worker bees always female?
6. Why is puberty necessary?
7. Which male animals can get pregnant?

5.1.3 Science inquiry

elog-0580

INVESTIGATION 5.1

Comparing reproductive strategies

In this investigation you will be conducting a review of the information from multiple sources and determining if this information is reliable and consistent, as looking at information from others is a critical skill for scientists.

Aim

To compare the reproductive strategies of a placental mammal and a marsupial mammal

Method

In teams of two or more choose one example of a marsupial mammal and one example of a placental mammal to investigate.

Research the reproductive strategies of these two animals. Ensure you find answers to the following for both the marsupial and placental mammal:

1. How long is the pregnancy (gestation period)?
2. How well developed are the offspring at birth?
3. How big is the offspring at birth?
4. How does the young access milk from the mother?
5. How long until the offspring can find their own food and live independently?
6. Suggest an advantage of each strategy.

Results

1. Use a full-page table, with an informative title, to compare the animals of your choice. Discuss how you should draw your table with your group before you start to ensure you show your findings clearly.
2. Check each piece of information on at least three websites and make a note at the bottom of the page if you think a particular website is reliable (trustworthy) or unreliable.

Discussion

1. Share your research findings with your class and add new or interesting ideas you have to your table.
2. Share your ideas as a class regarding which internet sources you think are reliable and which you find less trustworthy. Explain why.

Conclusion

Write a conclusion summarising your results. Remember to refer to the aim.

on Resources

eWorkbooks	Topic 5 eWorkbook (ewbk-4872) Student learning matrix (ewbk-4874) Starter activity (ewbk-4875)
Practical investigation eLogbook	Topic 5 Practical investigation eLogbook (elog-0578)
learnon	Access and answer an online Pre-test and receive **immediate corrective feedback** and **fully worked solutions** for all questions.

5.2 Asexual reproduction

LEARNING INTENTION

At the end of this subtopic you will be able to describe how some organisms reproduce asexually with examples of some of the main strategies, such as binary fission, budding and spores.

5.2.1 Asexual reproduction

Imagine looking exactly like your parent — and all of the rest of your family!

Not all organisms reproduce by sexual methods. In some types of organisms, a single parent produces one or more genetically identical offspring. This is called **asexual reproduction**. Binary fission, spore formation, budding and vegetative propagation are examples of this type of reproduction.

Unlike sexual reproduction, asexual reproduction does not require the fusion of sex cells. It also does not require sex cells from another organism. Because all the genetic information comes from a single individual, all offspring of asexual reproduction are identical to each other — and to their parent.

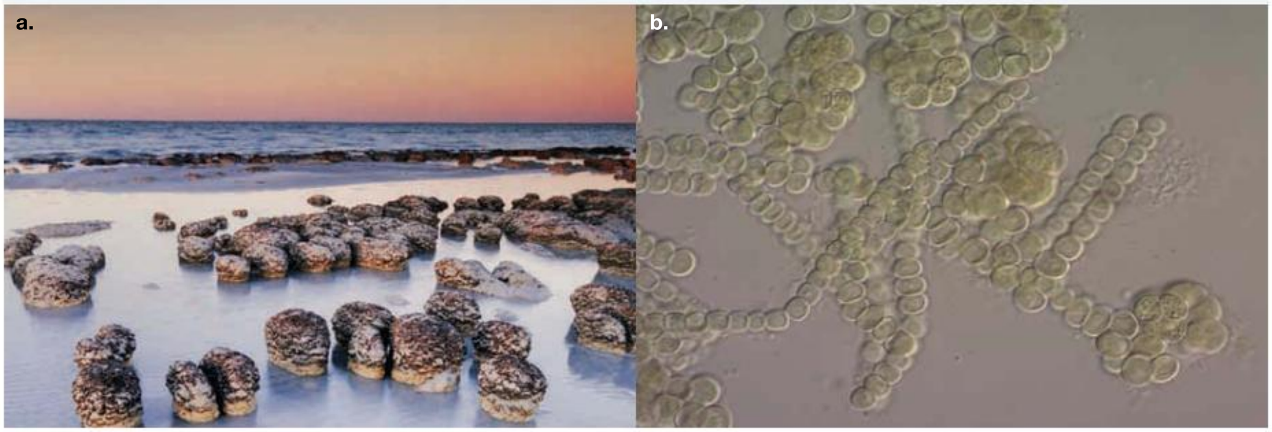
Individuals that have identical genetic information to each other are called **clones**. As well as occurring in nature, technology has also used **cloning** to produce genetically identical organisms.

5.2.2 Binary fission — let's split

Life began more than 3.7 billion years ago with the first living organisms on Earth being microscopic organisms called cyanobacteria whose fossils can be seen in rocks off the Western Australian coast. These microorganisms have relatives living today that we believe have a similar structure and reproduce in the same way, by splitting in half to produce two identical offspring.

asexual reproduction a type of reproduction that does not require the fusion of sex cells (gametes)
clone an identical copy
cloning the process used to produce genetically identical organisms

FIGURE 5.3 First life on Earth. **a.** *Stromatolites* might look like rocks; however, they are in fact colonies of simple life. Single-celled organisms called cyanobacteria are responsible for forming these layered boulders and have been doing so for billions of years. **b.** Cyanobacteria were the first living thing on Earth and have been living and reproducing for longer than any other living thing.



Some unicellular organisms reproduce by **binary fission**. In this type of asexual reproduction, when an organism has grown to a certain size, it divides into two. Prior to this division, the genetic material in the cell is replicated. The cytoplasm then divides, producing two cells with identical genetic information.

Binary fission can occur in both prokaryotes (such as bacteria) and eukaryotes (such as *Amoeba, Euglena* and *Paramecium*). While the same term is used, the actual processes involved for these different types of organisms are different. In eukaryotes, a type of cell division called mitosis is involved, whereas in prokaryotes it is not. The process in prokaryotes is less complex and faster. For example, one bacterial cell could produce about 16 million offspring in eight hours. Some types of bacteria can also produce more than two cells per division. This is called **multiple fission**. Multiple fission is very efficient and allows for an even greater increase in numbers within a short time frame.

binary fission reproduction by the division of an organism (usually a single cell) into two new organisms

multiple fission a reproduction method where a single-celled organism divides into more than two cells

FIGURE 5.4 Amoeba are unicellular eukaryotic organisms. They have no need for complex tissues or systems, and lead a highly successful life by engulfing their food and expelling their waste products as a single cell.

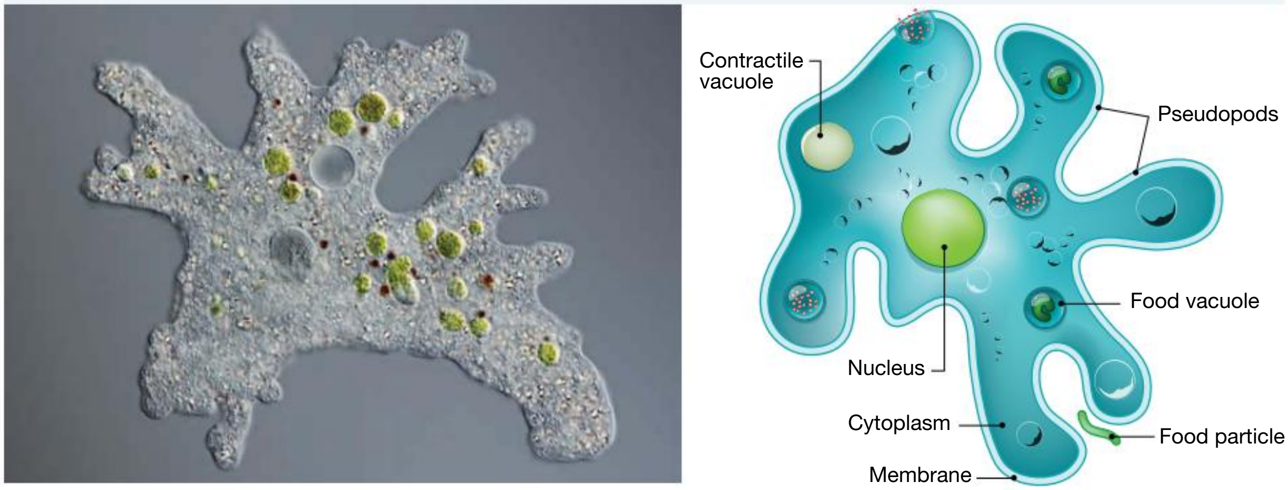
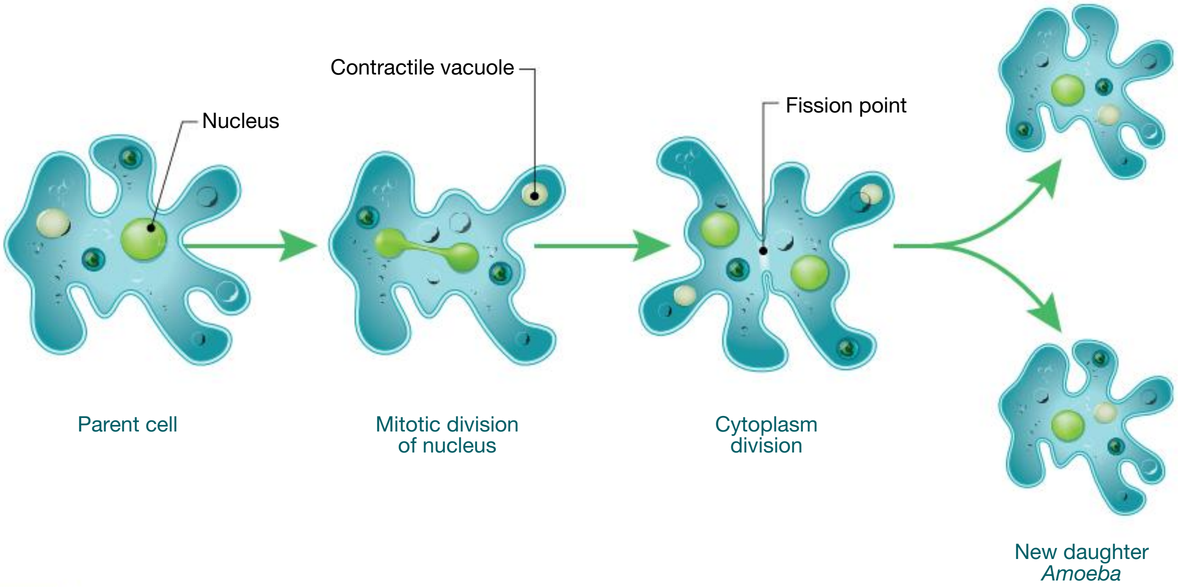


FIGURE 5.5 Binary fission in amoeba. This simple yet effective life form reproduces by duplicating all of the essential parts of the cell, such as the nucleus and mitochondria, to ensure the offspring have their own genetic information and can turn food into energy. The amoeba then divides into two daughter cells which are genetically identical to the parent cell. This is called binary fission.



on Resources

Video eLesson Binary fission (eles-2306)

Watch a paramecium dividing into two cells by binary fission.

budding the formation of a new organism from an outgrowth (bud) of the parent

5.2.3 Budding offspring

Imagine your offspring beginning as a simple swelling on your side and then developing its own mouth and features. When its development is complete, it merely detaches itself and independently continues its own life. This is the sequence of events that happens in yeasts (figure 5.7) and also in freshwater hydra (figure 5.8). The initial swelling is called a bud and hence this process is often called **budding**.

FIGURE 5.6 Tiny new jellyfish (medusae) that have formed by budding

FIGURE 5.7 Yeast are unicellular organisms from the same kingdom as mushrooms and mould, kingdom Fungi. Yeast are the living organisms that are used in many industries such as brewing and baking. Yeast reproduce by budding off their offspring from the parent cell.

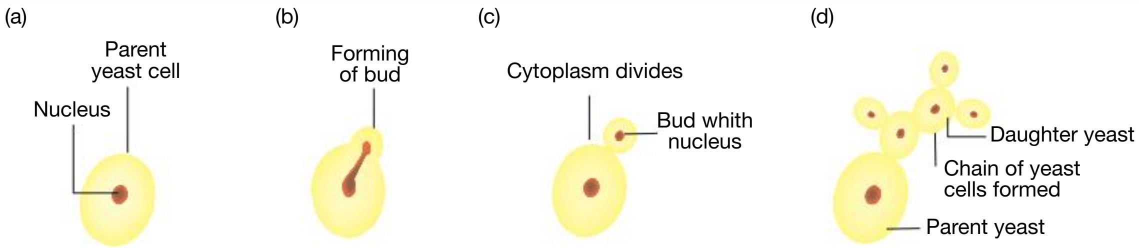
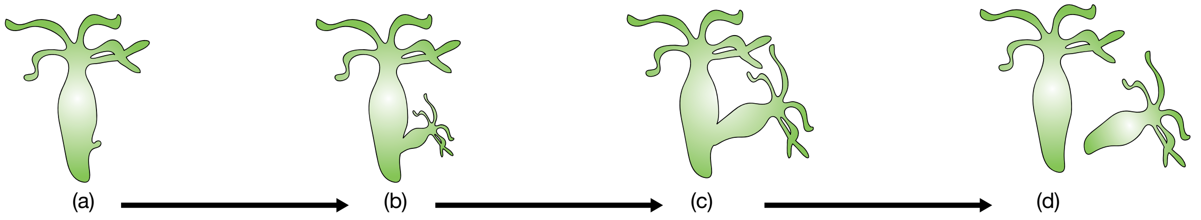


FIGURE 5.8 Hydra are a small multicellular freshwater organisms, from the phylum cnidaria, that also reproduce by budding.



Jellyfish, such as the common *Aurelia aurita*, reproduce both sexually and asexually. The mature medusa are the familiar free floating organisms with round transparent bodies. These adults release eggs and sperm into the environment which, once successfully fertilised, result in offspring known as polyps. The polyps attach to hard rocky surfaces to grow and reproduce by budding as each polyp will release many small disc-like jellyfish into the water in the form of miniature medusae.

FIGURE 5.9 Jellyfish reproduce both sexually and asexually.

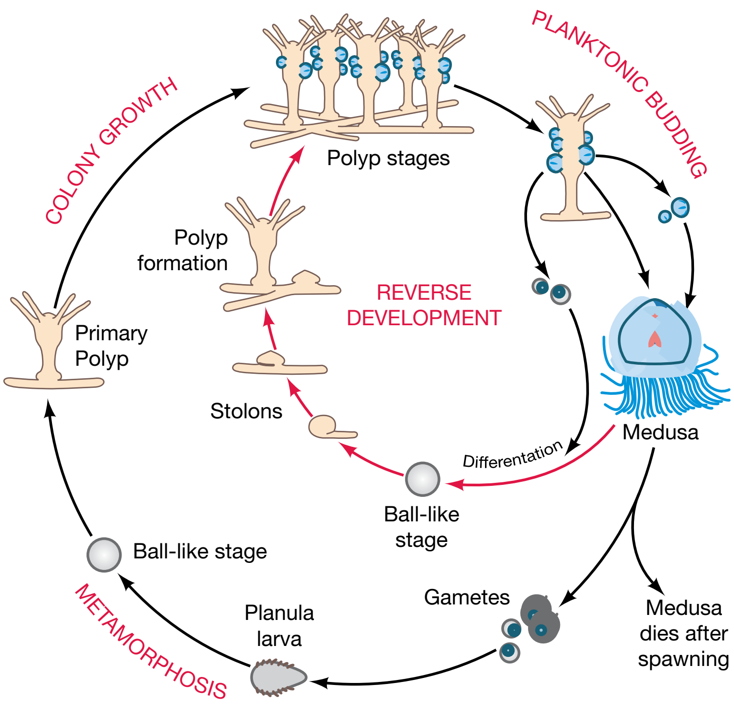
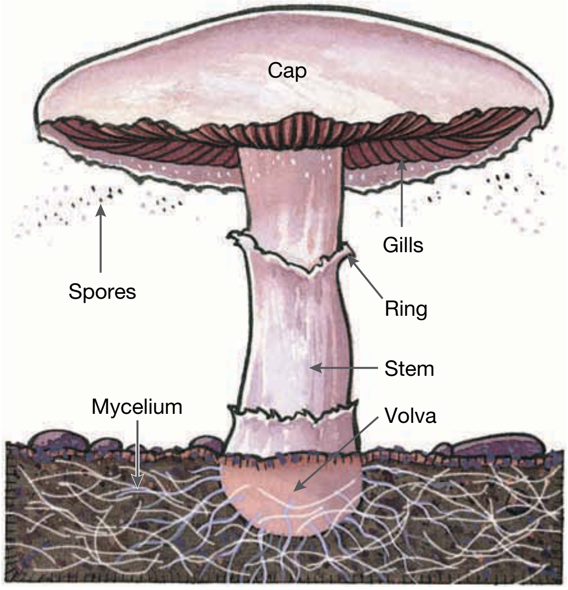


FIGURE 5.10 Jellyfish reproduce both sexually and asexually.

5.2.4 Spores

Some fungi (such as mushrooms, and bread and fruit mould) have **spores** that, when released, may develop into offspring identical to the parent fungi. These spores are merely a group of unspecialised body cells, combined with a source of nutrients and packaged in a resistant coat. They can provide an effective means of dispersing future generations, and may also overcome adverse conditions by waiting until conditions are favourable before they begin to grow.

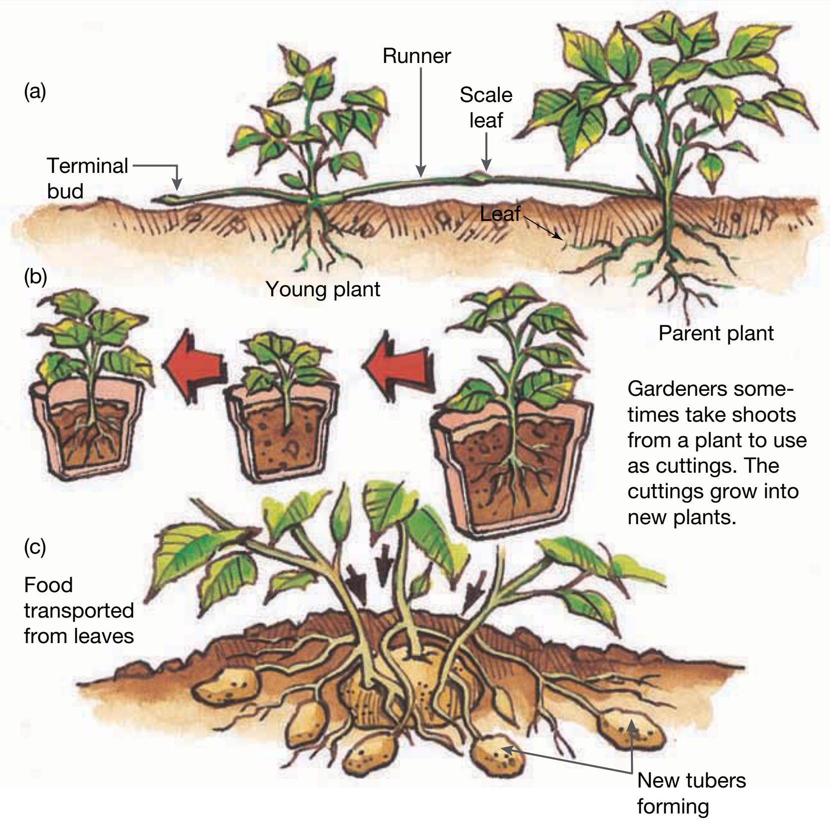
FIGURE 5.11 Some fungi have spores that may develop into offspring genetically identical to the parent fungi.



5.2.5 Vegetative propagation

In **vegetative propagation**, the non-sexual parts of the plant are used to develop new individuals of the same type. Examples include bulbs (e.g. daffodils), stem tubers (e.g. potatoes), runners (e.g. native violets) and cuttings (e.g. roses).

FIGURE 5.12 Examples of vegetative propagation: **a.** runners, **b.** cuttings and **c.** tubers



spores reproductive cells capable of developing into a new individual without fusion with another reproductive cell

vegetative propagation the reproduction of plants using parts other than sex cells

5.2.6 Regeneration

Flatworms and starfish are animals with some strange reproductive abilities. Fragmentation is commonly observed in flatworms. During this type of reproduction, the parent flatworm breaks into several pieces and, over time, each piece develops into a new adult flatworm. Regeneration is a similar type of reproduction that can be seen in starfish. While some starfish can regenerate replacement new limbs, others, such as the *Linckia* starfish, can regenerate completely new organisms from a severed arm.

FIGURE 5.13 Tiny new starfish growing at the end of a discarded *Linckia* starfish arm

5.2.7 Parthenogenesis

In some animals, the females produce eggs, but these develop into embryos without fertilisation taking place. The scientific name for the development of new individuals from an unfertilised egg is **parthenogenesis**. Worker bees, for example, develop from unfertilised eggs laid by the queen bee.

Some gecko lizard groups are parthenogenetic and form all-female families. An example is Bynoe's gecko (*Heteronotia binoei*), which is found only in Australia. A population of these geckos would contain only females. Births that result without any meeting between eggs and sperm are often referred to as **virgin births**.

FIGURE 5.14 Worker bees develop from unfertilised eggs laid by the queen bee (parthenogenesis).

parthenogenesis the development of new individuals from unfertilised eggs

virgin births births that do not involve the joining of eggs and sperm

elog-0582

INVESTIGATION 5.2

Asexual reproduction

Aim

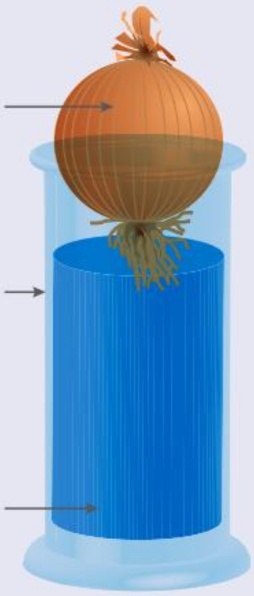
To observe asexual reproduction in plants

Materials

- large onion
- potato
- grass runner
- leaf–stem cutting from geranium or impatiens. *Note*: A leaf–stem cutting is a piece of the plant's stem that is cut just below a joint or growing point and has at least three leaves.
- leaf from an African violet, jade plant or snake plant
- rooting medium (this can be purchased from a nursery)

A leaf-stem cutting

An onion with its base in water



Method

1. Fill a gas jar almost to the top with water and place the onion in the mouth of the gas jar so that its base is sitting in the water as shown in the diagram.
2. Leave the potato in a dark cupboard.
3. Remove the lower leaves from the leaf–stem cutting. Quarter fill a beaker or glass jar with water and place the cutting in the water.
4. Place some rooting medium in a pot. Add water to the rooting medium until it feels moist. Cut a 3 cm section from the leaf of the African violet, jade or snake plant. Stand the piece of leaf upright in the rooting medium.
5. Cut a piece of the grass runner. Ensure the section you have cut has at least one growing point. Press the piece of grass runner into the rooting medium (laying it flat on the surface).
6. Leave all the plant parts undisturbed for two weeks. You may need to top up the water over that time.

Results

Copy and complete the table given, and remember to include a title for your table. You may need to dig the leaf–stem cutting and the runner from the rooting medium and wash them to see what has happened to them.

Plant part	Description after two weeks	Diagram
Onion		
Potato		
Leaf–stem cutting		
Leaf		
Runner		

Discussion

1. In your own words, summarise your observations for each of the plant parts.
2. Based on your observations, what conclusions can you make?
3. Explain why each of the examples in the table above are forms of asexual reproduction.
4. What are the advantages of growing plants using one of the techniques described above rather than growing them from seeds?
5. Suggest improvements to the design of the investigation.

Conclusion

Write a conclusion summarising your results. Remember to refer to the aim.

on Resources

eWorkbook — Asexual reproduction (ewbk-4902)
assess**on** — Additional automatically marked question sets

5.2 Exercise

learn**on**

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 4, 6, 10	Questions 3, 5, 7, 11	Questions 8, 9, 12

Remember and understand

1. State what is meant by the term 'asexual reproduction' and give examples.
2. Identify the missing words to complete the sentences.
   a. When a single parent produces one or more genetically identical offspring it is called _________ reproduction.
   b. Unlike sexual reproduction, asexual reproduction does not require the _________ of sex cells or sex cells from _________ organism because the single parent contributes _________ of the genetic information to their offspring.
   c. In organisms that use _________ reproduction, the _________ are genetically identical to each other as well as being genetically _________ to the parent.
   d. Individuals that have identical genetic information to each other are called _________.
3. Identify the type of asexual reproduction that is occurring in the descriptions.

Description	Type of asexual reproduction
a. When a cell reaches a certain size, it replicates its genetic material, and then divides in two.	
b. When a cell reaches a certain size, it replicates its genetic material, and then divides into more than two cells.	
c. Involves growth and development of a swelling on the parent, which when completed, detaches itself and then lives independently of the parent	
d. Involves the release of a group of unspecialised body cells, combined with a source of nutrients and packaged in a resistant coat	
e. Involves use of the non-sexual parts of a plant to develop new individuals of the same type	
f. Involves parts of the parent breaking into pieces and each piece developing into a separate organism	
g. In which embryos develop from unfertilised eggs	

4. Identify the type of asexual reproduction used by the following organisms:

TABLE Types of asexual reproduction in various organisms

	Starfish	Yeast	Amoeba	Mushrooms
Budding				
Spores				
Binary fission				
Regeneration				

5. Identify whether the statement is true or false. Justify any false responses.

Statement	True or false
a. The processes involved in binary fission in prokaryotes and eukaryotes are the same.	
b. A population of Bynoe's gecko lizards (*Heteronotia binoei*) would contain only males.	
c. Worker bees develop from unfertilised eggs laid by the queen bee.	
d. Births that result without any meeting between eggs and sperm are often referred to as virgin births.	

6. Match the type of plant with the type of vegetative propagation that it can use to reproduce.

Type of plant	Type of vegetative propagation
a. Daffodil	A. Cuttings
b. Native violets	B. Bulbs
c. Potatoes	C. Runners
d. Roses	D. Tubers

Apply and analyse

7. Describe what is meant by the term 'clone'. Are you a clone? Explain.
8. SIS Sexual reproduction results in variation among the offspring, whereas asexual reproduction does not. Summarise the advantages and disadvantages for each type of reproduction in a table format as shown.

TABLE Advantages and disadvantages of asexual reproduction

Advantages of asexual reproduction	Disadvantages of asexual reproduction

9. Suggest why many insects, which would usually reproduce sexually, use parthenogenesis to produce offspring in favourable conditions.

Evaluate and create

10. SIS
    a. Place a carrot top on moist cottonwool until leaves appear, then transfer the plant to a plastic pot containing moist potting mix. Record what happens.
    b. Try this with a variety of other vegetables. Summarise your findings.
11. SIS Find out about three organisms that use parthenogenesis and present your findings in a table, poster or infographic. Use the following questions to guide your research.
    - What types (classes or orders) of organisms use parthenogenesis?
    - Do they always use parthenogenesis or only sometimes?
    - Why do you think they use this strategy?
    - What conclusions can you draw from your research about parthenogenesis?
12. SIS Research some uses of cloning and organise three arguments for and three arguments against cloning that could be used in a debate on the issues of cloning.

Fully worked solutions and sample responses are available in your digital formats.

5.3 Sexual reproduction in flowering plants

LEARNING INTENTION

At the end of this subtopic you will be able to describe how some plants reproduce sexually with pollen and ovules as their reproductive cells. In addition, you will be able to explain how seeds are dispersed and germinate.

angiosperms plants that have flowers and produce seeds enclosed within a carpel

flowers the reproductive part of angiosperms containing petals, stamens and carpels. They are often colourful to attract pollinating insects

petals the coloured parts of a flower that attract insects

nectaries parts of a flower, at the base of the petals, that secrete nectar

pollen the fine powder containing the pollen grains (the male sex cells of a plant)

stigma the female part of a flower, at the top of the carpel, that catches the pollen during pollination

5.3.1 Flowers and pollination

Like animals, many plants can reproduce sexually. Flowering plants (**angiosperms**) have their reproductive structures located in their flowers.

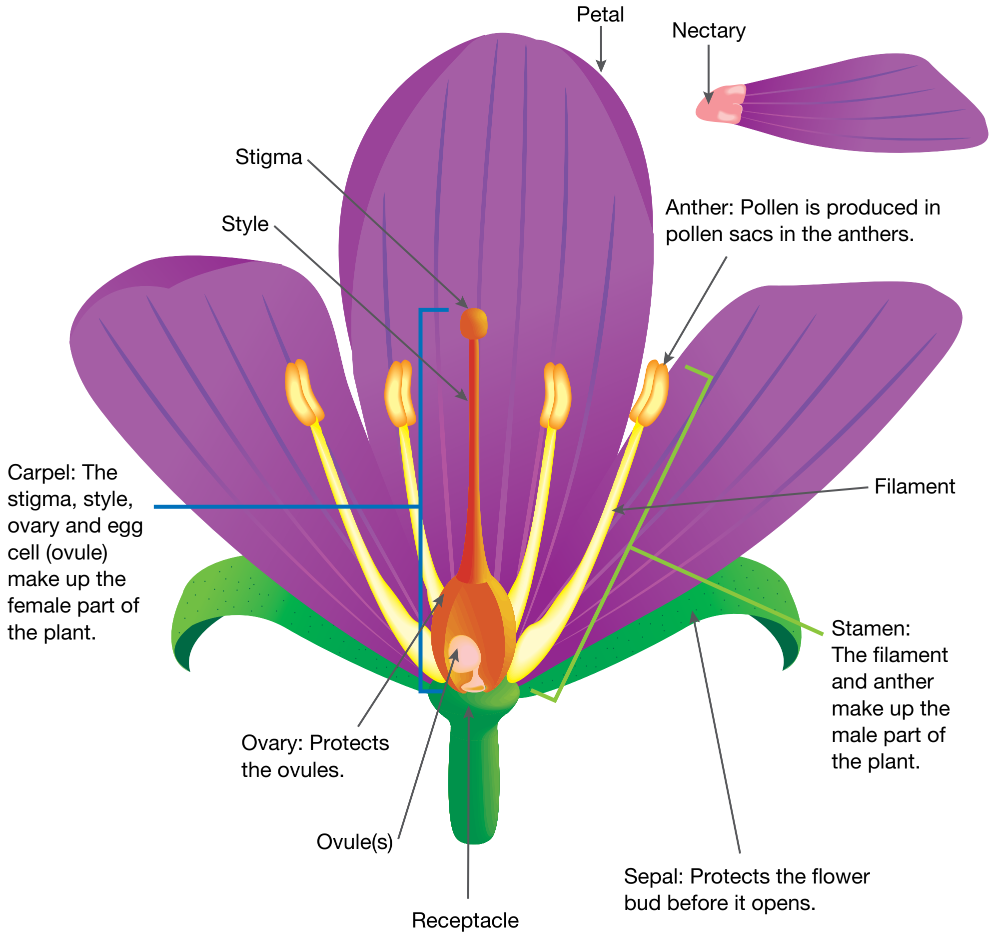
Flowers are involved in reproduction. As plants are not mobile and cannot go looking for a suitable mate they rely on other ways to bring the male and female gametes together. The **petals** and **nectaries** are often used to lure insects and other animals to assist in the delivery of 'sperm' or **pollen**. Flowers are designed to increase the chances of pollen grains making contact with the sticky **stigma**.

FIGURE 5.15 Flowering plants, angiosperms, reproduce sexually therefore have male and female sex cells in a similar way to animals. Plants often use insects to move their reproductive cells, and also their seeds, around for them. In this image a bee is covered in pollen, the plant equivalent of sperm. The bee will visit a number of flowers collecting nectar for itself and distributing pollen from one flower to the next in the process.

int-3407

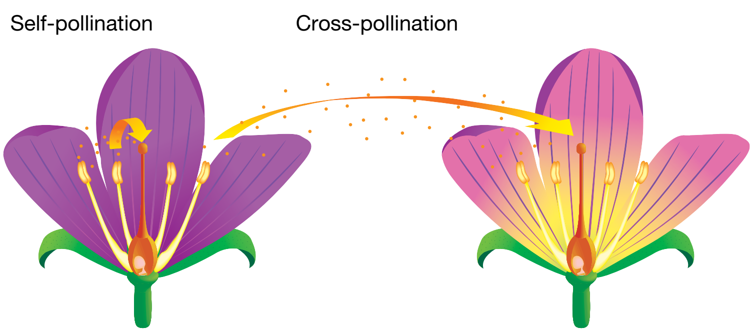
ewbk-4899

FIGURE 5.16 Each part of a flower has a specific function that allows the flower to bloom, fruit or seed.



Pollination describes the way in which pollen grains reach the stigma. Plants may pollinate themselves (**self-pollination**). More often, however, they obtain the pollen from the flower of a different plant of the same species (**cross-pollination**). Cross-pollination increases the variation among the offspring and gives them a better chance of survival. The pollen grains may be transferred to other flowers by wind, insects or other animals.

FIGURE 5.17 The difference between self-pollination and cross-pollination



pollination the transfer of pollen from the stamen (the male part) of a flower to the stigma (the female part) of a flower

self-pollination the transfer of pollen from the flower's own stamen to its stigma

cross-pollination the transfer of pollen from stamens of one flower to the stigma of a flower of another plant of the same species

Insect-pollinated flowers usually have attractive, brightly coloured petals and nectaries. The pollen grains themselves may be in a shape that makes them become easily attached to the insect.

Wind-pollinated flowers are usually less conspicuous and have no large scented petals or nectar. Their shape enables small, light pollen grains to be shaken from the plant and carried away with even the slightest gust of wind. The **anthers** hang outside the flower and the feathery stigmas spread out to catch airborne pollen grains.

FIGURE 5.18 A sunflower is an example of an insect-pollinated flower.

FIGURE 5.19 A wind-pollinated flower receives pollen carried by the wind from another flower.

TABLE 5.1 Comparing flowers that are pollinated by insects versus flowers pollinated using wind

	Insect pollination	Wind pollination
Petals	• Large • Scented • Contain nectaries • Brightly coloured	• Maybe none, or small • No scent • No nectaries • Dull colours
Anthers	• Positioned where insects might brush against them	• Hang loosely on thin filaments • Shake easily in the wind to distribute pollen
Stigma	• Positioned where insects might brush against them • Sticky and flat or lobe shaped to capture pollen	• Long branching and feathery • Reaches out into air to catch pollen blowing in the wind
Pollen	• Rough or sticky surface to stick to insects • Small amounts produced • Grains are large	• Small light grains • Large amounts produced • Easily carried in wind

The titan arum (*Amorphophallus titanum*) is a rare plant, native to Sumatra, that has a two-metre flower that smells of rotting flesh, giving it the nickname the 'corpse flower' (figure 5.20). The smell of this flower, although repulsive to humans, attracts insects which take pollen, the male sex cells, and deliver it to another plant resulting in fruit and seeds to begin the next generation.

insect-pollinated flowers flowers that receive pollen carried on the body parts of insects from other flowers

wind-pollinated flowers flowers that receive pollen carried by the wind from another flower

anther the male part of a flower that makes pollen

FIGURE 5.20 The corpse flower, titan arum (*Amorphophallus titanium*), smells of rotting flesh, which is a reproductive strategy that improves the chances of insects visiting and pollinating.

pollen grains the male gametes of a flower

pollen tube a long tube growing from a pollen grain through the style to the ovule

style the supporting part of a flower that holds the stigma

ovule the receptacle within an ovary that contains egg cells

ovaries female gonads, produce the female gametes (egg cells; ova)

endosperm the food supply for the embryo plant in a seed

seed a product of a fertilised ovule

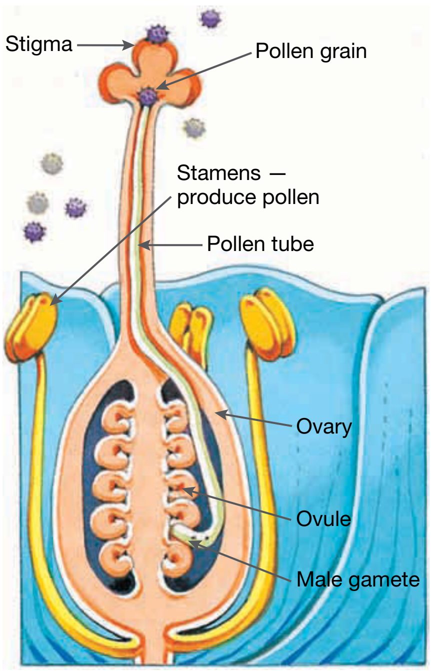
seed coat the protective layer around a seed

fruit a ripened ovary of a flower, enclosing seeds

5.3.2 Fertilisation

As in animals, only a few of the **pollen grains** produced actually fertilise an egg cell. After pollen grains are on the stigma of a flower, a long hollow tube called a **pollen tube** is formed. This pollen tube grows down the **style**. Male gametes (sex cells) travel down these tubes to the **ovules** inside the **ovary**, where they fuse with the ovum (female gamete or egg). This joining of male and female gametes is called fertilisation. The fertilised egg is called a zygote.

FIGURE 5.21 Fertilisation



5.3.3 Plant babies

Once the flower has done its job and the egg cell has been fertilised by the pollen nucleus, another sequence of events takes place. Inside the ovule, the fertilised egg, or zygote, divides into a little ball of cells that becomes an embryo. Special tissue called **endosperm** surrounds the embryo and supplies it with food. The ovule becomes the **seed**, and tissue forms around it to provide a protective **seed coat**.

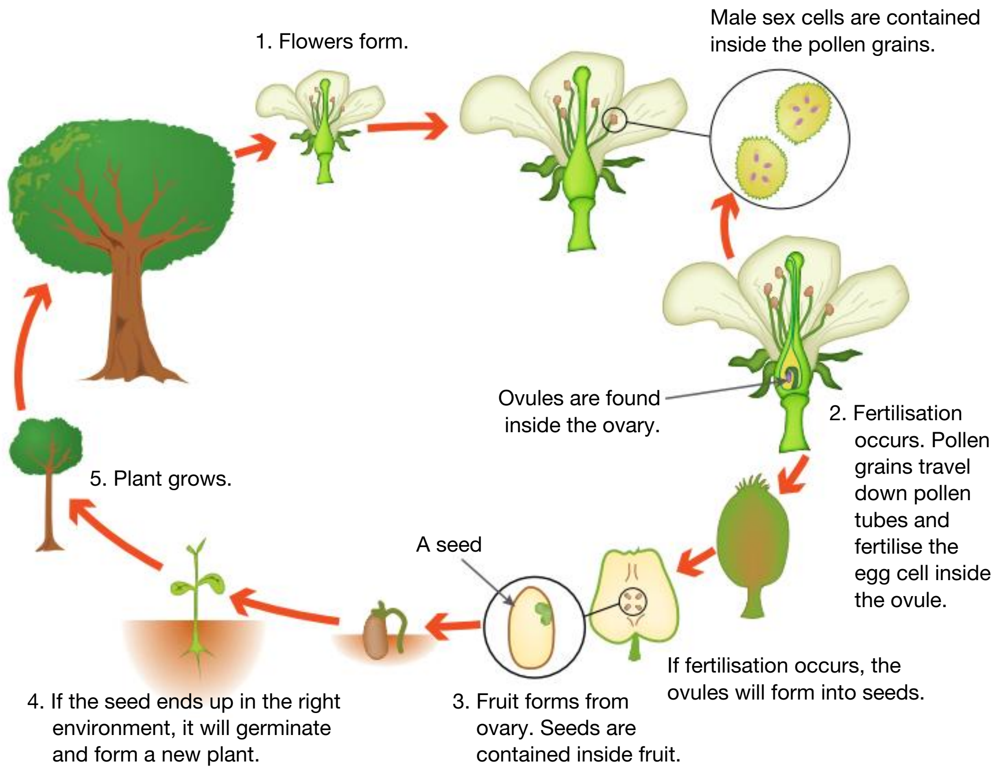
Are you aware that when you bite into an apple, cherry or orange you are actually eating the enlarged ovary of the plant? Did you know that these swollen ovaries contain the plant's 'babies' in their embryonic form? The plants are using you as a way of distributing their 'young' out into the world.

During the formation of the seed, the ovary expands and turns into a **fruit**.

The fruit of some plants can be sweet, which makes them attractive to animals, including humans, as a source of food. The animals that eat the fruit aid the plant by dispersing the seeds over a much wider area than the plant could achieve by itself.

eles-2064

FIGURE 5.22 The life cycle of a flowering plant

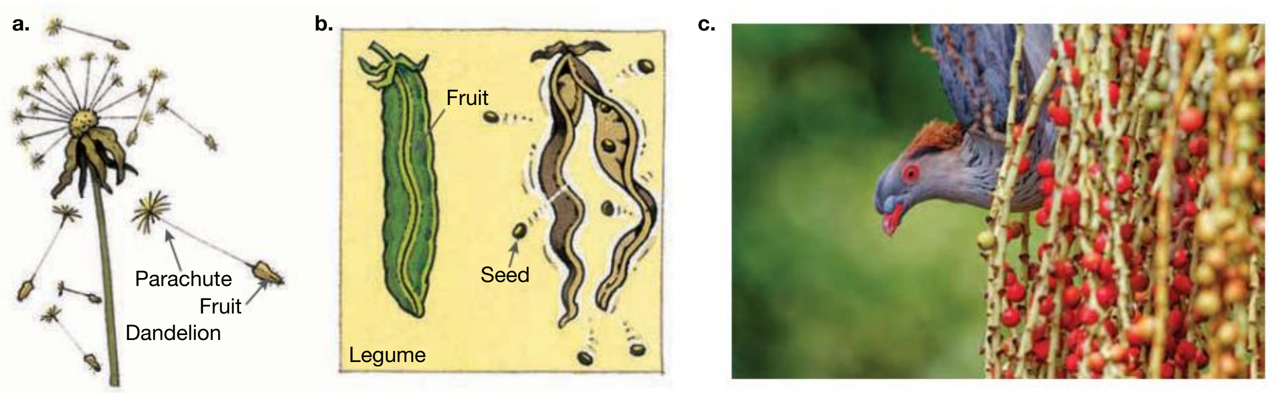


5.3.4 Seed dispersal

One of the main jobs that fruits do is to help **disperse** or spread the seeds. Plants disperse their seeds in a variety of ways: dispersal may involve animals, including birds (such as in tomatoes, grapes and apples); water (such as in coconuts); or wind (such as in grasses and dandelions). Some plants can disperse their seeds by themselves. For example, the fruits of some plants in the pea family (legumes) split open suddenly when they are ripe and dry, throwing the seeds long distances.

disperse the scattering of the seeds from plants

FIGURE 5.23 Seed dispersal can use **a.** wind, rain and rivers, **b.** or seeds can be propelled out of the pod, or **c.** fruit can be eaten by animals and the seeds distributed in droppings. The Australian topknot pigeon, *Lopholaimus antarcticus*, is a frugivore, a fruit eating bird, found in rainforest areas of northern and eastern Australia. This bird plays a critical role in distributing seeds from native plants by helping to regenerate deforested areas as well as helping to increase the number of native plants compared to introduced plants in these areas.



SCIENCE AS A HUMAN ENDEAVOUR: Emu poo study

Research by Mathew Fielding from the University of Tasmania has shown that the extinction of emus in Tasmania in the 1800s has had a significant impact on the ecosystem and the distribution of plants. Emus consume seeds and fruit as they travel up to 50 km per day. Emu droppings containing the seeds from within the fruit were scattered far and wide, enabling plants to inhabit new areas. Researchers are currently considering whether they should reintroduce the emu in an attempt to return the Tasmanian fauna back to the diversity it had before the emu became extinct.

FIGURE 5.24 Emu poo effectively scatters seeds, thereby enabling plants to inhabit new areas.

5.3.5 Seed germination

The embryo, inside the seed, is made up of three different parts: the baby shoot (**plumule**), the baby root (**radicle**) and one or two thick, wing-like **cotyledons**.

When the conditions are right, the seed bursts open and a new plant grows out. This process is called germination. When **germination** is complete, the embryo has become a young plant or **seedling**.

FIGURE 5.25 Parts of a seed

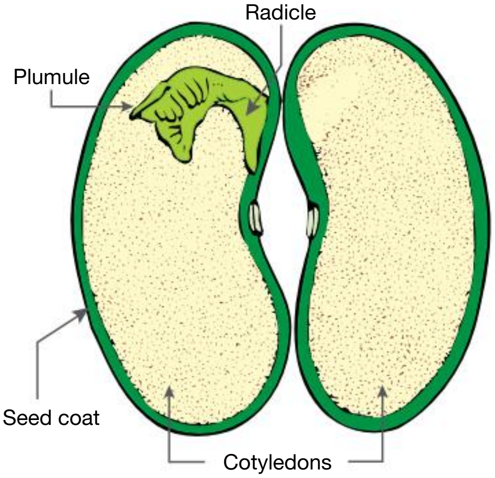


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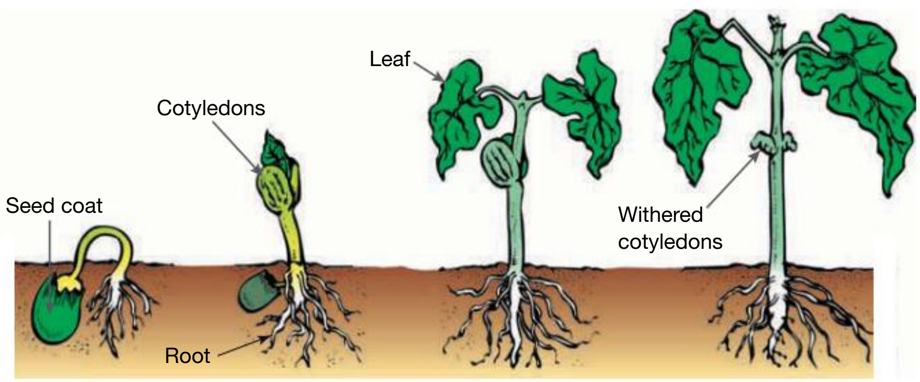
FIGURE 5.26 Germination of a broad bean



plumule a small bud at the tip of the embryo plant in a seed

radicle the beginnings of a root making up part of a plant embryo inside a seed

cotyledons special leaves of the embryo plant inside a seed that provide food for the developing seedling

germination the first sign of growth from the seed of a plant

seedling a young plant produced from the embryo in the seed after germination

elog-0584

INVESTIGATION 5.3

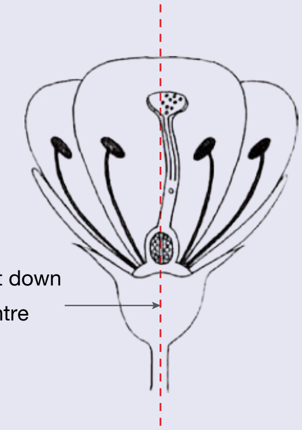
What's in a flower?

Aim

To identify the parts of a flower and relate their structure to their function

Materials

- flowers
- sharp knife or razor blade
- cutting board
- hand lens
- tweezers



Method

1. Draw a diagram of your flower before dissection.
2. Identify and label the male and female parts you can see.
3. Place the flower on the cutting board and hold it with the tweezers.
4. Carefully cut the flower in half down the middle (a vertical cross-section).
5. Use the hand lens to look at the ovary and eggs.
6. Repeat for each flower.

Results

1. Draw a diagram of your flower prior to dissection. Locate, count and label the petals and sepals.
2. Draw the cross-section and label the female parts inside the flower.

Discussion

1. Identify ways in which the flowers you observed were (a) similar and (b) different.
2. Suggest reasons for (a) similarities between the flowers and (b) differences between the flowers.
3. **a.** Predict which parts of the flower become seeds and may grow into fruit.
   b. Justify your predictions.
   c. Check references to see if your predictions were accurate and comment on your findings.
4. Describe possible relationships between the parts of the flower in your diagram.
5. Describe how the various structures of the flower that you have observed assist the plant in reproduction.
6. Suggest how the investigation could be improved.

Conclusion

Write a conclusion summarising your results. Remember to refer to the aim.

elog-0586

INVESTIGATION 5.4

Investigating features of flowers

Aim

To identify a feature of a flowering plant and investigate its relationship to reproduction

CAUTION

Be responsible in your fieldwork and handle the plant parts very gently and carefully. Do not pick, break, tread, trample or climb the plants. Remember that you are dealing with living things.

Materials

- 5 pieces of blank A4 paper
- pencil
- flowering plants growing in local environment

Method

1. Identify a research question that relates to either the structure or a feature of a flower that may increase its chances or effectiveness of pollination.
2. Find five plants, each with different types of flower.
3. Using a separate page for each plant, at the top of the page:
   i. Record your name and the date.
   ii. Record the plant's name, or, if unknown, record it as 'specimen A, B, C' etc.
   iii. Give a general description of the location in which the plant is found.
4. Divide the rest of your A4 sheet into three sections:
   i. half-page sketch of a flower
      - Try to show the parts listed in table 5.1 and label them.
      - Count or estimate how many stamens, stigma, petals and sepals are present.
   ii. quarter-page sketch of a leaf — include any veins that you see.
   iii. quarter-page sketch of the plant's overall appearance.

Results

1. Draw a half-page sketch of a flower.
   - Try to show the parts listed in table 5.1 and label them.
   - Count or estimate how many stamens, stigma, petals and sepals are present.
2. Draw a quarter-page sketch of a leaf — include any veins that you see.
3. Draw a quarter-page sketch of the plant's overall appearance.
4. Record the structure or feature of your flower identified in your research question from the method.

Discussion

1. In regards to your chosen floral structure or feature, identify ways in which the flowers you observed were (a) similar and (b) different.
2. Suggest reasons for (a) similarities between the flowers and (b) differences between the flowers.
3. Research your observed plants using databases and the internet. Construct a table, field guide, cluster map or multimedia format to summarise your findings on the following:
   a. possible identification
   b. labelled sketch or image of flower and fruit
   c. type of pollination and type of seed dispersal
   d. an interesting fact.
4. Based on your observations and your research:
   a. suggest how your chosen floral structure or feature may influence the effectiveness of the pollination of the plant to which it belongs
   b. construct a relevant hypothesis that may be investigated.
5. Identify strengths and limitations of this investigation and suggest possible improvements.

Conclusion

Write a conclusion summarising your results. Remember to refer to the aim.

on Resources

eWorkbooks	Those fabulous flowers! (ewbk-4900) Plant reproduction (ewbk-4901) Labelling parts of a flower (ewbk-4899)
Video eLesson	Growing plants in Australia (eles-0055)
assess on	Additional automatically marked question sets

5.3 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3, 7	Questions 4, 5, 8, 10, 13	Questions 6, 9, 11, 12, 14

Remember and understand

1. Identify the missing words to complete the sentence.
   a. Flowering plants (_________) have their _________ structures located in their _________
   b. Flowers are designed to increase the chances of _________ grains making contact with the _________.
2. MC Identify the term used to describe the way in which pollen grains reach the stigma.
   A. Fertilisation B. Germination C. Pollination D. Seed dispersal
3. Identify the term used to describe the processes.

Process	Term
a. The process in which plants pollinate themselves	
b. The process in which pollen from the flower of a different plant of the same species is used to pollinate the plant	
c. The process that increases the variation among offspring, potentially giving them a better chance of survival	

4. Match the words in the left-hand column with those in the right-hand column.

Part of the plant	Alternative term or description
a. Sepal	A. Sperm
b. Petal	B. Sugar
c. Pollen	C. Leaflet
d. Nectary	D. Colour
e. Ovule	E. Egg cell

5. Describe the relationship between:
   a. stigma and stamen
   b. ovule and seed
   c. ovary and fruit
   d. pollen and anthers.

Apply and analyse

6. Distinguish between the following terms.
   a. Self-pollination and cross-pollination
   b. Pollination and fertilisation
   c. Plumule and radicle
   d. Germination and fertilisation
7. Rearrange the following terms to construct a flowchart that shows the correct sequence for flowering plant: reproduction, fertilisation, seed dispersal, germination, pollination.
8. Suggest why some orchid flowers closely resemble female wasps.
9. Use storyboards or timelines to summarise how plants reproduce.

Evaluate and create

10. Find and research examples of wind-pollinated and insect-pollinated plants. Construct models that show what you have found out about their structures.
11. What does pollen have to do with hayfever?
12. What are the conditions needed by most plants for germination?
13. SIS Is there a relationship between the colour of the flower and the strength of its scent? Make a prediction, design a short investigation and collect some data to help you to answer the question.
14. SIS Use your research skills to explain why some flowers are red and some flowers are yellow. (*Hint*: It relates to the pollinator.)

Fully worked solutions and sample responses are available in your digital formats.

5.4 Comparing reproductive strategies in animals

LEARNING INTENTION

At the end of this subtopic you will be able to describe some different reproductive strategies seen in the animal kingdom.

5.4.1 Reproductive cells in animals

Animals usually reproduce sexually, which means a male and a female reproductive cell join together and form a fertilised early **embryo**. The reproductive cells are called **gametes** and carry half the genetic material needed to produce viable offspring, so are known as **haploid** cells. The female cell is known as the **ova**, or egg, whereas the male cell is known as the **sperm** cell. The function of these cells is to carry the parents' genetic information to the offspring. This usually means the sperm cell travelling to meet the ova. The moment the ova and sperm come together is called **fertilisation** which results in an early embryo called a **zygote** containing both sets of genetics from each parent. The zygote contains a full set of genetic information and therefore is known as a **diploid** cell. Although developed from a single cell, this early embryo has all of the genetic material it needs to develop into an adult. The embryo begins to gain new cells by each cell dividing into two, then four, then eight and onwards. Initially these cells are the same; however, later in development, different cell types and tissue types appear and the offspring starts to resemble the organism it will become.

Although both ova and sperm contain the same amount of genetic information, the ova is usually much larger in size as it contains all of the organelles and structures needed to support the first part of embryo development. In fact, a chicken's egg contains everything the offspring needs until it hatches; whereas, a human ova can only sustain the developing embryo for just over a week, after that it needs to implant into the mother's uterus and use her as a nutrient supply (figure 5.28).

embryo a group of cells formed from the zygote and is developing into different body organs

gametes (reproductive cells) reproductive cells (sperm or ova) containing half the genetic information of normal cells

haploid containing a single set of chromosomes

ova female gametes or sex cells. Singular = ovum.

sperm the male reproductive cell. It consists of a head, a middle section and a tail used to swim towards the egg

fertilisation fusion of the male gamete (sperm) and the female gamete (ovum)

zygote a cell formed by the fusion of two gametes; fertilised ovum before it starts to divide into more cells

diploid containing two sets of chromosomes

ewbk-4906

FIGURE 5.27 Both sperm and ova are reproductive cells and carry only half of the information for the new offspring. Once these two cells join together at fertilisation an embryo forms. In humans, the sperm head is approximately 5 μm in diameter (200 can fit into a mm), while the ova is one tenth of a mm in size (or 100 μm). The human ova are just visible with the human eye.

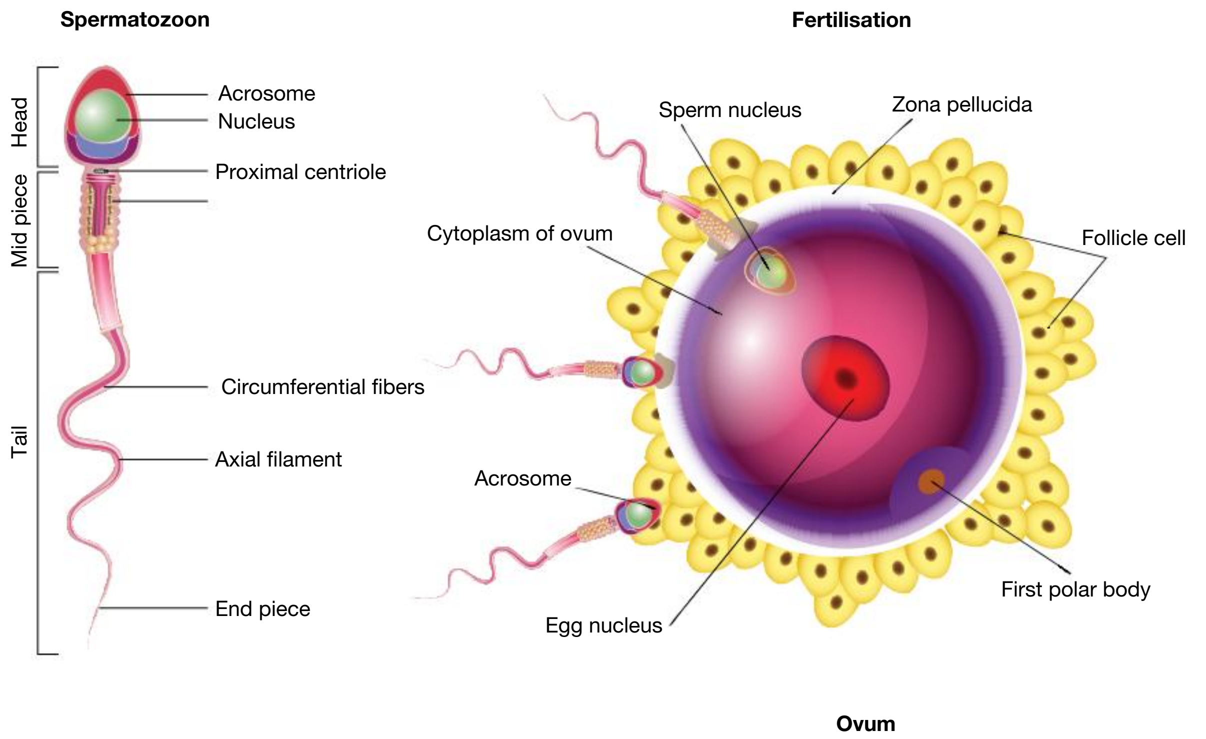


FIGURE 5.28 Both human ova and chicken's ova are fertilised internally following mating between a male and female; however, after fertilisation the chicken's egg becomes encased in a shell and then she lays the egg into her nest where the chicks develop. In a human, and other mammals, fertilisation, embryo development and growth of the young occurs inside the mother's body.

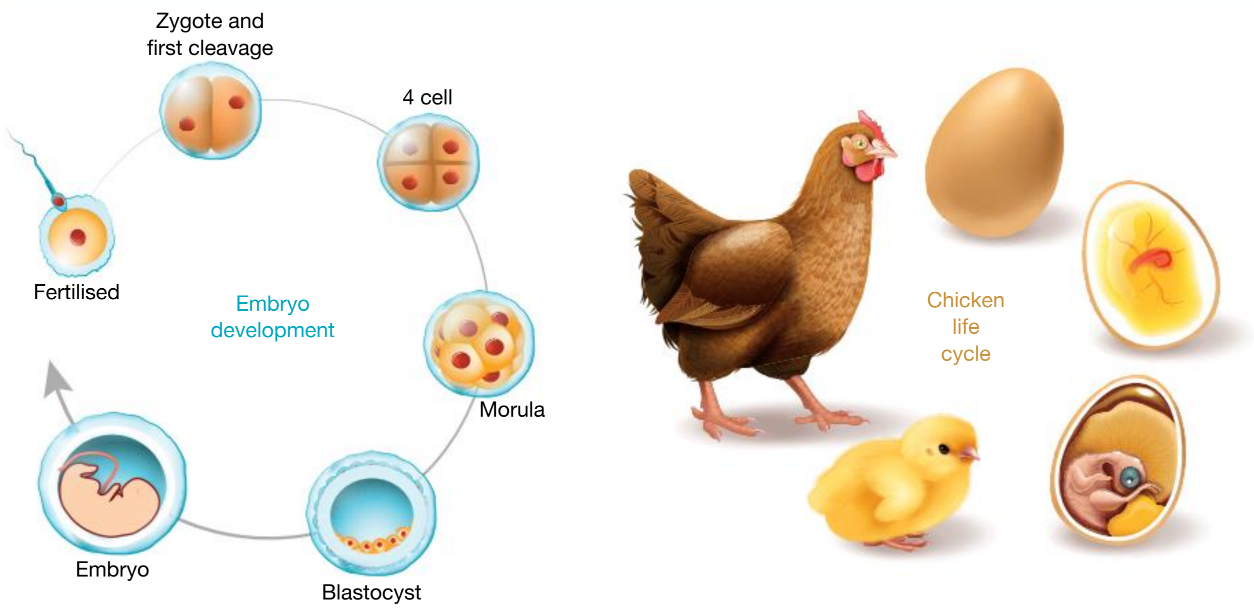
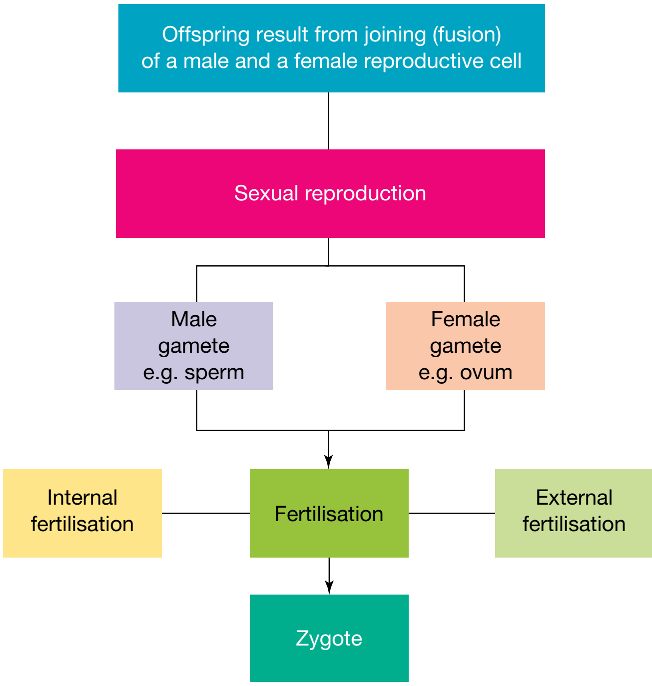


FIGURE 5.29 Sexual reproduction involves fusion of gametes.



internal fertilisation reproduction occurs when the egg remains in the female and is fertilised by sperm inserted into the female

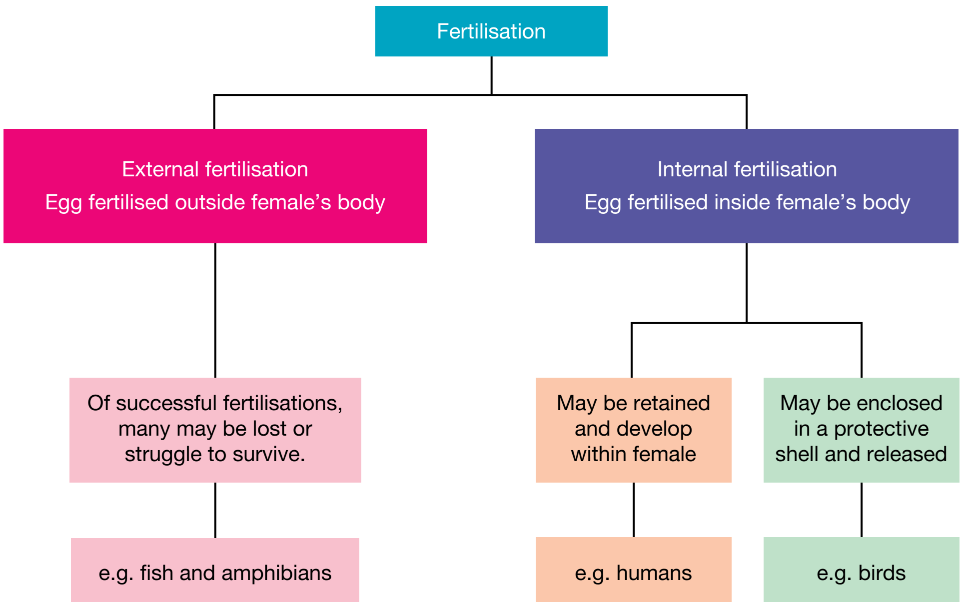
sexual intercourse the act of inserting sperm into the female; also called copulation or mating

external fertilisation reproduction occurs when the eggs are released by the female into water and fertilised by sperm released nearby

5.4.2 Where fertilisation occurs

Internal fertilisation is used by many animals. The sperm cells are usually delivered into the reproductive system of the female during mating by copulation (or **sexual intercourse**). The embryo may continue to develop inside the female, as occurs in mammals; or the female lays a batch of eggs, which go on to develop outside of the female's body such as for birds and reptiles. Sometimes, however, **external fertilisation** happens outside of the body. In the case of the clown fish, the female lays a batch of between 100 and 1000 eggs and then the male covers the eggs in sperm cells. The male guards the nest from predators for the next week until they hatch.

FIGURE 5.30 Some differences between internal and external fertilisation



SCIENCE AS A HUMAN ENDEAVOUR: Marine ecology

Dr Emily Fobert is a Canadian-born scientist who now researches marine ecology at the University of Melbourne. She fell in love with the coral reef and the tropical marine ecosystem on a three-week field course adventure in Cuba while she was at university. Since then she has travelled the world with her research, studying marine life in lakes and rivers of Canada and Europe as well as the reefs around Australia, Indonesia, French Polynesia and the Maldives.

FIGURE 5.31 Dr Emily Fobert

What do you love about marine ecology?

'Ecology is an incredibly multi-disciplinary field, and to understand how organisms interact with each other and their environment, you need to consider aspects of biology, physiology, behaviour and evolution, as well as the physical aspects of their environment — it never gets boring!'

FIGURE 5.32 Coral reefs are one of the most diverse ecosystems in the world.

Research: Light stops clown fish eggs from hatching

Emily has made an interesting discovery about clown fish reproduction. This recent study, a collaboration between Flinders University and the University of Melbourne, showed that exposing clown fish eggs to artificial light at night stopped them from hatching. Although at first it may seem hard to imagine why this is important, consider the lights around Australia's popular coral reefs cast by boats doing night cruises, hotels and floodlights shining on the reef to ensure visitors can observe this wonder throughout the night. All of these have now been shown to have negative effects on a coral reef.

What difference do you hope your research will make?

'I like to ask research questions that can have somewhat applied outcomes, so that my research is working towards improving management and conservation practices, and overall reducing our impact on the planet. I think we are often unaware of how our actions are impacting animals and natural systems, and by asking these questions and highlighting what the consequences of our actions can be, I hope that more people recognise that what we do can affect all life on Earth, and think more about how we can reduce these impacts.'

Dr Fobert's work raises many questions about the impact of our actions.

- What do you think are the possible consequences if we continue to expose clown fish habitats to artificial light at night time?
- Why do you think it may stop them from hatching?

FIGURE 5.33 Clown fish form symbiotic mutualisms with sea anemones.

5.4.3 Did you know that ...

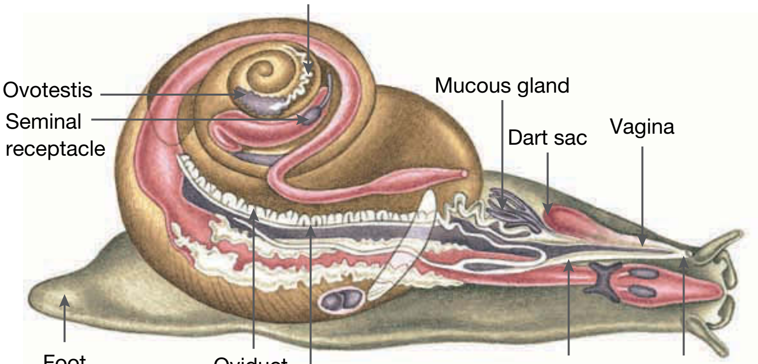
- Some reptiles and rodents actually 'cement' up the female's genitalia by using some of the semen, which sets into a hard plug, not allowing other sperm to get in.
- Male starworms are 'live-in lovers', spending their entire lives within the female's vagina. Her eggs are fertilised by these parasitic males (which live off her vaginal fluids) as soon as they are released.
- Some butterflies have eyes on their genitals to help guide the hooks and claspers of the male to the appropriate nooks and crannies in the female during copulation.
- The Australian gastric brooding frog (now thought to be extinct) swallowed its externally fertilised eggs and then developed them in its stomach. A special chemical produced by the eggs stopped them from being digested. More than 25 baby frogs would crawl out of the female's stomach and into her mouth.
- Leadbeater's possums are tiny marsupials endemic to the Victorian high country. The mother gives birth two weeks after mating and keeps her two offspring in her pouch for another 12 weeks. The young stay with the mother for up to ten months but are not reproductively mature until about two years of age. The lifespan of a Leadbeater's possum is approximately six years.

FIGURE 5.34 Some male damselflies have a penis with a special hook on the end. He uses it to remove other sperm left inside his mate by previous lovers before he makes his own deposit.

FIGURE 5.35 Leadbeater's possums. After emerging from the pouch, young stay with the mother for up to ten months but are not reproductively mature until about two years of age.

Did you know that ancestral reptiles were the first vertebrates to have a penis, and that snails contain both male and female reproductive organs? While there is considerable diversity in the organisation of reproductive systems in organisms, there are also patterns and similarities. Although reproductive organs may appear structurally different, they often perform similar specialised functions that enable their species to survive and reproduce. In figure 5.36 can you identify similarities to our human reproductive systems? If so, what are they?

FIGURE 5.36 Snails are **hermaphrodites** because they have both egg-producing and sperm-producing organs.



5.4.4 Big families

Reproduction can be a risky business — but when the stakes are high it can be worth it! Some animals have some pretty tricky ways of reproducing …

Many organisms produce more eggs than can survive. Imagine what would happen if the 2000 eggs laid by a female house fly all survived! Environmental factors and predators kill many offspring before they get a chance to develop to the stage at which they themselves can reproduce. Sea urchins, for example, discharge millions of gametes into the sea at one time. The coordinated timing of this release increases the chances of fertilisation occurring. However, most of the young sea urchins die. These deaths are caused by many factors, such as competition for food and resources, and predation by other animals. If this reduction in the numbers of sea urchins did not occur, they would soon over-populate the oceans. A high juvenile death rate is also quite common in many other organisms.

hermaphrodites organism that has both male and female reproductive organs

CASE STUDY: Green turtles

Green turtles, *Chelonia mydas*, reach reproductive maturity between 30 and 50 years of age and will continue breed and nest every five years for the next 30 years. In a nesting year a turtle will nest in the sand every two weeks laying 100–200 eggs per nest. The adult turtle then leaves the nest and never returns. About two months later the hatchlings start to appear, scrambling to the water hoping to avoid a predator. Only an estimated 1 in 1000 hatchlings survive to become adult turtles. Although this sounds like a poor reproductive strategy you might argue that it is exactly the opposite as these animals have survived on Earth for 110 million years.

FIGURE 5.37 Green turtles lay thousands of eggs every year.

5.4.5 Dad's having a baby

Seahorses are very unusual fish, especially when it comes to making babies! It is the female that inserts part of her body (an ovipositor) into the male. She pumps eggs into a pouch at the front of his body and he then fertilises them with his sperm. Labour can sometimes take two days. The male gives birth to 50–100 little seahorses, squeezing them out one at a time. No wonder he's called a big-bellied seahorse.

There are some amazing stories to tell about other types of seahorses. The male *Photocorynus* seahorse never grows larger than 10 cm and leads a parasitic life in which he is permanently attached to the female, hanging on by his mouth! This is useful to the female because it means that she doesn't have to search dark ocean depths to find a mate when her eggs are ready for fertilisation.

FIGURE 5.38 Male *Hippocampus abdominalis* seahorses try to get females to select them to carry eggs by inflating their pouches into a white balloon.

on Resources

Video eLesson The weedy seadragon (eles-2067)

5.4.6 Guess who's coming to dinner

In some fish species in which the male is in charge of protecting a clutch of eggs, it is not unusual for him to indulge in eating some of his own offspring. Honey, I ate the kids!

This carnivorous trend also appears in some spider groups. The male Australian redback spider, for example, is usually eaten by his sexual partner while mating with her. He is even considerate enough to position his body directly in front of her jaws after he has inserted his coil-shaped sexual organ into her. Male redbacks have a short lifespan; locating a female is extremely competitive and often the tip of their sexual organ breaks off during sex!

FIGURE 5.39 The male Australian redback spider, for example, is usually eaten by his sexual partner while mating with her.

Recent studies have found that males that are consumed increase their chances of fertilising the female's eggs. By being eaten, they distract the female so that they may mate for longer. It was found that males that were eaten were able to mate for 25 minutes compared with 11 minutes for those that escaped. Hence, the eaten males had twice the chance of fertilising the eggs with their sperm. So, although being eaten for dinner seems like a high price to pay for sex, it does have some long-term rewards.

on Resources

Video eLesson Redback spiders (eles-2541)

5.4.7 Sending out signals

Using smell

Chemicals called **pheromones** can play an important role in communications between members of the same species. This type of communication makes it very easy for animals to locate a mate, even in sparsely populated areas.

When a female dog is about to ovulate, she comes 'on heat'. During this time she releases a pheromone into her urine to notify male dogs that she is ready for mating (figure 5.40). Likewise, female moths use scented chemicals that sexually attract male moths from as far away as 8 kilometres.

Using light

Fireflies can make part of their body glow different colours (figure 5.41). A chemical reaction produces a bright yellow, green or blue colour, which is used to help males and females find each other so that they can mate. Not all females, however, have reproduction on their minds. Females of a particular type of firefly have a different activity in mind. They flash their glowing abdomens on and off in a particular pattern, usually suggestive of a mating invitation. Sadly, instead of a romantic rendezvous, the males become a tasty meal.

FIGURE 5.40 During ovulation, a female dog releases a pheromone into her urine.

FIGURE 5.41 A chemical reaction in fireflies produces a bright yellow, green or blue colour, to help males and females find each other so that they can mate.

pheromones chemicals that are important in communication between members of the opposite sex

on Resources

Video eLesson *Photuris* firefly (eles-2542)

Using sound

Whales may become separated by long distances, so in order to reproduce it is important that they can communicate. The male humpback whale sings a song during the mating season to advertise his sexual availability to females.

FIGURE 5.42 The male humpback whale sings a song during the mating season to advertise his sexual availability to females.

Birds also use their songs to attract potential mates. Frogs and crickets may not sound so melodic, but they have their own way of making it known that they are available for sex. Male crickets make their chirping song by rubbing their forewings together. Often they build their own version of a stereo amplifier by digging an underground nest with a twin-horned tunnel entrance. By sitting at the junction of the horns they can beam out their message loud and clear for all to hear.

5.4.8 Tammar trends

Researchers are studying the reproductive biology of the Tammar wallaby, a marsupial mammal native to South and Western Australia; this research may help us to understand more about ourselves.

A baby Tammar wallaby is born about 26 days after conception. At birth, it weighs only 400 mg, is about the size of the end of your little finger, and is blind and hairless. After leaving the birth canal, it crawls up into its mother's pouch and attaches itself to one of her teats. At this stage, its external sex organs have not yet developed; researchers already know that these develop in stages quite different from those in many other mammals.

After suckling for about five months, it emerges from the pouch as a young joey. Although a joey can continue to suckle for up to a year, the mother can suckle another wallaby at a different stage of development at the same time. She does this by simultaneously producing two different types of milk. Research on how she does this could help us to improve milk production in farmed animals and our own human nutrition.

The mother Tammar wallaby can suspend the development of a fertilised egg until its older brother or sister has left the pouch, or until environmental conditions are more suitable. Finding out how she achieves this may help us develop new fertility and development technologies for other mammals, including humans.

FIGURE 5.43 A newborn Tammar wallaby sucking on its mother's teat

FIGURE 5.44 Will Tammar wallabies provide clues to our future reproductive technologies?

on Resources

Video eLesson Tammar wallaby (eles-2543)

assess on Additional automatically marked question sets

5.4 Exercise

learn on

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 3, 6, 12, 16	Questions 2, 4, 7, 10, 13, 15	Questions 5, 8, 9, 11, 14

Remember and understand

1. Identify the missing words to complete the sentence.
   Environmental factors, ____________ and ____________ for food and resources can result in the death of many ____________ before they get a chance to develop to the stage at which they can ____________.
2. Identify whether the statement is true or false. Justify any false responses.

Statement	True or false
a. Many organisms produce more eggs than can survive.	
b. In seahorses, the father can give birth to the young.	
c. Some male damselflies have a penis with a special hook on the end to remove sperm left inside his mate by previous lovers before he makes his own deposit.	
d. If eaten by his sexual partner, the male red-back spider has an increased chance of fertilising her eggs.	
e. Some reptiles 'cement' up the female's genitalia by using semen that sets into a hard plug so that other sperm cannot get in.	
f. Pheromones are a group of chemicals that play an important role in communication between members of the same species.	
g. Hermaphrodites are animals that have both egg-producing and sperm-producing organs.	
h. Fireflies make part of their body glow different colours to help find mates, but never to lure mates and then eat them.	
i. The male humpback whale sings a song during mating season to advertise his sexual availability to females.	
j. The Tammar wallaby can only suckle one infant at a time.	

3. Match the correct terms to the following definitions.

Definition	Term
a. Name given to reproductive cells	A. Pheromones
b. Male reproductive cell	B. Fertilisation
c. Female reproductive cell	C. Sperm
d. Name of early embryo just following fertilisation	D. Ovum (ova)
e. Chemical signal released outside of the body to communicate to other members of the species	E. Gametes
f. The joining of a male and female reproductive cell to form an embryo	F. Zygote

4. What is the name of the group of chemicals that can play an important role in communications between members of the same species?
5. Suggest three ways in which smell is important to reproduction.
6. Describe what it means when a dog is 'on heat'.
7. **SIS** Using the graph paper accurately, show the relative sizes of a human ova and sperm. *Hint*: Decide on and mark 1 mm first then indicate how large each cell is in relation to 1 mm.

Apply and analyse

8. Compare internal and external fertilisation using an example from the text of each one and ensure you use comparative language.
9. Describe one way in which the following males may increase the chances of their sperm fertilising the female's ova.
   a. Redback spider
   b. Starworms
   c. Damselflies
   d. Some reptiles and rodents.

10. Compare the reproductive strategies of the green turtle and Leadbeater's possum. Consider the following features of each:

Features	Green turtle	Leadbeater's possum
How many young are born (or hatch)?		
How do the parents care for their young?		
How many years do they reproduce for?		
How many of their young are likely to survive to adulthood?		

11. SIS Which reproductive strategy do you think is more successful in terms of ensuring the species survives? Justify your answer.

Evaluate and create

12. Making connections. Using the examples from this section, identify three ways in which chemicals are important in reproduction to different animals.
13. SIS The Tammar wallaby can suspend, or pause, the development of a fertilised embryo. Suggest why this is an advantage for both the mother and offspring.
14. SIS Suggest why reproduction is worth the risks that may be involved.
15. SIS How might we support organisms that are at risk of extinction to survive for more generations?
16. Construct a poster advising tourists visiting the Great Barrier Reef on the impacts of their actions to organisms in the reef. Your poster must:
    - make specific reference to the research of Dr Fobert and her findings on the impact of artificial light on clown fish reproduction
    - suggest the long-term effect on the reef clown fish population if artificial light use continues at night around the reef
    - list possible changes that people and organisations could make to reduce their impact
    - identify areas for further research that should be investigated to identify how big the issue of light contamination is on marine organisms.

Fully worked solutions and sample responses are available in your digital formats.

5.5 Human reproduction

LEARNING INTENTION

At the end of this subtopic you will be able to explain the role of gametes in human reproduction including where they are produced and how they combine to result in a pregnancy and birth.

FIGURE 5.45 Human sperm cells surround an ovum.

Human reproduction is a complex and intriguing process. Its success is determined by a range of factors and manipulated by people wishing to control the timing of reproduction as well as the number of offspring they have. It is a dynamic and fascinating area of research that links biology to many other fields within science and medicine.

5.5.1 Gonads and gametes

Gonads are the site of gamete production. They are specialised organs that contain many different specialised cells needed to support growth and development of healthy gametes. In human males the gametes, sperm cells, are produced continuously for most of the adult life. The female gametes, however, are all present at birth in an immature state. Throughout a female's reproductive years a complex cycle called the menstrual cycle supports the growth and maturation of an ovum and its release.

5.5.2 Female reproductive system

The female gonads are called ovaries this is the site for production of the female gametes (sex cells), the ova. There are two ovaries each connected to the **uterus** via their own fallopian tube.

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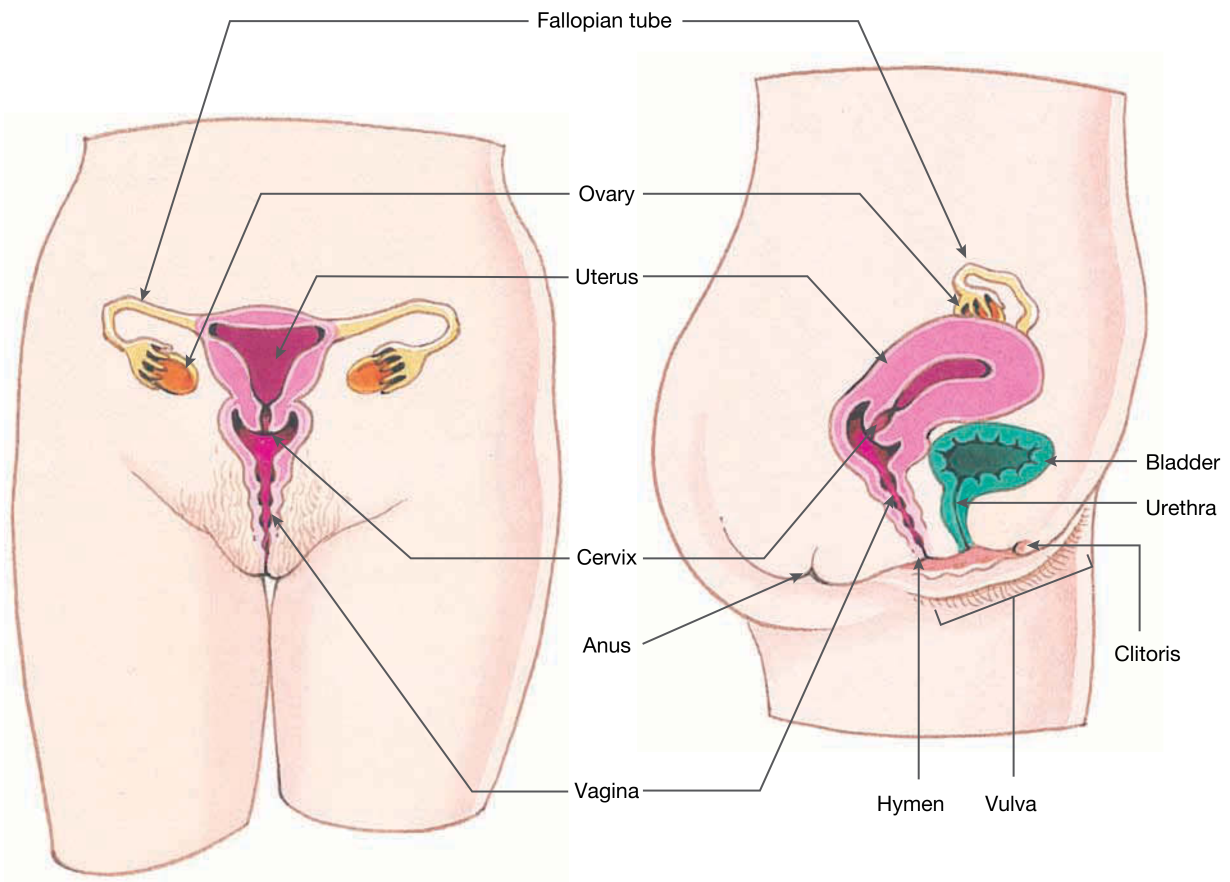
FIGURE 5.46 The human female reproductive system



Human ova are produced during development of the female fetus before birth, and once the baby is born no more ova can be produced. From birth to puberty the number of ova decline; by the time a young female enters puberty there are usually about 400 000 ova in each ovary although it is likely that only two or three of these will become new offspring.

Each month a small number of ova grow within a fluid-filled follicle in the ovary. Usually only one follicle completes its growth and releases a mature ovum during the process of **ovulation** into the fallopian tube.

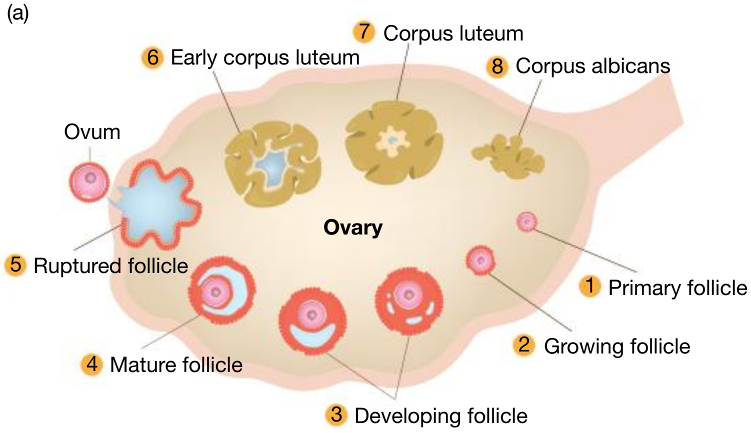
gonads reproductive organs where gametes are produced; the testes and ovaries

uterus the site of embryo implantation, and supports the developing fetus from implantation to birth. About the size of a pear if not pregnant

ovulation the release of an ovum from a mature follicle in the ovary into the fallopian tube

FIGURE 5.47 a. Development of an ovum occurs inside the follicle of the ovary over a number of weeks. Initially the ovum and its follicle are small; however, both growth of the ovum and expansion of the follicle occur in response to hormones (chemical messengers) circulating around the female's bloodstream. The follicle eventually fills with so much fluid it ruptures and releases the mature ovum into the fallopian tube where it can be fertilised. **b.** This process can be seen at its different stages using a powerful microscope as illustrated by the section of the cat ovary shown here.

(a)



(b)

FIGURE 5.48 Human ova are approximately one tenth of a millimetre in size.

A mature ovum is a large cell (approximately 100 μm) that contains half of the genetic material needed to begin embryonic development but nearly all of the cellular machinery needed. A single human ovum contains approximately 100 000 **mitochondria** needed to meet the energy demands of fertilisation and early embryo development. In addition, the ova can produce proteins in its ribosomes, absorb nutrients and break them down, and remove waste.

Interestingly, mitochondria in the ova have their own DNA which will be handed directly from the mother to the offspring. Only recently have we started to understand the importance of **mitochondrial DNA (mtDNA)** and the information held within the mitochondria for developing our understanding of evolution as well as a range of genetic diseases.

mitochondria small rod-shaped organelles that are involved in the process of cellular respiration, which results in the conversion of energy into a form that the cells can use. Singular = mitochondrion

mitochondrial DNA (mtDNA) genetic material from the mitochondria, which is only passed to offspring from the mother

TABLE 5.2 Summary of the human female reproductive system

Part	Function
Ova (plural), ovum (singular)	Female gamete, egg
Ovaries	Female gonads, one ovum matures and is released on a monthly basis from one of the two ovaries
Fallopian tubes/oviducts	Tubes through which the ovum must travel to reach the uterus. The site of fertilisation if sperm is present after intercourse
Uterus	The site of embryo implantation, supports the developing fetus from implantation to birth. About the size of a pear if not pregnant

Endometrium	The lining of the uterus. Is shed during menstrual bleeding, or period, if an embryo does not implant
Cervix	The passageway between the vagina and the uterus. Dilates during childbirth to allow the baby to be delivered through the vagina
Vagina	Elastic entry to the female reproductive system. The site for semen to enter during intercourse and delivery of a baby during childbirth
Clitoris	Small accessory organ that swells during sexual arousal

5.5.3 Male reproductive system

The male gonads are called **testes**, and they are suspended outside of the body to keep the temperature 3º C cooler than body temperature, which is optimal for producing sperm. The testes are continuously producing gametes from **puberty** for most of the male's lifetime.

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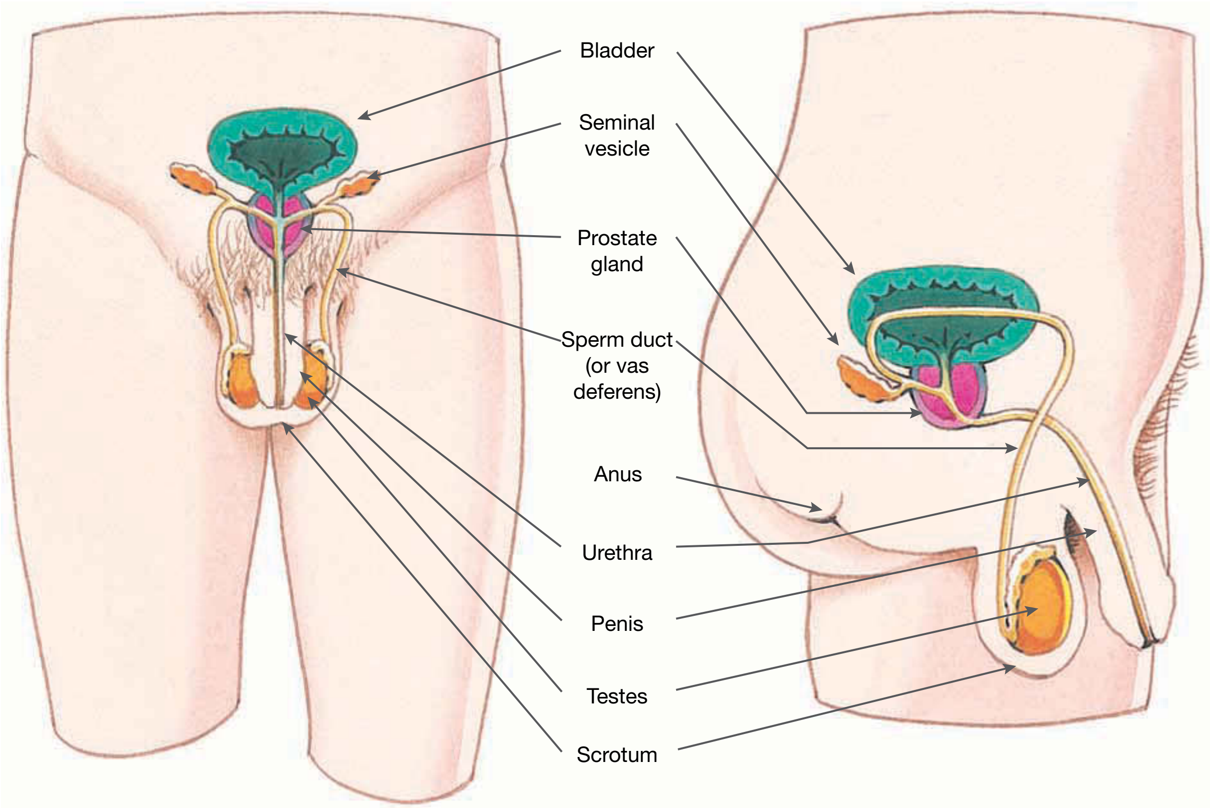
FIGURE 5.49 The human male reproductive system



A typical ejaculate can contain 300 million sperm cells that are ejaculated in a sticky fluid called **semen**. Sperm are about one-twentieth the size of a human ovum and are much simpler cells containing less organelles and cytoplasm than the ovum. This reflects their role, which is simply to deliver the genetic information to the ovum. Sperm are motile cells that have the ability to swim by beating their long flagella and propelling themselves forwards and therefore need mitochondria to provide the energy for swimming. Only sperm with the correct shaped head and a good level of motility will be able to reach the fallopian tube and fertilise the ovum. It is common for only 5 per cent of sperm cells to have the correct shape to fertilise an ovum.

testes organs that produce sperm and sex hormones

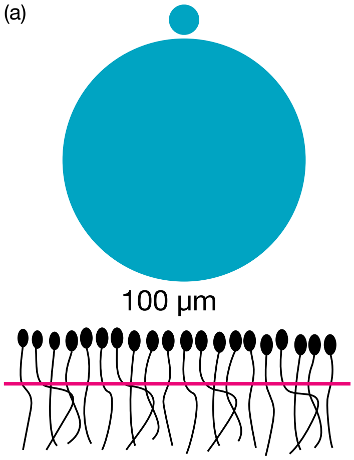
puberty the life stage when the sex glands become active and bodily changes occur to enable reproduction

semen ejaculate from the male reproductive organs made up of sperm and secretions essential for its viability

Most sperm cells do not progress through the cervix and into the uterus, even less make it into the fallopian tube where a mature ovum may be waiting. Only one sperm cell can fertilise an ovum in the fallopian tube and contribute its genetic material to the offspring.

FIGURE 5.50 a. Sperm are about 20 times smaller than ova. **b.** Photomicrograh shows their long tail for motility.

(a)



(b)

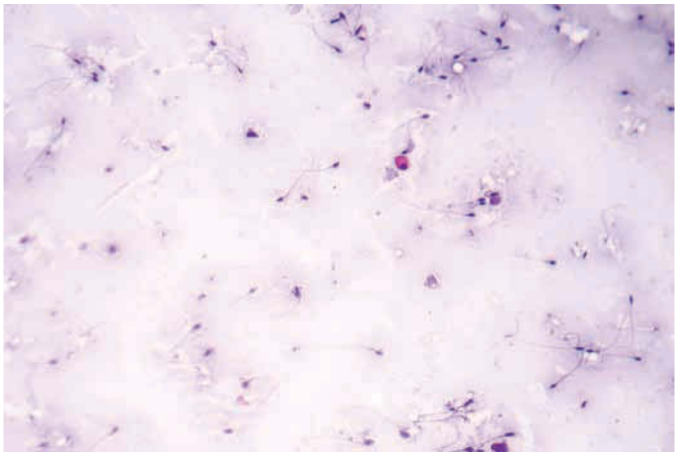
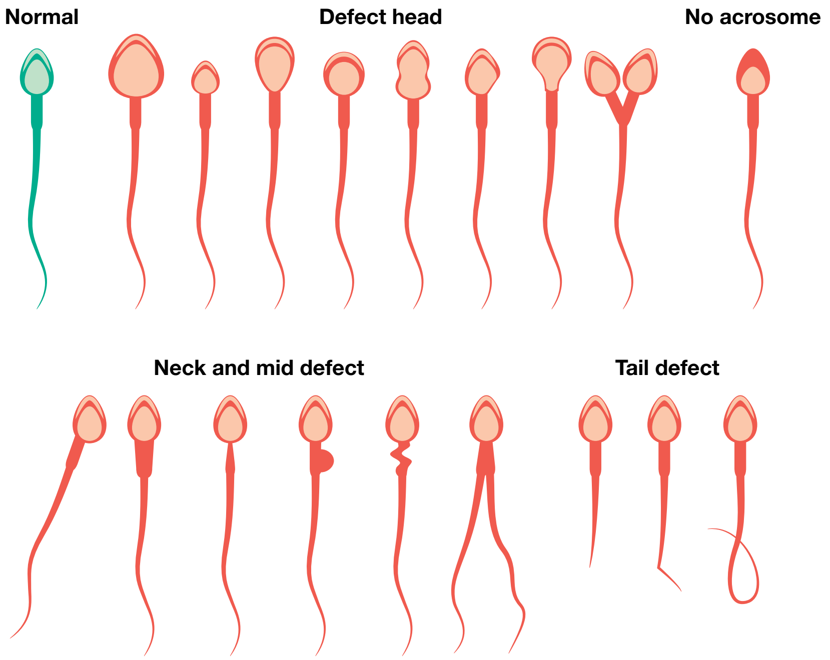


FIGURE 5.51 Sperm morphology, or shape, is very important as sperm cells without the correct head, midpiece or tail shape will not be capable of fertilising the ovum.



EXTENSION: Amazing sperm

Sperm cells are less than half a millimetre long. Viewed through a microscope lens, spermatozoa (sperm, for short) remind you of tadpoles — a big head and a thin, whippy tail. They form in the testes, but only when the temperature is just right — a few degrees lower than body temperature. This is where the scrotum — a natural thermostat — does its job. It shrivels and scrunches up closer to the body when you are cold (keeping sperm warmer) and hangs away from your body when you are hot (cooling them down).

Sperm by the millions

The average amount of semen produced during an ejaculation (about a teaspoonful) contains about 200–500 million sperm cells! You might think it would take a long time for the testes to make 400 million sperm. Not so. Some 200 million sperm cells are manufactured each day by a fertile adult male. That's around 73 billion sperm cells in a year!

Which animal has the longest sperm? Not an elephant, whale or human, but a fruit fly. Fruit flies of the species *Drosophila bifurca* have sperm about 5.8 cm long! That's about 20 times longer than their own body and around 1000 times longer than human sperm.

FIGURE 5.52 A sperm cell under a microscope

on Resources

eWorkbooks Human male reproductive system (ewbk-4896)
Human female reproductive system (ewbk-4897)

Video eLessons Human ovum in utero and sperm cells (eles-2539)
Live human sperm (spermatozoa motion) under microscope (eles-2544)

TABLE 5.3 Summary of the human male reproductive system

Part	Function
Sperm	Male gamete
Testes	Male produce sperm cells continuously throughout reproductive life.
Scrotum	Surround the testes and keep them suspended outside of the body to keep the testes at about 34° C, about three degrees Celsius cooler than core body temperature.
Seminal fluid, semen	A liquid containing sperm cells produced in the testes and fluids from the prostate and seminal vesicle. Highly viscous to support delivery of sperm into the reproductive system.
Vas deferens	The tube through which mature sperm cells travel from the testes to the penis.
Prostate gland	About the size of a walnut, the prostate secretes fluid to support sperm function and maintain the pH of the semen.
Seminal vesicle	Provides sugar and nutrients to the semen to support sperm function.
Urethra	Tube inside the penis through which urine and semen leave the body.
Penis	External sexual organ that swells during arousal. Semen containing sperm cells are released, or ejaculated, into the vagina during sexual intercourse.

SCIENCE AS A HUMAN ENDEAVOUR: Andrology

Extensive research into sperm and sperm function has been conducted over the years with significant discoveries being made here in Australia by scientists working in the field of andrology.

Dr De-Yi Liu is a scientist working between Melbourne University, the Royal Women's Hospital and The Royal Children's Hospital. Dr Liu has spent many years investigating factors that lead to failure of fertilisation of human ova by sperm. He has discovered that despite seemingly normal morphology, or shape, that some sperm are not capable of binding to the ovum resulting in couples who are not able to conceive. Dr Liu developed a laboratory test to identify this, which has supported couples who are unsuccessful in trying to fall pregnant.

Another Melbourne-based andrology researcher, Dr Fabrizzio Horta Nunez, has spent ten years researching the male gamete. Recent findings from an investigation of more than 1500 patients at Monash IVF found that despite the fact that sperm production does not significantly decline with age in men, the male age is important to the chances of conceiving. His research found a significant decline in the success rate after the age of 40.

FIGURE 5.53 Dr Liu and Dr Horta Nunez have spent years researching sperm and sperm function.

5.5.4 Puberty

Puberty is the process of change that occurs as children become adults and reach reproductive maturity. Each change is the result of a chemical or hormonal change in the body. Hormonal and chemical changes in the body cause a range of observable physical changes (figure 5.54). Many of these changes can feel annoying and sometimes upsetting but are an essential part of becoming an adult who is fertile and capable of reproducing. It is at this time that males start to produce sperm cells and females release an ova as part of their monthly **menstrual cycle**.

FIGURE 5.54 Both boys and girls experience a growth spurt around the time of puberty, before they stop getting taller altogether.

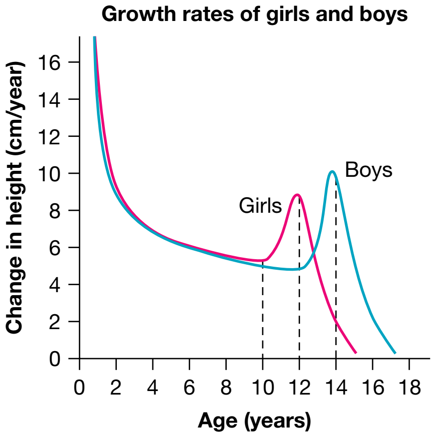


TABLE 5.4 The main changes observed during puberty

Boys	Girls
Testes grow	Breasts grow
Pubic hair develops	Pubic hair develops
Penis growns	Menstrual cycle begins
Increase in body hair on face, arms, legs, armpits and chest	Increase in body hair on arms, legs and armpits
Grows taller	Growth slows
Body shape changes: increased muscle growth broadens shoulders	Body shape changes: increased curves, hips widen
Increased oil secretion in the skin results in pimples due to hormonal changes	Increased oil secretion in the skin results in pimples due to hormonal changes
Sweat production increases	Sweat production increases
Voice deepens	

menstrual cycle beginning of one period to the beginning of the next period

In addition to these physical changes, changes in mood, confidence, voice and interest in romance are all common in young people during puberty. Hormones are the reason for all of these changes. Hormones are chemicals that circulate around the body in the bloodstream and can have multiple effects on different organs such as the skin, brain and reproductive organs. After the rapid and significant changes that occur during teenage puberty, the hormones settle down as young people enter adulthood.

FIGURE 5.55 Other changes that occur during puberty include the growth of hair in the pubic region, under the arms and on boys' faces. Both boys and girls can experience acne as well as changes in the shape of their bodies.

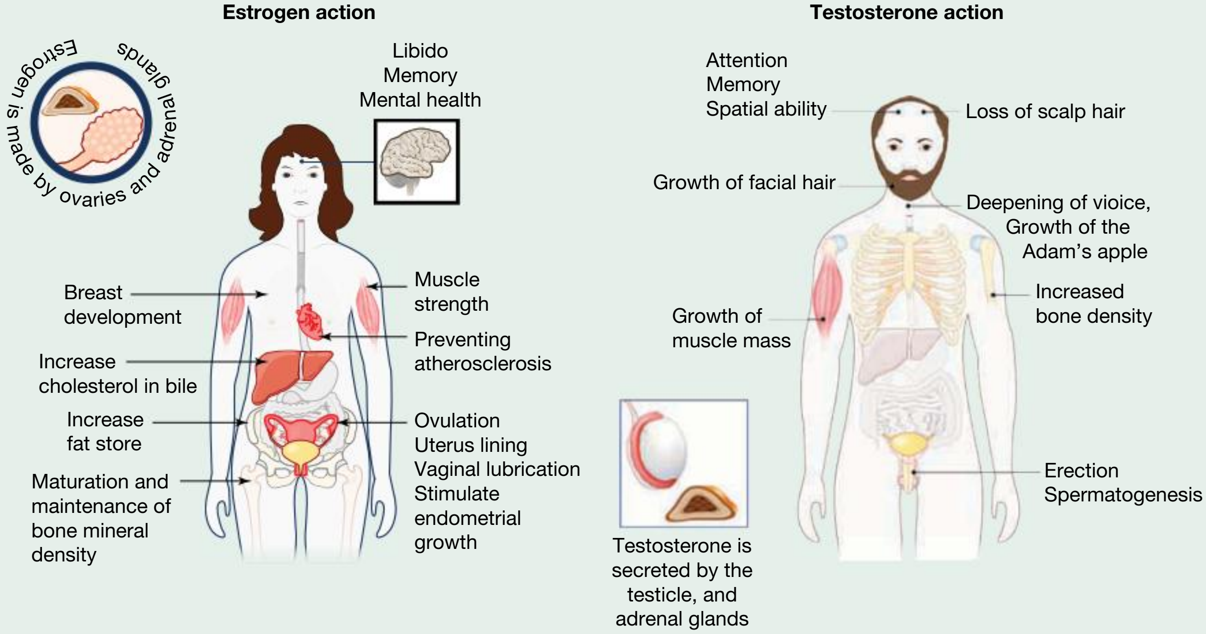
target cell a specific cell in which a hormone can cause a response

EXTENSION: What are hormones?

Hormones are chemical messengers that travel around in the circulation and cause a change in a particular type of cell known as the **target cell**. Hormones are produced in a gland and can have an effect in many different tissue types a long distance from where they are produced.

There are many different hormones circulating in the human body at the same time. Some that may be familiar to you include adrenaline, which increases the heart rate and reaction time; testosterone, which regulates reproduction in both males and females; and insulin**,** which controls blood glucose levels. Hormones control human metabolism, growth, core body temperature, mood, water balance and reproduction.

FIGURE 5.56 The role of two important reproductive hormones is summarised in these diagrams.



5.5.5 Menstrual cycle

The most significant change in a young female during puberty is the commencement of the menstrual cycle.

This cycle usually begins between the ages of 11 and 14 and is indicated by the first menstrual bleed, or menarch. **Menstruation**, known as a period, is actually a shedding of the uterine lining, the endometrium, that has thickened over the previous month in preparation for an embryo to implant. Unless an embryo implants into the endometrium it is shed and starts to build again in preparation for the next time an ovum is released. The cycle begins on the first day of menstrual bleeding and ovulation usually occurs at the halfway point, after about 14 days of a 28–day cycle. A typical menstrual cycle is 25–36 days long.

menstruation the monthly bleeding, also called 'periods'. It occurs as the lining of the uterus is released.

eles-2538

FIGURE 5.57 Changes in hormone levels and the endometrium throughout the menstrual cycle

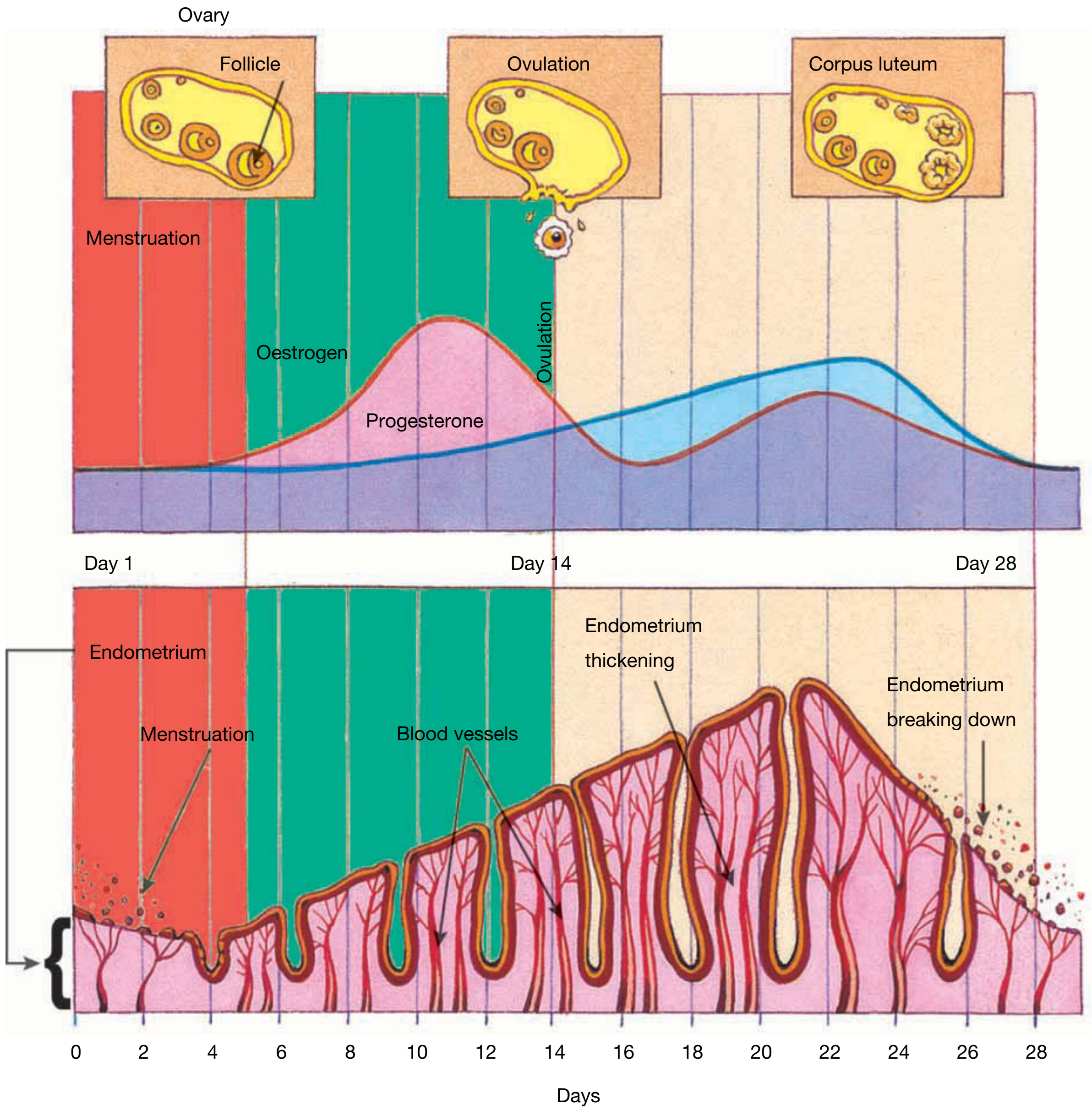
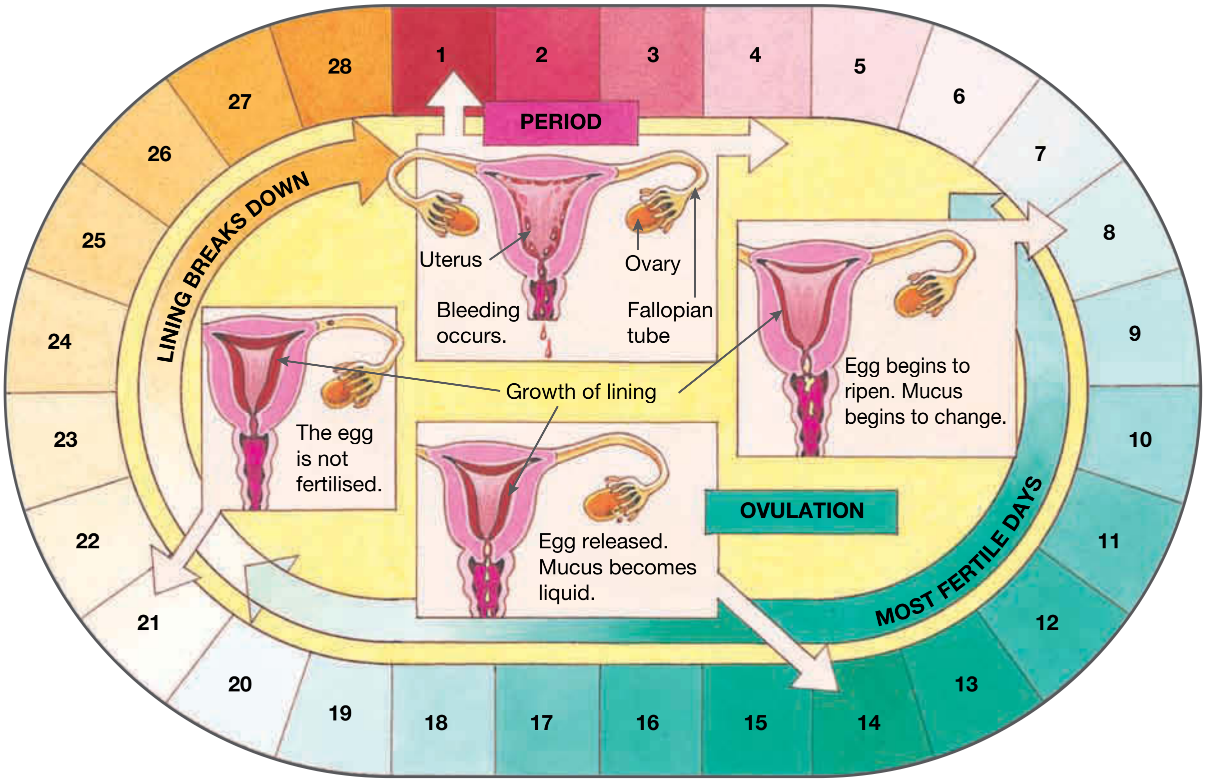


FIGURE 5.58 Menstrual cycle



on Resources

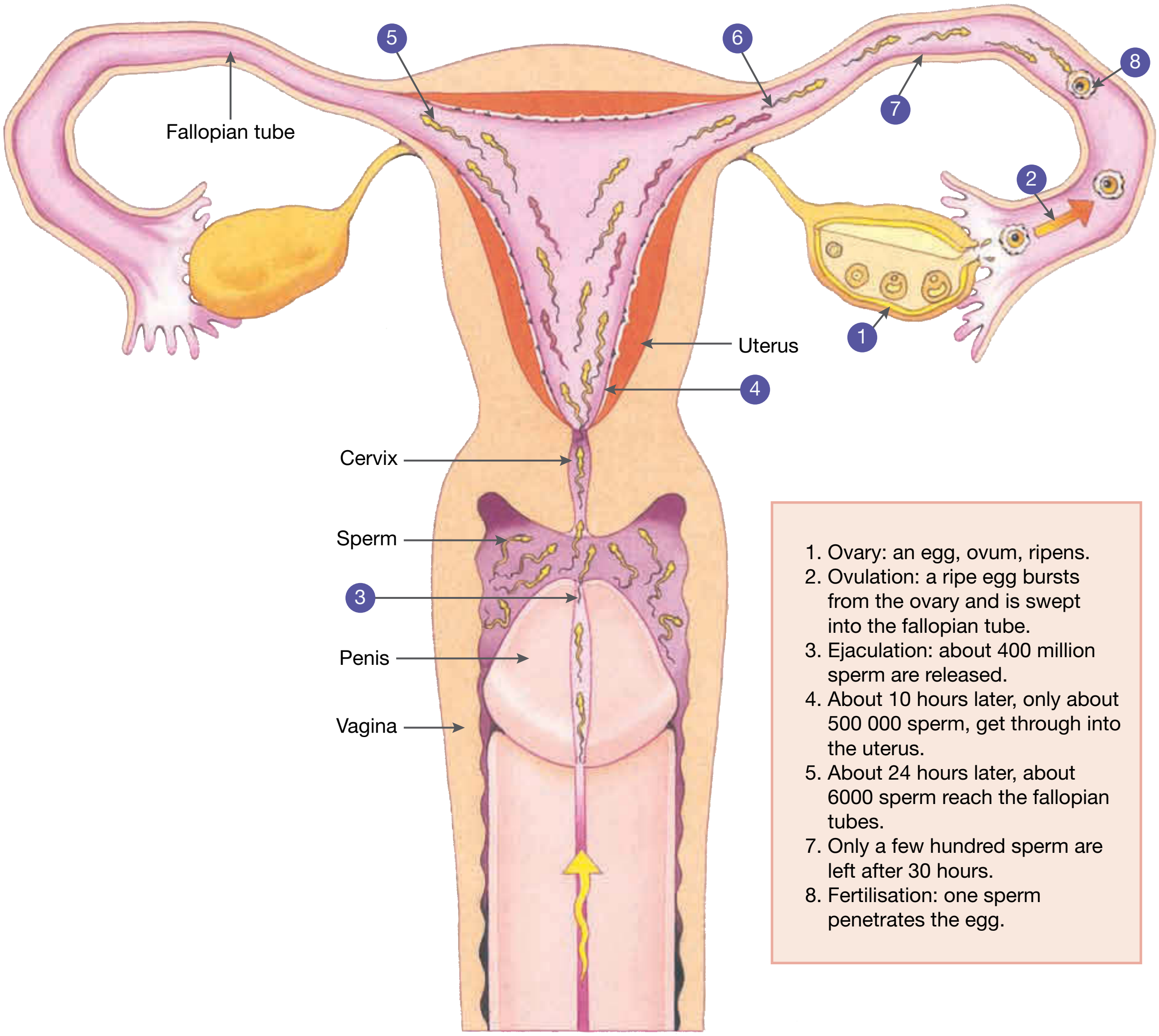
eWorkbook Menstruation (ewbk-4903)

5.5.6 Conception

For sexual reproduction to be successful in humans, a number of things need to occur at the same time. First, there must be a mature egg in the fallopian tube, although this cannot be more than a few hours old. Second, a healthy sperm with normal morphology that is capable of fertilising must be in exactly the same place as the ovum, release enzymes to digest through a large number of cells surrounding the ovum and then bind to the outside shell, or **zona pellucida**, of the ovum. The single sperm must then successfully penetrate the zona and fuse with the cell while initiating a block to other sperm preventing them from entering the ovum.

zona pellucida surrounds the ovum and embryo for the first week of development

FIGURE 5.59 Sexual intercourse — getting the sperm to the egg



If this all occurs correctly, the sperm can combine its genetic information, its haploid set of DNA, with the ovum's haploid set of DNA resulting in fertilisation and formation of an early embryo known as a zygote. The successful fertilisation of an ovum can be confirmed using a light microscope if two nuclei are visible inside the ovum.

FIGURE 5.60 Human unfertilised ovum (bottom left) and three fertilised zygotes each showing two nuclei indicating one set of genetic information from the ovum and one set from the sperm

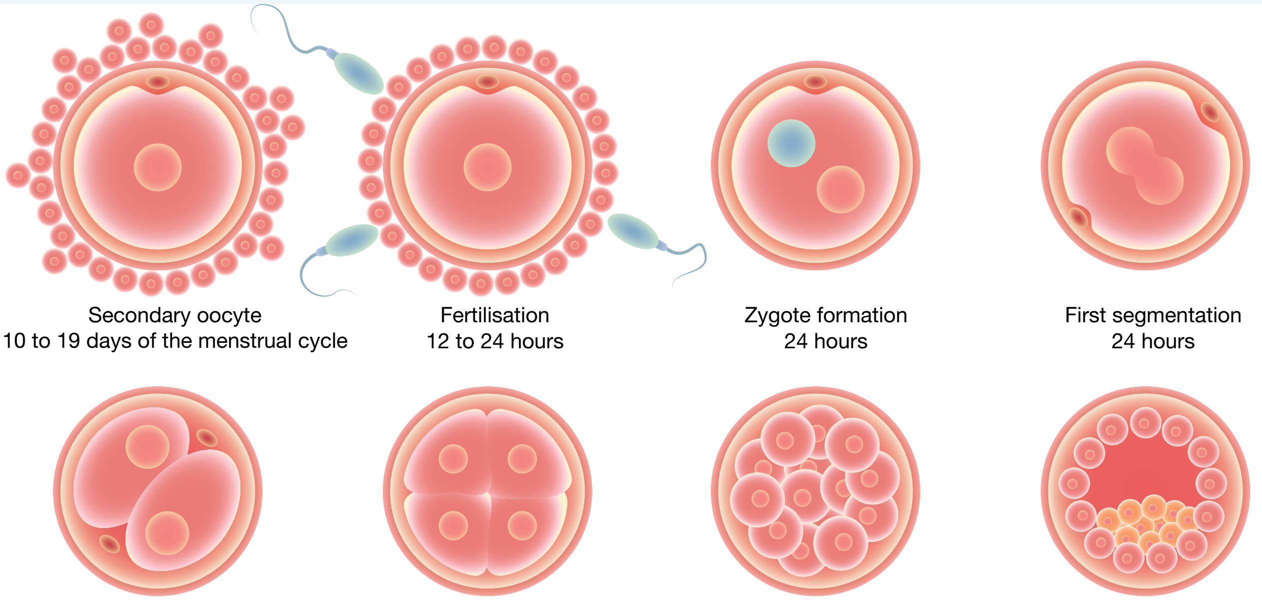
5.5.7 Developing embryo

Once fertilisation occurs embryo development continues for about a week before implanting into the uterus. Initially only one cell, the embryo can reach more than 100 cells by day six. The **blastocyst** stage occurs around day five or six after fertilisation. Until this stage, every cell is identical; after this stage, the cells have a different destiny. **Differentiation** occurs where some cells become destined to become the fetus while other cells are destined to become the placenta to support the fetus. After six days of development the embryo can hatch out of the zona pellucida and attach to the lining of the uterus. This stage is called **implantation** and marks the point at which the embryo can use the nutrients from the mother.

Many embryos do not fertilise or develop correctly and therefore fail to implant, which explains why some people have difficulty falling pregnant.

FIGURE 5.61 Image of a human blastocyst days after fertilisation with cells beginning to hatch out of the zona pellucida or shell

FIGURE 5.62 Embryo development in the first week of pregnancy



5.5.8 Pregnancy

The first eight weeks

Conception occurs when the egg cell and sperm unite to form a zygote. When the zygote has divided into many more cells, it is known as an embryo. About ten days after fertilisation, the embryo completely embeds itself in the uterus lining (endometrium). This process is called implantation.

blastocyst an embryo with a fluid-filled cavity that is beginning to differentiate, five or six days after fertilisation

differentiation when cells become different to each other and start to become specialised

implantation the process whereby the embryo becomes embedded in the wall of the uterus

conception the successful embedding of a fertilised egg in the uterus wall

int-3408

FIGURE 5.63 The process of fertilisation through to conception

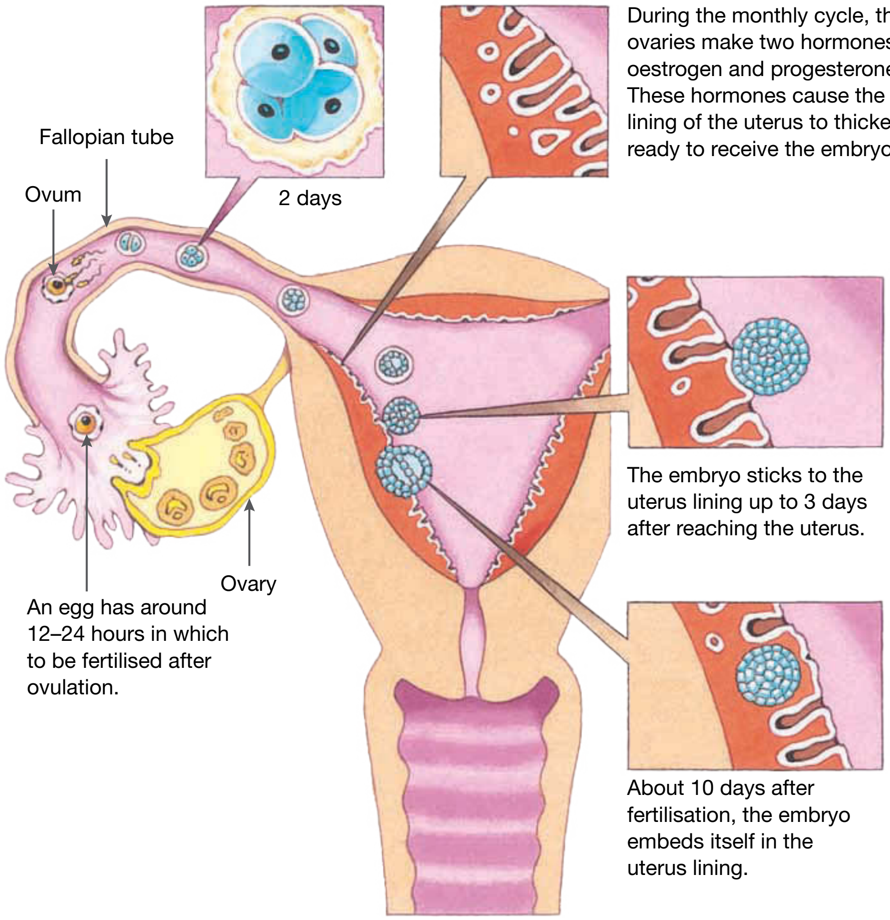
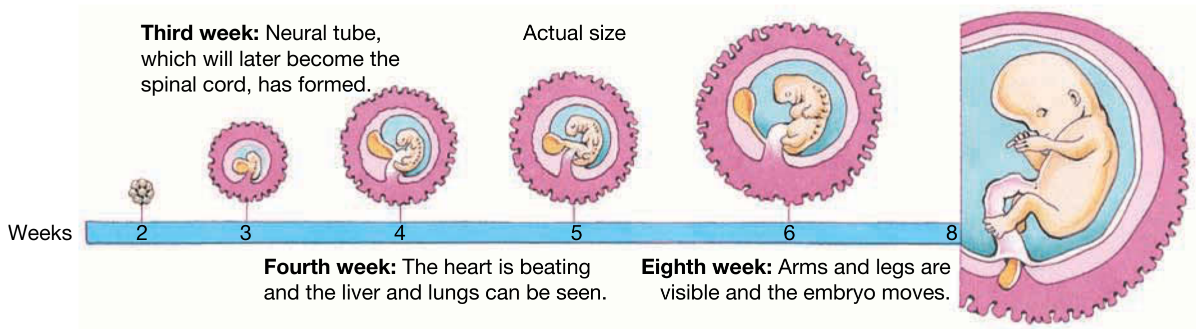


FIGURE 5.64 The first eight weeks



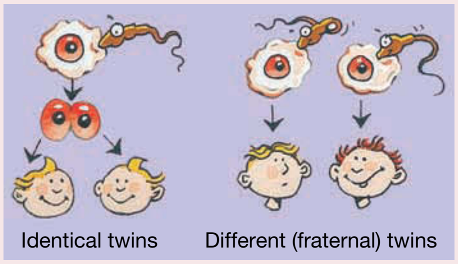
TWO OR MORE?

Sometimes in the very early stages of division following fertilisation the embryo splits in two, so that two identical offspring are produced. This happens in the case of **identical twins**. They will always be the same gender as they both have the same genetic make-up.

identical twins twins developed from the same fertilised egg

Usually, only one ovum is released at a time. However, if several are released, twins or more can result from fertilisation by different sperm. In this case, the babies are not identical because they have different genetic combinations. These are called **fraternal twins**.

The use of fertility drugs and treatments has resulted in an increase in the number of multiple births. This is because fertility treatments can affect ovulation, so that more than one egg is released at a time. Some of these drugs can increase the chance of twins by 25 times and of triplets up to 350 times!



After eight weeks

In humans, at about eight weeks, when the embryo has developed a distinct head, arms and legs, it is called a **fetus**. The fetus obtains nutrients and oxygen through a special organ called the **placenta**. This organ is connected to the mother's blood vessels through the uterus. The placenta also absorbs fetal waste products and acts as a barrier against harmful substances. The unborn child continues to develop inside a sac that is filled with fluid (called amniotic fluid) for the rest of its time within the uterus. The total time spent in the uterus is often called the **gestation** period. In humans, this is usually about 40 weeks. If a baby is born before 37 weeks, it is called **premature** and usually requires extra care and assistance.

TABLE 5.5 Approximate size of a fetus at different stages of development

Development (weeks)	Length (cm)	Mass (g)
8	1.6	1
12	5.4	14
16	11.6	100
20	16.4	300
24	30.0	600
28	37.6	1005
32	42.4	1702
36	47.4	2622
40	51.2	3462

fraternal twins twins developed from different fertilised eggs

fetus the unborn young of an animal that has developed a distinct head, arms and legs

placenta an organ formed in the mother's womb through which the baby receives food and oxygen from the mother's blood and the baby's wastes are removed

gestation the time spent by offspring developing in the uterus

premature a baby born less than 37 weeks after conception

FIGURE 5.65 A human embryo at 32 days

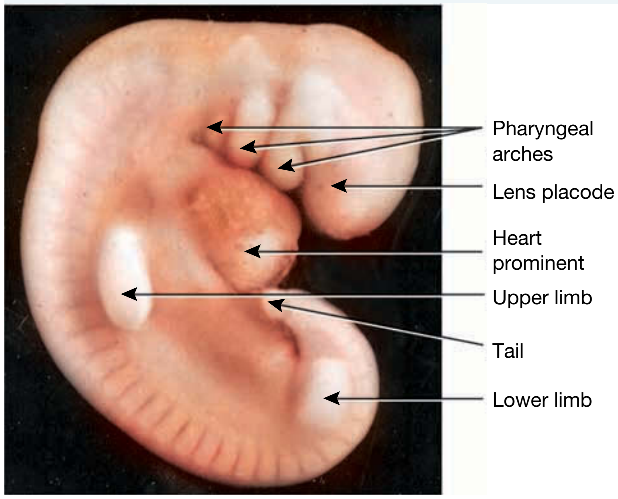
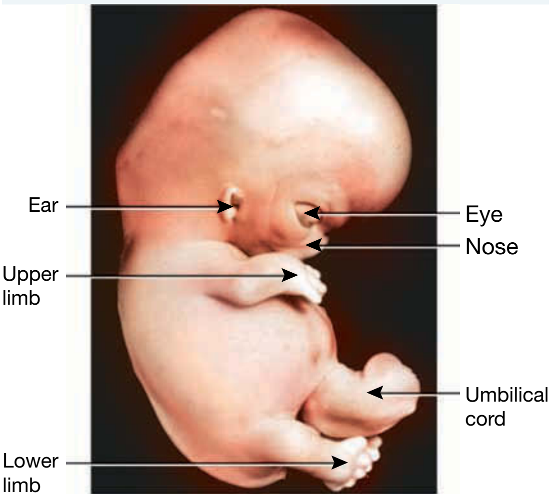


FIGURE 5.66 A human embryo at 52 days

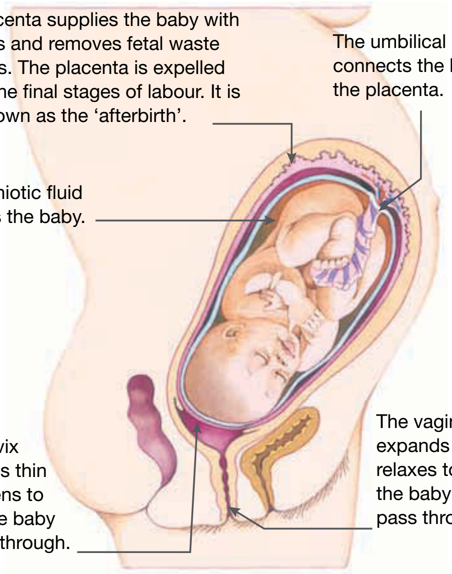


5.5.9 Giving birth

Three stages are involved in giving birth to a baby. Giving birth is referred to as **labour** because it can be a lot of hard work for the mother. During the first stage, the cervix gradually widens. In the second stage, the woman feels a strong urge to push with each contraction of the uterus. During this stage the baby is born through the vagina, or birth canal. Usually the baby is born head first. Sometimes the baby is born bottom or feet first; this is referred to as a **breech** birth and is often more difficult. The third stage lasts from the baby's delivery until the placenta is delivered.

In some cases, the baby or mother need extra assistance. A **caesarean** may be performed in which doctors surgically remove the baby by cutting through the mother's abdomen to her uterus.

FIGURE 5.67 Ready for birth — the baby at 40 weeks' gestation



labour the process of delivering the baby, placenta and umbilical cord from the uterus

breech a birth in which the baby is born feet or bottom first

caesarean an operation to remove a baby by cutting the mother's abdomen

EXTENSION: Oxytocin — the 'trust' hormone

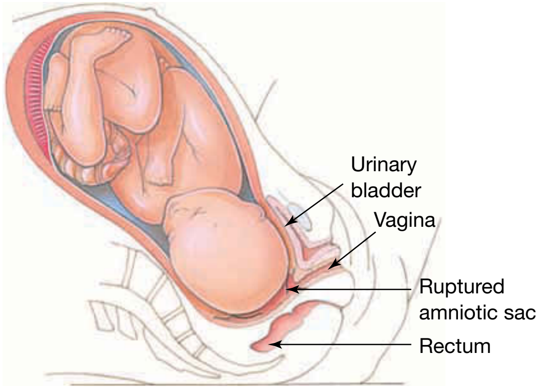
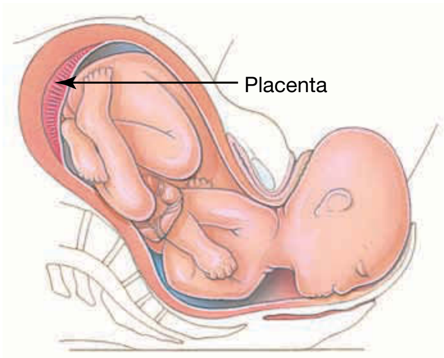
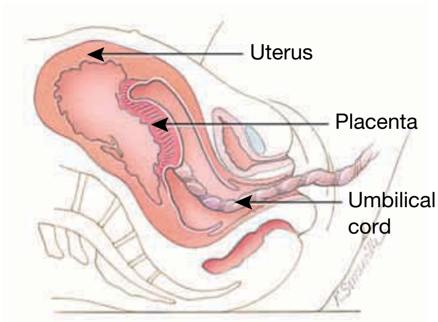
Hormones can have a variety of effects on our bodies. Oxytocin is an example of a hormone that not only has the potential to change how we feel, but also has important reproductive roles. This hormone causes the uterus to contract during childbirth and has a key role in breastfeeding. When a baby suckles on the mother's nipple, oxytocin is released in the mother, triggering the 'let down' response in which milk is released for the baby.

Oxytocin is also thought to be involved in the promotion of trust, love, empathy and social recognition. It has been described as the 'cuddle chemical', as it is released when mothers cuddle their babies. The release of oxytocin may assist in the formation of bonds not only between mothers and their babies, but also between people in close relationships.

FIGURE 5.68 Cuddling and breastfeeding can result in the release of oxytocin, which can promote feelings of trust, love and bonding.

With trust comes power! Nasal sprays containing oxytocin have been marketed as 'trust sprays'. These are being advertised as having commercial value as they may contribute to feelings of trust in potential clients and customers. The development of oxytocin nasal sprays also provides an opportunity for researchers to investigate the potential use of this hormone in the development of treatments for specific autism spectrum disorders (ASD) and in treatments to increase empathy and learn successful face recognition.

FIGURE 5.69 Stages of giving birth

First stage	
Uterus begins to contract at regular intervals that get closer and closer together. These contractions begin pushing down on the baby. At some point, the sac holding the amniotic fluid breaks; the fluid leaks out of the mother's vagina. As contractions continue, the cervix stretches open, until it is about 10 cm wide. This stage can last for many hours, especially for first-time mothers.	
Second stage	
The mother gets a fierce urge to push (a bit like with a bowel motion) every time the uterus contracts. Bit by bit, this pushes the baby further down the vagina (birth canal).	
Third stage	
The placenta is delivered after the baby is born. By this stage of the pregnancy it is a flattish, dinner-plate-shaped organ that looks a bit like a large piece of liver.	

on Resources

Video eLesson Giving birth (eles-2070)

on Resources

eWorkbook Inside the womb (ewbk-4905)

assess on Additional automatically marked question sets

5.5 Exercise

learnON

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 5, 6, 9, 10, 16	Questions 3, 4, 7, 14, 15, 17	Questions 8, 11, 12, 13, 18, 19

Remember and understand

1. Identify the parts of the female reproductive system that:

Description	Name
a. produces ova	
b. through which ova must travel to reach the uterus	
c. in which fertilisation of the ovum by the sperm occurs	
d. in which the embryo implants and is 'home' for the developing baby	
e. is the passageway between the vagina and the uterus	
f. through which semen containing sperm enters during sexual intercourse	
g. through which babies pass through from the uterus during birth.	

2. Identify the parts of the male reproductive system that:

Description	Name
a. produces sperm	
b. through which sperm cells travel from the testes to the penis	
c. in which the testes are located	
d. through which semen travels through the penis to leave the male's body	
e. swells during sexual arousal and through which semen containing sperm is ejaculated.	

3. Put the following words into sentences.
   a. Testes, scrotum, sperm
   b. Ovaries, ova, follicles
   c. Vas deferens, fallopian tube, ovaries, testes
   d. Ovum, fallopian tube, sperm, fertilisation, ovary
4. Draw a table as shown. Classify the following organs and list them in the correct column of your table. fallopian tube, penis, urethra, testes, prostate gland, bladder, uterus, seminal vesicle, ovary, vas deferens, scrotum, cervix, vagina

TABLE Features of the male and female reproductive system

Found in males only	Found in females only	Found in both males and females

5. Identify whether the statement is true or false. Justify any false responses.

Statement	True or false
a. In males, during puberty, the voice box gets smaller, which makes their voice deeper.	
b. Sex hormones, such as testosterone, can make glands in the skin produce extra oil, which may result in pimples.	
c. Everybody goes through puberty at the same age.	
d. Eventually all the eggs that girls are born with will mature throughout their lifetime.	
e. The menstrual cycle is 28 days in all women.	
f. If you are having periods, it means that you may be physically able to get pregnant and have a baby.	

6. Match the term to the correct process.

Process	Term
a. The release of a mature ovum from the ovary into the fallopian tube	**A.** Menstrual cycle
b. The monthly shedding of the lining of the uterus through the vagina	**B.** Menarche
c. The first period experienced by a female	**C.** Menstruation
d. The time from the first day of one period to the first day of the next	**D.** Ovulation

7. Use the figure 5.58 to help you answer the following questions.
   a. On which day in a 28-day cycle is ovulation likely to occur?
   b. At which time in the cycle is the sperm most likely to meet (and fertilise) an egg?
   c. On which days in a 28-day cycle is menstruation likely to occur?
8. Use figure 5.57 to help you answer the following questions.
   a. Which hormone is found in the highest concentration just before ovulation?
   b. Which hormone is found in the highest concentration when the uterine lining is thickest?
   c. At which time in the cycle would the lining provide the best 'home' for a fertilised egg?
9. Identify whether the statement is true or false. Justify any false responses.

Statement	True or false
a. Conception occurs when the egg cell and sperm unite to form a zygote.	
b. The total time the unborn baby spends in the uterus is often called the gestation period.	
c. If a human baby is born after 40 weeks, then it is called premature.	
d. The placenta is expelled during the final stages of labour and is called the 'afterbirth'.	
e. Oxytocin is a hormone that causes the uterus to contract during childbirth.	
f. When a baby suckles on the mother's nipple, oxytocin is released in the mother, which triggers the release of milk.	
g. Fertilisation of the egg occurs in the uterus.	
h. Oestrogen and progesterone cause the lining of the uterus to become thinner	
i. The placenta is connected to the mother's blood vessels through the uterus.	
j. A breech birth is when the baby is born bottom or feet first.	

10. Fill in the the blanks to describe conception.
Human reproductive cells are known as ____________. When an ovum is released from the ____________, it needs to be ____________ by a sperm cell for a zygote to form. The zygote then divides into an ____________ which moves down the fallopian tube and into the uterus where it will ____________ into the endometrium.

Apply and analyse

11. After puberty, the testes continue making sperm for the rest of a man's life. How is this different from gamete production in a woman? What are the consequences of this?
12. If a female has menstrual cycles, is she potentially able to have babies? Explain.
13. Why aren't all menstrual cycles, penises and breasts the same?
14. Explain why sexual intercourse does not always result in a pregnancy.
15. Suggest why women with blocked fallopian tubes are unable to have babies.
16. Carefully observe figures 5.46 and 5.49.
    a. Identify three organs for each gender and state their function.
    b. Suggest how the structure of each organ suits it for its function.

Evaluate and create

17. SIS Using the data provided:
    a. Construct a graph showing the changes in length of an fetus from conception to birth (40 weeks).
    b. Construct a graph showing the changes in weight of an fetus from conception to birth (40 weeks).
    c. Compare the shapes of the two graphs. What do you notice after week 20?

Development (weeks)	Length (cm)	Mass (g)
0	0.01	0
8	1.6	1
12	5.4	14
16	11.6	100
20	16.4	300
24	30	600
28	37.6	1005
32	42.4	1702
36	47.4	2622
40	51.2	3462

18. SIS Use your understanding of the menstrual cycle to explain why the menstrual cycle does not continue during pregnancy and what the possible consequences would be if this were not the case.
19. Draw a descriptive timeline that includes: ovulation, ejaculation, sexual intercourse, the various stages of the sperm's travels through the female's reproductive tract, and fertilisation.

Fully worked solutions and sample responses are available in your digital formats.

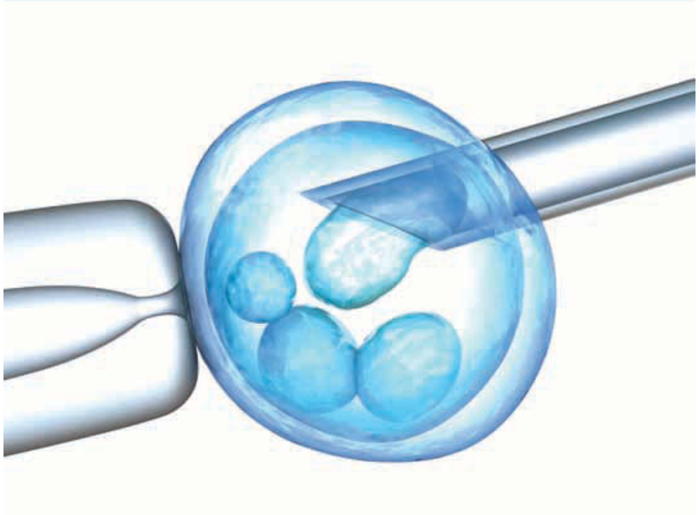
5.6 Reproductive technologies and contraception

LEARNING INTENTION

At the end of this subtopic you will be able to describe a range of reproductive technologies including those used to avoid conception (contraceptives) and those used to help couples conceive, as well as how and when genetic testing can be performed.

For hundreds of years humans have tried to control when to have their offspring and how many offspring to have. The contraceptive industry has grown and changed dramatically over the last 50 years with many new strategies available for couples wishing to control their fertility and avoid pregnancy.

FIGURE 5.70 Artificial insemination



In addition, many people experience difficulty conceiving or continuing a pregnancy and having children. In fact, up to 20 per cent of Australians seek medical support to help them to have a family. The causes of **infertility** are varied and complex; some individuals do not produce gametes in their gonads, or have a blockage preventing fertilisation; other couples have difficulty conceiving due to genetic factors or may be at a high risk of having a child with a genetic disease. All of these factors may lead couples to seek medical support and access **assisted reproductive technologies (ART)**.

5.6.1 Preventing pregnancies

Conception involves the production of a zygote and its implantation into the wall of the uterus. Techniques that prevent this happening are called **contraception**.

Contraceptives are the devices or substances used to prevent unplanned pregnancies. There are two main types of contraceptives: those that prevent fertilisation taking place and those that prevent the fertilised ovum from implanting in the uterus.

on Resources

Video eLesson Methods of contraception (eles-0127)

Contraceptive devices vary in their efficacy, that is how effective they are. Some are expensive and long term, perhaps even irreversible while others are cheaper and easy to reverse but perhaps less effective.

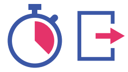
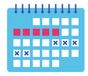
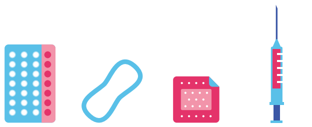
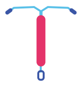
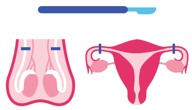
infertility the inability to have children

assisted reproductive technologies (ART) medical procedures used primarily to address infertility

contraception the prevention of fertilisation of an egg or prevention of a fertilised egg becoming embedded in the uterus wall

contraceptives devices or substances that prevent fertilisation of an egg or prevent a fertilised egg becoming embedded in the uterus wall

TABLE 5.6 Effectiveness of different contraceptive methods

Effectiveness	Method	
Least effective	• **Withdrawal method (coitus interruptus)** • Involves removal of the penis prior to ejaculation • Not effective as some sperm are released before ejaculation • **Vaginal douche** • Flushing the vagina with a chemical that may damage sperm cells	
	• **Spermicides** • Cream or jelly containing chemicals that kill sperm • Introduced to the vagina before intercourse • **Rhythm method** • Abstaining from intercourse during the most fertile stages of th menstrual cycle (around the time of ovulation)	
Highly effective	• **Condom** • Made of thin, strong latex • Male condom rolled onto erect penis just prior to intercourse • Female condom inserted into vagina prior to intercourse • Barrier to STIs • Most effective if used with spermicide • **Diaphragm** • Thin rubber dome placed in vagina • Prevents sperm from reaching the cervix • Most effective if used with spermicide • **Hormonal medications** • Hormonal control used by women administered as a daily tablet, patch, injection or implant just under the skin • Prevents ova developing and prevents ovulation • **IUD device (coil)** • Intrauterine device • Interferes with sperm movement and implantation • Also often contains progesterone, a hormone that interferes with ovulation • **Morning after pill** • Emergency contraception • Prevents implantation if taken within 72 hours ofintercourse	   
Most effective	• **Abstinence** • No intercourse • **Vasectomy** • Cutting and sealing of the male's vas deferens • Sperm production continues; however, sperm are blocked and cannot be ejaculated • **Tubal ligation** • Fallopian tubes are cut and sealed preventing fertilisation • Irreversible	

SCIENCE AS A HUMAN ENDEAVOUR: Professor Alan Trounson

Professor Alan Trounson is an Australian scientist who has spent a great part of his working life perfecting the technique for creating embryos outside the human body. He was part of the team that produced the first test-tube baby in Australia in 1980. He has also done a lot of work on embryonic stem cells. In 2000, his team showed that it was possible to produce nerve cells from embryonic stem cells.

In 2003, he was named the Australian Humanist of the Year. Between 2007 and 2014, he was appointed as the president of the California Institute for Regenerative Medicine, which specialises in stem cell research. He is now an Emeritus Professor of Melbourne University.

FIGURE 5.71 Alan Trounson, an Australian scientist who is one of the world's top stem cell researchers

on Resources

Weblink Prof. Alan Trounson on pioneering IVF

SCIENCE AS A HUMAN ENDEAVOUR: HPV vaccines

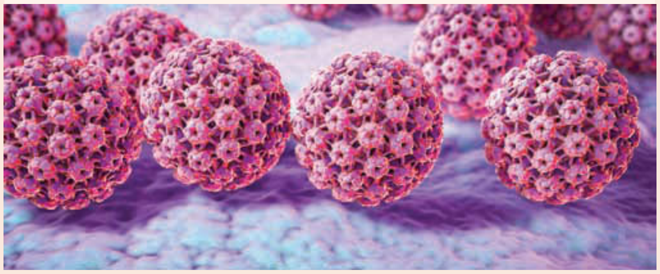
Contraceptives are more than just pregnancy prevention. It is important to choose a contraceptive that protects against sexually transmitted infections (STIs) as well as unwanted pregnancy. One of the most common STIs is human papillomavirus (HPV); this is often identified as genital warts but can lead to a wide range of life-threatening diseases.

Professor Rachel Skinner is a researcher in the area of child and adolescent health at The University of Sydney Children's Hospital Westmead. Professor Skinner is known internationally for her investigations into the efficacy of HPV vaccines, with a particular focus on school vaccination programs.

It is known that many cancers can result from a HPV infection:
- almost all cases of genital warts and cervical cancer
- 90% of anal cancers
- 65% of vaginal cancers
- 50% of vulvar cancers
- 35% of penile cancers.

FIGURE 5.72 Professor Rachel Skinner

FIGURE 5.73 Human papillomaviruses (HPV) cause warts located mainly on the hands and feet. Some strains infect the genitals and can cause cervical cancer.



In Australia, all boys and girls are vaccinated against two of the most common types of HPV at the age of 12–13 years. This is a free, three-dose vaccination program that aims to bring the rate of cervical cancer and other HPV cancers to zero in the vaccinated generation.

In addition, in 2017 a HPV screening test replaced the pap smear program to identify high risk HPV infections in the population with an aim to reducing the mortality rate by 20 per cent. The HPV screening test is a five-yearly screen of the cervix to identify any presence of HPV.

Professor Skinner's research has demonstrated how effective Australia's vaccination program has been in reducing the spread of the virus, along with cervical screening programs. The global research in this area shows that Australia has one of the lowest rates of HPV-related cancers in the world thanks to a rigorous vaccination program and HPV screening. It is, however, critical that young people continue to protect themselves from STIs using forms of contraception that form a barrier to infection.

FIGURE 5.74 a. The HPV vaccine is delivered over three doses.
b. HPV cervical screening is once every five years.

5.6.2 Looking for new and improved contraceptive options

SCIENCE AS A HUMAN ENDEAVOUR: Reversible male contraceptive

Research is ongoing into new, more effective, easier and cheaper methods for humans to avoid pregnancy while still having intercourse. Professor Paula Cohen's Cornell University Lab in the United States is working on a method of blocking sperm maturation in the testes. They are striving for a reversible male contraceptive option and utilise the very latest gene manipulation technology to induce a short-term change to the genetics inside the testes.

FIGURE 5.75 Cells in the testes where sperm are continuously produced and released. Look carefully and you can see the tails of sperm in the spaces inside the tubules indicating that sperm are maturing.

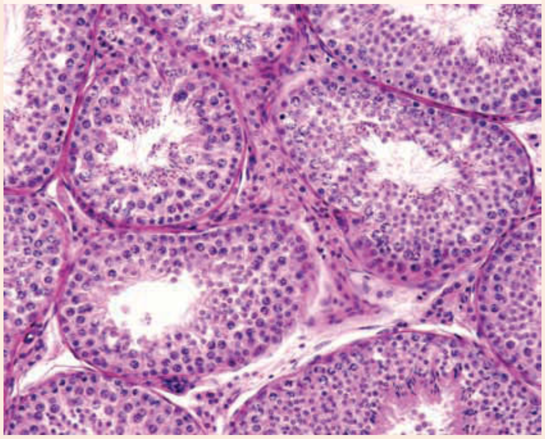
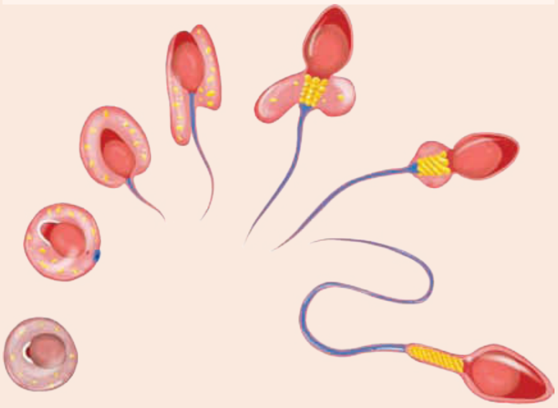


FIGURE 5.76 The process of sperm maturation from a small circular cell, spermatogonia, to a mature sperm cell with a fully formed head, midpiece and tail. Blocking this process by changing the genetic information could lead to a new male contraceptive.

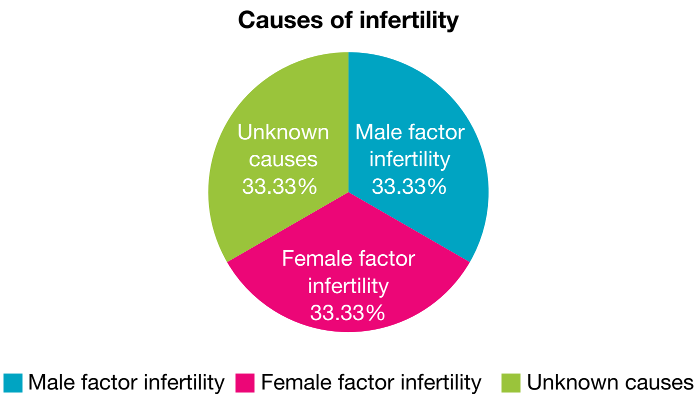


This means that Cohen's group need to explore the genetics of immature sperm cells, spermatogonia, and find the most important parts that cause the sperm to mature in the testes. The genetics team at the College of Veterinary Medicine hope to be able to change the genetic sequence in these immature cells and switch off sperm production.

5.6.3 Infertility

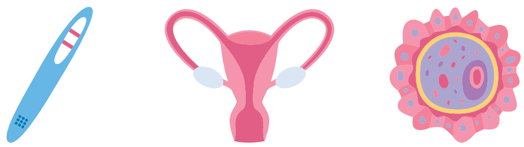
Causes of infertility can be diagnosed by a medical doctor following a range of investigations. About one third of cases of infertility are identified as female factor infertility associated with ova production, ova quality, a blockage preventing the ovum being fertilised or an endometrial factor. A third of cases are identified as male factor infertility resulting from gamete, sperm, production quality or function and another third of cases cannot be explained following the usual investigations.

FIGURE 5.77 Infertility can sometimes result from factors in the male or in the female; it is, however, common for both partners to contribute to infertility or for the exact cause to be unknown.



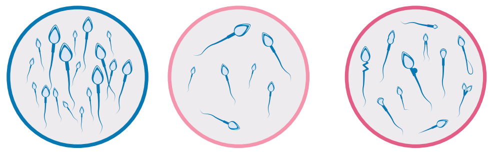
Female fertility can be affected by:

- A woman's age
- Tubal disease or problems with the fallopian tubes
- Ovulation disorders
- Endometriosis
- Polycystic ovarian syndrome
- Fibroids
- Salpingitis (pelvic inflammatory disease) caused by sexually transmitted disease



Male fertility can be affected by:

- Physical problems with the testicles
- Blockages in the ducts that carry sperm
- Hormone problems
- A history of high fevers or mumps
- Genetic disorders
- Lifestyle or enviromental factors



5.6.4 Treatment options

There are many different treatment options for couples who need infertility treatment. The most appropriate treatment is chosen by their infertility specialist and may be a simple inexpensive treatment or require a long, costly period of medical management. Unfortunately, despite many years of research and advances in this field the success rates for a couple beginning fertility treatment are still low, with only 20–30 per cent of patient cycles resulting in a baby.

Artificial insemination

The least invasive treatment for infertility is assisted or artificial insemination (or AI). This usually involves monitoring ovulation to ensure follicles, containing an ovum, are developing correctly followed by injecting a washed sperm sample into the uterus just before ovulation. Sperm can last for many days in the female reproductive tract. Sometimes the female partner may be given medication to cause ovulation to happen.

Artificial insemination is a technique used in agriculture and animal breeding programs to control the timing and parentage of offspring.

IVF

In the 1970s, research into infertility resulted in the first successful fertilisation of a human ovum outside of the body known as **IVF (invitro fertilisation)**. The first child born from this treatment was in 1978 in Cambridge, UK — the world's first test-tube baby. The birth was the result of a 20-year collaboration between Dr Steptoe, a gynaecologist, and Robert Edwards, a biologist. Since then more than three million births have resulted from IVF treatment. Steptoe developed a method of retrieving the ova from the follicles in the ovaries of a patient and Edwards developed a method of fertilising ova in a laboratory environment.

IVF (invitro fertilisation) the fertilisation between eggs and sperm and the culture of embryos in the laboratory for fertility treatment

Since the first IVF cycles in the 1970s and 1980s, treatment has changed significantly. Women are now treated with hormones to encourage more than one follicle to develop allowing many ova to be collected, this is called super-ovulation. Once the follicles reach the correct size a long needle is used to collect the ova from each follicle, often resulting in ten ova in the laboratory instead of just one.

FIGURE 5.78 Egg collection procedure in an operating theatre is completed under a local or general anaesthetic with a number of doctors, nurses and scientists (embryologists) present. Gametes are then prepared and observed by an embryologist.

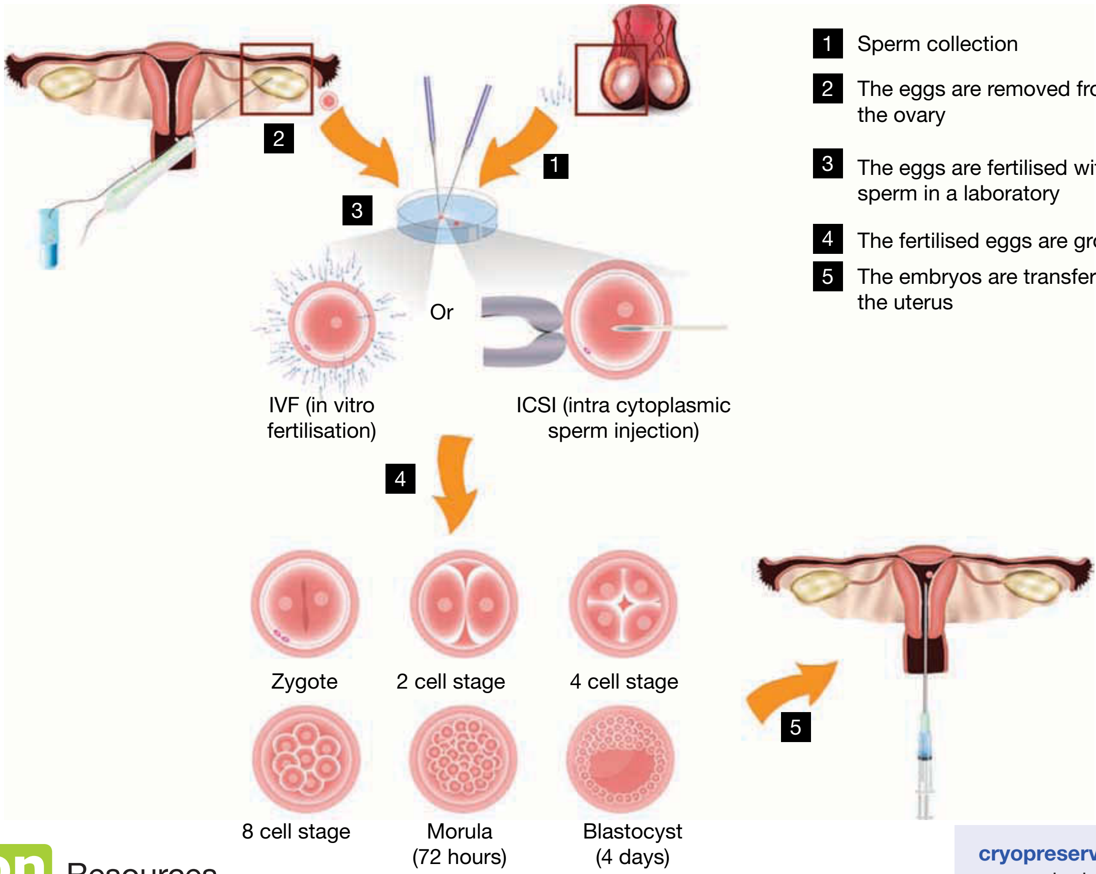
A sperm sample is collected from the male partner, checked for quality and motility, cleaned and concentrated before mixing with the ova.

FIGURE 5.79 A semen sample and prepared sperm ready for inseminating the ovum (right)

FIGURE 5.80 Sometimes fertilisation will not occur by mixing ova and sperm in a Petri dish. In these cases an additional treatment may be required known as ICSI (intracytoplasmic sperm injection). In ICSI, a single sperm is inspected on a high powered microscope (x400), collected using a fine glass needle, immobilised and then injected into the centre of the ovum.

Once fertilisation has occurred the embryologists monitor the development of the embryos to select the one or two embryos that are most likely to achieve a pregnancy, with any spare embryos being cryopreserved, frozen, for the future.

FIGURE 5.81 The process of IVF from retrieval of gametes, insemination and fertilisation to embryo development followed by an embryo being transferred back into the uterus.



on Resources

Video eLesson In-vitro fertilisation (eles-2540)

cryopreservation when cryoprotectant chemicals and cooling are used to safely freeze biological material such as human embryos

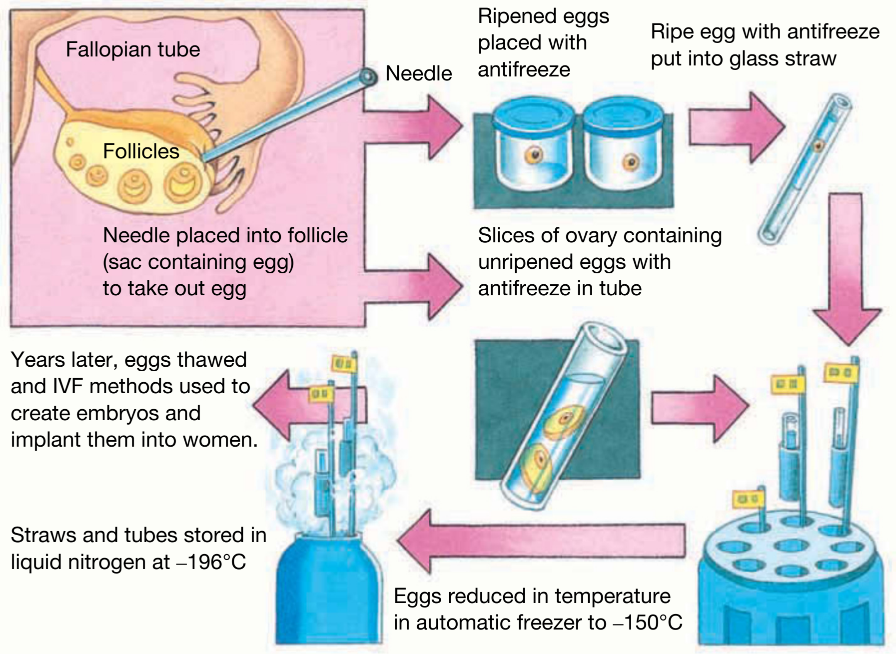
Cryopreservation

It is common for there to be excess gametes and embryos in an IVF treatment cycle. **Cryopreservation** is the freezing of gametes or embryos. It is a delicate process that removes water from the cells and replaces the water with a special chemical called cryoprotectant that does not form damaging ice crystals and helps to keep the cells intact during cooling. Gametes and embryos are cooled in a controlled manner in a freezing machine or using specific devices that result in a high level of cells surviving. Once the gametes or embryos are frozen they can be stored in liquid nitrogen for many years without ageing. The gametes or embryos can be warmed up at any stage and used for treatment.

FIGURE 5.82 Embryologist thawing human embryos for a frozen embryo replacement cycle. This type of cycle is much less costly or invasive as the treatment does not require the collection of ova. The female patient's endometrium is prepared and thawed embryos are transferred into the uterus ready for implantation.

Patients choose to freeze their gametes or embryos for later use or for donating to another couple at a later date.

FIGURE 5.83 Frozen egg technology



Gamete or embryo donation

Sometimes couples need to use a donor to achieve a family of their own. This may be due to one or both partners having no gametes, they are **sterile**, or their gametes are poor quality and cannot produce a healthy embryo. In these cases, couples can seek a gamete, (sperm or ovum) donor who will give them gametes to use in fertility treatment. The couple receiving the gametes or embryos are known as recipients. The female **recipient** will have an embryo transferred into her uterus and carry the pregnancy herself. The couple are the legal parents of any children born although they may have different genetics to the children and are not biologically related. In Australia, donors are not paid for their gametes or embryos; however, in other countries a gamete donor can be paid significant amounts of money.

5.6.5 Genetic testing

In recent years we have gained a much greater understanding of inherited diseases and how to identify these. Assisted reproduction can offer couples who have or carry a genetic disease the opportunity to have their embryos tested and then only use embryos that are identified as healthy; this is known as **preimplantation genetic diagnosis (PGD)**. The process involves producing embryos through IVF and then testing embryos by removal of a small number of cells from the embryo. The embryo is not usually harmed in the process and can continue to develop well while the scientists analyse the cells they have taken to look for evidence of genetic disease.

In addition, many couples are now choosing to have their embryos screened for abnormalities in a treatment known as PGS, **preimplantation genetic screening**. This treatment looks at all of the genetic material in the cells removed to identify any abnormalities. PGS is used to improve a couple's chances of pregnancy by eliminating embryos that have errors in their genetics and are therefore less likely to implant or may result in a miscarriage.

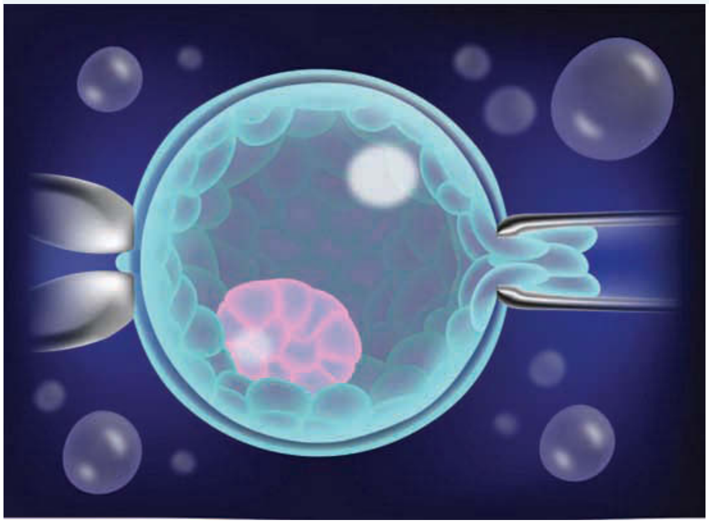
sterile a person unable to produce reproductive cells

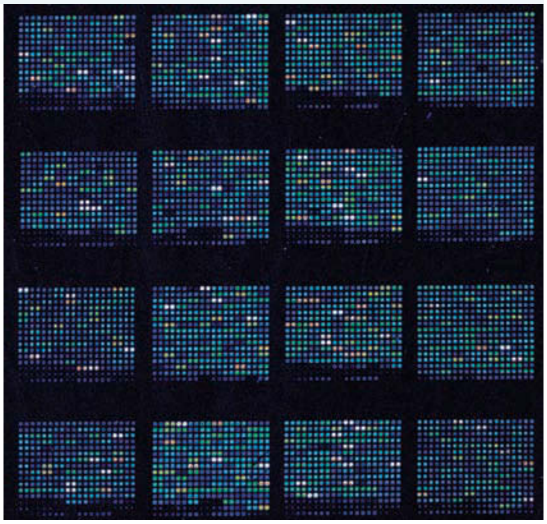
recipient the person or couple receiving embryos or gametes from another person

preimplantation genetic diagnosis (PGD) a procedure to diagnose and exclude genetic abnormalities in embryos before implantation into the mother's body

preimplantation genetic screening the screening of embryos for genetic abnormalities to improve pregnancy and live birth rates

FIGURE 5.84 A blastocyst can have a number of cells removed by an embryologist using a high powered microscope and small micromanipulation tools. The nucleus of each cell is then analysed to identify if there is a particular disease or error present in the genetic material.





There are also tests that can be conducted once a pregnancy is established to detect abnormalities in the fetus. Most expectant mothers in Australia will have some kind of investigation to confirm that their pregnancy is healthy.

There are a number of different tests available for testing the pregnancy with different levels of risk involved and some being more accurate than others. For a fetus with a higher risk of abnormality, **amniocentesis** or **chorionic villus sampling** may be used. They pose a higher risk to the fetus and the pregnancy than non-invasive tests as they involve using a needle to take a sample from very close to the fetus inside the mother; however, these tests provide the most accurate information about the health of the fetus.

amniocentesis the removal and testing of fluid from the amniotic sac surrounding the fetus

chorionic villus sampling a procedure in which cells from the developing placenta are removed for testing at 10–12 weeks of pregnancy, allowing certain abnormalities to be detected

FIGURE 5.85 In chorionic villus sampling, cells from the developing placenta are removed for testing at around 10–12 weeks of pregnancy.

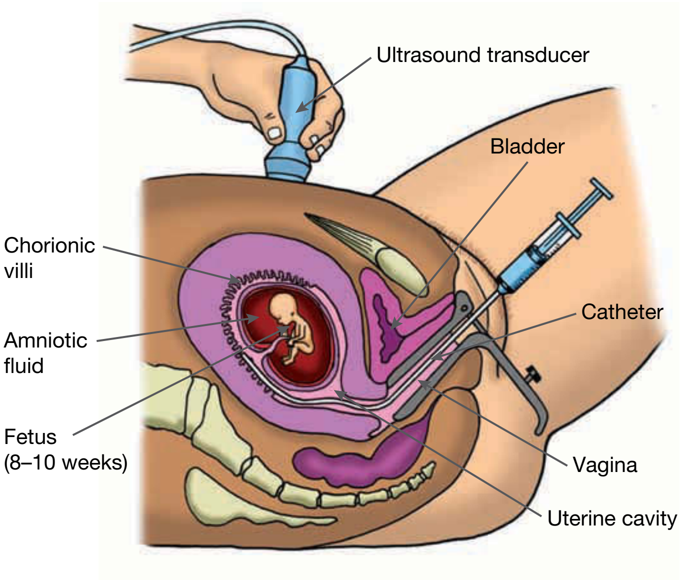
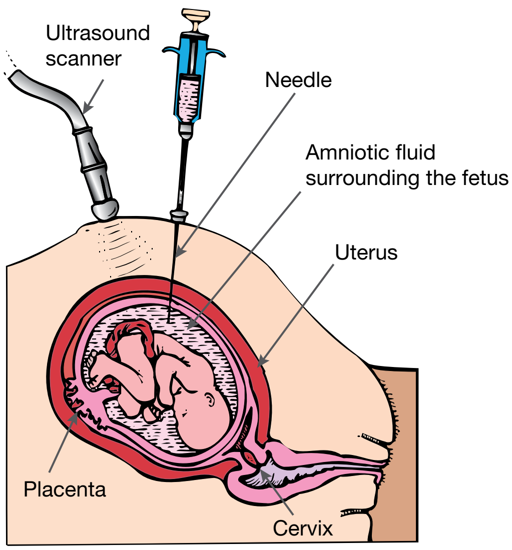


FIGURE 5.86 During amniocentesis, a fine needle is inserted into the amniotic sac of the fetus at around 14–16 weeks of the pregnancy and a small amount of fluid is drawn out to be tested.



Using ultrasound imaging is non-invasive and involves observing the fetus for signs of abnormality, which is very safe but provides less information. In addition, a relatively new method of screening the unborn child for abnormalities is using maternal blood screening (**non-invasive prenatal screening**, or NIPS) which can indicate if there are genetic abnormalities in the fetus by taking a sample of the mother's blood.

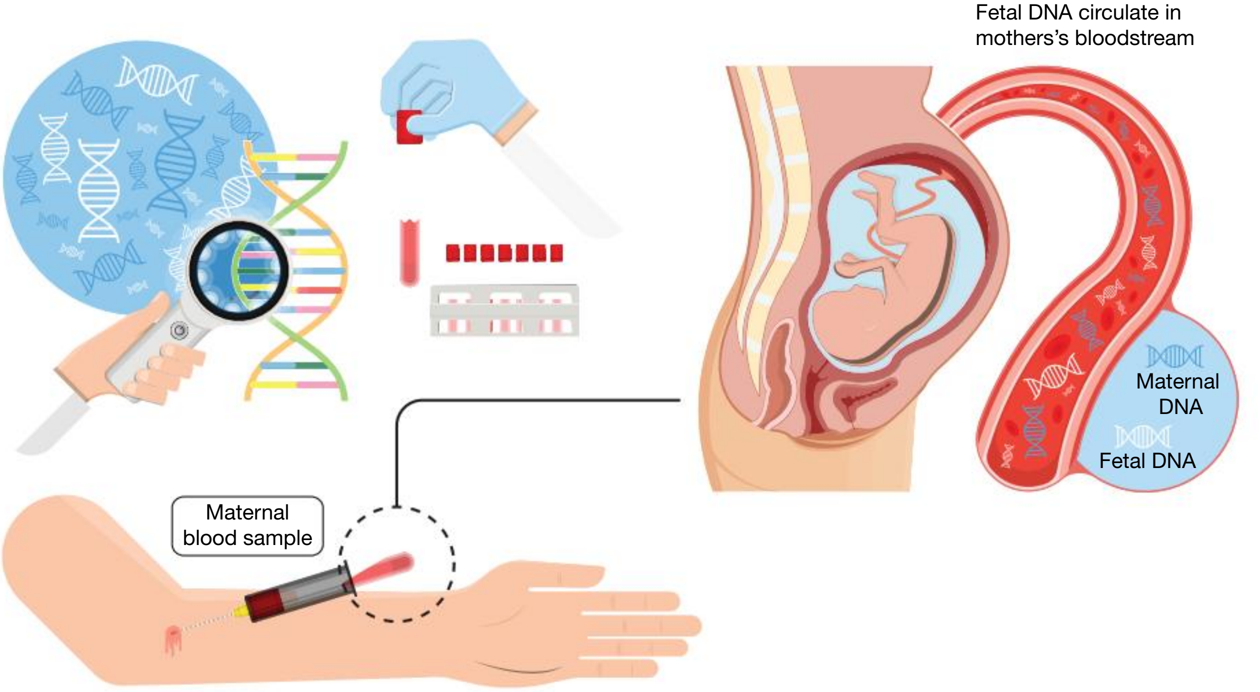
FIGURE 5.87 Ultrasound involves the use of sound waves to produce images of an unborn child inside the mother's body.

non-invasive prenatal testing (NIPS) the testing of maternal (mother's) blood for signs of chromosomal abnormality in the fetus

Resources

Video eLesson Medical ultrasound of human fetus at 26 weeks gestation (eles-4234)

FIGURE 5.88 Non-invasive prenatal testing is the most recent advance in testing the genetic health of a fetus. It involves assessment of the mother's blood to detect genetic abnormalities in the fetus.



SCIENCE AS A HUMAN ENDEAVOUR: Clinical embryologist

Dr Petra Wale is a graduate of the University of Tasmania, receiving a Bachelor of Science with Honours in Marine and Antarctic Studies. Dr Wale started working in IVF laboratories part-time while completing her Honours thesis in 1999 and has worked in assisted reproduction ever since.

Science, skiing and travel

Dr Wale has travelled the world working as an embryologist and presenting her research. One highlight was a move to Denver, Colorado where she worked in one of the world's most successful IVF clinics with Professor David Gardner and was able to explore the ski resorts in the nearby Rocky Mountains. Petra says 'science is a fantastic degree if you want to travel!'

Both Dr Wale and Professor Gardner returned to Australia and worked together as Petra undertook postgraduate training at the University of Melbourne. Petra has spent much of her professional career investigating human embryos and has always been focused on improving laboratory protocols that will directly benefit fertility patients. With two small children of her own, Petra is delighted to raise her family in Tasmania while helping others create their own.

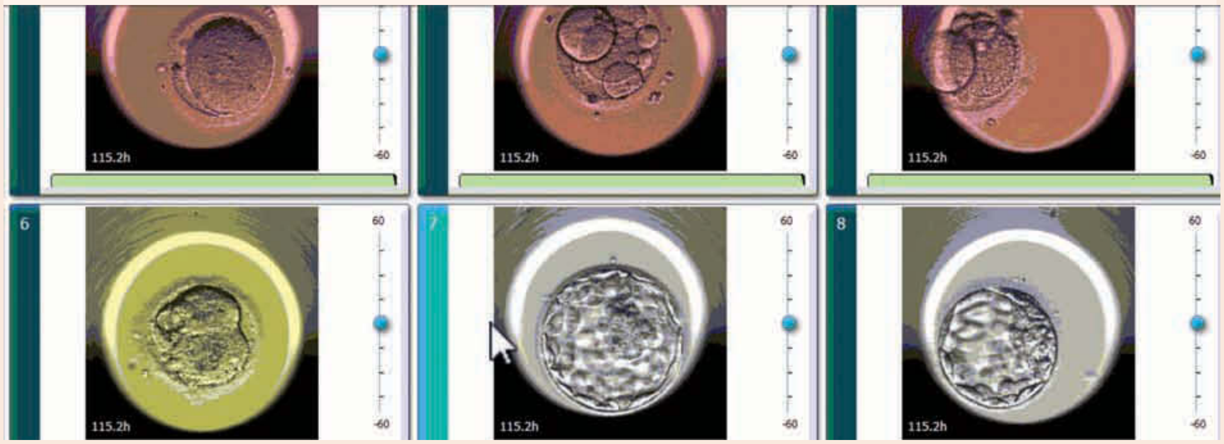
What does the future hold for IVF?

Dr Wale is particularly excited about the combination of artificial intelligence and time-lapse microscopy technology as this will help scientists improve their ability to predict the embryos that will lead to pregnancy, therefore reducing the time it takes for a couple to fall pregnant.

FIGURE 5.89 Dr Petra Wale, clinical embryologist and research scientist

FIGURE 5.90 A time-lapse incubator, which can provide scientists a view of embryos as they develop without disturbing them

FIGURE 5.91 Time-lapse images of embyro development



A typical day in an IVF clinic for a reproductive scientist may include any of the following:

- Collecting eggs and sperm samples from patients then preparing these for treatment in the laboratory
- Inseminating (fertilising) eggs with sperm
- Observing zygotes under the microscope to check for normal fertilisation
- Monitoring embryo development by checking embryos under a microscope multiple times or using a time-lapse incubator that monitors embryos continuously
- Choosing embryos for transfer
- Cryopreserving any spare embryos for later use
- Meeting patients and discussing treatment
- Discussions with other members of the team regarding a patient's treatment, such as with medical doctors, nurses or counsellors
- Analysing data collected to develop greater insight into how we can predict which embryos will be successful and which may not be

FIGURE 5.92 Inseminating (fertilising) an egg with sperm in IVF procedure

SCIENCE AS A HUMAN ENDEAVOUR: Preimplantation genetic diagnosis

Dr Leeanda Wilton is a pioneer in the field of preimplantation genetic diagnosis, paving the way for many of the technologies that are currently available and emerging in the field of assisted reproduction. Dr Wilton's early work with mouse embryos involved investigating how a cell could be taken without damaging the embryo's development.

FIGURE 5.93 Dr Leeanda Wilton

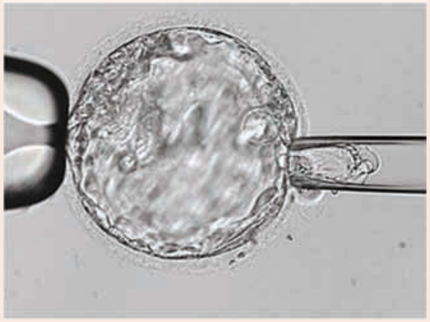
Dr Wilton says: 'My first post-doctoral job was in cell biology with the objective of developing embryo biopsy techniques. Once that was achieved it was a natural progression to move into genetics so that we could test the biopsied cells for inherited disease. Some families are affected by serious genetic diseases, many of which have continued through generations. Testing early embryos for these diseases means that we have been able to guarantee the birth of healthy babies and in some cases rid the family of the disease forever'.

Dr Wilton's career has included many years of scientific research, as the Scientific Director of Preimplantation Genetics at Melbourne IVF and now in a consultancy role offering advice on reproductive genetics.

What was your favourite subject at school?

'I always loved maths because I found it so satisfying to get the right answer to a problem. In my more senior school years I found biology fascinating. I just loved the elegance of physiological systems and how they demonstrated the power of natural selection and evolution.'

FIGURE 5.94 Preimplantation genetic diagnosis



How has PGD changed over the years?

'I am astounded at how rapidly and widely preimplantation genetic diagnosis (PGD) has been adopted around the world. This, along with the dramatic improvements in genetic testing technologies, means that hundreds of thousands of healthy babies have been born because of PGD.'

What do you think the future holds?

'The future looks very exciting. I think there will be a shift from just diagnosing genetic errors in embryos to correcting those errors using advances like CRISPR. I hope I'm around to see it.'

on Resources

eWorkbook IVF — discussing the issues (ewbk-4919)

assess on Additional automatically marked question sets

5.6 Exercise

learn on

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 5, 12	Questions 3, 4, 6, 9, 13	Questions 7, 8, 10, 11, 14

Remember and understand

1. Identify the most appropriate terms to complete the sentences.
   a. ___________ involves the production of a zygote and its implantation into the wall of the uterus.
   b. ___________ involves the use of techniques to prevent the production of a zygote or its implantation into the wall of the uterus.
2. Match the contraceptives with how they work.

Term	Process
a. Condom	A. Prevents sperm from being released
b. Diaphragm	B. Prevents the egg from being released
c. Intrauterine device (IUD)	C. Prevents the fertilised egg from implanting into the uterus
d. Tubal ligation	D. Prevents sperm released into the female from reaching the egg
e. Vasectomy	E. Prevents sperm from being released into female

3. Observe the following list of contraceptives and techniques. Place them in order of most effective to lease effective.
   Abstinence, Condom, Daily contraceptive pill, Intrauterine device (IUD), Rhythm method, Vasectomy, Withdrawal method
4. Construct a table that has six columns, with headings for: the type of contraceptive, a summary of how it works, who uses it (male or female), suggested advantages, suggested disadvantages, and a prediction of how many pregnancies may occur if 100 sexually active, fertile couples were to use it.
5. Identify the most appropriate terms to complete the sentences.
   a. ___________ describes the inability to conceive or carry a pregnancy to a live birth.
   b. A common cause of infertility is the inability of either a male or female to produce ___________, which means that the person is ___________.
6. Identify whether the statement is true or false. Justify any false responses.

Statement	True or false
a. It is possible to freeze fertilised eggs so that they may be implanted at a later time.	
b. Hormone injections can be used to increase the number of eggs released during ovulation.	
c. Test-tube babies develop in test tubes for the first eight weeks of their development.	

d. A cell can be removed from the developing embryo to be tested for genetic abnormalities.	
e. Surrogacy can involve surgically removing eggs from one woman, fertilising them using IVF techniques and then placing the fertilised eggs into a different woman's uterus to develop.	
f. The gender of a baby cannot be determined until it is born.	
g. Ultrasound involves the use of UV waves to produce images of an unborn child inside the mother's body.	
h. Using IVF, it is possible for 'twins' to be born years apart.	

7. Match the terms with the definition and descriptions.

Term	Definition	Description
a. IVF	**A.** intracytoplasmic sperm injection	**1.** Cooling gametes and embryos so that they can be used at a later date, perhaps months or years later
b. cryopreservation	**B.** preimplantation genetic diagnosis	**2.** Fertilisation of eggs with sperm in the laboratory rather than inside the body
c. ICSI	**C.** invitro fertilisation	**3.** Testing embryos for genetic disease prior to transferring them into the uterus to help reduce the chance of passing on a genetic disease
d. PGD	**D.** egg, sperm and embryo freezing	**4.** Injection of a sperm into an egg using a very fine needle to increase the chance of fertilisation

Apply and analyse

8. Distinguish between:
  a. artificial insemination and invitro fertilisation
  b. ultrasound and amniocentesis.

9. Outline, in point form, the steps involved in IVF.

10. What are 'test-tube' babies? Is this an adequate name for them? Explain.

Evaluate and create

11. Research and identify the risks linked to reproductive technologies. Why do you think patients still access the treatment if there are risks involved?

12. **SIS** Produce a poster or infographic aimed at young adults to explain the advantages and disadvantages of a range of available contraceptive options. Ensure your information is accurate, eye-catching and clearly written. Include references and sources you have used.

13. **SIS** Use research to construct a report that compares the options for genetic and prenatal testing, and ensure you explain the benefits and risks thoroughly.

14. **SIS** Find out about some of the research conducted by one of the scientists featured in this subtopic: Dr Petra Wale, Dr Leeanda Wilton or Professor Rachel Skinner. What research have they conducted and what were some of their findings?

Fully worked solutions and sample responses are available in your digital formats.

5.7 Issues in reproduction

LEARNING INTENTION

At the end of this subtopic you will be able to explain how treatments such as gamete donation, surrogacy, genetic testing and genetic manipulation pose issues to people and society.

Reproductive technologies have presented a range of issues over the last 50 years that people, society and the law had not previously considered. People working in the field of reproduction (such as medical doctors, scientists, counsellors, nurses and business managers) must consider new technology from a number of different perspectives that may differ from their own.

5.7.1 Issues and ethics

The issues that are raised often fall into one of four categories: **ethical**, social, economic and legal.

TABLE 5.7 Issues in reproductive technology

Type of issue	Explanation	Consider, for example:
Ethical	Is it right, does it consider the rights of the person or people involved. Is it unfair?	Until 2020, couples having IVF treatment in Victoria had to have a police check before being allowed treatment. No fertile couple needs a police check to conceive and no other state or country has done this. Is it fair to do? Is it ethical?
Social	What are the impacts on society?	Public funds being spent on assisted reproduction instead of areas that affect all Australians could be considered a societal issue. How much public funding should be given to couples trying to conceive? What conditions should be asked? Do you already have children, how much do you earn? Do you smoke?
Legal	What should the laws be in relation to reproductive technologies?	Legally the person giving birth to a child is the parent. How does this affect those who cannot give birth to their own child so ask someone else to have the pregnancy (surrogacy)? When are ova, sperm and embryos allowed to enter into Australia? Some countries do not keep records in as much detail or have the laboratory processes we expect so should Australian clinics allow movement of eggs, sperm and embryos into their laboratories?
Economic	What are the costs to the state, the business or Australia?	What is the cost of investing in research to further reproductive technology? The research is slow and expensive. What might be the benefits of developing research and expertise in a scientific area?

5.7.2 Donating embryos and gametes

Many couples are unable to use their own gametes or embryos to conceive a child and need to become recipients. In Australia there is a shortage of sperm, egg and embryo donors and therefore many couples waiting to find a donor. A couple may find a donor from within their family and friendships or through advertisements in newspapers or on the internet.

In March 2017, the laws changed in Victoria to allow all individuals born from donor eggs, embryos or sperm to trace their genetic parents. Before this date, some people who donated had their identity protected, therefore many of these donors, largely sperm donors, were expecting that they would never be traced by potential offspring.

ethical issues issues that consider the moral implications, fairness and equity involved in an issue

Is the thought of being contacted by unknown offspring likely to put some potential donors off? Is it likely that some people would only donate gametes or embryos if the process was truly anonymous? Or is it important for offspring to be able to contact and meet their biological parents?

In Australia, donors cannot donate to an unlimited number of couples, there is a limit of ten families that can have children through a particular donor. Why do you think that is? What would be the risks of a Melbourne man donating sperm to 100 different families locally?

5.7.3 Surrogacy

Some couples need to use the uterus of another woman to carry a pregnancy for them. Their eggs and sperm, and embryos, may be of good quality but the uterus may not be able to support a healthy pregnancy and therefore they need to find a surrogate mother to have the baby for them. **Surrogacy** means that a woman carries a pregnancy for someone else. The embryo is created in a laboratory, usually using the eggs and sperm from the parents, but then the embryo is transferred into the uterus of the surrogate rather than the mother. The surrogate will then carry the pregnancy for nine months before handing the baby to the biological parents shortly after the birth.

surrogacy a pregnancy that occurs when the fertilised egg is placed in the uterus of another woman who did not produce the egg

Surrogacy was legalised in Victoria in 2008; however, different states within Australia have slightly different regulations. Surrogates in Australia must be altruistic; that is, must not be paid for being a surrogate except for any reasonable expenses, whereas in many countries a surrogate can earn a substantial amount of money as a result of carrying someone else’s child. Legally the baby born is the child of the surrogate mother for a few weeks after the birth until paperwork can be completed to make the biological parents the legal parents.

FIGURE 5.95 Surrogacy offers an opportunity for couples who cannot carry a pregnancy the chance of having their own family. Some couples access surrogacy as the female partner does not have a uterus capable of maintaining a pregnancy, other couples such as homosexual males need both an egg donor and a surrogate before they can start a family.

DISCUSSION

There are many issues around surrogacy that need to be considered by medical professionals, potential surrogates and the infertile couple.

- What should the surrogate eat or not eat during the pregnancy?
- What kind of birth will the surrogate have?
- How much contact will the surrogate have with the family after the baby is born?
- What if the surrogate wants to keep the baby?
- What if the commissioning couple separate during the pregnancy?

5.7.4 Designer babies

Genetic testing of embryos for disease or an abnormality has been a possible reproductive treatment since the 1990s; however, what about selecting embryos based on other features? Selecting male or female embryos to determine if you have a girl or boy is legal in Australia but only if you have a history of a genetic disease that means sex selection is more than preference. For example, haemophilia is an example of a sex-linked genetic disease that is much more common in boys, therefore is a common reason for couples carrying this disease to choose to have only girl embryos transferred. What about if you already have three girls and want another baby but only want a boy? Should that be allowed? In many countries this is fine and is referred to as family balancing. What about choosing the embryos based on features other than gender?

FIGURE 5.96 Should parents have the right to select certain characteristics in their children?

Professor Julian Savulescu, an ethicist from Oxford University, argues that parents should be able to use genetic testing combined with IVF to choose the genetic characteristics of their children. Currently it is possible to test embryos created by IVF to find out which carry certain disease-causing genes. Embryos found to carry the genes are not implanted. Professor Savulescu argues the technique should be further developed to allow parents to select genes for anything ranging from hair colour to intelligence or sporting ability.

DISCUSSION

Which embryo would you choose?

	Embryo 1	Embryo 2	Embryo 3	Embryo 4	Embryo 5	Embryo 6
						
Gender	**Male**	**Male**	**Female**	**Male**	**Female**	**Female**
Eye colour	Blue	Brown	Blue	Brown	Brown	Brown
Height	Tall	Short	Medium	Medium	Medium	Short
Intelligence	Low	High	High	Medium	High	Low
Sport skill	High	Low	Medium	Medium	High	Low

Imagine all of these embryos have been tested using preimplantation genetic diagnosis. You have been given some information about the embryos and need to consider the following questions.

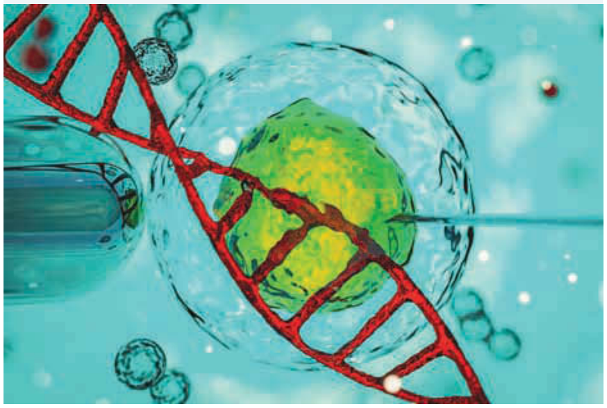
- Which embryos would you like to use first?
- What if you would like three children, which three would you choose first?
- What will you do with the other embryos?
- Do you think everyone in the class would choose the same?
- If everyone was allowed and able to choose the features of their children, do you think people would all choose the same features?
- How would that change our society?

5.7.5 Modifying embryos and gametes

Taking a step further than choosing the embryos based on what their characteristics are, we now have the ability to change the genetic information inside a cell, inside an embryo.

In fact, it has already been done. At the end of 2018 a Chinese scientist, Dr He Jiankui, announced that he had used a **gene editing** tool known as **CRISPR Cas9** to change the genetics of human embryos, and the children, with altered genetics, were born in 2019. Dr He Jiankui used genetic engineering techniques in an attempt to protect the offspring from HIV (human immunodeficiency disease).

FIGURE 5.97 Gene editing technology allows scientists to change the genetics of a cell or whole organism. Do you think that we should change the genetic information in human embryos?



The announcement caused outrage across the world and in the scientific community as Dr He Jiankui had conducted experiments on human embryos breaking both the law and the ethical codes that govern science and medicine. He has been jailed for three years and the children are being protected and monitored closely by the Chinese government.

Although this news of editing human embryos has caused outrage, most scientists believe it will be something that is utilised in the future to eliminate genetic disease and perhaps even modify other features.

gene editing changing the genetics of a cell or organism

CRISPR Cas9 a tool used for gene editing

on Resources

assesson Additional automatically marked question sets

5.7 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3, 7	Questions 4, 5, 6	Questions 8, 9, 10

Remember and understand

1. Identify whether the statement is true or false. Justify any false responses.

Statement	True or false
a. The treatment of some types of cancer can make women infertile or damage their eggs.	
b. Unfertilised eggs can be frozen and fertilised years later.	
c. All thawed unfertilised eggs will result in pregnancies once fertilised.	
d. Eggs are more difficult to freeze than semen or embryos because they contain more water and ice crystals can form inside the egg.	
e. Genetic testing combined with IVF provides the opportunity for parents to choose the genetic characteristics of their children.	

2. MC Identify the technique that could be used to introduce sperm from the father into the surrogate mother.
   A. Amniocentesis
   B. Artificial insemination
   C. Chorionic villi sampling
   D. Invitro fertilisation
3. MC Identify the technique that could be used to produce a fertilised egg that could then be transferred into the surrogate mother.
   A. Amniocentesis
   B. Artificial insemination
   C. Chorionic villi sampling
   D. Invitro fertilisation

Apply and analyse

4. Outline some situations where women may consider having their eggs frozen.
5. Explain what the chance is of producing a baby from a frozen egg. Why is the success rate so low?
6. Discuss whether there should be an age limit for IVF treatment. Should this age limit apply to the mother only or to both parents? Justify your answer.
7. Think of some issues that may arise between a surrogate and a commissioning couple and describe these.

Evaluate and create

8. Create a PMI chart about the following statement: A woman should be allowed to use her dead husband's sperm to conceive a child.
9. SIS With a shortage of egg and sperm donors in Australia what do you think will be the advantages and disadvantages of releasing donor details to their offspring? Produce a newspaper article reporting on the change in legislation and possible impact on sperm and egg donors and recipients.
10. SIS In groups of four or more, discuss each issue statement in the table provided.
    a. Write a list of people's 'gut reactions' or immediate responses to each statement.
    b. Make a list of arguments for, and a list of arguments against, each statement.
    c. Suggest what factors influenced your opinions on these issues.
    d. Did the opinions differ between members of your group? Suggest reasons why.
    e. Report your findings back to the class, or organise a debate.
    f. Write a summary paragraph about the class's overall response to each statement.

Technique	Issue statement	Your opinion (Explain your response with arguments for and against the issue.)
Artificial insemination	• Sperm should be used only from males with a high IQ, brown eyes and red hair. • All women should be artificially inseminated with sperm selected by their parents.	
IVF	• The IVF program is too expensive and should be abandoned. • IVF technology should be used to build a superior race.	
Donor gametes; surrogacy	• Donors and surrogates should be anonymous and have no rights over the offspring produced. • Sperm should be collected from all males at the age of 18 and only this is to be used for fathering children.	

Frozen embryos	• These embryos should be available to other couples if they are not used within six months. • These embryos should be developed so that they provide a supply of blood and organs for transplants.	
Ultrasound; amniocentesis	• These tests should be made compulsory for all women. Any abnormalities should result in immediate removal of the fetus. • These techniques should be used to select the gender of the child.	

Fully worked solutions and sample responses are available in your digital formats.

5.8 Stem cells

LEARNING INTENTION

At the end of this subtopic you will be able to explain where stem cells come from and describe some possible uses of stem cells, as well as why there are some objections to their use.

5.8.1 What are stem cells?

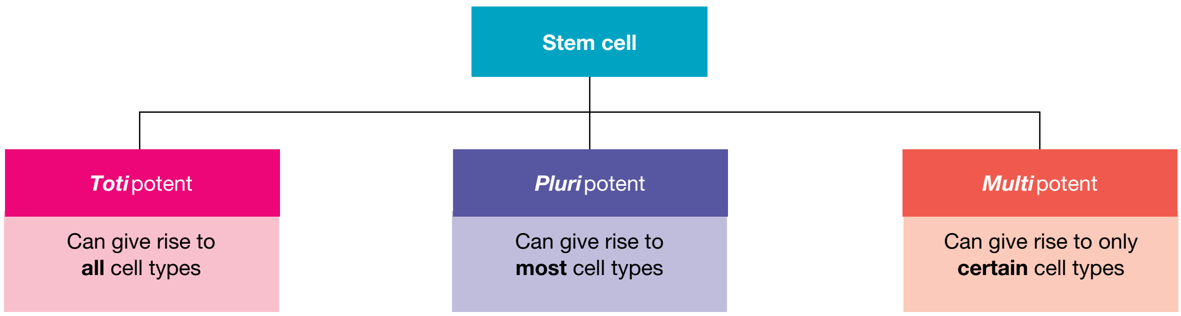
Have you heard or read about the issues regarding **stem cells**? What's the stem of the trouble? What are stem cells and why are people arguing about them?

Stem cells are unspecialised cells that can reproduce themselves indefinitely. They have the ability to differentiate into many different and specialised cell types. Stem cells are categorised based on how flexible they are and the number of tissue types they can become. During the early stages of embryo development, the cells are identical and can become any cell type, known as **totipotent** — they have the ability to differentiate into any type of cell. The source of the stem cell determines the number of different types of cells that it can differentiate into.

stem cells undeveloped cells found in blood and bone marrow that can reproduce themselves indefinitely

totipotent the most powerful stem cells that can give rise to all cell types

FIGURE 5.98 Stem cells can be divided into categories on the basis of their ability to produce different cell types.

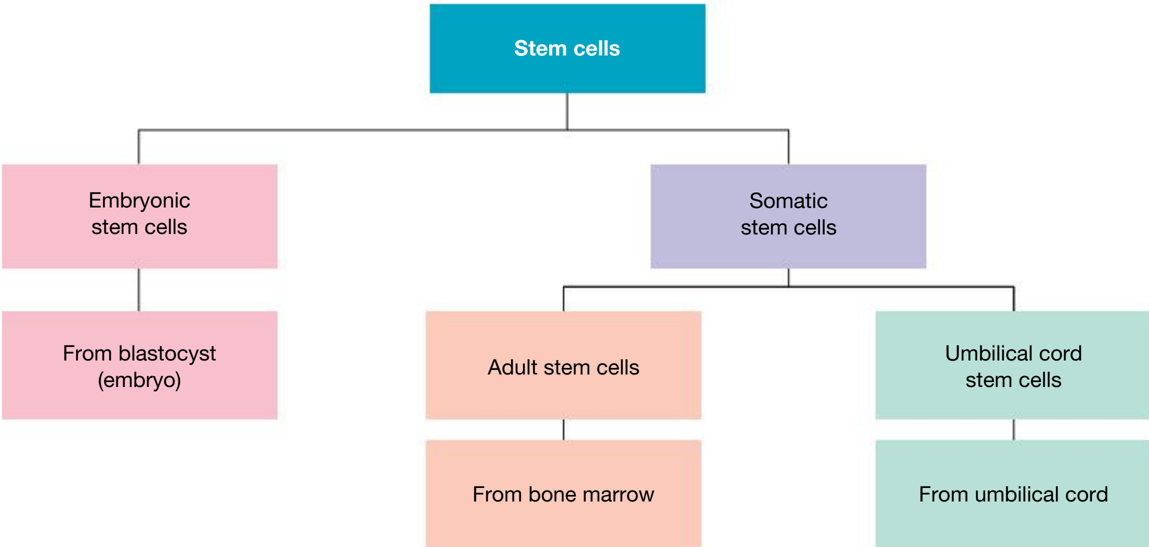


The ability to differentiate into specific cell types makes stem cells invaluable in the treatment and possible cure of a variety of diseases. For example, they may be used to replace faulty, diseased or dead cells. The versatility of stem cells is what makes them very important.

What are the sources of stem cells?

Embryonic stem cells can be obtained from the inner cell mass of a blastocyst. Blastocyst is the term used to describe the mass of cells formed at an early stage (5–7 days) of an embryo's development. Embryonic stem cells are **pluripotent** and can give rise to most cell types; for example, blood cells, skin cells, nerve cells and liver cells.

FIGURE 5.99 Stem cells can be described in terms of their source.



Adult stem cells or **somatic stem cells** can come from children and adults. They are not derived from embryos but from tissues that contain stem cells such as bone marrow, blood or the umbilical cord after a pregnancy. Stem cells obtained from the bone marrow are often referred to as adult stem cells. These cells are **multipotent** and can develop into many kinds of blood cells.

embryonic stem cells stem cells derived from the inner cell mass of a blastocyst. These cells are pluripotent and can give rise to most cell types

pluripotent stem cells that can give rise to most cell types; e.g. blood cells, skin cells and liver cells

adult stem cells undeveloped cells found in blood and bone marrow

somatic stem cells derived from bone marrow, skin and umbilical cord blood. These cells are multipotent and can give rise to only certain types of cells

multipotent stem cells that can give rise to only certain cell types, e.g. various types of blood or skin cells

FIGURE 5.100 Bone marrow stem cells can develop into different types of blood cells.

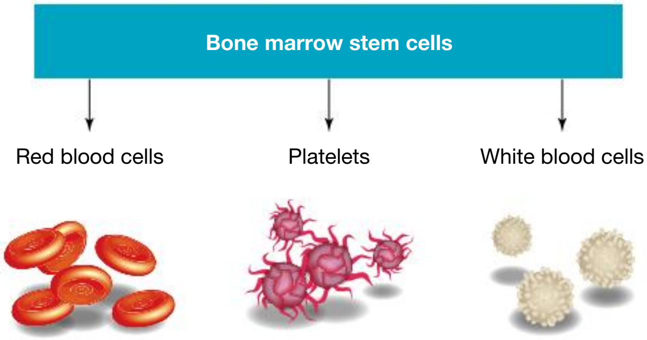
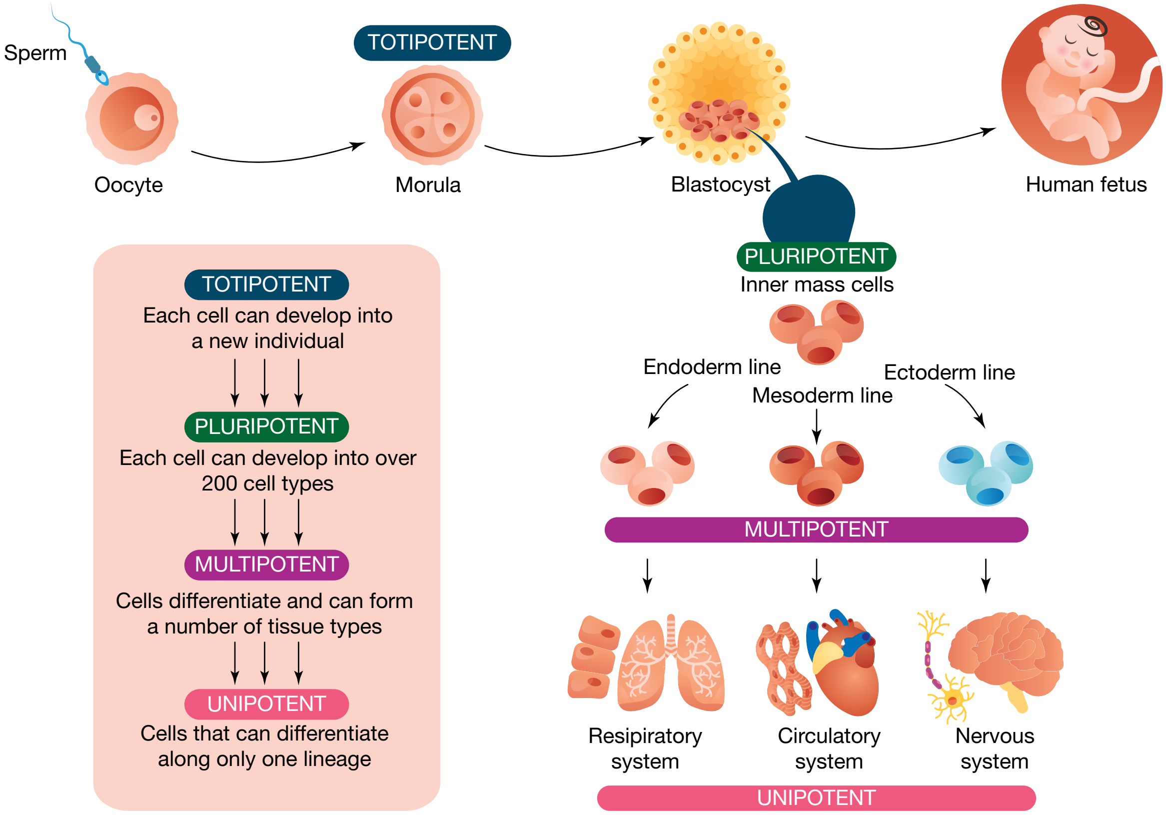


FIGURE 5.101 Stem cells are categorised based on how flexible they are and the number of tissue types they can become. During the early stages of embryo development, the cells are identical and can become any cell type, known as totipotent. After the blastocyst stage the cells are less flexible and are considered pluripotent. Adult stem cells, or somatic stem cells, can come from children and adults. They are derived from tissues that contain stem cells such as bone marrow, blood or the umbilical cord after a pregnancy.



5.8.2 Using stem cells

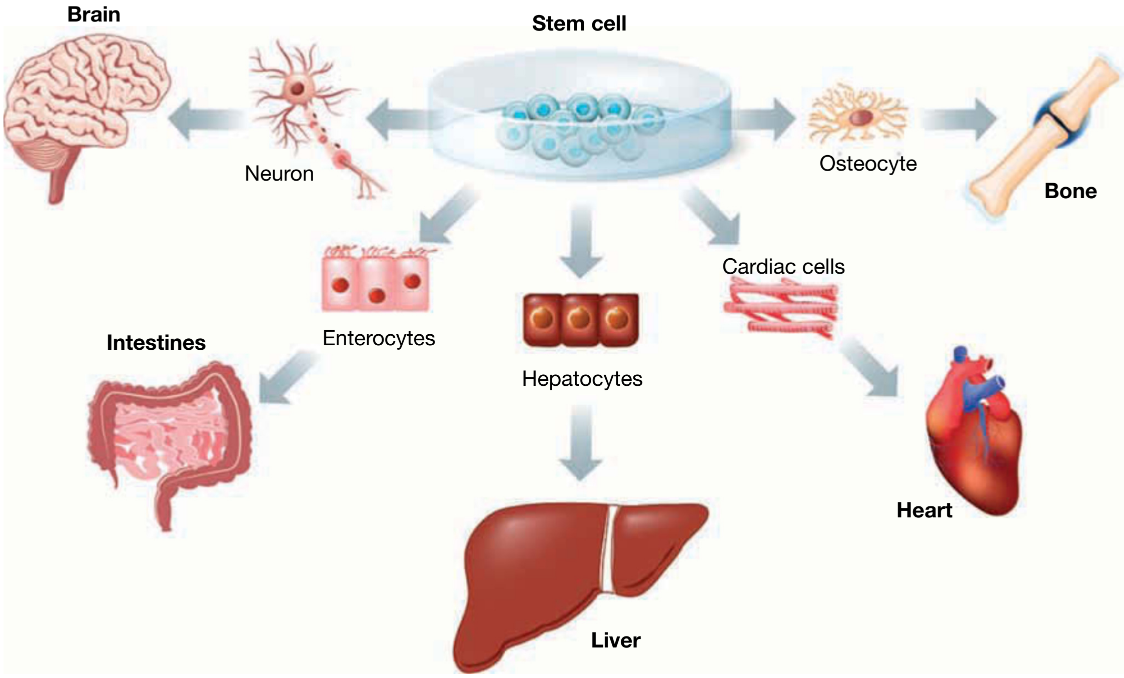
Stem cells can be derived from a person's own body, but not all stem cells can be programmed effectively yet. Many people store the umbilical cord once a child has been born as this is a good source of stem cells for the future; however umbilical cord stem cells are multipotent therefore can only be used to generate a small number of tissue types. In the future; however, it may be possible to redirect these multipotent cells into becoming more flexible and so offering more uses in medical treatment.

Embryonic stem cells, particularly stem cells from the early embryo, are the most flexible type of stem cell and therefore the most useful in stem cell therapy. However, human embryos are not readily available and research and therapies utilising human embryos are very strict. This has driven research into how we might be able to utilise other types of stem cells in treatment.

Some parents have decided to have another child for the sole purpose of being able to provide stem cells for a child who is ill or has a disease. In this case, the blood from the umbilical cord or placenta is used as the source. Some suggest that this is not the 'right' reason to have a child and that children should not be considered a 'factory' for spare parts for their siblings.

FIGURE 5.102 Scanning electron micrograph of embryonic stem cells

FIGURE 5.103 There are many diseases that stem cells could offer a solution to. Some examples of these include macular degeneration (loss of sight), spinal cord injury, stroke, burns, heart disease, diabetes, osteoarthritis and rheumatoid arthritis. Stem cells could potentially be programmed to differentiate into tissues that can treat these diseases.



SCIENCE AS A HUMAN ENDEAVOUR: The axolotl

The axolotl, *Ambystoma mexicanum,* is an amphibian that is famous for its ability to regenerate limbs in a similar way to the starfish seen in section 5.2.6; however, not as a mechanism for reproduction but to regenerate and heal itself following an injury. It is thought they are able to turn specialised cells back into stem cells so that full limbs and organs can be reformed as it was during its early stages of embryonic development. The axolotl is known to regenerate its heart, testes, brain and bones.

FIGURE 5.104 The axolotl can regenerate limbs and heal itself.

Groups such as the Australian Regenerative Medicine Group, based at Monash University in Melbourne, think that researching the mechanisms for regeneration in the salamanders may provide some insights into how the healing process in mammals, including humans, could be redirected into regeneration of tissues in the future.

5.8.3 Issues with stem cells

The use and manipulation of human embryos is the main source of concern regarding stem cell research. Many people believe that embryos must be protected as they have the potential to become a new life. Many people are concerned about how the embryos are handled and consider the use of embryonic cells unethical as embryos are dismantled in the process.

DISCUSSION

Try to consider some of the reproductive technologies outlined in this topic from the perspectives of groups of people who are different to you, such as:

- those from different religions
- pro-life groups who consider that life begins at fertilisation
- people over the age of 70 years
- people who are have very different levels of wealth, much richer or poorer
- people with a genetic disease in their family
- people who live in countries where access is blocked by law
- people whose religion does not allow certain treatments
- people who are not educated and do not have access to information about these treatments.

5.8 Exercise

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To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 5	Questions 3, 6, 7	Questions 4, 8, 9

Remember and understand

1. Identify the missing words to complete the sentences.
   a. Stem cells are ___________ cells that can ___________ themselves indefinitely and have the ___________ to differentiate into many different and ___________ cell types.
   b. The ___________ of the stem cell determines the ___________ of different types of cells that it can differentiate into.
   c. Stem cells can be ___________ into categories on the basis of their ___________ to produce ___________ cell types.
2. What are stem cells?
3. Match the terms with the correct definition

Term	Definition
a. Totipotent	A. Can develop into any type of cell, originates from an early embryo
b. Pluripotent	B. Can develop into many kinds of cells, obtained from the inner cell mass of a blastocyst embryo (later stage)
c. Multipotent	C. Can develop into a few different types of cells, derived from somatic cells in an adult or child, not from an embryo

4. List sources of stem cells.
5. Identify whether the statement is true or false. Justify any false responses.

Statement	True or false
a. The ability to differentiate into specific cell types makes stem cells valuable in the treatment and possible cure of a variety of diseases.	
b. Bone marrow stem cells can develop into red blood cells, white blood cells, platelets and nerve cells.	
c. In the process of obtaining stem cells from blastocysts, the embryo is destroyed.	
d. The source of embryonic stem cells has raised many issues.	

Analyse and apply

6. Explain two issues regarding stem cell research.
7. Describe a scientific contribution made by the Australian scientist Professor Alan Trounson.

Evaluate and create

8. **SIS** Investigate some of the following questions.
  a. Which inherited genetic diseases are potentially treatable with stem cells?
  b. How many different kinds of adult stem cells exist and in which tissues can they be found?
  c. Why have adult stem cells remained undifferentiated?
  d. What are the factors that stimulate adult stem cells to move to sites of injury or damage?
9. Investigate how stem cell research is regulated in Australia and in one other country. What are the similarities and differences of the regulations? Discuss the implications of this with your team mates.

Fully worked solutions and sample responses are available in your digital formats.

5.9 Thinking tools — Storyboards

5.9.1 Tell me

What is a storyboard?

A storyboard is a very useful thinking tool that allows you to use both your imagination and organisational skills to capture and share your thoughts and ideas. Using storyboards, you can identify the main scenes in a story or event. They are sometimes called a comic strip.

FIGURE 5.105 A storyboard

A Outline of scene 1	B Outline of scene 2	C Outline of scene 3
D Outline of scene 4	E Outline of scene 5	F Outline of scene 6

Why use a storyboard over a Gantt chart?

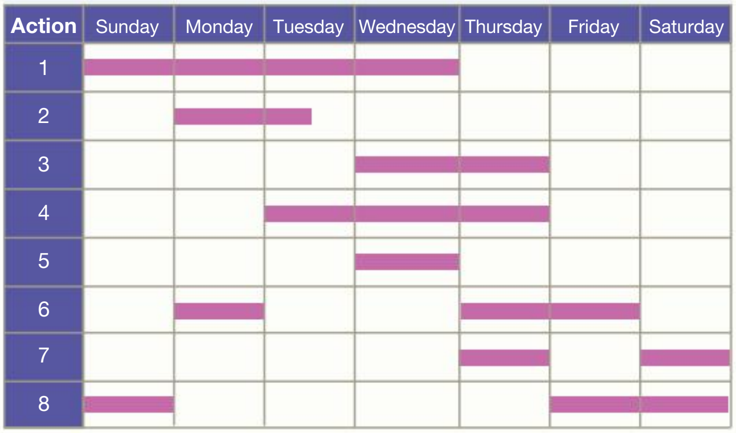
Similar to storyboards, Gantt charts show a sequence or time frame, and typically show planned dates of actions. Storyboards, however, use sketches or diagrams, whereas Gantt charts use tables, as shown in figure 5.106.

5.9.2 Show me

To create a storyboard:

1. Decide how many scenes you need in your story. Often, 6–8 is a good number. Divide your page into this number of equal sections.
2. Consider which will be the three main events in your story and draw them roughly in the first, middle and last sections of your page.
3. Brainstorm the scenes that come between these. Select the most appropriate and add them as intermediate scenes.
4. Mentally stand back and examine your story outline; make any desired changes to enhance its dramatic impact.

FIGURE 5.106 A Gantt chart



5.9.3 Let me do it

5.9 ACTIVITIES

1. Construct storyboards for the following:
   a. how you have changed between birth and ages two, four, six, eight and ten, and your current age
   b. the 'life of a sperm' or the 'life of an egg'.
2. Read through the information in the 'Week by week' article in your eWorkbook available in the resources panel of your digital resources.
   a. Mind map what you consider to be the key points.
   b. Construct storyboards to show from fertilisation until week 12 of the pregnancy:
      i. the changes experienced by the mother ii. the baby's development.
   c. Construct a Gantt chart to sequence your key points from fertilisation until week 12 of the pregnancy:
      i. the changes experienced by the mother ii. the baby's development.
3. Construct a Gantt chart or storyboard that includes seed dispersal, pollination, fertilisation, germination and development into a seedling.

Fully worked solutions and sample responses are available in your digital formats.

on Resources

eWorkbook Week by week article (ewbk-6636)

5.10 Review

Access your topic review eWorkbooks

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-4884	ewbk-4886	ewbk-4888

on Resources

5.10.1 Summary

- Organisms must reproduce for the species to survive beyond a single generation.
- Parent organisms reproduce and pass their genetic information to the next generation.
- Once the offspring reach reproductive maturity they reproduce, and the generations continue.
- Life cycles vary from one organism to the next with some having long life cycles and others having short life cycles.
- Species that do not continue to reproduce become extinct.

Sexual reproduction

- Sexual reproduction combines a male and female gamete, reproductive cell, and combines the genetic information of both parents in the offspring.
- Animals usually reproduce sexually with the male's egg fertilising the female's ova.
- Fertilisation can occur internally, following mating, or externally, when both gametes are released into the environment.
- Each species has its own strategies for increasing the likelihood of successful reproduction.

Sexual reproduction in flowering plants

- Flowering plants, angiosperms, reproduce sexually just as animals do.
- The equivalent cell to the sperm is the pollen that travels to fertilise the ova, or ovule in plants.
- Flowers have both pollen and ovules in the same flower so could pollinate themselves or pollinate the flowers on other plants.
- The seed is the beginnings of a new plant and is often found inside a fruit.
- Pollen and seeds can be dispersed by animals or the environment, such as by wind over a wide area.
- Seeds can remain dormant for long periods of time waiting for the correct conditions before they start to grow into a new plant (germinate).

Comparing reproductive strategies in animals

- Many organisms reproduce asexually instead of sexually, or sometimes they do both, such as the jellyfish *Aurelia aurita.*
- Asexual reproduction results in offspring that are very similar or identical to the parent organism (clones).
- The offspring can result from a single adult dividing into two or four offspring, binary fission.
- The offspring can bud off from the parent organism (budding), emerge from runners, cuttings or bulbs (vegetative propagation) or from part of the adult organism (regeneration).
- Sometimes offspring can come from an ova that has been activated without a sperm resulting in a female clone, parthenogenesis.

Human reproduction

- Human reproduction is a complex process that requires delivery of the sperm cells to the fallopian tubes soon after a mature ovum is released from the follicle into the fallopian tubes (ovulation).
- The male testes produce millions of sperm each day and sperm production continues throughout life, whereas in females no more ova are produced after birth.
- The female menstrual cycle is coordinated by a series of hormones and begins with a menstrual bleed, followed by ovulation and preparation of the uterus for an embryo.
- If fertilisation occurs an embryo will develop and implant into the endometrium (uterus) about a week later.
- Human gestation is 38–40 weeks or nine months after which labour begins and a child is born.

Reproductive technologies and contraception

- Humans manipulate their fertility in many different ways with most couples using some kind of contraception at some time in their life to avoid an unwanted pregnancy.
- Contraception is an important strategy for avoiding some STIs such as human papillomavirus, which can have life-threatening consequences.
- Many couples need to access assisted reproductive technologies to achieve a pregnancy, such as IVF treatment.
- In addition, genetic testing can be used to detect genetic abnormalities or increase a couple's chance of pregnancy.

Issues of reproduction

- Many different perspectives must be considered regarding research on and use of eggs, sperm and embryos.
- Treatment can be expensive and is often emotionally and physically difficult.
- Aspects of assisted reproduction are acceptable to some people but are not acceptable to others depending on the values and beliefs of the people involved.
- The laws in each state or country are designed to protect patients from harm, protect the embryos and ensure treatments are only available once they have been shown to be safe.

Stem cells

- Stem cells are cells that have not differentiated (do not have a specific job or structure yet).
- Stem cells can be directed into becoming different types of cells with some types of stem cells able to become any other cell type and some types of stem cells more restricted.
- Embryonic stem cells are the most useful but can only be obtained from human embryos that are not readily available and are protected by many regulations.
- Many people object to using human embryos for research or medical treatment as they believe the embryo is a life, or potential life, that should not be used as a medicine.

5.10.2 Key terms

adult stem cells undeveloped cells found in blood and bone marrow
amniocentesis the removal and testing of fluid from the amniotic sac surrounding the fetus
angiosperms plants that have flowers and produce seeds enclosed within a carpel
anther the male part of a flower that makes pollen
asexual reproduction a type of reproduction that does not require the fusion of sex cells (gametes)
assisted reproductive technologies (ART) medical procedures used primarily to address infertility
binary fission reproduction by the division of an organism (usually a single cell) into two new organisms
blastocyst an embryo with a fluid-filled cavity that is beginning to differentiate, five or six days after fertilisation
breech a birth in which the baby is born feet or bottom first
budding the formation of a new organism from an outgrowth (bud) of the parent
caesarean an operation to remove a baby by cutting the mother's abdomen
chorionic villus sampling a procedure in which cells from the developing placenta are removed for testing at 10–12 weeks of pregnancy, allowing certain abnormalities to be detected
clone an identical copy

cloning the process used to produce genetically identical organisms
conception the successful embedding of a fertilised egg in the uterus wall
contraception the prevention of fertilisation of an egg or prevention of a fertilised egg becoming embedded in the uterus wall
contraceptives devices or substances that prevent fertilisation of an egg or prevent a fertilised egg becoming embedded in the uterus wall
cotyledons special leaves of the embryo plant inside a seed that provide food for the developing seedling
CRISPR Cas9 a tool used for gene editing
cross-pollination the transfer of pollen from stamens of one flower to the stigma of a flower of another plant of the same species
cryopreservation when cryoprotectant chemicals and cooling are used to safely freeze biological material such as human embryos
differentiation when cells become different to each other and start to become specialised
diploid containing two sets of chromosomes
disperse the scattering of the seeds from plants
diverse a variety of different features within a population or different organisms in an ecosystem
egg the female reproductive cell in animals and plants; an ovum
embryo a group of cells formed from the zygote and is developing into different body organs
embryonic stem cells stem cells derived from the inner cell mass of a blastocyst. These cells are pluripotent and can give rise to most cell types
endosperm the food supply for the embryo plant in a seed
ethical issues issues that consider the moral implications, fairness and equity involved in an issue
external fertilisation reproduction occurs when the eggs are released by the female into water and fertilised by sperm released nearby
extinction the state or process of being or becoming extinct
fertilisation fusion of the male gamete (sperm) and the female gamete (ovum)
fetus the unborn young of an animal that has developed a distinct head, arms and legs
flowers the reproductive part of angiosperms containing petals, stamens and carpels. They are often colourful to attract pollinating insects
fraternal twins twins developed from different fertilised eggs
fruit a ripened ovary of a flower, enclosing seeds
gametes (reproductive cells) reproductive cells (sperm or ova) containing half the genetic information of normal cells
gene editing changing the genetics of a cell or organism
generation refers to all offspring at the same stage of development
genetic screening is the study of a person's DNA in order to identify genetic differences or susceptibility to particular diseases or abnormalities
germination the first sign of growth from the seed of a plant
gestation the time spent by offspring developing in the uterus
gonads reproductive organs where gametes are produced; the testes and ovaries
haploid containing a single set of chromosomes
hermaphrodites organism that has both male and female reproductive organs
identical twins twins developed from the same fertilised egg
implantation the process whereby the embryo becomes embedded in the wall of the uterus
infertility the inability to have children
insect-pollinated flowers flowers that receive pollen carried on the body parts of insects from other flowers
internal fertilisation reproduction occurs when the egg remains in the female and is fertilised by sperm inserted into the female
IVF (invitro fertilisation) the fertilisation between eggs and sperm and the culture of embryos in the laboratory for fertility treatment
labour the process of delivering the baby, placenta and umbilical cord from the uterus
life cycle the cycle of one organism's life from birth through reproductive age to death; may include distinct stages and forms
menstrual cycle beginning of one period to the beginning of the next period
menstruation the monthly bleeding, also called 'periods'. It occurs as the lining of the uterus is released.
mitochondria small rod-shaped organelles that are involved in the process of cellular respiration, which results in the conversion of energy into a form that the cells can use. Singular = mitochondrion

mitochondrial DNA (mtDNA) genetic material from the mitochondria, which is only passed to offspring from the mother
multiple fission a reproduction method where a single-celled organism divides into more than two cells
multipotent stem cells that can give rise to only certain cell types, e.g. various types of blood or skin cells
nectaries parts of a flower, at the base of the petals, that secrete nectar
non-invasive prenatal testing (NIPS) the testing of maternal (mother's) blood for signs of chromosomal abnormality in the fetus
offspring the young born of a living organism
organisms living things
ova female gametes or sex cells. Singular = ovum.
ovaries female gonads, produce the female gametes (egg cells; ova)
ovulation the release of an ovum from a mature follicle in the ovary into the fallopian tube
ovule the receptacle within an ovary that contains egg cells
parthenogenesis the development of new individuals from unfertilised eggs
petals the coloured parts of a flower that attract insects
pheromones chemicals that are important in communication between members of the opposite sex
placenta an organ formed in the mother's womb through which the baby receives food and oxygen from the mother's blood and the baby's wastes are removed
plumule a small bud at the tip of the embryo plant in a seed
pluripotent stem cells that can give rise to most cell types; e.g. blood cells, skin cells and liver cells
pollen the fine powder containing the pollen grains (the male sex cells of a plant)
pollen grains the male gametes of a flower
pollen tube a long tube growing from a pollen grain through the style to the ovule
pollination the transfer of pollen from the stamen (the male part) of a flower to the stigma (the female part) of a flower
preimplantation genetic diagnosis (PGD) a procedure to diagnose and exclude genetic abnormalities in embryos before implantation into the mother's body
preimplantation genetic screening the screening of embryos for genetic abnormalities to improve pregnancy and live birth rates
premature a baby born less than 37 weeks after conception
puberty the life stage when the sex glands become active and bodily changes occur to enable reproduction
radicle the beginnings of a root making up part of a plant embryo inside a seed
recipient the person or couple receiving embryos or gametes from another person
reproductive maturity the age at which an organism can reproduce
seed a product of a fertilised ovule
seed coat the protective layer around a seed
seedling a young plant produced from the embryo in the seed after germination
self-pollination the transfer of pollen from the flower's own stamen to its stigma
semen ejaculate from the male reproductive organs made up of sperm and secretions essential for its viability
sexual intercourse the act of inserting sperm into the female; also called copulation or mating
somatic stem cells derived from bone marrow, skin and umbilical cord blood. These cells are multipotent and can give rise to only certain types of cells
sperm the male reproductive cell. It consists of a head, a middle section and a tail used to swim towards the egg
spores reproductive cells capable of developing into a new individual without fusion with another reproductive cell
sterile a person unable to produce reproductive cells
stem cells undeveloped cells found in blood and bone marrow that can reproduce themselves indefinitely
stigma the female part of a flower, at the top of the carpel, that catches the pollen during pollination
style the supporting part of a flower that holds the stigma
surrogacy a pregnancy that occurs when the fertilised egg is placed in the uterus of another woman who did not produce the egg
survival is the ability to continue life, species survival depends on reproductive success
target cell a specific cell in which a hormone can cause a response
testes organs that produce sperm and sex hormones
totipotent the most powerful stem cells that can give rise to all cell types
uterus the site of embryo implantation, and supports the developing fetus from implantation to birth. About the size of a pear if not pregnant

vegetative propagation the reproduction of plants using parts other than sex cells
virgin births births that do not involve the joining of eggs and sperm
wind-pollinated flowers flowers that receive pollen carried by the wind from another flower
zona pellucida surrounds the ovum and embryo for the first week of development
zygote a cell formed by the fusion of two gametes; fertilised ovum before it starts to divide into more cells

on Resources

Digital document	Key terms glossary (doc-34942)
eWorkbooks	Study checklist (ewbk-4877) Literacy builder (ewbk-4878) Crossword (ewbk-4880) Word search (ewbk-4882)
Practical investigation eLogbook	Topic 5 Practical investigation eLogbook (elog-0578)

5.10 Exercise

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Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 7, 10, 13, 20, 25, 26, 31	Questions 3, 4, 5, 8, 11, 12, 17, 21, 24, 27, 28	Questions 6, 9, 14, 15, 16, 18, 19, 22, 23, 29, 30

Remember and understand

1. Identify whether the statement is true or false. Justify any false responses.

Statement	True or false
a. Pollination in plants is the equivalent of fertilisation in animals.	
b. Gametes are reproductive sex cells.	
c. Binary fission in prokaryotes involves mitosis.	
d. Sperm production in humans is controlled by hormones.	

2. Match the term with its most appropriate description.

Term	Description
a. Sperm	**A.** Female gamete
b. Ova	**B.** Male gamete(s) in animals
c. Ovum	**C.** Female gametes
d. Pollen grain	**D.** Male gamete in plants

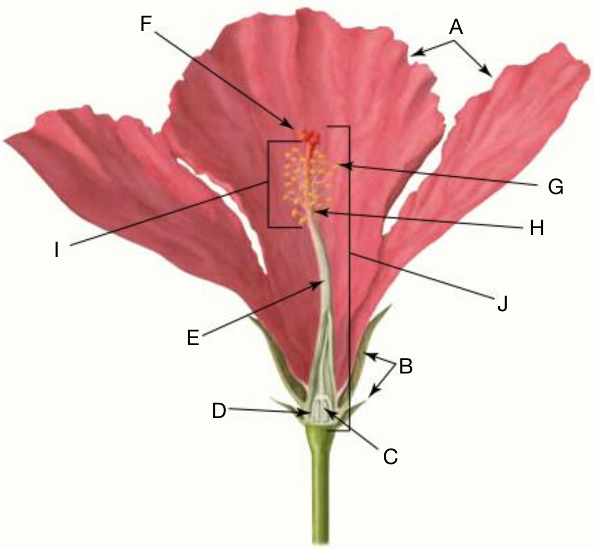
3. Match the term with the best matching description.

Term	Function
a. Pollination	**A.** Fusion of male and female gametes
b. Ejaculation	**B.** Process in which the embryo completely embeds itself in the uterus lining
c. Germination	**C.** Release of semen from the male's penis
d. Fertilisation	**D.** Way in which the pollen grains reach the stigma of a plant
e. Implantation	**E.** When the seed bursts open and a new plant grows old

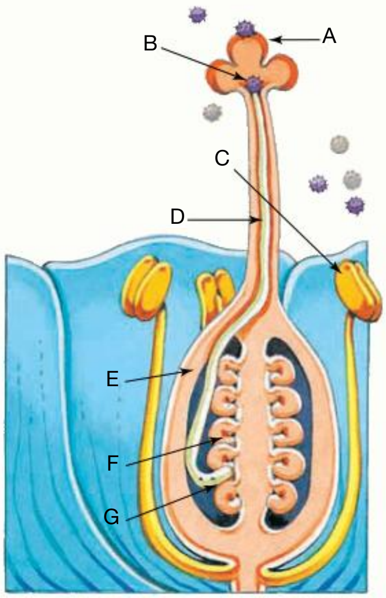
4. Match the part of the flower to its function.

Part of flower	Function
a. Style	**A.** Produces pollen
b. Ovule	**B.** Supports the anther
c. Stigma	**C.** Contains ovule and becomes the fruit
d. Anther	**D.** When pollen lands here, pollination has occurred
e. Ovary	**E.** Site of fertilisation of egg cell
f. Filament	**F.** Supports the stigma and is the structure through which the pollen tube grows

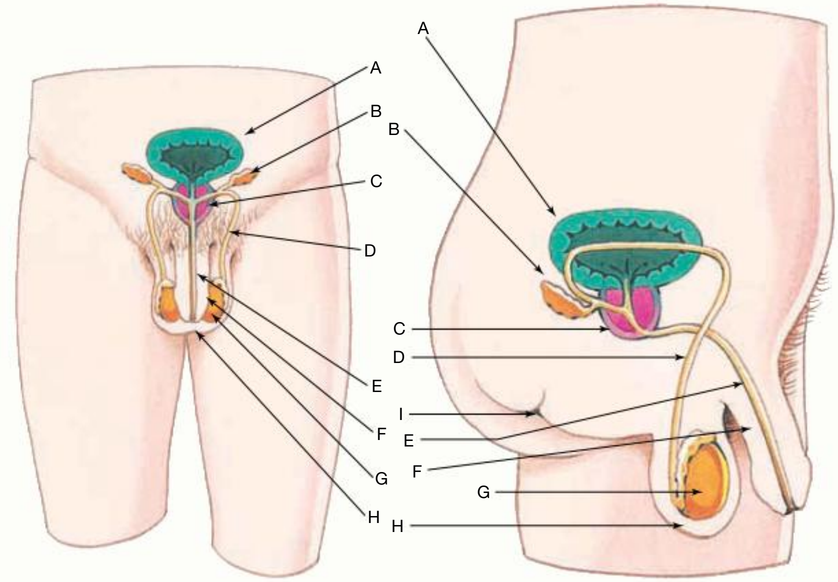
5. Write down in your workbook which letter in the following diagram corresponds to each of these terms: ovules, sepals, filament, style, stigma, ovary, anther, petals, stamen, carpel.

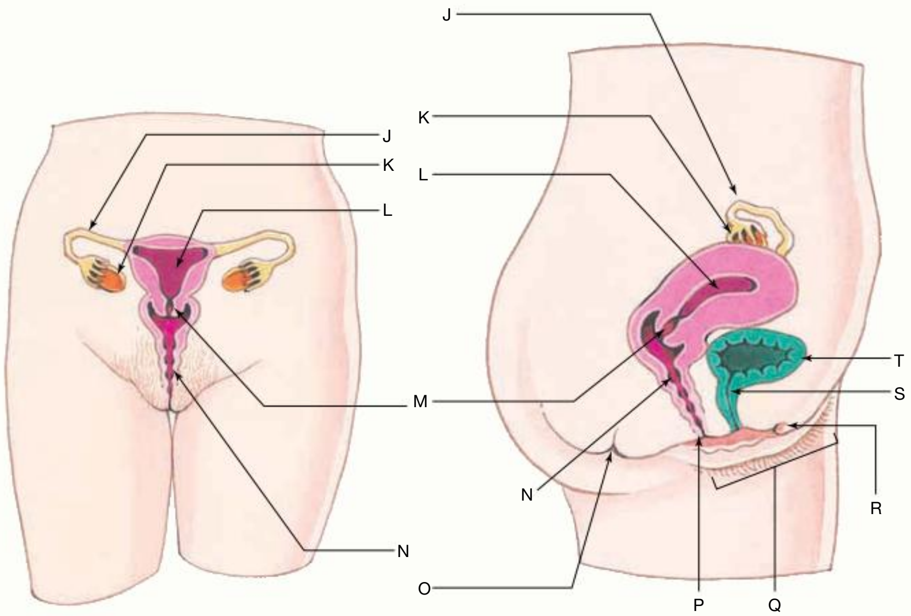


6. Label the parts of the plant in the diagram using the following terms: stigma, male gamete, pollen grain, pollen tube, stamen, ovary, ovule.



7. Identify the parts labelled A–T in the diagrams shown. Write one function of at least two parts in each diagram.



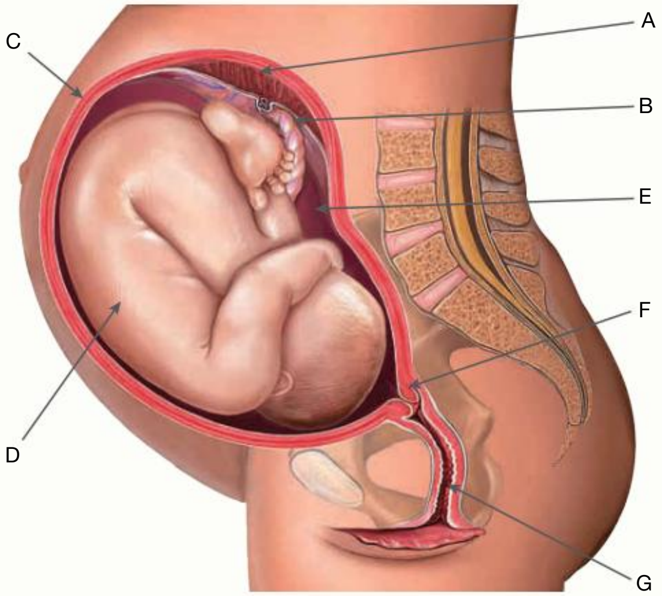


8. Summarise the disadvantages and advantages of sexual and asexual reproduction.
9. A paramecium is a single-celled organism that reproduces asexually.
   a. Make a list of the advantages and disadvantages of reproducing this way.
   b. Compare your list with that of your team. Discuss any differences.
   c. Find out more about paramecia and, as a team, write and perform a paramecium puppet play about their lives.

10. Match the contraceptives listed with the way they prevent conception and their effectiveness.

Contraceptive	How it prevents conception	Effectiveness
a. Condom with spermicide	**A.** Prevents ova from developing	**1.** Extremely effective
b. Diaphragm without spermicide	**B.** The fallopian tubes or vas deferens are cut and sealed	**2.** Unreliable
c. Daily contraceptive pill	**C.** Keeps sperm and semen from entering the woman's vagina after ejaculation	**3.** Highly effective
d. Surgical: vasectomy and tubal ligation	**D.** Removal of male's penis from the vagina before ejaculation	**4.** Highly effective
e. Coitus interruptus (withdrawal method)	**E.** Prevents sperm cells from reaching the cervix	**5.** Moderately effective

11. Design a calendar of the menstrual cycle and then outline the events that occur at each stage on your calendar.
12. Unscramble the following types of asexual reproduction.
    a. taevvegeti gatponproai
    b. gatienreoner
    c. narybi sfionis
    d. sheneipartognes
13. Label the parts A–G in this diagram.



14. Construct a table naming the organs of the human male and female reproductive systems. For each organ, describe its structure and function.

Apply and analyse

15. On the basis of what you have learned in this section of your studies, suggest responses to the following questions.
    a. How can there be weeds in the garden if I didn't plant them there?
    b. Why don't twins always look the same?
    c. Why doesn't a caged bird lay eggs that can hatch into baby birds?

16. **SIS** Describe an issue related to the following types of technology that matches the category provided in the table.

Technology	Type of issue	Example
Surrogacy	Ethical issue	
Genetic testing of embryos	Social issue	
Genetic manipulation of embryos	Legal issue	
IVF	Ethical issue	

17. **SIS** Charlotte wanted to find out if temperature affects the growth of plants. She bought four seedlings. She put one seedling in the fridge and one in her garage (which has no windows so is dark and cooler than her house). She put the third seedling on the windowsill (in full sun) and the fourth seedling on her desk (out of the sun but in daylight). Charlotte measured the height of each seedling every day for ten days. Her results are shown in the table.
   a. Write an aim for Charlotte's experiment.
   b. Suggest three improvements to Charlotte's experiment.
   c. Graph Charlotte's results.
   d. Write a conclusion for this experiment.

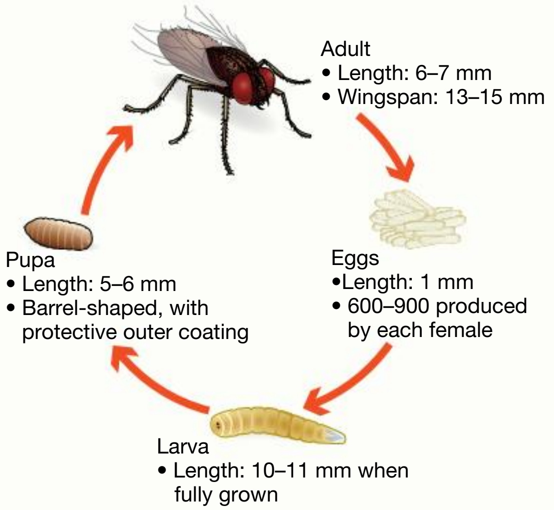
Heights (cm) of seedlings

Position	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10
Fridge	5.0	5.5	6.0	6.2	6.6	7.0	7.3	7.5	7.7	8.0
Garage	5.0	5.6	6.2	6.6	7.0	7.3	7.6	7.9	8.4	8.8
Windowsill	5.0	6.0	6.7	7.5	8.0	8.5	9.0	9.6	10.2	10.6
Desk	5.0	5.8	6.3	7.0	7.5	8.0	8.5	9.1	9.6	10.0

Complete the following activities to produce a learning and thinking journal for this chapter.

18. Draw a diagram of an insect-pollinated flower and use descriptive labels to show what each part does.

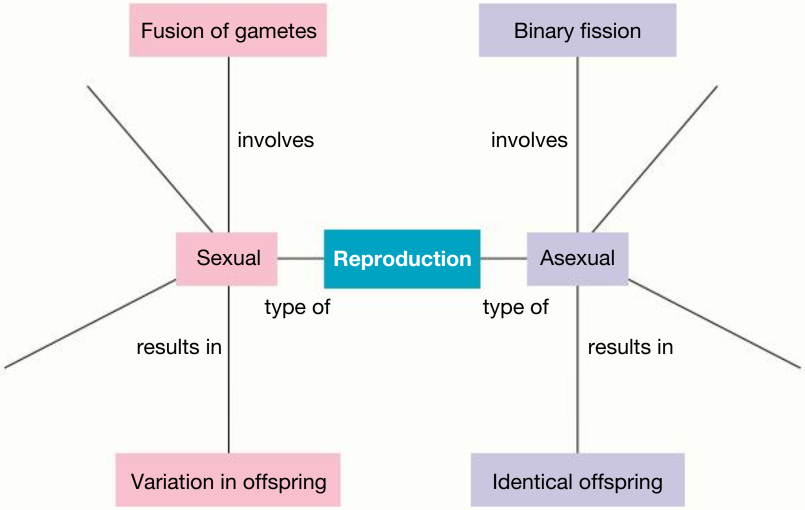
19. **SIS**
   a. Use a table to show differences between the sizes, shapes and structures of a fly during each stage of its life cycle.
   b. Construct a graph to show the differences in length during the adult, egg, larval and pupal stages of the life cycle.
   c. Suggest possible survival advantages for the differences throughout the life cycle.



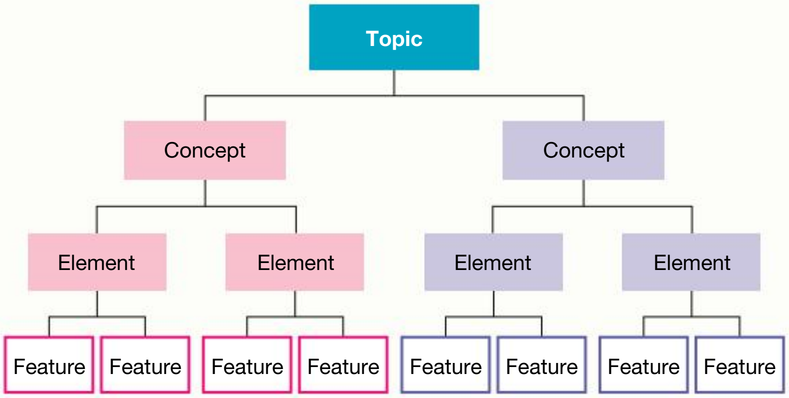
Evaluate and create

20. Invent, design and make your own creature. Describe its courting and mating behaviour, and give details about the way it reproduces.
21. Construct a working model that simulates some aspect of this topic.
22. It has been said that we are currently in the midst of a biotechnological revolution with new technologies offering us many more reproductive options. Is this true for all parts of the world? Hold a discussion about the global impact of reproductive technologies.
23. Suggest how scientific knowledge about the life cycles of plants and animals can be used to develop regulations about importation of foodstuffs into Australia. Suggest reasons for these regulations.
24. Suggest how knowledge of the life cycle of a particular plant or animal may influence the practices of an agriculturalist.
25. Produce a job advertisement for a scientist who works in assisted reproduction or a related field, such as one of the scientists featured in this topic. Ensure you include the title of the job, the place of work (e.g. a hospital, university or elsewhere), what duties are performed in the role, holiday entitlement and likely pay-scale.
26. Use a flowchart to show an example of a life cycle of a flowering plant. Include pollination, fertilisation, development, seed dispersal and germination.

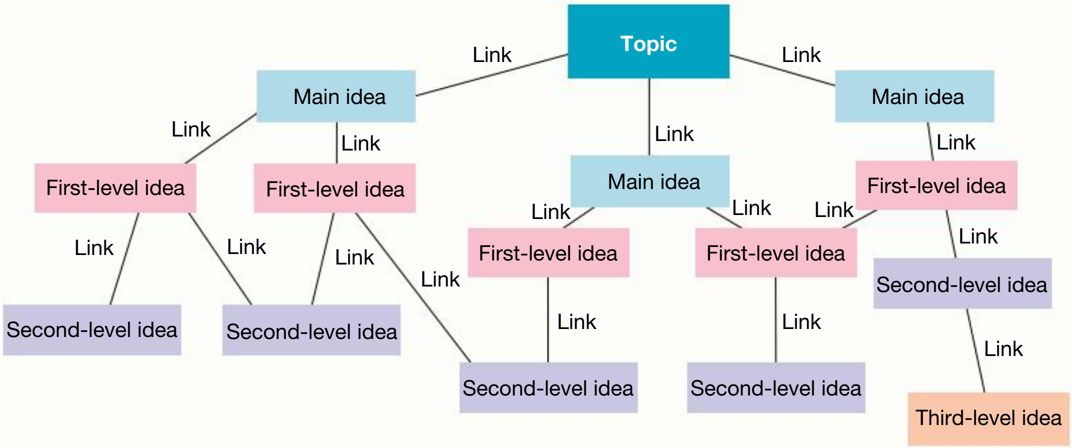
27. Use the figure shown to help you construct a summary of the differences between sexual and asexual reproduction. What other features can you add?



28. Use a tree map to show two sides of a discussion about plant reproduction and animal reproduction.



29. Construct a concept map like the one here to summarise what you know about reproduction.



30. Increased knowledge and understanding of reproductive processes have led to the development of new reproductive technologies. Construct a PMI chart for issues associated with one of these technologies.
31. Make up (and perform) a song or poem to summarise something that you have learned in this topic.

Fully worked solutions and sample responses are available in your digital formats.

on Resources

eWorkbook Reflection (ewbk-3038)

teachon

Test maker
Create customised assessments from our extensive range of questions, including teacher-quarantined questions. Access the assignments section in learnON to begin creating and assigning assessments to students.

RESOURCE SUMMARY

on Resources

Below is a full list of **rich resources** available online for this topic. These resources are designed to bring ideas to life, to promote deep and lasting learning and to support the different learning needs of each individual.

5.1 Overview

eWorkbooks
- Topic 5 eWorkbook (ewbk-4872)
- Student learning matrix (ewbk-4874)
- Starter activity (ewbk-4875)

Practical investigation eLogbooks
- Topic 5 Practical investigation eLogbook (elog-0578)
- Investigation 5.1: Comparing reproductive strategies (elog-0580)

Video eLesson
- Medical ultrasound of human fetus at 26 weeks gestation (eles-4234)

5.2 Asexual reproduction

eWorkbook
- Asexual reproduction (ewbk-4902)

Practical investigation eLogbook
- Investigation 5.2: Asexual reproduction (elog-0582)

Video eLesson
- Binary fission (eles-2306)

5.3 Sexual reproduction in flowering plants

eWorkbooks
- Those fabulous flowers! (ewbk-4900)
- Plant reproduction (ewbk-4901)
- Labelling parts of a flower (ewbk-4899)

Practical investigation eLogbooks
- Investigation 5.3: What's in a flower? (elog-0584)
- Investigation 5.4: Investigating features of flowers (elog-0586)

Video eLessons
- Pollination to seed (eles-2064)
- Seeds growing (eles-2065)
- Growing plants in Australia (eles-0055)

Interactivity
- Anatomy of a flower (int-3407)

5.4 Comparing reproductive strategies in animals

eWorkbook
- Labelling reproductive cells (ewbk-4906)

Video eLessons
- The weedy seadragon (eles-2067)
- Redback spiders (eles-2541)
- *Photuris* firefly (eles-2542)
- Tammar wallaby (eles-2543)

5.5 Human reproduction

eWorkbooks
- Labelling the female reproductive system (ewbk-4907)
- Labelling the male reproductive system (ewbk-4908)
- Human male reproductive system (ewbk-4896)
- Human female reproductive system (ewbk-4897)
- Menstruation (ewbk-4903)
- Inside the womb (ewbk-4905)

Video eLessons
- Female reproductive system (eles-2069)
- Male reproductive system (eles-2068)
- Human ovum in utero and sperm cells (eles-2539)
- Live human sperm (spermatozoa motion) under microscope (eles-2544)
- Menstrual cycle (eles-2538)
- Giving birth (eles-2070)

Interactivities
- Fertilisation (int-3408)
- Labelling the female reproductive system (int-8239)
- Labelling the male reproductive system (int-8240)

5.6 Reproductive technologies and contraception

eWorkbook
- IVF — discussing the issues (ewbk-4919)

Video eLessons
- Methods of contraception (eles-0127)
- In-vitro fertilisation (eles-2540)
- Medical ultrasound of human fetus at 26 weeks gestation (eles-4234)

Weblink
- Prof. Alan Trounson on pioneering IVF

5.9 Thinking tools — Storyboards

eWorkbook

- Week by week article (ewbk-6636)

5.10 Review

eWorkbooks

- Topic review Level 1 (ewbk-4884)
- Topic review Level 2 (ewbk-4886)
- Topic review Level 3 (ewbk-4888)
- Study checklist (ewbk-4877)
- Literacy builder (ewbk-4878)
- Crossword (ewbk-4880)
- Word search (ewbk-4882)
- Reflection (ewbk-3038)

Practical investigation eLogbook

- Topic 5 Practical investigation logbook (elog-0578)

Digital document

- Key terms glossary (doc-34942)

To access these online resources, log on to **www.jacplus.com.au**.

6 States of matter

LEARNING SEQUENCE

6.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

6.1.1 Introduction

Everything around you and in you is made of matter. Your desk, your mobile phone, the clothes you are wearing, the food that you eat and the air that you breathe are substances that are made of matter. Generally, anything that has **mass** and takes up space is **matter**. Different types of matter have different properties. A precious and essential form of matter is water — we cannot exist without it. Most of the Earth is covered in water and it is interesting to note that it exists naturally on Earth in three states. The North and South poles are covered in solid water. Between the poles there are liquid oceans and seas, and in the atmosphere immediately above the Earth's surface there is **water vapour**. Water is an amazing substance and has some unusual properties.

FIGURE 6.1 Water naturally occurs on Earth in three states: solid (ice), liquid and gas (vapour). Water vapour is not visible. The clouds consist of liquid water (tiny droplets).

In this topic you will investigate the various properties of the solid, liquid and gas states. In order to explain the behaviour of solids, liquids and gases, the particle model will be introduced. When heated or cooled the state of substances can be changed and the particle model will be used to explain what is happening during this change of state.

mass the quantity of matter in an object (usually measured in grams or kilograms)

matter everything that takes up space and has mass is matter

water vapour water in the gaseous state

on Resources

Video eLesson Three states of water (eles-3524)

Water naturally occurs on Earth in three states: solid (ice), liquid and gas (vapour). Watch this video to explore the properties of water as it changes states.

6.1.2 Think about states of matter

1. Why does ice melt?
2. What is dry ice and why doesn't it melt?
3. Why do car windows fog up in winter?
4. What are clouds made of?
5. What is the difference between hail and snow?
6. Why are there small gaps in railway lines?

6.1.3 Science inquiry

Bathroom science

1. Why does the mirror fog up in the bathroom after someone has had a hot shower?
2. On really hot days, you may have a cold shower to cool down. Does the bathroom mirror fog up when you do this?
3. Some showers have shower curtains rather than glass shower screens. When people have warm showers, the curtain tends to move in towards the person and stick to them. Give possible explanations for why this happens.
4. When you have a hot shower, the bathroom fills with water vapour. Is this water vapour a gas or a liquid or both? Explain your reasoning.
5. At what temperature does water become too hot to touch?
6. Does water vapour always rise?
7. Are water vapour and steam the same thing?
8. Can you see water vapour or steam?

FIGURE 6.2 Does the bathroom mirror fog up when you have both hot and cold showers?

elog-0081

INVESTIGATION 6.1

Investigating the properties of solids, liquids and gases

Aim

To compare the properties of solids, liquids and gases

Materials

- ice cube
- plastic syringe
- spatula
- balloon
- beaker of water
- balance
- 250 mL beaker (empty)

Method

Copy the table in the results section of this investigation, and use your observations to complete it.

Ice

1. Weigh the ice cube and record the mass.
2. Pick up an ice cube and place it on the bench. Using a spatula, try to squash it or compress it to make it smaller.

Water

3. Take the beaker of water and draw a small amount up into the syringe. Place your finger over the opening at the end of the syringe and press down on the plunger.
4. Place the beaker on the balance and zero the balance, release the water back into the beaker and record the mass.

Gas

5. Partially inflate a balloon with air and hold the opening tightly closed. Try to squeeze the balloon.
6. Release your hold on the opening of the balloon.

7. Place 250 mL beaker on the balance and zero the balance. Add the deflated balloon and record the mass. Blow the balloon up and tie it, and sit it on the beaker to hold it still and record the mass again.

Results

TABLE Properties of solids, liquids and gases

Substance	State of substance	Can the shape be changed easily?	Does it take up space?	Can it be compressed?	Does it have mass?
Ice	Solid				
Water	Liquid				
Air	Gas				

Discussion

1. How do you know that air takes up space?
2. How do you know that air has mass?
3. Where did the air in the balloon go when you released the opening?
4. Which state(s) can be compressed?
5. Which state(s) can change its shape depending on the container?

Conclusion

Summarise your findings about the properties of solids, liquids and gases. Remember that you must only include the findings of this experiment and not include any other properties that were not tested.

on Resources

eWorkbooks Topic 6 eWorkbook (ewbk-2976)
Student learning matrix (ewbk-0265)
Starter activity (ewbk-2977)

Practical investigation eLogbook Topic 6 Practical investigation eLogbook (elog-0082)

learnon Access and answer an online Pre-test and receive **immediate corrective feedback** and **fully worked solutions** for all questions.

6.2 States of matter

LEARNING INTENTION

At the end of this subtopic you will be able to describe the three states of matter and the properties of each of these states. You will also be able to measure the volume of an irregular object.

6.2.1 Solids, liquids and gases

Every substance in the universe is made up of matter that can exist in a number of different forms called states. Almost all matter on Earth exists in three different states: **solid**, **liquid** and **gas**. These states of matter have very different **properties**. That is, they are different in the way they behave and appear.

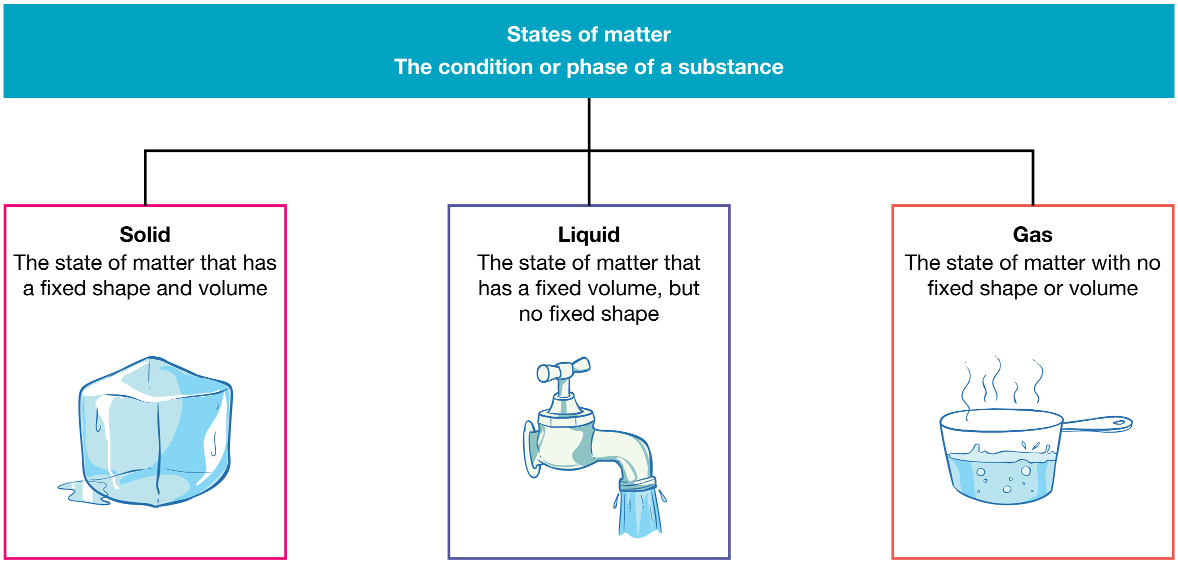
solid state of matter that has a fixed shape and volume

liquid state of matter that has a fixed volume, but no fixed shape

gas state of matter with no fixed shape or volume

properties characteristics or features of an object or substance

FIGURE 6.3 States of matter



Solids

Solids, such as ice, have a very definite shape that cannot easily be changed. They take up a fixed amount of space and are generally not able to be compressed.

Most solids cannot be poured, but there are some, such as salt, sand and sugar, that can be.

on Resources

Interactivity Crystalline solids (int-5333)

Liquids

Liquids, such as water, do not have a fixed shape. The shape of a liquid changes to that of the container in which it is kept. Like solids, liquids take up a fixed amount of space.

If a liquid is poured into a glass, it will take up the shape of the glass. If you continue to pour, it will eventually overflow onto the bench or floor.

Gases

Gases spread out and will not stay in a container unless it has a lid. Gases move around, taking up all of the available space; such as when a roast is cooking, the smell can drift from the kitchen throughout the house. This movement is called **diffusion**. In figure 6.4, iodine gas is being formed and is spreading, or diffusing, throughout the gas jar.

diffusion movement of one substance through another due to a movement of particles, for example from a region of higher concentration to lower concentration

Gases, unlike solids and liquids, can be compressed, making them take up less space. An inflated balloon can be compressed by squeezing it.

DISCUSSION

Salt crystals are able to be poured and also take up the shape of their container.
Are salt crystals liquid or solid?

FIGURE 6.4 The purple iodine gas diffuses, taking up all of the available space inside the glass jar.

FIGURE 6.5 Iodine diffusing in a fume cupboard

Resources

Video eLesson Diffusion (eles-2035)

elog-0083

INVESTIGATION 6.2

Ranking substances

It is useful to refer to properties of substances to decide if substances are solids, liquids or gases. Examples of properties include appearance, colour, shape, how they feel or smell, if they are heavy, if they can be poured, melting point and boiling point.

Aim

To determine whether materials are solids, liquids or gases based on their properties

Materials

- a brick
- Vegemite®
- playdough
- green slime
- orange cordial
- tomato sauce
- salt
- sugar
- steam
- air

Green slime — is it solid or liquid? How do you know?

Method

1. Prepare a table as shown in the results section of this investigation to fit all of the materials.
2. Working in small groups, make accurate and detailed observations of the properties of each of the materials and record them in the results table.

Results

TABLE Results of investigation 6.2

Substance	Properties	Solid, liquid or gas
Brick	Hard Feels rough Heavy Cannot be poured	
Playdough		

Discussion

1. Based on your observations decide whether to classify each material as solid, liquid or gas.
2. Rank the following substances in order from most solid-like to most liquid-like to most gas-like.
3. Compare your rankings with those of other groups. Comment on any differences between the rankings.
4. Which properties were most useful in classifying the materials?
5. Suggest further investigations that might assist you in relating properties to different states of matter.

Conclusion

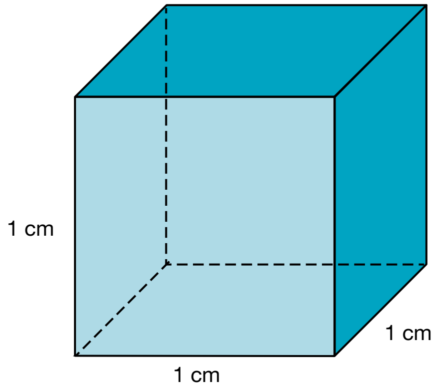
Which substances were most difficult to classify as solid, liquid or gas? Explain why they were difficult to classify.

6.2.2 Measuring matter

The amount of matter in a substance, whether solid, liquid or gas, is called mass. The most commonly used unit of mass is the kilogram (kg), which is equal to 1000 grams (g). Mass is measured with an electronic scale or beam balance.

The amount of space taken up by a substance is called its **volume**. The volume of solids is usually measured in cubic metres (m^3) or cubic centimetres (cm^3). The volume of fluids is measured in millilitres (mL). One millilitre occupies the same volume as 1 cm^3. A **fluid** is a substance that can flow. All liquids and gases are fluids.

FIGURE 6.6 This cube has a volume of 1 cm^3 and can hold 1 mL of a fluid.



$$1 \text{ mL} = 1 \text{ cm}^3$$
$$1 \text{ L} = 1000 \text{ cm}^3$$
$$1000 \text{ L} = 1 \text{ m}^3$$

volume the amount of space taken up by an object or substance

fluid a substance that flows and has no fixed shape. Gases and liquids are fluids.

on Resources

Interactivity Volume (int-3791)

elog-0084

INVESTIGATION 6.3

Measuring the volume of an irregular-shaped solid

Aim

To measure the volume of an irregular-shaped solid

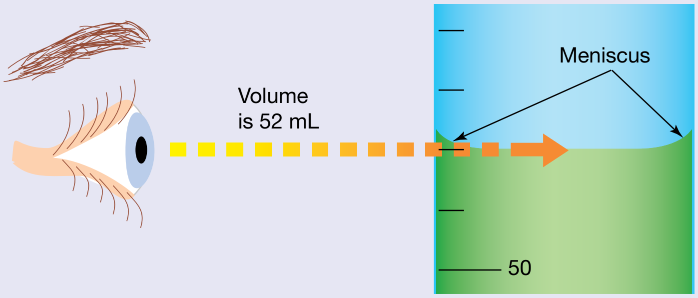
Materials

- 100 mL beaker
- 100 mL measuring cylinder
- stone or pebble that will fit into the measuring cylinder

Method

1. Half fill (approximately) a 100 mL beaker with water.
2. Carefully pour the water into the measuring cylinder and accurately record the volume.
3. Carefully place the pebble into the measuring cylinder. Take care not to spill any water and accurately record the new volume.

The curved upper surface of the liquid is called the meniscus. When you are reading the volume of a liquid in a measuring cylinder, your eye should be level with the flat part in the centre of the meniscus.



Results

1. Accurately record the volume of water in the measuring cylinder using the technique shown in figure 6.8. Do not forget to include units.
2. Accurately record the new volume once the pebble has been added.

Discussion

1. What was the volume of the solid in mL?
2. What was the volume of the solid in cm^3?
3. Suggest another way of measuring the volume of the solid object.
4. Which is the more accurate piece of equipment for measuring volume: a 100 mL beaker or a 100 mL measuring cylinder? Explain why.

Conclusion

State the volume of the pebble including units.

on Resources

assesson Additional automatically marked question sets

6.2 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3, 6, 11	Questions 4, 7, 8, 9, 13, 14	Questions 5, 10, 12, 15

Remember and understand

1. **MC** Identify the term for anything that has mass and takes up space.
   A. Solid **B.** Liquid **C.** Gas **D.** Matter
2. **MC** Identify the state that cannot flow.
   A. Solid **B.** Liquid **C.** Gas **D.** Matter
3. List as many solids, liquids and gases that you can remember coming into contact with before leaving for school today. Organise them into a table under three headings: Solids, Liquids and Gases, or into a cluster, mind or concept map. You can list items between columns if they displayed properties of both states.

Solids	Liquids	Gases

4. **a.** Recall and write down three properties that most solids have in common.
   b. Would liquids have the same three properties? If not, what differences might be expected?
5. **a.** What is the unit used to measure small volumes, such as for liquid medicines?
   b. How could you measure such a volume?

Apply and analyse

6. Recall and write down which properties of gases are different from those of liquids.
7. Both steel and chalk are solids. What properties of steel make it more useful than chalk for building bridges?
8. Are plasticine and playdough solids or liquids? Explain.
9. What is diffusion? Give two examples of this occurring around your house.
10. Is it possible for a solid to behave like a fluid? Explain your answer.

Evaluate and create

11. At the petrol station, the safety sign asks for the car engine to be switched off before you fill the petrol tank. Use your knowledge of diffusion to explain why this is necessary.
12. **SIS** There is a fourth state of matter known as plasma, which is not very common on Earth. Research and report on:
    a. how plasma is different from solids, liquids and gases
    b. where plasma can be found
    c. how plasma can be used on Earth.
13. **SIS** Different liquids pour or flow in different ways. Test this by pouring honey, shampoo, cooking oil and water from one container to another. Write your hypothesis first and make sure it is a fair test by considering the variables. Record the time each liquid takes to pour. Record the results in a table and write a conclusion based on your observations and results.
14. Make up a short poem about the properties of solids, liquids and gases.
15. **SIS** Olivia says that when a candle burns it is a solid that burns, Henry says that it is a liquid that burns and Zahra says that it is a gas. Write a hypothesis about what you think is occurring and then observe a candle burning (you could do it yourself or watch it on Youtube). Decide who is correct and write a summary of your findings.

Fully worked solutions and sample responses are available in your digital formats.

6.3 Changing states

LEARNING INTENTION

At the end of this subtopic you will be able to describe the relationship between change of state and temperature. You will also be able to explain the difference between boiling and evaporation.

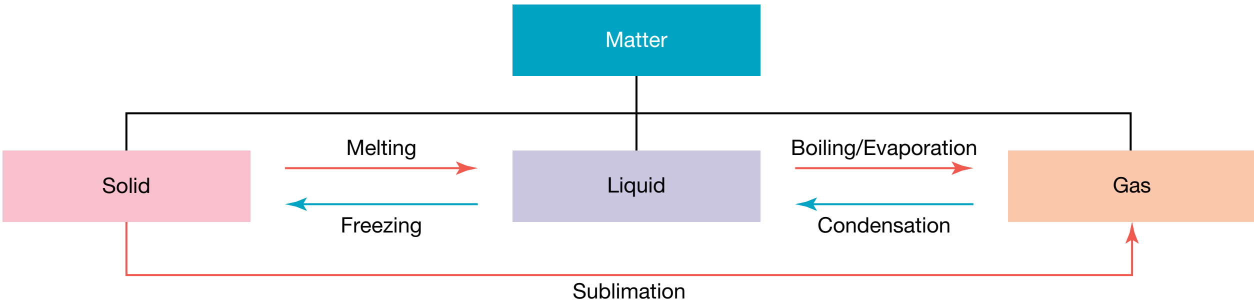
6.3.1 Changing states

Water is the only substance on Earth that exists naturally in three different states at normal temperatures. It is in the oceans, in the polar ice and in the air as water vapour. Water is constantly moving and changing states. You can observe water changing states in the kitchen.

To change the state of any substance, including water, it must be heated or cooled, or the pressure changed.

FIGURE 6.7 Unfortunately, the ice sculpture in this photograph won't last for very long. Even as the sculptor works, it is melting as heat moves into it from the warmer air around it.

FIGURE 6.8 The processes involved in changing states



Melting point and boiling point

The **state of matter** of any substance depends on **pressure** and its **temperature**. The temperature at which a substance changes from a solid into a liquid (melts) is called its **melting point**. A liquid changes into a solid (freezes) at the same temperature. Water has a melting point of 0 °C, so to melt ice it has to be heated to a temperature of 0 °C. To freeze water it has to be cooled to a temperature of 0 °C.

Melting and boiling points change with the height above sea level. This is because the air gets thinner and the air pressure gets lower as you move away from the Earth's surface. If you were climbing Mount Everest and made a cup of coffee near its peak, you would find that the water boiled at about 70 °C instead of 100 °C.

state of matter condition or phase of a substance. The three main states of matter are solid, liquid and gas.

pressure the force exerted per unit area

temperature a measure of how hot or cold something is

melting point the temperature at which a solid substance turns into a liquid (melts) or a liquid turns into a solid (freezes)

The **boiling point** is the temperature at which a substance boils. At this temperature, the substance changes from liquid into gas (**evaporates**) quickly. At the same temperature, a gas changes into a liquid (**condenses**). The boiling point of water is 100 °C. The melting and boiling points of some common substances are shown in table 6.1.

TABLE 6.1 Melting and boiling points of some common substances at sea level

Substance	Melting point (°C)	Boiling point (°C)
Water	0	100
Table salt	804	1413
Iron	1535	2750
Aluminium	660	1800
Oxygen	–218	–183
Nitrogen	–210	–196

Sublimation

At a concert or special event, you may have seen a thick 'smoke' used for effect. This smoke is produced when solid carbon dioxide, called 'dry ice', changes state from a solid directly to a gas. This very unusual change of state is called **sublimation**. The 'smoke' is actually tiny droplets of water that condense from the air as the cold dry ice sublimes. Dry ice sublimes at a temperature of –78.5 °C. Iodine also sublimes. Diamonds sublime at a temperature of 3550 °C.

FIGURE 6.9 Smoke effects are produced when solid 'dry ice' changes state from a solid directly to a gas.

boiling point the temperature at which a liquid changes to a gas

evaporation changes state from a liquid to a gas. Evaporation occurs only from the surface of a liquid.

condensation the change of state by which a gas changes into a liquid

sublimation the change in state from a solid into a gas without first becoming a liquid

on Resources

Video eLessons Gold melting (eles-2075)
Sublimation (eles-2038)

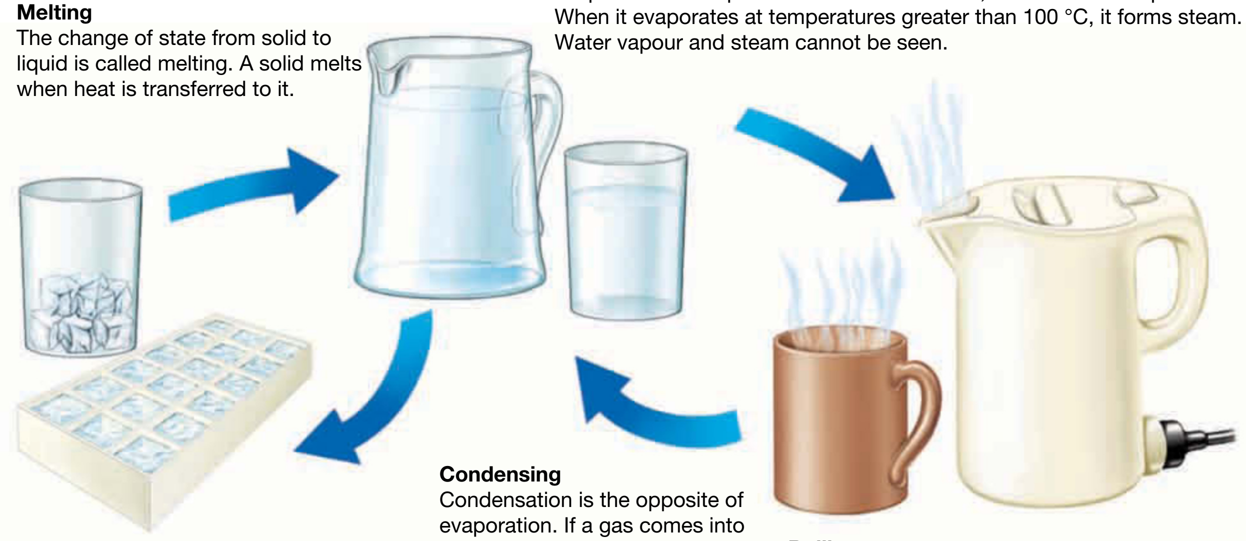
DISCUSSION

When butter is melted in a frying pan before putting the food in to fry, why doesn't the frying pan melt as well?

ewbk-2978

int-7684

FIGURE 6.10 The changing states of water in the kitchen



The state of an object depends on its temperature and the pressure surrounding the object.

on Resources

eWorkbook Changing the boiling point of water (ewbk-2979)

assess on Additional automatically marked question sets

6.3 Exercise

learn on

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

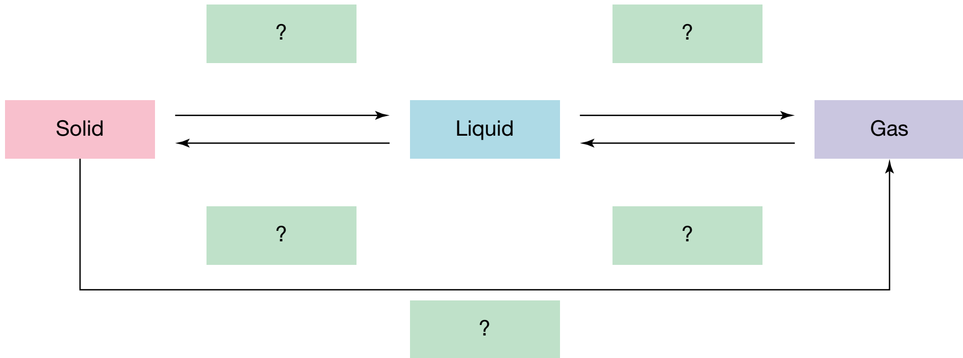
Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 6	Questions 3, 4, 8	Questions 5, 7, 9

Remember and understand

1. Complete the diagram shown, by labelling the changes of state.

Change of state



2. State the name given to the change of state from liquid water to steam. What happens to make this occur?
3. Describe what happens to liquid water when it is cooled below 0 °C? Has heat moved into or out of the liquid?
4. **MC** At higher altitudes, water boils at a temperature less than 100 °C because:
   A. temperature of higher altitudes is low.
   B. atmospheric pressure is low.
   C. temperature of higher altitudes is higher.
   D. atmospheric pressure is high.
5. When water evaporates it can change state from a liquid to a gas in the form of either steam or water vapour. Explain the difference between steam and water vapour.

Apply and analyse

6. Why is dry ice useful to produce a 'smoke' effect? Name another use for dry ice.
7. Explain the difference between evaporation and boiling.

Evaluate and create

8. **SIS** Examine the data recorded in the table.

TABLE Melting and boiling points of some common substances at sea level

Substance	Melting point (°C)	Boiling point (°C)
Water	0	100
Table salt	804	1413
Iron	1535	2750
Aluminium	660	1800
Oxygen	–218	–183
Nitrogen	–210	–196

   a. At what temperature would you expect table salt to melt? At what temperature would it freeze?
   b. Would you expect aluminium to be found as a solid, liquid or gas at:
      i. 200 °C **ii.** 680 °C **iii.** 1900 °C?
   c. Which substance — oxygen or nitrogen — would freeze first if the temperature were gradually lowered?
9. **SIS** Dry the outside of a very cold can of soft drink or carton of milk and allow it to stand on a table or bench for about ten minutes. (Don't forget to put it back in the fridge afterwards.)
   a. What change occurred on the outside of the can?
   b. Where did the water come from?
   c. What change of state has occurred?

Fully worked solutions and sample responses are available in your digital formats.

6.4 The state of the weather

LEARNING INTENTION

At the end of this subtopic you will be able to describe the differences between different forms of precipitation such as rain, hail, snow and sleet. You will also be able to recognise how scientists predict the weather.

6.4.1 Water and the weather

Rain, hail, snow and sleet are all types of **precipitation**. Precipitation is falling water, whether in solid or liquid form. All precipitation occurs because energy from the Sun melts ice and causes liquid water to evaporate to become water vapour in the atmosphere. When the temperature in the atmosphere gets low enough, the water vapour condenses or freezes. That's when we get rain, hail, snow or sleet.

The type of precipitation we get depends mostly on the temperature in the clouds and the air around them. It also depends on the amount of water vapour in the air and the air pressure.

precipitation falling water in solid or liquid form. The type of precipitation depends mostly on the temperature in the clouds and the air around them.

Rain

Rain forms when water vapour condenses in cold air, forming tiny droplets of water. These droplets are so small that they are kept up by moving air, forming clouds.

As the droplets join together they become too heavy to remain in the air. They fall to the ground as rain. When air currents are low, very tiny drops of rain may fall as a fine mist known as drizzle.

FIGURE 6.11 Clouds are formed by tiny droplets of water, kept up by air currents.

Hail

If drops of rain freeze, they may form hailstones. Air currents within clouds move raindrops from the bottom of the cloud upwards to the top of the cloud. The top of the cloud is much colder than the bottom and the rising raindrops freeze very quickly. The frozen raindrops fall back towards the bottom of the cloud. If the air currents are strong enough, the frozen raindrops rise again, adding a new layer of ice. They fall again, then rise again to form another layer of ice. This can happen over and over again, each time adding a new layer of ice. When the ice has built up many layers, it gets heavy enough to fall to the ground as a hailstone. Hailstones can be extremely large and cause extensive damage.

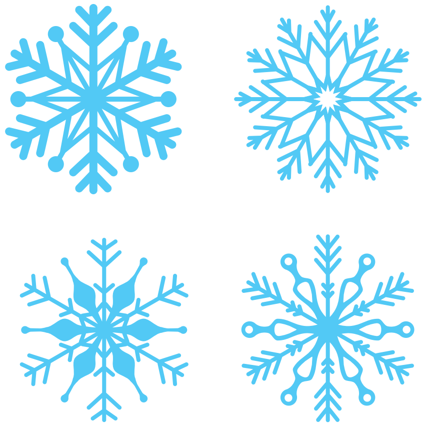
FIGURE 6.12 In summer, warm rising air helps to keep the hailstones in the clouds for longer, forming even more layers of ice than usual. These hailstones can reach masses of over one kilogram before they fall.

Snow

Snow consists of crystals of ice that have frozen slowly in clouds. Many different shapes and patterns can be found in snowflakes. The shape and size depend on how cold the cloud is, its height and the amount of water vapour it holds. Crystals of ice form when clouds have temperatures below –20 °C. The crystals join together and fall. As they fall, they become wet with moisture but then refreeze as snowflakes.

If the air between the cloud and the ground is colder than 0 °C, the snowflakes fall as very powdery, dry snow. If the air is warmer, the ice crystals melt and fall as rain or sleet.

FIGURE 6.13 Snowflakes form many different shapes and patterns but always have six ‘sides’.



Sleet

Sleet is snow that is melting or raindrops that are not completely frozen. Sleet forms when the air between the clouds and the ground is warm enough to melt ice.

6.4.2 Predicting the weather

SCIENCE AS A HUMAN ENDEAVOUR: Studying the weather

The scientists who predict, or forecast, the weather are **meteorologists**. Meteorology is the study of the atmosphere and includes the observation, explanation and prediction of weather and climate. Numerous observations of temperature, precipitation, wind speed, air pressure, humidity and more are needed to make weather forecasts. Humidity is a measure of the amount of water vapour in the air.

FIGURE 6.14 A meteorologist releases a weather balloon in Antarctica

Before the first weather balloon was launched in 1882, observations with instruments such as thermometers, barometers and rain gauges could be made only on land or ships. Not long after the invention of the first ‘flying machine’ in 1903, weather instruments were attached to the wings of planes, allowing them to be taken higher in the atmosphere.

As new technology becomes available, the number and quality of observations improve. Improved weather balloons, together with radar, satellite images and computer modelling, allow meteorologists to make predictions further ahead and more accurately than ever before.

DISCUSSION

Why is it that in social situations people so frequently discuss the weather?

meteorologist a scientist who uses observations of the atmosphere to predict or explain the weather

on Resources

Video eLesson Understanding a weather forecast (eles-0161)

assess on Additional automatically marked question sets

6.4 Exercise

learnON

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Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3, 4, 7, 10	Questions 5, 8, 11, 12	Questions 6, 9, 13, 14

Remember and understand

1. What are clouds made of?
2. Recall and describe what meteorology is concerned with.
3. What is humidity a measure of?
4. Using words and a labelled diagram, explain how hailstones are formed.
5. How can hailstones get as large as the one in figure 6.12 (the photograph in section 6.4.1)?
6. Suggest why extra-large hailstones are more common in summer than in winter.

Apply and analyse

7. Explain the difference between snow and sleet.
8. Make a list of leisure activities that rely on predictions about the weather.
9. Ski resort operators suffer when there is a shortage of snow in some years. What conditions would they look for to predict coming snowfall?

Evaluate and create

10. In which occupations do each of the following types of weather prevent activity?
    a. Extreme heat
    b. Heavy rain
    c. Thunderstorms
11. **SIS** Record the predictions of the maximum temperature of your nearest capital city made in a 7-day forecast. For each day of the 7-day period, also record the maximum temperature predicted on the day before. These forecasts can be found online on the Bureau of Meteorology website (www.bom.gov.au), on the TV news or in daily newspapers.

    Then record the actual maximum temperature for each day as reported on the evening news or www.bom.gov.au. Use a table like the one provided to record your data.

    TABLE Daily maximum temperatures (°C)

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Prediction in 7-day forecast							
Forecast the day before							
Actual maximum temperature							

    a. How does the accuracy of the 7-day forecast compare with the accuracy of the previous day's forecast?
    b. State your opinion about the accuracy of the forecast made on the day before.
    c. Apart from temperature, what other aspects of the weather forecast are reported in newspapers and on the TV news?

d. Graphs make it easier to read and interpret information, find trends and draw conclusions. Examine the data in the table, and reference subtopic 1.10. Decide which type of graph would best suit this data. Then construct a graph representing the different temperatures over the week, ensuring you use a different colour for the three temperature measurements.

12. SIS Find out what relative humidity is, and with which instrument it is measured.

13. SIS Research and report on what a hydrologist does.

14. SIS Find out and describe the difference between weather and climate.

Fully worked solutions and sample responses are available in your digital formats.

6.5 The particle model

LEARNING INTENTION

At the end of this subtopic you will be able to describe the particle model and explain the properties of the three states of matter using this model.

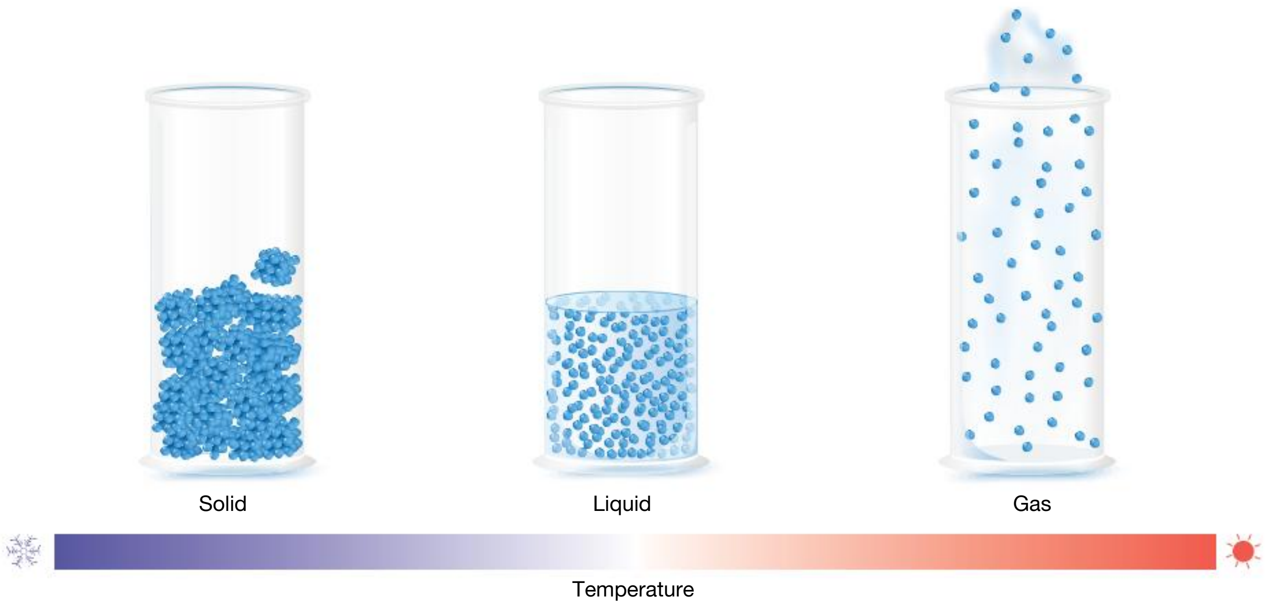
6.5.1 The particle model

How do you explain why ice has properties that are different from those of water or steam? Scientists use a model to explain the different properties of solids, liquids and gases. A model is a way of representing something that is like the object or idea but not exactly the same as the object or idea. This model is called the **particle model**.

particle model a description of the moving particles that make up all matter and how they behave. The model explains the properties of solids, liquids and gases.

According to the particle model:
- all substances are made up of tiny particles
- the particles in liquids and solids are attracted towards other surrounding particles
- the particles are always moving
- the hotter the substance is, the faster the particles move.

FIGURE 6.15 A particle model for different states — solid, liquid and gas



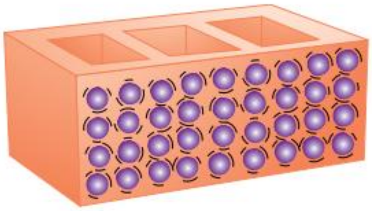
WHAT DOES IT MEAN?

The word particle comes from the Latin word *particula*, meaning ‘part’.

6.5.2 Particles in a solid

In solids the particles are very close together, so they cannot be compressed. The attraction between neighbouring particles in a solid is usually strong. Because there are such strong bonds between the particles, solids usually have a fixed shape and a constant volume. The particles in solids cannot move freely; instead they vibrate in a fixed position.

FIGURE 6.16 Particles in a solid



6.5.3 Particles in a liquid

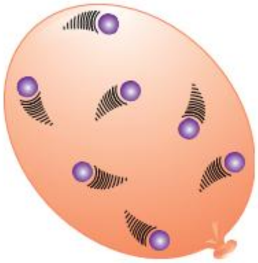
In liquids the particles are held together by attraction, but the bonds between them are not as strong as those in solids. The weak particle attraction allows the particles to roll over each other, but they can’t ‘escape’. For this reason, liquids have a fixed volume but the rolling motion of the particles allows them to take up the shape of their container. As in solids, the particles in liquids are still very close together. Liquids cannot be compressed into smaller spaces.

FIGURE 6.17 Particles in a liquid

6.5.4 Particles in a gas

The particles in a gas have much more energy than those in solids or liquids, and they are in constant motion. The attraction between the particles in a gas is so weak that they are able to move freely in all directions. They spread out to take up any space that is available. This means that gases have no fixed shape or volume. Because of the large spaces between particles, gases can be compressed.

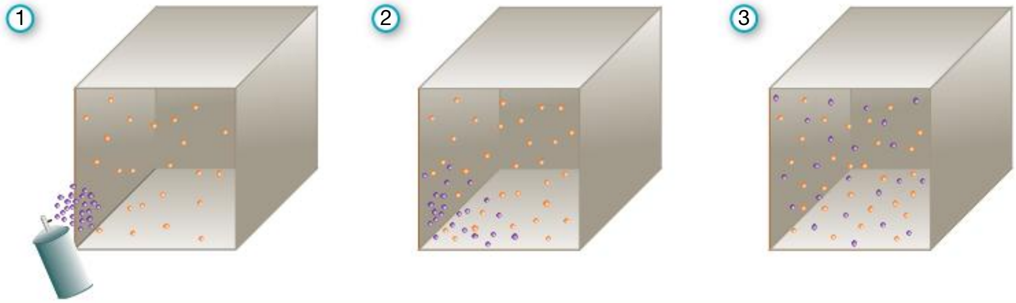
FIGURE 6.18 Particles in a gas



Spreading out

The spreading of one substance through another is called diffusion. This can happen only when the particles of one substance can spread through the particles of another substance. Diffusion is possible in liquids and gases because the particles move around. You would expect diffusion to happen faster in gases than in liquids because the particles move faster. Particles in a solid vibrate in a fixed position, so diffusion can’t occur.

FIGURE 6.19 The particles of two gases spread through each other, over time (from 1 through to 3), until they are evenly mixed.



The particle model and balloons

The particle model can be used to explain what happens to a balloon when you inflate it. Particles of air inside the balloon constantly move in all directions. They collide with each other and with the inside wall of the balloon. But the wall is not rigid. It can stretch as more particles are added. The balloon **expands** until it can't stretch any more. When you let some of the air out of the balloon, fewer particles collide with the inside wall of the balloon. It gets smaller or **contracts**.

elog-0085

INVESTIGATION 6.4

Investigating diffusion

Aim

To compare diffusion of liquids and gases

Materials

- 250 mL beaker
- food colouring
- fragrant spray
- water
- eye-dropper

Method

1. Your teacher will release some fragrant spray in one corner of the classroom. Put your hand up when you can notice the smell. Record the time it takes for the smell to get to the students at the back of the room.
2. Place a drop of food colouring into a beaker of water and record your observations for several minutes, making sure the beaker is not moved.

Results

1. Using the recorded times, describe how the fragrant spray travelled across the classroom.
2. Draw a diagram to show the movement of the food colouring through the water.

Discussion

1. What is diffusion?
2. Describe how the fragrant spray moved through the air using the particle model.
3. This investigation shows diffusion in a liquid (water) and in a gas (air).
   a. In which state does diffusion occur faster? Explain why this occurs.
   b. Is it a fair test to compare the two observations? Explain.
   c. How could you make dispersion in water occur faster? Describe an investigation that you could do to test this.
   d. Explain whether you think diffusion occurs in solids.

Conclusion

Describe how diffusion happens in gases and liquids.

6.5.5 Gases under pressure

The fire extinguishers used to put out electrical fires are filled with carbon dioxide gas. Carbon dioxide can be used in this way only because huge amounts of it can be compressed, or squeezed, into a container. Gases can be compressed because there is a lot of space between the particles. Gases compressed into cylinders are used for barbecues, scuba diving, natural gas in cars and aerosol cans.

expand increase in size due to particles moving apart

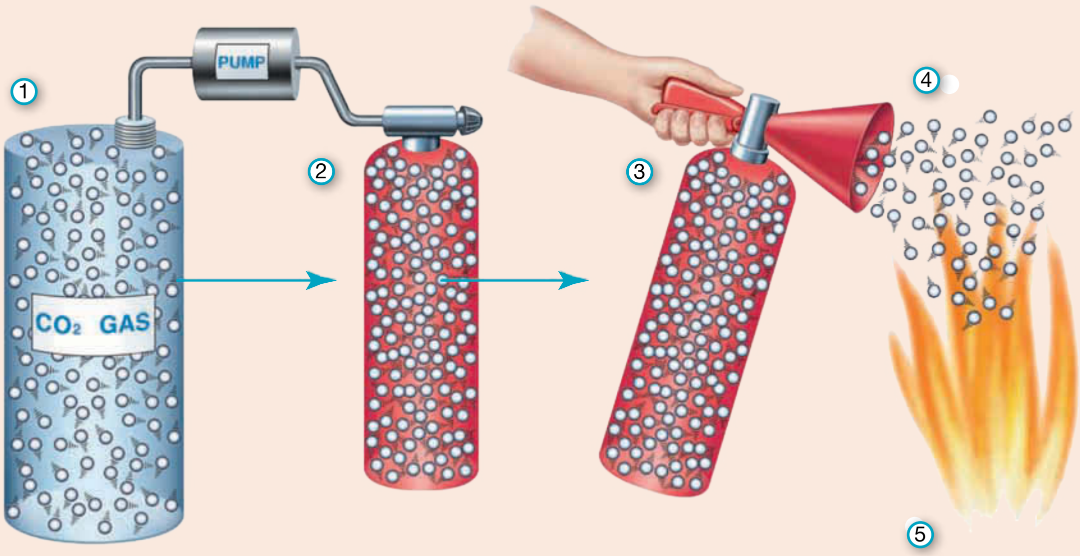
contract shorten or become smaller in size

CASE STUDY: How fire extinguishers use compressed gas

1. Gases, including carbon dioxide, have lots of space between their particles.
2. Carbon dioxide is compressed into a cylinder. The particles are squashed closer together.
3. The carbon dioxide particles are now under increased pressure. This means that the particles in the gas collide frequently with the walls of the cylinder and push outwards. The particles are trying to escape, but are held in by the container.
4. When the nozzle is opened, the pressure forces the carbon dioxide gas out very quickly through the opening.
5. The particles of gas quickly spread out over the fire. The gas smothers the fire, stopping oxygen from the air getting to it. Fires cannot burn without oxygen, so the fire goes out.

FIGURE 6.20 Carbon dioxide gas under pressure is used to extinguish fires.

int-5334



DISCUSSION

1. How is the particle model different from real particles of solids, liquids and gases?
2. **a.** Explain why this statement is incorrect: 'The particles of a liquid expand when heated'.
   b. Write the statement correctly.

on Resources

Video eLesson Under pressure (eles-0058)

eWorkbooks Fire! Fire! (ewbk-2980)
Particles in our lives (ewbk-2982)

assess on Additional automatically marked question sets

6.5 Exercise

learnon

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Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3, 6, 7	Questions 4, 8, 10	Questions 5, 9, 11, 12

Remember and understand

1. List the states of matter in order from the one with the smallest space between the particles to the one with the most space between the molecules particles.
2. What is diffusion? Explain which states of matter can diffuse.
3. SIS Explain why a model is needed to explain the properties and behaviour of different states of matter.
4. List the four main ideas of the particle model.
5. Use the particle model to explain why gases are compressible.

Apply and analyse

6. Describe an everyday example of diffusion.
7. Compare the motion of particles in a liquid with the motion in a gas. Include a diagram.
8. What happens to the particles in carbon dioxide gas when they are compressed into a fire extinguisher?
9. Use the particle model to explain what keeps car or bicycle tyres in the right shape when they are pumped up to a high air pressure.

Evaluate and create

10. Use the particle model to explain why:
    a. perfume can be smelled from a few metres away
    b. steam can be compressed, but ice cannot
    c. water vapour takes up more space than the same amount of liquid
    d. solids do not mix well, but gases and liquids mix easily in most cases.
11. a. Draw labelled diagrams of three containers with solid particles in the first, liquid in the second and gas in the third.
    b. How does this model of particles compare with the particles in an actual container?
12. Use the internet to investigate the safe storage of gas cylinders. Make a list of requirements and state the reason for each of them.

Fully worked solutions and sample responses are available in your digital formats.

6.6 Energy matters

LEARNING INTENTION

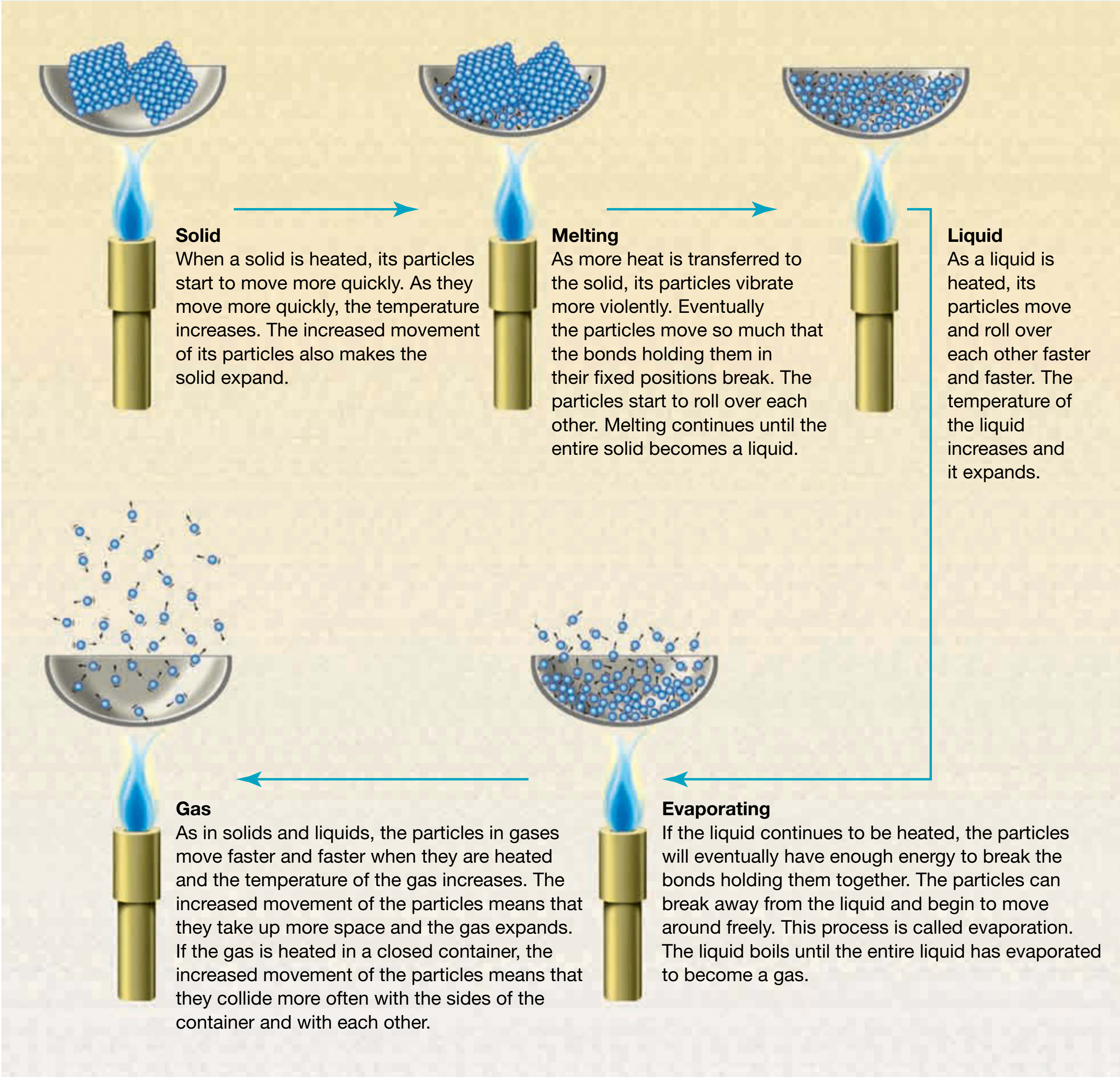
At the end of this subtopic you will be able to describe the effect of heating or cooling on particles of a substance. You will also be able to provide examples of heating and cooling.

6.6.1 Energy in and energy out

A change of state involves the heating or cooling of matter. As a substance is heated, energy is transferred to it. When a substance cools, energy moves away from it to another substance or to the environment. The change in energy causes the particles in the substance to move at different speeds.

An increase in the energy of the particles of a substance results in an increase in the temperature of the substance. A decrease in the energy of particles results in a decrease in the temperature of the substance.

FIGURE 6.21 This flowchart shows what happens to the particles that make up a substance when it changes from a solid state into a gas state. When a gas is cooled, the direction of the flowchart can be reversed as the substance changes from a gas state into a solid state.



elog-0086

INVESTIGATION 6.5

Explaining gases

Aim

To observe and explain the expansion and contraction of a gas

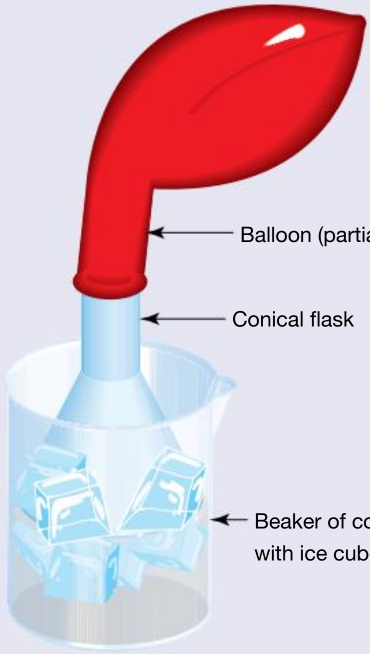
Materials

- balloon
- ruler

- 2 large beakers
- hot and cold water
- piece of string
- small conical flask
- ice cubes

Method

1. Ensure you have a copy of the results table to fill in for this task.
2. Inflate the balloon to its maximum size. Then deflate it. This makes it easier to stretch.
   - Inflate the balloon again, to a size slightly larger than an orange. Fit the neck of the balloon over the conical flask to seal it.
   - Wrap the string once around the widest part of the balloon to find its circumference. With a ruler, measure the length of the string that encircled the balloon.
   - Record your measurement in your table.
3. Half fill one of the beakers with ice cubes and a small amount of cold water.
   - Place the conical flask in the ice-water beaker and observe the balloon. After a few minutes, use the string to measure the circumference of the balloon again.
   - Record your measurement in your table.
4. Put some hot water into the second beaker. Take the conical flask from the ice-water and place it into the hot water.
   - Leave for a few minutes, then measure and record the balloon's circumference.



Results

TABLE Effect of temperature on air

Temperature of surroundings	Circumference of balloon (cm)
Room temperature	
Cold (ice water)	
Hot (hot water)	

Discussion

1. Was any air added to or removed from the balloon after it was placed over the conical flask?
2. After being in ice-water and hot water, were there any changes in the size of the balloon?
3. Using the particle model, try to explain what might have made the balloon contract and expand.
4. Identify which quantity was varied or changed in this experiment? What things were kept the same?
5. Describe what happens to the air in the balloon when it gets cold.

Conclusion

Describe what you observed. Provide an explanation for your results.

6.6.2 Examples of heating and cooling

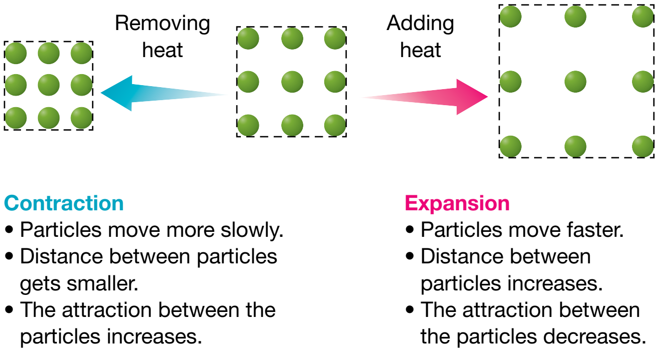
When a substance is heated, the particles gain energy, move faster, become further apart and take up more space, and a substance expands as the temperature increases.

The tyres on a moving car get quite hot. This makes the air inside expand and may even cause a blowout in extreme circumstances. Heating usually causes gases to expand much more than solids or liquids. Gases expand easily because the particles are spread out and not attracted to each other strongly. Solids, liquids and gases contract when they are cooled because the particles lose energy, slow down, need less space to move in and become more strongly attracted to each other.

Hot air balloons rise when the air inside them expands. The particles in the heated air move faster and take up more space. This makes each cubic centimetre of air inside the balloon lighter than each cubic centimetre of air outside the balloon, so the air inside the balloon rises, taking the balloon with it.

FIGURE 6.22 These hot air balloons rise when the air inside them expands. How do they get back down to the ground?

FIGURE 6.23 The volume of a substance changes when it is heated or cooled.



on Resources

Interactivity Heating and cooling (int-3413)

Architects and engineers allow for expansion and contraction of materials when designing bridges and buildings. Bridges have gaps at each end of large sections so that in hot weather, when the metal and concrete expand, they will not buckle. Railway lines also have gaps to allow for expansion. Electrical wires are hung from poles loosely so that when the weather cools, they will not become too tight and break as they contract. The amount by which a structure will expand or contract depends on the material it is made from; so when choosing a material, it is important to find out how much that material will expand or contract. The table *Expansion of materials* in 6.6 Exercise, question 9 shows how much some commonly used materials expand when the temperature increases by 10 °C.

An exception to the model

According to the particle model, the spaces between the particles in a liquid get smaller as the liquid is cooled, and the particles are closest once the liquid has become a solid. However, water is one of the few substances that does not behave exactly as the particle model predicts.

FIGURE 6.24 Oops! The reason why you shouldn't put a bottle full of water in the freezer

While the temperature of water is cooled from 100 °C to 4 °C, the particles behave as expected, with the spaces between them growing smaller. As water temperature drops below 4 °C; however, something strange happens — the spaces between the particles start to get larger again. By the time water freezes at 0 °C, the particles are further apart than they were at 4 °C! In general, the volume taken up by water particles increases by nearly 10 per cent when it becomes ice; you may have noticed this if you have ever put a full bottle of water in the freezer.

elog-0087

INVESTIGATION 6.6

Expansion of solids

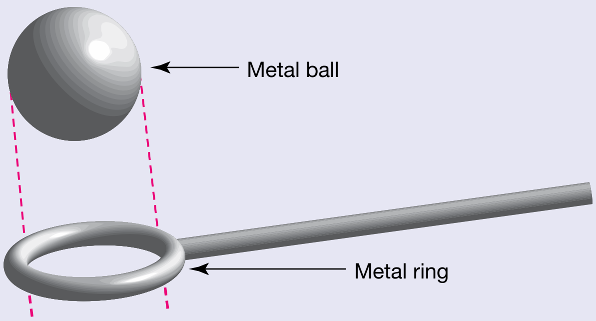
Aim

To observe and explain the expansion of a solid

Materials

- metal ball and ring set
- Bunsen burner and heatproof mat
- tongs

A ball and ring set



Method

1. Try to put the ball through the ring. Record your observations.
2. Use the Bunsen burner to heat the ring and use tongs to try to put the ball through it. Take care not to touch the hot metal.
3. Let the ring cool and try to put the ball through the ring again.

Results

Record your observations of the ball and ring before heating and after heating.

Discussion

1. Describe what happened to change the size of the ring.
2. Use the particle model to explain the change that took place in the ring.

Conclusion

Describe what happened when you heated the ring. Provide an explanation for your observations.

6.6.3 Thermometers

Bulb thermometers, like the one pictured in figure 6.27, use the expansion of liquids when they are heated to measure temperature. Most bulb thermometers consist of thin tubes and a bulb that contains a liquid. As the temperature rises, the liquid expands, moving up the tube, which is sealed at the top.

The two most commonly used liquids in thermometers are mercury and alcohol. Mercury has a low **freezing** point (–39 °C) and a high boiling point (357 °C). Alcohol, however, is much more useful in very cold conditions because it does not freeze until the temperature drops to –117 °C. On the other hand, alcohol boils at 79 °C, so it cannot be used for measuring higher temperatures.

The temperature of the human body ranges between 34 °C and 42 °C; it is normally about 37 °C. A clinical thermometer is designed to measure this range.

Look at the clinical thermometer in figure 6.25. The tube narrows near the bulb. Once the mercury has expanded, this narrowing prevents the mercury contracting and moving back into the bulb before the temperature can be read. Once a reading has been taken, the mercury has to be shaken back into the bulb before the thermometer can be reused.

freezing the change of state by which a liquid changes to a solid

FIGURE 6.25 a. A clinical thermometer and b. a digital thermometer. Digital thermometers are easier to read than bulb thermometers.

a.

b.

Bulb thermometers are gradually being replaced by digital thermometers, which don't rely on expansion and contraction of mercury or any other liquid. Digital thermometers contain a thermostat, which is a sealed solid, embedded inside. The thermostat's resistance to electric current depends on temperature. A tiny computer measures the thermostat's resistance and calculates the temperature, which is displayed on a small screen (making them easier to read).

elog-0088

INVESTIGATION 6.7

Expansion of liquids

Aim

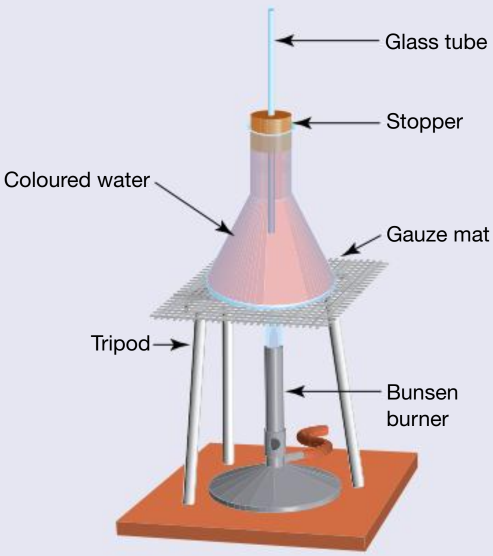
To observe and explain the expansion of a liquid

Materials

- 500 mL conical flask
- tripod and gauze mat
- eye-dropper
- narrow glass tube
- food colouring
- marking pen
- rubber stopper with one hole to fit the tube
- Bunsen burner, heatproof mat and matches

Method

1. Use an eye-dropper to place two or three drops of food colouring in the flask, then fill it with water right to the top.
2. Place the stopper in the flask with the glass tube fitted. Some coloured water should rise into the tube. Mark the level of the liquid in the tube with the marking pen.
3. Place the flask on the tripod and gauze mat, light the Bunsen burner and gently heat the liquid.
4. After about five minutes of heating, turn off the Bunsen burner and watch what happens to the liquid level in the tube. Measure and record the change in height.



Results

TABLE Results of investigation 6.7	
Change in height of water level when heated from initial height (cm)	
Change in height of water level after cooling (cm)	

Discussion

1. Describe what happened to the level of the liquid while it was being heated.
2. Describe what happened to the level of the liquid while it was cooling down.
3. Use the particle model to explain your responses to questions 1 and 2.

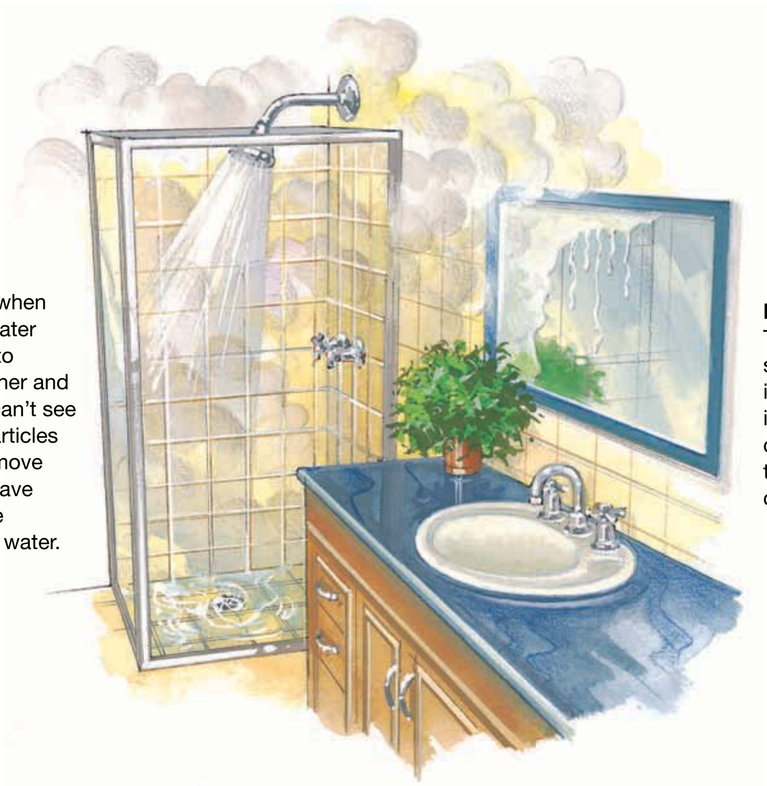
Conclusion

Describe what you observed when the liquid was heated.

6.6.4 Foggy mirrors

Have you noticed how the mirror in the bathroom 'fogs up' after a hot shower? The 'fog' is actually formed by invisible water vapour in the air cooling down when it contacts the cold glass. It condenses to become water.

FIGURE 6.26 Different states of water found in your bathroom



DISCUSSION

In movies, you sometimes see a mirror being held up to the mouth and nose of someone who is unconscious to check whether they are breathing. Explain why this would work.

on Resources

Interactivity Changes of state (int-0222)

eWorkbooks Changes of state (ewbk-2983)
Expansion of liquids (ewbk-2981)

assesson Additional automatically marked question sets

6.6 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 4, 7, 10	Questions 2, 5, 8, 11, 12, 13, 16	Questions 3, 6, 9, 14, 15, 17, 18

Remember and understand

1. Describe what happens to the movement of particles as a substance changes its state from a gas to a liquid.
2. Describe two changes in the properties of a substance when its particles move faster.
3. When a substance changes state from a solid to a liquid:
   a. describe what happens to the bonds between the particles
   b. explain how the motion of the particles change.
4. Explain why solids generally expand when they are heated.
5. The following statements are incorrect. Rewrite them correctly.
   a. Heating a liquid might make its particles stick closer together.
   b. Solids have a definite shape because their particles are free to move around.
   c. You can compress a gas because its particles are close together.
   d. When you heat a liquid, the particles expand.

6. a. Describe what change you expect to see when hot metal objects are cooling.
   b. Why does this happen? Explain, using the particle model.

Apply and analyse

7. List two examples of structures that contain gaps to prevent them buckling in hot weather.
8. Give one reason overhead electric power lines are not hung tightly.
9. SIS Use the table to answer the following questions.

TABLE Expansion of materials

Substance	Expansion (mm) of 100 m length when temperature increases by 10 °C
Steel	11
Platinum	9
Concrete	11
Glass — soda	9
Glass — Pyrex	3
Lead	29
Tin	21
Aluminium	23

   a. If a steel rod of 10 metres in length was heated so that its temperature rose by 10 °C, how long would the rod become?
   b. Explain why Pyrex, rather than soda glass, is used in cooking glassware such as casserole dishes and saucepans.
   c. Concrete is often reinforced with steel bars or mesh to make it stronger. Why is steel a better choice than another metal, such as aluminium or lead?
10. For each of the following changes of state of a substance, identify whether it involves adding energy to the particles or transferring energy away from the particles.
   a. Melting
   b. Condensation
   c. Boiling
   d. Freezing
   e. Sublimation
   f. Evaporation
11. Construct a flowchart like the one in section 6.6.1 to show how a gas changes state to become a liquid and then a solid. Include the names and descriptions of the two changes of state that take place.
12. Use the particle model to predict what will happen to the length and width of a solid substance if it is heated (without melting).
13. Hot air balloons have a gas heater connected to them.
   a. Describe what happens to the particles inside the balloon when the heater is turned on.
   b. Explain why the balloon rises.

Evaluate and create

14. SIS Suggest why icebergs float in Arctic and Antarctic waters. Do you think much of the iceberg is under the water, or is it mostly above? How could you test your hypothesis? Design a suitable experiment.
15. A jar with the lid jammed on tightly can be hard to open. If hot water is run over the lid, it becomes easier to open. Explain why.
16. The mercury thermometer was invented by a German named Daniel Gabriel Fahrenheit (1686–1736). A different set of markings is used to scale Fahrenheit thermometers. At what temperatures does water boil and freeze on this scale?
17. Under what conditions might you use an alcohol thermometer rather than a mercury thermometer?
18. SIS List the advantages of digital thermometers over mercury bulb thermometers for measuring human body temperature.

Fully worked solutions and sample responses are available in your digital formats.

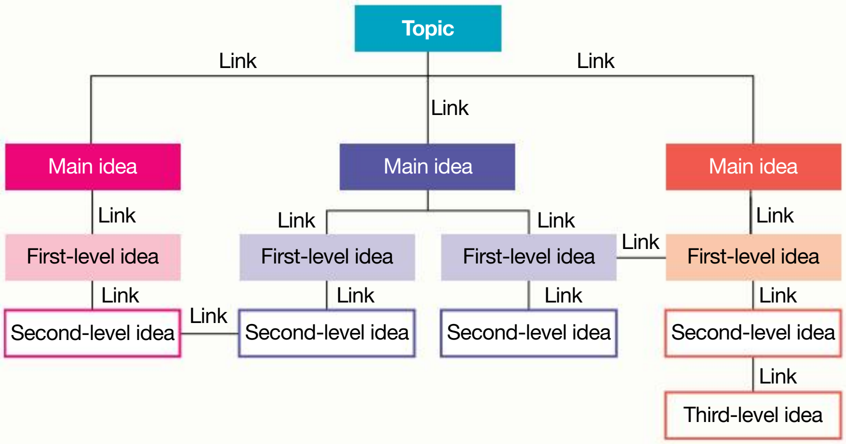
6.7 Thinking tools — Concept maps and mind maps

6.7.1 Tell me

What is a concept map?

A concept map is a useful thinking tool that can assist you to show what you understand about a particular topic. They graphically demonstrate the hierarchical structure of concepts related to a topic, and they also explain the links or relationships between the concepts and subtopics. They are sometimes called a knowledge map or concept web.

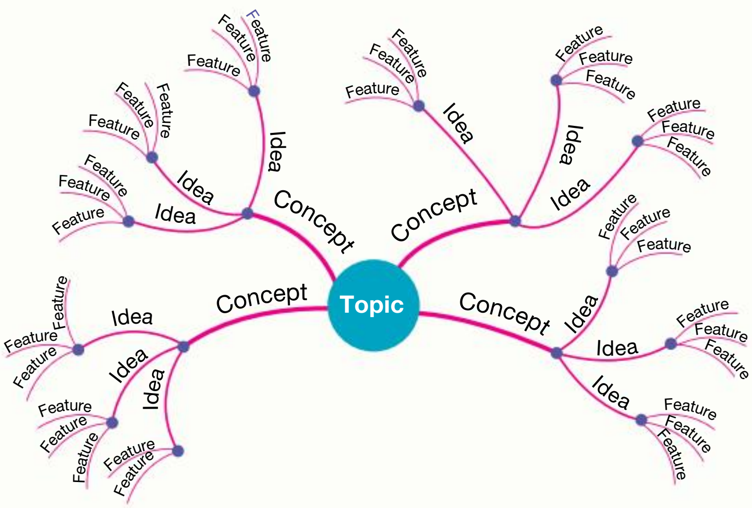
FIGURE 6.27 Concept map



Why use a concept map instead of a mind map?

Concept maps graphically show the structure of a topic in a hierarchical way and can explain the relationship between the parts or elements with statements on the links. Mind maps break down a topic into sections or groups of ideas, all curving out from the central topic in the middle. In a mind map, there are no straight lines, horizontal organisation or ordering like you will see in a concept map.

FIGURE 6.28 Mind map

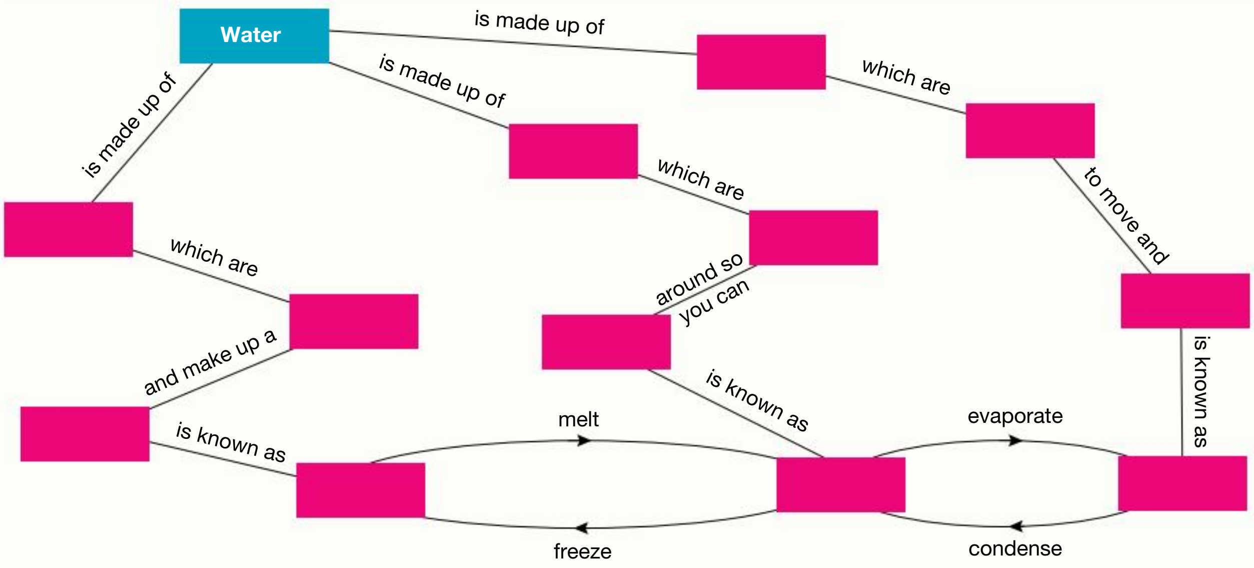


6.7.2 Show me

To create a concept map:

1. On small pieces of paper, write down all the ideas you can think of about a particular topic. You could also use software or an app to create your concept or mind map.
2. Select the most important ideas and arrange them under your topic. Link these main ideas to your topic and write the relationship along the link.
3. Choose ideas related to your main ideas and arrange them in order of importance under your main ideas, adding links and relationships.
4. When you have placed all your ideas, try to find links between the branches and write in the relationships.

FIGURE 6.29 An incomplete concept map about the three states of water



6.7.3 Let me do it

6.7 ACTIVITIES

1. Complete figure 6.29 to represent your knowledge about the three states of water.
2. Create a concept map of your own to represent your knowledge of how water in the atmosphere affects precipitation. Figure 6.30 shows one way of starting your concept map. You'll need to write in suitable link words yourself. (*Hint:* Start by writing down all of the important words or terms related to precipitation that you can think of and use as many of them as you can in your concept map.)
3. A mind map is similar to a concept map, but the topic is placed in the centre instead of at the top. There are no other boxes — just branches on which the keywords and terms are listed. Complete figure 6.31 to represent your knowledge of the states of matter.
4. The states of matter can be represented by a concept map or a mind map. Which map do you find easier to construct? Explain why.

FIGURE 6.30 A concept map of precipitation could begin like this.

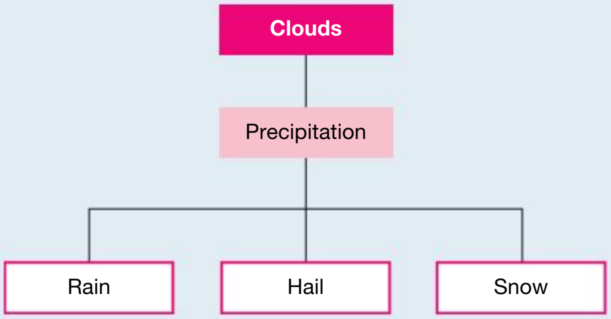
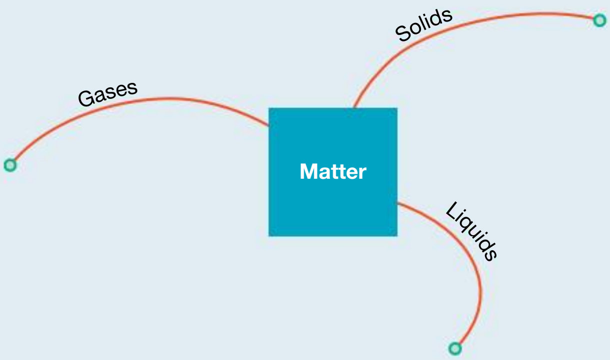


FIGURE 6.31 A mind map begins with the topic in the centre.



Fully worked solutions and sample responses are available in your digital formats.

6.8 Review

Access your topic review eWorkbooks

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-2988	ewbk-2989	ewbk-2990

on Resources

6.8.1 Summary

Matter

- Matter is anything that has mass and volume.
- Matter can be found as solids, liquids or gases.

Solids, liquids and gases

- Physical properties of solids:
  - Fixed volume and shape
  - Not compressible
  - Does not flow easily
- Physical properties of liquids:
  - Takes the shape of the container
  - Not compressible
  - Flows easily
- Physical properties of gases:
  - Fills the container
  - Compressible
  - Flows easily
- A fluid is a substance that flows, for example gases and liquids.
- The volume of a liquid can be measured using a measuring cylinder.
- The volume of an irregular solid can be measured by seeing how much water is displaced by it.
- The mass of an object can be measured using a balance.

Changes of state

- Melting requires heating matter and is a change of state from solid to liquid.
- Freezing requires cooling matter and is a change of state from liquid to solid.
- Evaporation requires heating matter and is a change of state from liquid to gas at different temperatures.
- Boiling requires heating matter and is a change of state from liquid to gas at the liquid's boiling point.
- Condensation requires cooling matter and is a change of state from gas to liquid.
- Sublimation requires heating matter and is a change of state from solid to gas.
- Melting point is the temperature at which a solid substance turns into a liquid (melts) or a liquid turns into a solid (freezes).
- Boiling point is the temperature at which a liquid changes to a gas.
- Rain, hail, snow and sleet are forms of precipitation. The type of precipitation depends on the temperature.

The particle model of matter

- The four major assumptions of the particle model of matter are:
  - all substances are made up of tiny particles
  - the particles of liquids and solids are attracted towards other surrounding particles
  - the particles are always moving
  - the hotter the substance is, the faster the particles move.
- The particles of a solid are closely packed in a fixed shape and have strong bonds between them; they vibrate in a fixed position.

- The particles of a liquid are less strongly held together than solids but still relatively close together, so they cannot be compressed. They can roll over each other so liquids can take the shape of their container.
- The particles of a gas have more energy than those in liquids and solids; they move constantly and spread out to fill any container, so they do not have a fixed shape. The large space between the particles means that they can be compressed.
- Diffusion is the spreading of one substance through another due to the movement of their particles. Diffusion can occur in gases and liquids.
- When matter is heated, energy is transferred into the object causing the speed of the particles to increase.
- When a solid is heated, its particles start to move quickly and the temperature rises. The particles spread out making the solid start to expand.
- As the heating continues, the particles vibrate more strongly and the bonds holding them in position start to break until the solid becomes a liquid.
- With further heating, the particles gain enough energy to completely break the bonds holding them together and the particles continue to spread out even further to become a gas.
- If the temperature continues to increase, the particles move faster and faster taking up more space and the gas expands. If the gas is in a closed container, the particles collide more often with each other and with the sides of the container, increasing the pressure.

Science as a human endeavour

- Meteorologists are scientists who observe, explain and predict the weather.
- Engineers and architects design structures with allowances for expansion and contraction of materials.

6.8.2 Key terms

boiling point the temperature at which a liquid changes to a gas
condensation the change of state by which a gas changes into a liquid
contract shorten or become smaller in size
diffusion movement of one substance through another due to a movement of particles, for example from a region of higher concentration to lower concentration
evaporation changes state from a liquid to a gas. Evaporation occurs only from the surface of a liquid.
expand increase in size due to particles moving apart
fluid a substance that flows and has no fixed shape. Gases and liquids are fluids.
freezing the change of state by which a liquid changes to a solid
gas state of matter with no fixed shape or volume
liquid state of matter that has a fixed volume, but no fixed shape
mass the quantity of matter in an object (usually measured in grams or kilograms)
matter everything that takes up space and has mass is matter
melting the change of state by which a solid changes to a liquid
melting point the temperature at which a solid substance turns into a liquid (melts) or a liquid turns into a solid (freezes)
meteorologist a scientist who uses observations of the atmosphere to predict or explain the weather
particle model a description of the moving particles that make up all matter and how they behave. The model explains the properties of solids, liquids and gases.
physical property property that you can either observe using your five senses — seeing, hearing, touching, smelling and tasting — or measure directly
precipitation falling water in solid or liquid form. The type of precipitation depends mostly on the temperature in the clouds and the air around them.
pressure the force exerted per unit area
properties characteristics or features of an object or substance
solid state of matter that has a fixed shape and volume
state of matter condition or phase of a substance. The three main states of matter are solid, liquid and gas.
sublimation the change in state from a solid into a gas without first becoming a liquid
temperature a measure of how hot or cold something is
volume the amount of space taken up by an object or substance
water vapour water in the gaseous state

Resources

Digital document	Key terms glossary (doc-34704)
eWorkbooks	Study checklist (ewbk-2987) Literacy builder (ewbk-2984) Crossword (ewbk-2985) Word search (ewbk-2986)
Practical investigation eLogbook	Topic 6 Practical investigation eLogbook (elog-0082)

6.8 Exercise

learnon

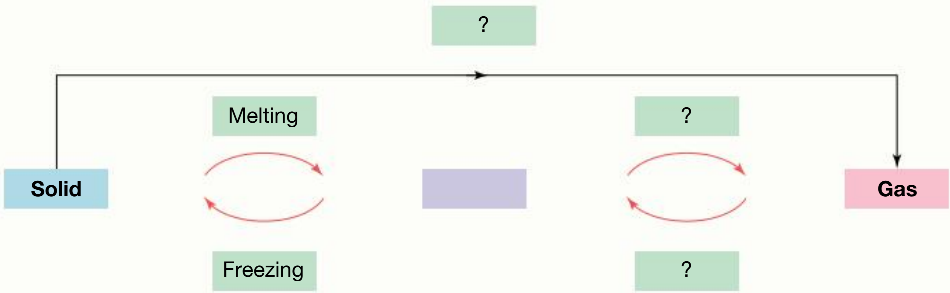
To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 6, 7, 9, 12	Questions 3, 4, 8, 10, 13, 14	Questions 5, 11, 15, 16

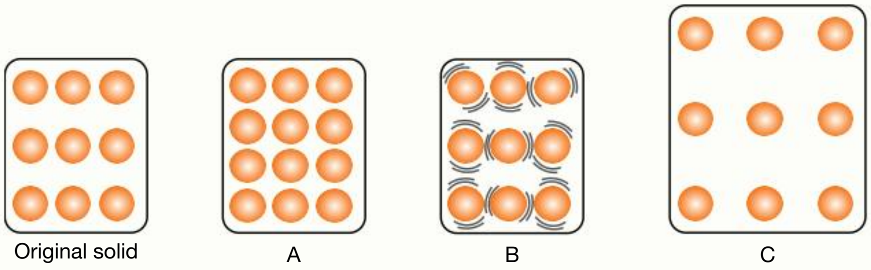
Remember and understand

1. Copy and complete the diagram shown, labelling the missing state and changes of state.



2. **MC** During a change of state:
   A. heat energy is always absorbed.
   B. the temperature remains constant until the change is complete.
   C. the temperature increases at a constant rate as the heat energy is absorbed.
   D. heat energy is neither absorbed nor lost.
3. **MC** When a substance sublimes it:
   A. changes from a liquid to a solid on cooling.
   B. changes from a liquid to a gas on heating.
   C. changes from a liquid to a solid on cooling.
   D. changes from a solid to a gas on heating.
4. In which state — solid, liquid or gas — do the particles have:
   a. the most energy
   b. the least energy?
5. In which state are the forces of attraction between the particles likely to be greatest?
6. Describe the changes of state involved in the formation of rain and hail.

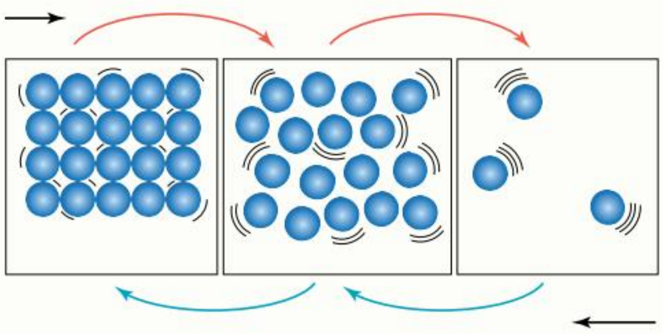
7. Which of the diagrams shown (A, B or C) best represents the particles of a solid after heating?



8. Use the particle model to explain why steam takes up more space than liquid water.

Apply and analyse

9. Copy and label the three diagrams to show which represents a solid, liquid or gas. Label each image and say whether energy is added or removed on the black arrows. Which properties are shown by each of these diagrams?



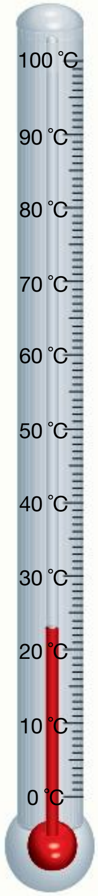
10. Copy and complete the table provided to summarise the properties of solids, liquids and gases. Use a tick to indicate which properties each state *usually* has.

TABLE Properties of solids, liquids and gases

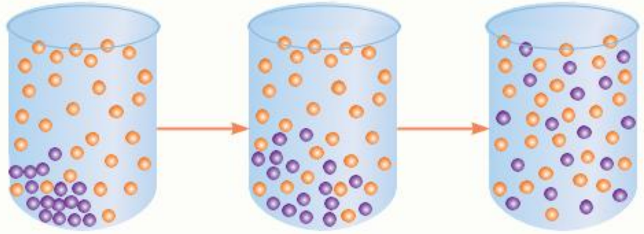
Property	Solid	Liquid	Gas
Has a definite shape that is difficult to change			
Takes up a fixed amount of space			
Can be poured			
Takes up all of the space available			
Can be compressed			
Is made of particles that are strongly attracted to each other and can't move past each other			
Is made of particles that are not held together by attraction			

11. Explain why perfume or aftershave lotion evaporates more quickly than water.

12. a. State the temperature shown on this thermometer.
    b. Explain how mercury and alcohol thermometers are able to provide a measure of temperature.



13. Name the process that is taking place in the following diagram and explain why it occurs only in liquids and gases.



14. Snow and hail are water in a solid state. Describe the difference between snow and hail, and explain how each of them is formed.

Evaluate and create

15. **SIS** Beatrice and Sam performed an investigation to find the volume of a cork stopper. The measuring cylinder was filled to the 80.0 mL level. A cork stopper was dropped into the measuring cylinder and the volume rose to 83.5 mL as the cork floated on the surface.
    a. Describe how to accurately read the initial measure of the volume on a measuring cylinder.
    b. Explain if this is a fair test to find the volume of the cork.
    c. What could you suggest to these students to improve the design of the experiment?
16. **SIS** Julia and Chris did an investigation about the rate of evaporation of ethanol in three different pieces of equipment. The containers used were a flat Petri dish, 100 mL beaker and 100 mL conical flask, and 10.0 mL of ethanol was used in each.
    The volume in each container after 45 minutes was as follows: Petri dish 9.3 mL, beaker 9.8 mL, and conical flask 9.6 mL.
    a. State the variables that would need to be controlled.
    b. State the independent variable.
    c. State the dependent variable.
    d. Propose a hypothesis for this investigation.
    e. State the aim.
    f. List the equipment and chemical required.
    g. List the steps of the method.
    h. Prepare a table to place the results showing initial and final volumes.
    i. In the discussion, suggest an explanation of your results.
    j. Suggest a way to improve this investigation.
    k. Write a conclusion.

Fully worked solutions and sample responses are available in your digital formats.

on Resources

eWorkbook Reflection (ewbk-3038)

teachon

Test maker
Create customised assessments from our extensive range of questions, including teacher-quarantined questions. Access the assignments section in learnON to begin creating and assigning assessments to students.

RESOURCE SUMMARY

on Resources

Below is a full list of **rich resources** available online for this this topic. These resources are designed to bring ideas to life, to promote deep and lasting learning and to support the different learning needs of each individual.

6.1 Overview

eWorkbooks
- Topic 6 eWorkbook (ewbk-2976)
- Student learning matrix (ewbk-0265)
- Starter activity (ewbk-2977)

Practical investigation eLogbooks
- Topic 6 Practical investigation eLogbook (elog-0082)
- Investigation 6.1: Investigating the properties of solids, liquids and gases (elog-0081)

Video eLesson
- Three states of water (eles-3524)

6.2 States of matter

Video eLesson
- Diffusion (eles-2035)

Practical investigation eLogbooks
- Investigation 6.2 Ranking substances (elog-0083)
- Investigation 6.3: Measuring the volume of an irregular-shaped solid (elog-0084)

Interactivities
- Crystalline solids (int-5333)
- Volume (int-3791)

6.3 Changing states

eWorkbooks
- Changing the boiling point of water (ewbk-2979)
- Labelling the changing states of water in the kitchen (ewbk-2978)

Video eLessons
- Gold melting (eles-2075)
- Sublimation (eles-2038)

Interactivity
- The changing states of water in the kitchen (int-7684)

6.4 The state of the weather

Video eLesson
- Understanding a weather forecast (eles-0161)

6.5 The particle model

eWorkbooks
- Fire! Fire! (ewbk-2980)
- Particles in our lives (ewbk-2982)

Practical investigation eLogbook
- Investigation 6.4: Investigating diffusion (elog-0085)

Video eLesson
- Under pressure (eles-0058)

Interactivity
- Fire extinguisher (int-5334)

6.6 Energy matters

eWorkbooks
- Changes of state (ewbk-2983)
- Expansion of liquids (ewbk-2981)

Practical investigation eLogbooks
- Investigation 6.5: Explaining gases (elog-0086)
- Investigation 6.6: Expansion of solids (elog-0087)
- Investigation 6.7 Expansion of liquids: (elog-0088)

Interactivities
- Heating and cooling (int-3413)
- Changes of state (int-0222)

6.8 Review

eWorkbooks
- Topic review Level 1 (ewbk-2988)
- Topic review Level 2 (ewbk-2989)
- Topic review Level 3 (ewbk-2990)
- Study checklist (ewbk-2987)
- Literacy builder (ewbk-2984)
- Crossword (ewbk-2985)
- Word search (ewbk-2986)
- Reflection (ewbk-3038)

Practical investigation eLogbook
- Topic 6 Practical investigation eLogbook (elog-0082)

Digital document
- Key terms glossary (doc-34704)

To access these online resources, log on to **www.jacplus.com.au**.

7 Elements, compounds and mixtures

LEARNING SEQUENCE

7.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

7.1.1 Introduction

It is incredible to realise that everything that you see around you is made of these very, very tiny particles called **atoms**, and it is even more amazing to find out that these atoms are made of even smaller particles. A substance that consists of only one type of atom is known as an **element**. Everything in the universe is made up of about 90 naturally occurring elements. Some elements will be familiar to you: helium in balloons, the oxygen that we breathe, silver in jewellery and iron in buildings. All the atoms in a helium balloon are the same because helium is an element. Elements have their own symbols — helium has the symbol 'He' to distinguish it from the element hydrogen, which has the symbol 'H'. Silver is a metallic element and hydrogen and helium are non-metallic elements.

When elements react together, they can form a **compound**. The properties of a compound are different from the elements that have reacted to make it. There are millions of different compounds but one we use every day is water. You probably already know that the chemical formula for water is H_2O. The chemical formula includes the symbols for the elements present in the compound.

When some atoms combine chemically to make a small group of atoms joined together like water, a **molecule** is formed. Molecules come in all sizes. A water molecule has only three atoms in each molecule but a DNA (deoxyribonucleic acid) molecule, which is shown in figure 7.1, has millions of atoms. DNA that is found in our cells has the instructions that determine an individual's characteristics such as hair colour and type.

The final group of substances that will be studied in this chapter is the most common one. Most of the substances that we see around us are **mixtures**. The air that we breathe is a mixture of the gaseous elements nitrogen, oxygen and a very small amount of argon, together with a small amount of the compound carbon dioxide; there are also minute quantities of other substances as well. Mixtures are substances that are not chemically combined and the substances retain their own properties. Unlike compounds, the parts of a mixture are not necessarily in fixed proportions, for example mixing sand, iron nails and sugar.

atoms very small particles that make up all things. Atoms have the same properties as the objects they make up.

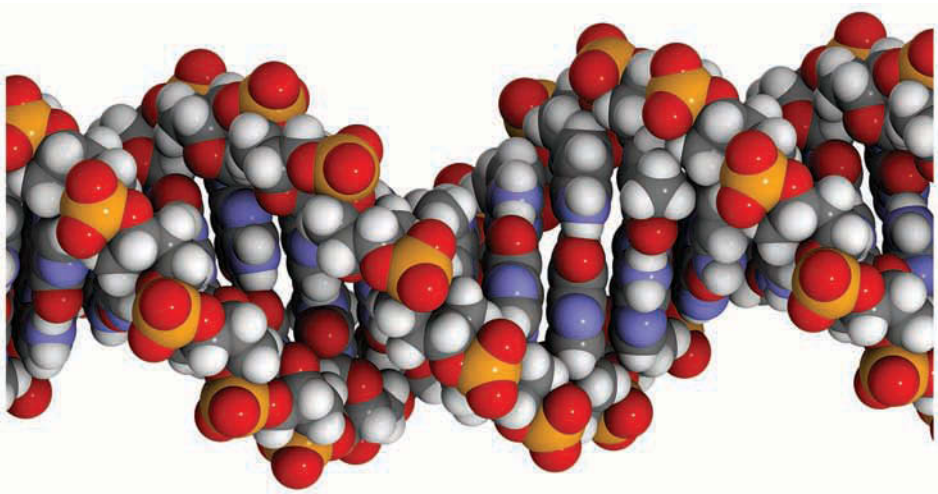
elements pure substances made up of only one type of atom

compound substance made up of two or more different types of atoms that have been joined (bonded) together

molecule two or more atoms joined (bonded) together

mixtures a combination of substances in which each keeps its own properties

FIGURE 7.1 A DNA (deoxyribonucleic acid) molecule has millions of atoms.



on Resources

Video eLesson A 3D view of the structure of DNA (eles-2030)

A 3D view of the structure of a DNA molecule. The structure of matter is one aspect that determines the properties of a substance.

7.1.2 Think about substances

1. How did plumbers get their name?
2. Which metal can drive you crazy?
3. Can water be split?
4. Can you breathe nitrogen gas?
5. What is most of an atom made up of?
6. Just what is 'plastic' made from?
7. Which precious gem is made from the same substance as charcoal and soot?

7.1.3 Science Inquiry

Investigating atoms

Atoms are tiny — so tiny that they are hard to visualise. But they can bring up some very big questions. Consider these questions and carry out investigation 7.1 to help you understand just how small, and how important, atoms really are.

1. Everything around you and in you is made of atoms, but what is an atom?
2. Who was the first person to say that everything is made of atoms?
3. Can we see individual atoms?
4. If matter is made of atoms, what are atoms made of?
5. How do we know what an atom looks like?
6. How many different types of atoms are there?
7. Are atoms of the same element the same?
8. What are the main types of atoms that are in us?
9. How small are atoms? How many hydrogen atoms do you think would fit on a pin head?

elog-0129

INVESTIGATION 7.1

How big is an atom?

Aim

To investigate division of matter

Materials

- a strip of paper cut from A4 paper (about 30 cm long)
- pair of scissors
- ruler

Method

1. Construct a table like the one in the results section of this investigation, and record the length of the strip of paper.
2. Cut the strip of paper in half. Put one half aside. Measure the length of the other half.
3. Cut the measured half in half again. Again, put one half aside, and measure and record the length of the other half.
4. Before you go any further, predict how many times you will be able to cut the strip in half.
5. Continue this process until you can no longer cut the strip in half.

The first three cuts along the strip of paper

Results

TABLE Results and predictions of investigation 7.1

Number of cuts	Length of strip (approximate)
0	30 cm
1	15 cm
2	7.5 cm (easy?)
3	
4	
5	
6	
7	
8	1 mm (you're doing well to get this far!)
9	
10	
12	Average width of human hair
14	
18	1 micron (1 millionth of a metre, one thousandth of a millimetre)
22	
26	
31	The size of a single atom

Note: Scale change after 10 cuts

Discussion

1. How many cuts were you able to make? Was it more or less than your prediction?
2. Estimate the number of cuts you would need to make before the strip would be too small to see.

Conclusion

The smallest piece of paper that I could cut was …

on Resources

eWorkbooks	Topic 7 eWorkbook (ewbk-3106) Student learning matrix (ewbk-3110) Starter activity (ewbk-3108)
Practical investigation eLogbook	Topic 7 Practical investigation eLogbook (elog-0145)
learnon	Access and answer an online Pre-test and receive **immediate corrective feedback** and **fully worked solutions** for all questions.

7.2 It's elementary

LEARNING INTENTION

At the end of this subtopic you will be able to recognise how the work of scientists today compares with the work of the early alchemists. You will also be able to describe the properties of some elements.

7.2.1 The alchemists

SCIENCE AS A HUMAN ENDEAVOUR: The alchemists

About 1000 years ago, when kings and queens lived in castles and were defended by knights in shining armour, there lived the **alchemists**.

They chanted secret spells while they mixed magic potions in their flasks and melted metals in their furnaces. They tried to change ordinary metals into gold. They also tried to find a potion that would make humans live forever. They studied the movements of the stars and claimed to be able to see into the future. Kings and queens took the advice of the alchemists very seriously.

FIGURE 7.2 Alchemists believed that the four basic elements in nature were air, fire, water and earth.

The alchemists never found the secrets they were looking for, but they did discover many things about substances around us. During the same period, people who worked with materials also helped us to understand many everyday substances. Blacksmiths worked with metals to make stronger and lighter swords and armour, fabric dyers learned how to colour cloth, and potters decorated their work with glazes from the earth. Without the knowledge passed down by these people, the world as we know it would be very different!

Twelve important substances were discovered during these ancient times: **gold, iron, silver, sulfur, carbon, lead, mercury, tin, arsenic, bismuth, antimony** and **copper**. Alchemists discovered five of these.

EXTENSION ACTIVITY: Medieval swords

Explore how swords were made in the middle ages.

7.2.2 Real science

In about the seventeenth century, people stopped thinking about magic and instead carried out **investigations** based on careful **observations**. These new seekers of knowledge were called **scientists**. They found that the 12 substances discovered during ancient times could not be broken down into other substances. Scientists investigated many common everyday substances as well, including salt, air, rocks, water and even urine! They discovered that nearly everything around us could be broken down into other substances. They gave the name 'element' to the substances that could not be broken down into other substances. Between 1557 and 1925, another 76 elements were discovered. We now know that 92 elements exist naturally. In recent years scientists working in laboratories have been able to make at least another 26 artificial elements.

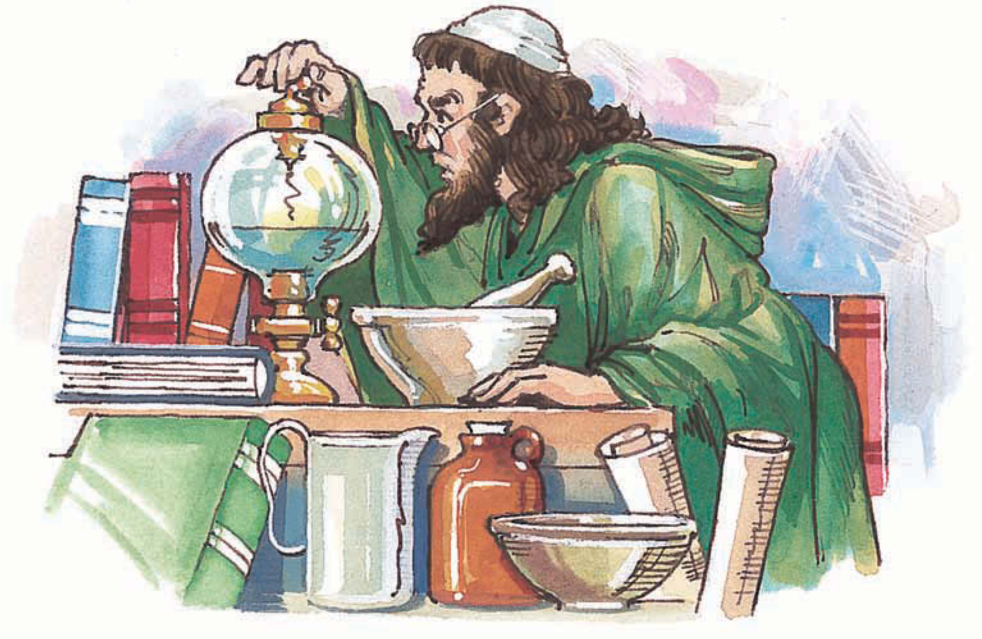
alchemist olden-day 'chemist' who mixed chemicals and tried to change ordinary metals into gold. Alchemists also tried to predict the future.

investigations activities aimed at finding information

observations information obtained by the use of our senses or measuring instruments

scientists people skilled in or working in the fields of science; scientists use experiments to find out about the material world around them

FIGURE 7.3 Seventeenth-century scientists carried out investigations based on careful observations.



Scientists use investigations based on observations to make discoveries.

on Resources

Video eLesson Lavoisier and hydrogen (eles-1772)

DISCUSSION

Discuss the similarities and differences between the work of the alchemists and the real scientists of the seventeenth century.

EXTENSION: Mercury poisioning

In days gone by, substances containing the element mercury were used to make hats. In those days it was not known that mercury is a very poisonous element. Poisoning by mercury can affect your nervous system and your mind. This sometimes happened to hat makers who were exposed to mercury for a long time; hence the expression ‘mad as a hatter’!

7.2.3 Examining elements

Most of the substances around you are made up of two or more elements. You will not be able to find many of the 92 naturally occurring elements in their pure, uncombined form. It is possible, however, to examine many of the elements in the school laboratory.

Many elements are safe to handle; however, there are also many that are not. The elements sodium, potassium and mercury, for example, need special care and handling. Sodium and potassium are soft metals that can be cut with a knife. They both get very hot if they come into contact with water. They are stored under oil so that water in the atmosphere cannot reach them.

elog-0130

INVESTIGATION 7.2

Checking out appearances of elements

Aim

To examine and describe the properties of a selection of elements

Materials

- samples of chemical elements (e.g. carbon, sulfur, copper, iron, aluminium, silicon)
- magnifying glass or stereo microscope
- iron nail

Method

1. Copy the table in the results section into your workbook or obtain a copy from your teacher.
2. Carefully examine the appearance of each of the elements in the set (look for colour, texture).
3. Test the hardness by scratching with a nail where possible.
4. Find out where the substance might be found.
5. Complete the table by filling in the description. Research or discuss with other students the substances that might include the element. One example is completed for you.

Results

TABLE Observations and predictions of elements observed

Elements	State	Description	In which substances might the element be present?
Hydrogen	Gas	Clear, colourless	Acids, water

Discussion

1. Using a periodic table, write the names and symbols of each of the elements.
2. Describe any similarities between the elements.
3. Divide the elements into groups according to one of the properties that you observed. Give the groups names.
4. Which element was the hardest to classify?
5. Discuss the accuracy of the test for hardness.
6. Suggest another test that could be performed to find out more about the elements.

Conclusion

Summarise the properties that you observed.

on Resources

eWorkbook How big is an atom? (ewbk-3098)

assesson Additional automatically marked question sets

7.2 Exercise

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Questions 1, 2, 5, 6, 7	Questions 3, 8, 9	Questions 4, 10, 11

Remember and understand

1. MC An element is:
   A. a substance that cannot be combined with other substances.
   B. a substance that cannot be broken down.
   C. a substance that is only stable in its pure form.
   D. a substance that is only stable in a combined form.
2. Which types of substances did blacksmiths help us to understand?
3. Recall what problems the alchemists of medieval times were trying to solve.
4. Explain why sodium and potassium need to be stored under oil.
5. State one harmful effect of mercury on humans.
6. Make three observations of the seventeenth-century scientist in figure 7.3 section 7.2.2.

Apply and analyse

7. MC Select one reason for displaying chemical safety symbols at the entrances of many buildings.
   A. Chemical safety signs let manufacturers know which chemicals are used in the building so they can be more easily ordered when they run out.
   B. Chemical safety signs let cleaners know which chemicals are stored and used in the building.
   C. Chemical safety signs warn people of the dangers of chemicals stored and used in the building.
   D. Chemical safety signs let delivery people know which chemicals to deliver to the building.
8. Is water an element? Give a reason for your answer.
9. How did the scientists differ from the alchemists in the seventeenth century?

Evaluate and create

10. SIS Many years ago, balloons were filled with hydrogen so that they could float high in the sky. However, hydrogen is no longer used in balloons because it explodes too easily. At fairs, carnivals and florist shops, you can often buy colourful gas-filled balloons that fly high into the sky if you let them go. These balloons are filled with an element called helium. Find out who discovered helium, where it was discovered and when.
11. SIS The element mercury was known to ancient people and was very important to the alchemists. Find out all you can about this liquid metal. What does its name mean? Where is it found? What has it been used for in the past? What is it used for now? What is the safety procedure if mercury is spilt?

Fully worked solutions and sample responses are available in your digital formats.

7.3 Elements — The inside story

LEARNING INTENTION

At the end of this subtopic you will be able to describe how the model of the atom developed. You will be able to describe sub-atomic particles and apply chemical symbols.

7.3.1 Atoms and elements

SCIENCE AS A HUMAN ENDEAVOUR: Developing models of the atom

Democritus

About 2500 years ago a teacher named Democritus lived in ancient Greece. He walked around the gardens with his students, talking about all sorts of ideas.

Democritus suggested that everything in the world was made up of tiny particles so small that they couldn't be seen. He called these particles *atomos*, which means 'unable to be divided'. Other thinkers at the time disagreed with Democritus. It took about 2400 years for evidence of the existence of these atoms (as we now call them) to be found.

FIGURE 7.4 Democritus (c. 460 – c. 370 BCE), an ancient Greek philosopher

on Resources

Interactivity Democritus and the atom (int-5744)

John Dalton

Even though the atom couldn't be seen, scientists did experiments over many years and they thought carefully about the information they gathered.

Finding evidence for the existence of atoms was not possible until Galileo wrote about the need for controlled experiments and the importance of accurate observations and mathematical analysis in the sixteenth century. Galileo's 'scientific method', along with the development of more accurate weighing machines, was used by John Dalton in 1803 to show that matter was made up of atoms. He proposed that atoms could not be divided into smaller particles and that atoms of different elements had different masses.

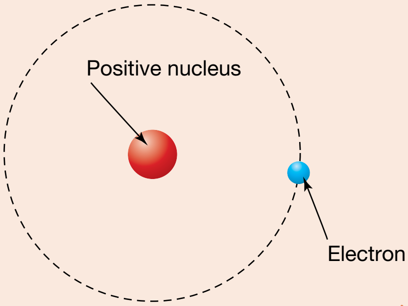
FIGURE 7.5 John Dalton (1766–1844), an English chemist, physicist and meteorologist

Ernest Rutherford

For the next 100 years, scientists thought the atom was a solid sphere, but discoveries including radioactivity and electric current, and new technology such as the vacuum tube and Geiger counters, allowed scientists to 'peek' inside. In 1897 Joseph Thomson, a British physicist, discovered the electron and a few years later in 1911, New Zealander Sir Ernest Rutherford used some of the new discoveries and inventions to prove that atoms were not solid particles.

He fired extremely tiny particles at a very thin sheet of gold. Most of the particles went straight through. Only sometimes did they bounce off as if they had hit something solid. He concluded that the tiny particles could be getting through only if each atom consisted of mostly empty space with a positive nucleus at the centre.

FIGURE 7.6 Rutherford's model of the atom



Niels Bohr

Niels Bohr proposed the next model of the atom. He suggested that the electrons circled the nucleus in shells and that in the first shell there were two electrons and in the second shell up to eight electrons.

In 1932 James Chadwick found another type of particle in the nucleus of the atom — the neutron.

FIGURE 7.7 Bohr's model of the atom

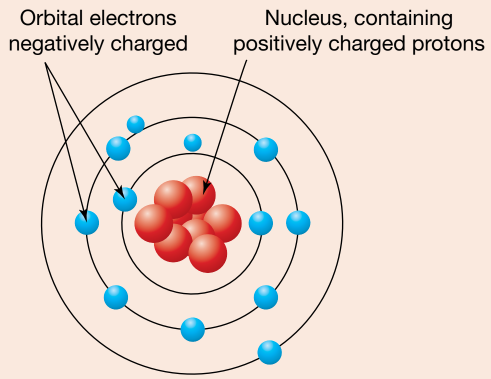
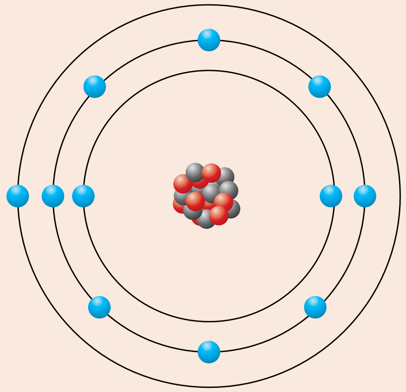


FIGURE 7.8 Chadwick–Bohr model of the atom



7.3.2 Inside the atom

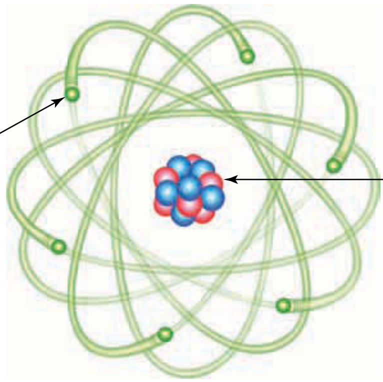
We now know that each element is made of its own particular kind of atom. Gold contains only gold atoms, oxygen contains only oxygen atoms, carbon contains only carbon atoms and so on. But what is it that makes atoms different from one another? To answer this question, we need to know a little bit more about the atom. It is now understood that all atoms are made up of even smaller particles, protons, neutrons and electrons.

The amount of negative charge carried by each electron is the same as the amount of positive charge carried by each proton. In an atom, the number of protons is equal to the number of electrons, so there is no overall electric charge.

FIGURE 7.9 If helium atoms are lighter than all others except hydrogen atoms, why do you think that helium is used in blimps?

int-3387

FIGURE 7.10 Diagram of the atom



Moving very rapidly around the nucleus are **electrons**. Electrons are much smaller in size and mass than both protons and neutrons. Each electron carries a negative electric charge.

The particles in the centre of an atom are called **protons** and **neutrons**. Together they form the **nucleus**. Each proton carries a positive electric charge. Neutrons have no electric charge.

Matter is made of atoms that contain protons, neutrons and electrons. Hydrogen is an exception because most hydrogen atoms do not have a neutron.

7.3.3 Atomic numbers

The number of protons in an atom is called its **atomic number**. Each element has a different atomic number. The blimp in figure 7.9 is filled with helium, which has an atomic number of 2. Helium atoms are lighter than all others except hydrogen atoms. All carbon atoms have six protons inside the nucleus, so the atomic number of carbon is 6. The number of neutrons in an atom can vary; most carbon atoms have six neutrons but some have seven or eight neutrons in their nuclei. For each proton in the carbon atom it also has one electron, meaning a carbon atom has six electrons. The lightest element is hydrogen, which has one proton in each atom and an atomic number of 1. The heaviest natural element is uranium with 92 protons in each atom.

on Resources

Video eLessons The hydrogen atom (eles-2269)
An atom of carbon (eles-2031)

electrons very light, negatively charged particles inside an atom. Electrons move around the central nucleus of an atom.

protons tiny, but heavy, positively charged particle found in the nucleus of an atom

neutrons tiny, but heavy, particle found in the nucleus of an atom. Neutrons have no electrical charge.

nucleus (in biology) roundish structure inside a cell that acts as the control centre for the cell; (in chemistry) the central part of an atom, made up of protons and neutrons. Plural = nuclei.

atomic number number of protons in the nucleus of an atom. The atomic number determines which element an atom is.

TABLE 7.1 Protons, neutrons and electrons in the first 12 elements

Name	Symbol	Protons (atomic number)	Electrons	Neutrons*
Hydrogen	H	1	1	0
Helium	He	2	2	2
Lithium	Li	3	3	4
Beryllium	Be	4	4	5
Boron	B	5	5	6
Carbon	C	6	6	6
Nitrogen	N	7	7	7

(continued)

TABLE 7.1 Protons, neutrons and electrons in the first 12 elements *(continued)*

Name	Symbol	Protons (atomic number)	Electrons	Neutrons*
Oxygen	O	8	8	8
Fluorine	F	9	9	10
Neon	Ne	10	10	10
Sodium	Na	11	11	12
Magnesium	Mg	12	12	12

*The number of neutrons can vary but this is the most common number of neutrons for these elements.

EXTENSION ACTIVITY: What is mass number of an element?

Research to find out what mass number refers to.
Calculate the mass number of the first 12 elements in the periodic table.

7.3.4 What's in a name?

As the early scientists discovered more and more elements, it became more important that they all agreed on what to call them. Each element was given a name and a **chemical symbol**.

The chemical symbols of most elements are very easy to understand. The symbol sometimes starts with the capital letter that is the first letter of the element's name. For some elements that is the complete symbol.

For example:

O = oxygen   C = carbon
N = nitrogen   H = hydrogen

When there is more than one element starting with the same capital letter, a small letter is also used.

For example:

Cl = chlorine   Ca = calcium
Cr = chromium   Cu = copper

If an element has a symbol that doesn't match its modern name, that's because the symbol is taken from the original Greek or Latin name.

For example:

Na = sodium (*natrium*)   Ag = silver (*argentum*)
Pb = lead (*plumbum*)   K = potassium (*kalium*)
Hg = mercury (*hydro argyros*)   Fe = iron (*ferrum*)

chemical symbol the standard way that scientists write the names of the elements, using either a capital letter or a capital followed by a lowercase letter. For example, carbon is C and copper is Cu.

SCIENCE AS A HUMAN ENDEAVOUR: Naming the elements

The names and symbols of some of the elements have some interesting origins.

- Einsteinium (Es) is named after the famous scientist Albert Einstein.
- Polonium (Po) was discovered by another famous scientist, Marie Curie. She named polonium after Poland, the country of her birth.
- Helium (He) was first discovered in the Sun. It is named after Helios, the Greek god of the Sun.
- Sodium (Na) was first called by the Latin name *natrium*.
- Lead (Pb) also used to have a Latin name, *plumbum*. That's where the word 'plumber' comes from. The ancient Romans, who spoke Latin, used lead metal to make their water pipes.

elog-0131

INVESTIGATION 7.3

Getting to know atoms

Aim

To investigate and prepare models of atoms

Materials

Selection of craft materials for example:

- thin card
- coloured paper
- wool
- buttons
- counters
- pipe cleaners
- string
- small beans

Method

1. In a group, discuss, design and produce a 2D or 3D model of an element with an atomic number between 3 and 12.
2. Include the correct placement of protons, neutrons and electrons.
3. Think about the size of the particles.
4. Include labels or a key.
5. Include the symbol and full name.
6. Write 5–7 sentences about the discovery, source and/or use of your element.

Results

Draw a diagram or take a photo of your model. Your teacher may ask you to present your element to the class.

Discussion

1. Outline what you learned about working in a group.
2. Describe how the atoms that the students in the class prepared are similar and how they are different.
3. In what ways is your model different from a real atom?

Conclusion

Summarise what you learned about atoms.

on Resources

Interactivity Periodic table (int-0758)

assesson Additional automatically marked question sets

7.3 Exercise

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To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3, 4, 5, 12	Questions 6, 7, 10, 11, 13	Questions 8, 9, 14, 15, 16, 17

Remember and understand

1. Recall the ideas that Democritus had around 2500 years ago about what substances were made up of.
2. How many types of naturally occurring atoms are there?
3. Draw and label a diagram of an atom. Ensure you state the location of each of the three parts of an atom.
4. What does the atomic number of an element tell you?

Apply and analyse

5. State the symbols of each of the following elements: hydrogen, carbon, oxygen, nitrogen, iron, calcium, copper, lead, mercury.
6. Explain why carbon atoms have six electrons.
7. MC Why don't electrons fly off their atoms?
   A. They are repelled from the external environment.
   B. They are attracted to the neutrons in the nucleus.
   C. They are directly bonded to the protons.
   D. They are attracted to the protons in the nucleus.
8. List some of the discoveries and inventions that scientists have used to learn more about the atom since the time of Democritus.
9. Describe what makes up most of every atom.
10. State the atomic number of uranium.

Evaluate and create

11. In what ways is an atom of carbon different from an atom of uranium?
12. a. Describe the nucleus of an atom.
    b. What type of electric charge does the nucleus of every atom have?
13. To which element does the atom illustrated in figure 7.10 belong?
14. Explain why it is important for scientists around the world to agree on the names and chemical symbols of the elements.
15. Find out the names, atomic numbers and uses of the elements with the following symbols. Construct a table in which to display your findings.

Symbol	Name	Atomic number	Uses
Sn			
Au			
Cu			
N			
Ne			
Sr			
Ca			

16. Draw a diagram of an atom that has three protons and one neutron in its nucleus. How many electrons will it have? Label them on your diagram.
17. SIS Research and report on what nanotechnology is and what connection it has with atoms.

Fully worked solutions and sample responses are available in your digital formats.

7.4 Compounding the situation

LEARNING INTENTION

At the end of this subtopic you will be able to describe the difference between elements, compounds and mixtures and that, unlike compounds, there cannot be a fixed chemical formula for mixtures.

7.4.1 Elements, compounds and mixtures

There are millions and millions of different substances in the world (explored further in subtopic 7.7). They include the paper of a book, the ink in the print, the air in the room, the glass in the windows, the wool of your jumper, the cotton and polyester in your shirt or dress, the wood of your desk, the paint on the walls, the plastic of your pen, the hair on your head, the water in the taps and the metal of your chair legs. The list could go on and on. All substances can be placed into one of three groups: elements, compounds or mixtures.

It is not always possible to tell if a substance is an element, compound or mixture by just looking at it; you need to have more information. Oxygen and carbon dioxide, for example, are both colourless gases but oxygen is an element and carbon dioxide is a compound. Water and seawater look the same but water is a compound and seawater is a mixture.

bonded joined by a force that holds particles of matter, such as atoms, together

chemical formula shows the ratio of the atoms of each element present in a molecule or compound

Elements

Elements are substances that contain only one type of atom.

- Very few substances exist as elements.
- Most substances around us are either compounds or mixtures.
- Examples of elements are hydrogen, oxygen, carbon and iron.

Compounds

Compounds are usually very different from the elements of which they are made. In compounds:

- the atoms of one element are **bonded** very tightly to the atoms of another element or elements.
- the elements that make up a compound are completely different substances from the compound. For example, pure salt (sodium chloride) that you might put on your French fries is a compound made up of the elements sodium (a silvery metal) and chlorine (a green, poisonous gas).
- a compound always contains the same relative amounts of each element. For example, the compound carbon dioxide is always made up of two atoms of oxygen for each atom of carbon. Its **chemical formula** is therefore CO_2. The compound sodium chloride always has one sodium atom for each chlorine atom and its formula is simple: NaCl.
- every compound has a formula comprising the symbols of the elements that make it up. Unlike mixtures, the elements within a compound cannot easily be separated from each other.

  When the atoms of different elements bond together, a compound is formed. When heated together, the elements iron and sulfur form a new compound called iron sulfide. Iron sulfide has the formula FeS.

FIGURE 7.11 A compound is completely different from the elements of which it is made. Pure salt consists of the elements sodium and chlorine. Table salt is a mixture that consists mainly of pure salt.

- elements can be separated from compounds in several ways. These include:
  - passing electricity through a compound
  - burning the compound
  - mixing the compound with other chemicals.

  Each of these methods involves a chemical reaction in which completely different substances are formed.

WHAT DOES IT MEAN?

The word compound comes from the Latin word *componere*, meaning 'to put together'.

Mixtures

Mixtures can be made up of two or more elements, two or more compounds or a combination of elements and compounds.

- Unlike compounds, the parts of a mixture are not always in the same proportion.
  For example:
  - seawater is the most common mixture on the Earth's surface, but the percentage of salt is not always the same. It can also include a variety of other elements and compounds in different quantities.
  - a coffee is a mixture that can contain different relative amounts of water, milk, coffee beans and sugar.
  - brass is a mixture of metals that can have different relative amounts of copper and zinc.
- There can be no unique chemical formula for mixtures.
- The substances that make up mixtures can usually be easily separated from each other.
- When the parts of a mixture are separated, no new substances are formed. For example, fizzy soft drink contains water, gas, sugar and flavours. If you shake the soft drink, the gas bubbles separate from the water and go into the air. You still have the water in the bottle and the gas in the air; they are just not mixed together anymore. The parts of the mixture can be separated relatively easily. The gas escapes when the lid of the container is opened, and the water can be separated by evaporation, leaving behind sugar and some other substances.

There can be no unique chemical formula for mixtures because, unlike compounds, the parts of a mixture are not always in the same proportion.

DISCUSSION

Substance X is a blue colour.

When it is heated a gas is given off leaving a black solid. Is substance X an element or a compound?

EXTENSION ACTIVITY: What is air a mixture of?

Air is a mixture. Find out what substances are present, whether they are elements or compounds and how much of each substance is present.

TABLE 7.2 Some common substances

Substance	Type	Composed of	Scientific name
Gold	Element	Gold	Gold
Diamond	Element	Carbon	Carbon
Water	Compound	Hydrogen and oxygen	Dihydrogen monoxide
Pure salt	Compound	Sodium and chlorine	Sodium chloride
Brass	Mixture	Copper and zinc	Brass
Soft drink	Mixture	Water, sugar, carbon dioxide and other compounds	
Seawater	Mixture	Water, sodium chloride and other compounds	

elog-0132

INVESTIGATION 7.4

Making a compound from its elements

Aim

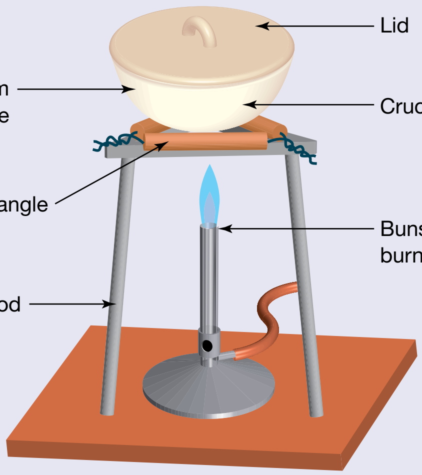
To use a chemical reaction to make a compound from its elements

Materials

- 4–5 cm strip of clean, shiny magnesium ribbon. It can be coiled to fit in the crucible.
- crucible with lid
- pipeclay triangle, tongs and safety glasses
- Bunsen burner, heatproof mat and matches
- emery paper
- electronic scales

Method

1. Examine the piece of magnesium and note its appearance before placing it in the crucible and covering it with the lid.
2. Put the crucible on the pipeclay triangle as shown in the diagram.
3. Heat the crucible with a strong blue flame, monitoring the reaction by occasionally lifting the lid a little with tongs.
4. When all the magnesium ribbon has been changed, turn off the flame and leave the crucible on the tripod to cool.



Results

Record your observations of the magnesium before heating and the substance in the crucible after heating.

Discussion

1. Is magnesium an element or a compound? Give a reason for your decision.
2. Magnesium is one of the reactants in this experiment. What is the other reactant?
3. Is the substance remaining in the crucible an element or a compound? What is its name?
4. What is the evidence that a new substance has been made?
5. Apart from observing whether the reaction is complete, give another reason for lifting the lid of the crucible a little with tongs during the burning.
6. Do you think that the mass of the contents of the crucible will be the same, higher or lower after heating? Explain your answer.

Conclusion

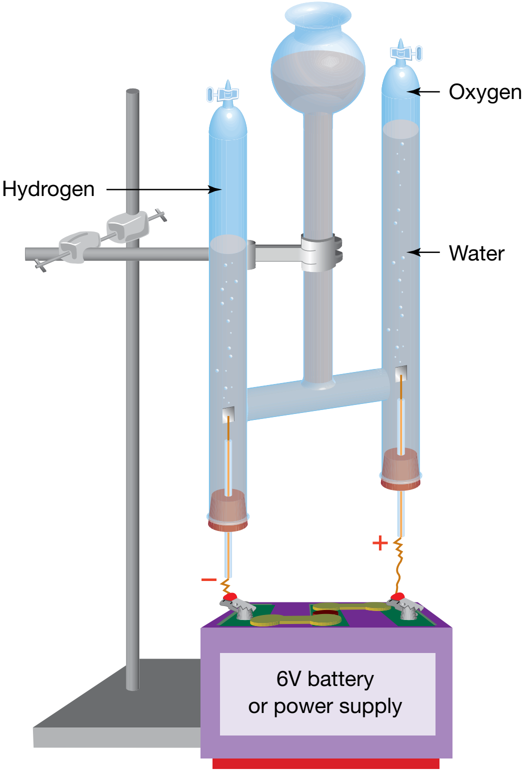
Describe and name the compound formed.

- Elements are made up of one type of atom.
- Compounds are made up of two or more different types of atoms that are chemically combined.

7.4.2 Splitting water

We are surrounded by water. It is in our taps, in our bodies, in the rivers, in the sea, in the air and it comes down as rain. We wash in it, cook with it and drink it. We cannot live without water. Water is not an element — it can be broken down into simpler substances. Figure 7.12 shows an apparatus called a Hofmann voltameter. Water is placed in the voltameter, which is connected to a battery. The electricity splits the water into the elements of which it is made: the colourless and odourless gases **hydrogen** and **oxygen**. Hydrogen and oxygen are both elements and have quite different properties from water.

FIGURE 7.12 Water is split in a Hofmann voltameter. The clear gas in the left tube is hydrogen. The gas in the right tube is oxygen. What do you notice about the amounts of hydrogen and oxygen that are produced?



Oxygen

- Is the gas that all living things need to stay alive.
- Is necessary for substances to burn — even hydrogen does not burn without it.
- Is present in water, air, rocks and even hair bleach.

Hydrogen

- Is a much less dense gas than oxygen. This means that a balloon filled with hydrogen will float up very high, but one filled with oxygen will not.
- Is present in almost all acids. By placing a piece of certain metals in an acid, the hydrogen is forced out. The hydrogen can be collected and tested with a flame. This is called the 'pop test'.
- When burned, it combines with oxygen in the air to form water. This releases a lot of energy. If large amounts of hydrogen and oxygen are used, enough energy can be released to lift a space rocket.
- Is a possible fuel for the future as it produces water when it burns; however, it needs a cheap form of energy to separate it from water.

on Resources

Interactivity Hofmann voltameter (int-3389)

hydrogen the element with the smallest atom. By itself, it is a colourless gas and combines with other elements to form a large number of substances, including water. It is the most common element in living things.

oxygen atom that forms molecules (O_2) of tasteless and colourless gas; it is essential for cellular respiration for most organisms and is a product of photosynthesis

elog-0133

INVESTIGATION 7.5

Let's collect an element

Aim

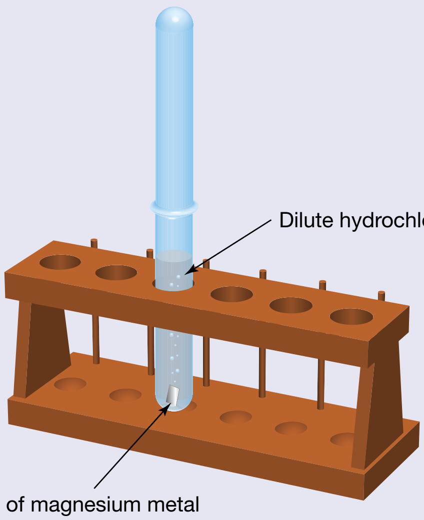
To observe a chemical reaction between a metal and an acid

Materials

- safety glasses
- 2 test tubes and test-tube rack
- matches
- dilute hydrochloric acid
- measuring cylinder
- magnesium metal

Method

1. Measure 10 mL of hydrochloric acid and pour it into the test tube.
2. Add a piece of magnesium and place the second test tube on top of the first as shown in the diagram. Carefully observe what happens.
3. After one minute, take the second test tube off the first. While it is still inverted, immediately light the gas in the second test tube with a match.



Results

1. Record your observations of what happened when you put the magnesium strip in the test tube with the acid.
2. Record your observations of what happened when you put the match below the upside-down test tube.

Discussion

1. Describe what happened in the test tube containing the metal and the acid.
2. What does hydrogen gas look like?
3. What happened when you lit the gas?
4. Look closely at the second test tube. Describe what you see inside it.
5. Compare the properties of the elements that reacted and the compound that was formed.
6. Do you think that all metals and acids would react the same way? Describe some steps that would help you answer this question.

Conclusion

Write a sentence describing what happens when a metal, like magnesium, is added to an acid.

on Resources

eWorkbook Pure substances and mixtures (ewbk-3100)

assess on Additional automatically marked question sets

7.4 Exercise

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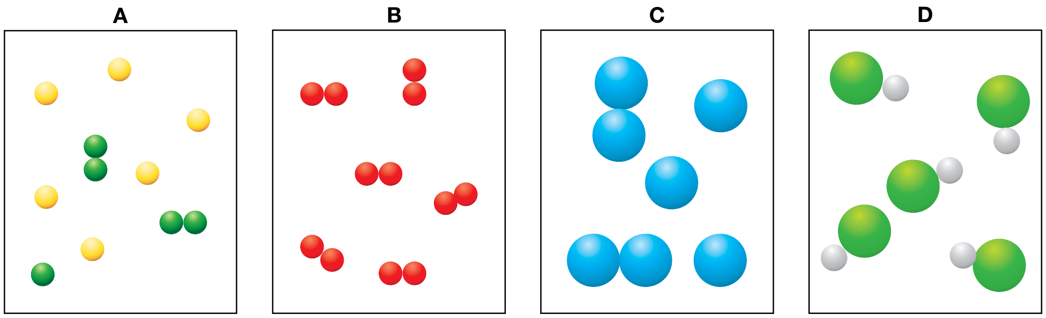
To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3, 4	Questions 5, 6, 9	Questions 7, 8, 10, 11

Remember and understand

1. What is an element? List five examples of elements and where they are used.
2. Which elements are bonded together to form table salt?
3. MC How do compounds differ from elements?
   A. Compounds contain atoms of more than one type of element.
   B. Compounds contain more than one atom.
   C. Compounds are always solid.
   D. Compounds are not reactive.
4. What are the important differences between a mixture and a compound?
5. Which of the diagrams shown represent:
   a. elements
   b. compounds
   c. mixtures?



Apply and analyse

6. SIS Fizzy soft drink is a mixture of several compounds. List three of the compounds and suggest how each of them could be separated from the mixture.
7. What happens when atoms are bonded together?
8. List three ways in which elements can be separated from their compounds.

Evaluate and create

9. How do you know that water is a compound and not simply a mixture of hydrogen and oxygen?
10. Magnesium oxide is a compound of magnesium and oxygen. How do you know that it is a completely different substance from each of the two elements it is made up of?
11. SIS Joseph Priestley was one of the first scientists to discover the element oxygen. He also discovered many compounds that are gases. Research and report on the life of Joseph Priestley.

Fully worked solutions and sample responses are available in your digital formats.

7.5 Types of elements

LEARNING INTENTION

At the end of this subtopic you will recognise the properties of the types of elements in the periodic table: metals, non-metals and metalloids.

7.5.1 Grouping elements

It is often convenient to group objects that have features in common. Shops provide a good example of this. In a department store, the goods are grouped so that you know where to buy them. You go to the clothing section for a new pair of jeans, to the jewellery section for a new watch and to the food section for a packet of potato chips.

Scientists also organise objects into groups. Biologists organise living things into groups. Animals with backbones are divided into mammals, birds, reptiles, amphibians and fish. Geologists organise rocks into groups. The elements that make up all substances can also be organised into groups.

on Resources

Video eLesson Malleability (eles-2033)

The two main types of elements in the periodic table are metals and non-metals.

metals elements that conduct heat and electricity; shiny solids that can be made into thin wires and sheets that bend easily. Mercury is the only liquid metal.

non-metals elements that do not conduct electricity or heat. They melt and turn into gases easily and are brittle and often coloured.

7.5.2 Metals and non-metals

Scientists have divided the elements into two main types: the **metals** and the **non-metals**.

Metals

The metals have several features in common, they:

- are solid at room temperature, except for mercury, which is a liquid
- can be polished to produce a high shine or lustre
- are good conductors of electricity and heat
- can all be beaten or bent into a variety of shapes. We say they are malleable.
- can be made into a wire. We say they are ductile.
- usually melt at high temperatures. Mercury, which melts at –40 °C, is one exception.

Non-metals

Only 22 of the elements are non-metals. At room temperature, 11 of them are gases, 10 are solid and 1 is liquid. The solid non-metals have most of the following features in common. They:

- cannot be polished to give a shine like metals; they are usually dull or glassy
- are brittle, which means they shatter when they are hit
- cannot be bent into shape
- are usually poor conductors of electricity and heat
- usually melt at low temperatures.

FIGURE 7.14 Common examples of non-metals are sulfur, carbon and oxygen.

on Resources

Video eLesson Liquid nitrogen (eles-2271)

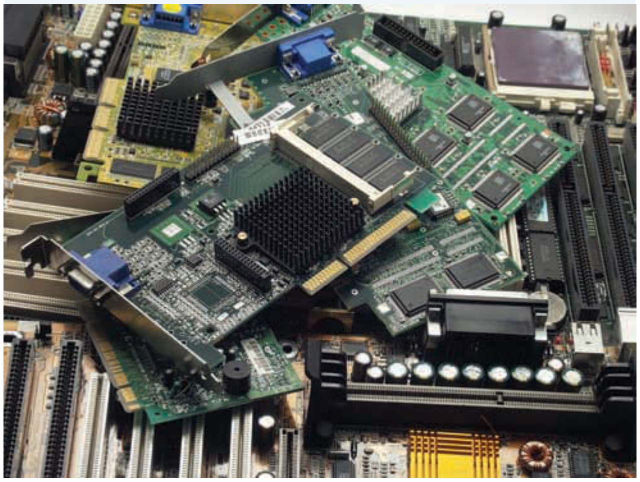
DISCUSSION

Make a list of five items in the classroom that are made of metal. Explain what the property is that lead to its use.

Metalloids

Some of the elements in the non-metal group look like metals. One example is silicon. While it can be polished like a metal, silicon is a poor conductor of heat and electricity, and cannot be bent or made into wire. Those elements that have features of both metals and non-metals are called **metalloids**. There are eight metalloids altogether: boron, silicon, arsenic, germanium, antimony, polonium, astatine and tellurium.

FIGURE 7.14 Metalloids are important materials often used in electronic components of computer circuits.



metalloids elements that have the appearance of metals but not all the other properties of metals

EXTENSION ACTIVITY: Exploring metalloids

Prepare a fact sheet on the source, properties and use of one of the eight metalloids previously listed

elog-0134

INVESTIGATION 7.6

Looking for similarities

Aim

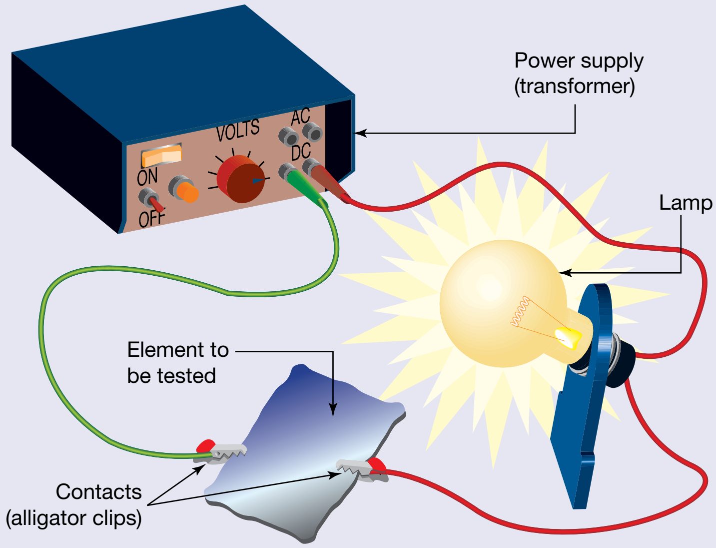
To describe the characteristics of a variety of elements

Materials

- safety glasses
- samples of sulfur, zinc, tin, carbon, silicon, copper
- steel wool or very fine sandpaper
- battery or power pack
- wires with alligator clips
- light globe

Method

1. Make a copy of the table in the results section of this investigation and use it to record your observations for each of the substances.
2. Rub each of the elements with the fine sandpaper and observe whether they are shiny or dull.
3. Try to bend the element.
4. Connect the circuit as shown in the diagram to determine whether electricity passes through each of the elements.
5. Connect your element sample into this circuit.



Results

TABLE Characteristics of some elements

Element	Shiny or dull?	Does it bend?	Does it conduct electricity?
Sulfur			
Zinc			
Tin			
Carbon			
Silicon			
Copper			

Discussion

1. Identify the elements that have a shiny surface when polished.
2. Identify the elements that do not have a shiny surface when polished.
3. Identify the elements that can be bent.
4. Identify the elements that cannot be bent.
5. Identify the elements that allow electricity to pass through.
6. Identify the elements that do not conduct electricity.
7. Attempt to divide the elements into two groups based on your observations. Suggest names for these groups.
8. Which of the six elements tested does not seem to fit into either of these two groups?
9. Refer to the aim of this investigation and suggest how the design of this experiment might be improved.

Conclusion

Write sentences that state which substances:
- just had properties of metals
- just had properties of non-metals
- had properties of metals and non-metals.

on Resources

eWorkbook Metals and non-metals (ewbk-3102)

assess on Additional automatically marked question sets

7.5 Exercise

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Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3	Questions 4, 5, 6	Questions 7, 8, 9

Remember and understand

1. Outline four features that metals have in common.
2. Outline four features that non-metals have in common.
3. What is a metalloid? List three examples.
4. Recall which metal is liquid at room temperature.

Apply and analyse

5. MC What does 'metallic lustre' mean?
   A. Able to be drawn out into wires
   B. Shiny or a high level of light reflection
   C. Able to be beaten or bent into different shapes
   D. Melts at a very high temperature

Evaluate and create

6. While all metals have similar characteristics, there are also differences between them. List three ways in which metals can differ from one another.
7. Silicon is used in the 'chips' of computer circuits, but it is never used in the connecting wires of electric circuits. Why not?
8. SIS Imagine that you are a scientist who has discovered what appears to be a new element. It is golden in colour and very shiny. What experiments would you do to test whether it was a metal or non-metal? What results would you expect to get if it was a metal?
9. SIS Polonium is a metal discovered by Marie Curie. She also discovered another metal. Find out its name and the important role it played in medicine.

Fully worked solutions and sample responses are available in your digital formats.

7.6 Putting elements in order

LEARNING INTENTION

At the end of this subtopic you will be able to explain how the elements are organised in the periodic table into groups and periods.

7.6.1 The periodic table

As more and more elements were being discovered, the early scientists began to find that some of them had things in common.

Because some elements had things in common, scientists decided to organise them into groups. It took a long time and a lot of experimenting to work out the groups. A Russian scientist called Dmitri Mendeleev finally worked out a system for grouping the elements. His system is called the **periodic table** and a modern version is used by scientists today.

The elements in the periodic table are arranged in order of increasing atomic number, beginning with hydrogen. An atom of hydrogen has just one proton in its nucleus. Metals are found on the left and in the centre of the periodic table, and non-metals can be found in the top right-hand side.

DISCUSSION

Why is the periodic table called the periodic table?

EXTENSION ACTIVITY: Mendeleev

Research to find out about the life and work of the Russian scientist Dimitri Mendeleev.

In the periodic table, 'groups' refer to the vertical columns and 'periods' refer to the horizontal periods.

on Resources

Interactivities It's elementary (int-0229)
Metals, non-metals and metalloids (int-3388)

7.6.2 Looking for similarities

A vertical column on the periodic table is called a **group**. Elements in the same group on the periodic table always have some features in common. Sometimes these common features are easy to observe, but some of the similarities are not so obvious. For example, neon and argon are gases that do not change when mixed with other elements except under extreme circumstances. They are said to be **inert**. These two gases are found in the last group of the periodic table along with three other inert gases. The group containing the inert gases is called the **noble gas** group.

periodic table a table listing all known elements. The elements are grouped according to their properties and in order of the number of protons in their nucleus.

group in the periodic table of elements, a single vertical column of elements with a similar nature

inert not reactive

noble gas elements in the last column of the periodic table. They are extremely inert gases.

Alkali metals → Group 1

Alkaline earth metals → Group 2

Key

79	Atomic number
Gold	Name of element
Au	Symbol of element
197.0	Relative atomic mass

Transition metals (Groups 3–9)

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9
Period 1	1 Hydrogen **H** **1.0**								
Period 2	3 Lithium **Li** **6.9**	4 Beryllium **Be** **9.0**							
Period 3	11 Sodium **Na** **23.0**	12 Magnesium **Mg** **24.3**							
Period 4	19 Potassium **K** **39.1**	20 Calcium **Ca** **40.1**	21 Scandium **Sc** **45.0**	22 Titanium **Ti** **47.9**	23 Vanadium **V** **50.9**	24 Chromium **Cr** **52.0**	25 Manganese **Mn** **54.9**	26 Iron **Fe** **55.8**	27 Cobalt **Co** **58.9**
Period 5	37 Rubidium **Rb** **85.5**	38 Strontium **Sr** **87.6**	39 Yttrium **Y** **88.9**	40 Zirconium **Zr** **91.2**	41 Niobium **Nb** **92.9**	42 Molybdenum **Mo** **96.0**	43 Technetium **Tc** **(98)**	44 Ruthenium **Ru** **101.1**	45 Rhodium **Rh** **102.9**
Period 6	55 Caesium **Cs** **132.9**	56 Barium **Ba** **137.3**	57–71 Lanthanides	72 Hafnium **Hf** **178.5**	73 Tantalum **Ta** **180.9**	74 Tungsten **W** **183.8**	75 Rhenium **Re** **186.2**	76 Osmium **Os** **190.2**	77 Iridium **Ir** **192.2**
Period 7	87 Francium **Fr** **(223)**	88 Radium **Ra** **(226)**	89–103 Actinides	104 Rutherfordium **Rf** **(261)**	105 Dubnium **Db** **(262)**	106 Seaborgium **Sg** **(266)**	107 Bohrium **Bh** **(264)**	108 Hassium **Hs** **(267)**	109 Meitnerium **Mt** **(268)**

Lanthanides

57 Lanthanum **La** **138.9**	58 Cerium **Ce** **140.1**	59 Praseodymium **Pr** **140.9**	60 Neodymium **Nd** **144.2**	61 Promethium **Pm** **(145)**	62 Samarium **Sm** **150.4**	63 Europium **Eu** **152.0**

Actinides

89 Actinium **Ac** **(227)**	90 Thorium **Th** **232.0**	91 Protactinium **Pa** **231.0**	92 Uranium **U** **238.0**	93 Neptunium **Np** **(237)**	94 Plutonium **Pu** **(244)**	95 Americium **Am** **(243)**

on Resources

assess on Additional automatically marked question sets

Metals

Non Metals

Metaloids

Halogens → Group 17

Noble gases → Group 18

Group 10	Group 11	Group 12	Group 13	Group 14	Group 15	Group 16	Group 17	Group 18
								2 Helium **He** **4.0**
			5 Boron **B** **10.8**	6 Carbon **C** **12.0**	7 Nitrogen **N** **14.0**	8 Oxygen **O** **16.0**	9 Fluorine **F** **19.0**	10 Neon **Ne** **20.2**
			13 Aluminium **Al** **27.0**	14 Silicon Si 28.1	15 Phosphorus **P** **31.0**	16 Sulfur **S** **32.1**	17 Chlorine **Cl** **35.5**	18 Argon **Ar** **39.9**
28 Nickel **Ni** **58.7**	29 Copper **Cu** **63.5**	30 Zinc **Zn** **65.4**	31 Gallium **Ga** **69.7**	32 Germanium **Ge** **72.6**	33 Arsenic **As** **74.9**	34 Selenium **Se** **79.0**	35 Bromine **Br** **79.9**	36 Krypton **Kr** **83.8**
46 Palladium **Pd** **106.4**	47 Silver **Ag** **107.9**	48 Cadmium **Cd** **112.4**	49 Indium **In** **114.8**	50 Tin **Sn** **118.7**	51 Antimony **Sb** **121.8**	52 Tellurium **Te** **127.6**	53 Iodine **I** **126.9**	54 Xenon **Xe** **131.3**
78 Platinum **Pt** **195.1**	79 Gold **Au** **197.0**	80 Mercury **Hg** **200.6**	81 Thallium **Tl** **204.4**	82 Lead **Pb** **207.2**	83 Bismuth **Bi** **209.0**	84 Polonium **Po** **(210)**	85 Astatine **At** **(210)**	86 Radon **Rn** **(222)**
110 Darmstadtium **Ds** **(271)**	111 Roentgenium **Rg** **(272)**	112 Copernicium **Cn** **(285)**	113 Nihonium **Nh** **(280)**	114 Flerovium **Fl** **(289)**	115 Moscovium **Mc** **(289)**	116 Livermorium **Lv** **(292)**	117 Tennessine Ts **(294)**	118 Oganesson **Og** **(294)**

64 Gadolinium **Gd** **157.3**	65 Terbium **Tb** **158.9**	66 Dysprosium **Dy** **162.5**	67 Holmium **Ho** **164.93**	68 Erbium **Er** **167.26**	69 Thulium **Tm** **168.93**	70 Ytterbium **Yb** **173.04**	71 Lutetium **Lu** **174.97**
96 Curium **Cm** **(247)**	97 Berkelium **Bk** **(247)**	98 Californium **Cf** **(251)**	99 Einsteinium **Es** **(252)**	100 Fermium **Fm** **(257)**	101 Mendelevium **Md** **(258)**	102 Nobelium **No** **(259)**	103 Lawrencium **Lr** **(262)**

7.6 Exercise

learnon

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Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 4	Questions 2, 5	Questions 3, 6, 7

Remember and understand

1. Complete the table by stating the symbols for the following elements:

Elements	Symbol
a. Hydrogen	
b. Carbon	
c. Oxygen	
d. Nitrogen	
e. Iron	
f. Tin	
g. Calcium	
h. Sulfur	
i. Copper	
j. Krypton	

2. Review a copy of the periodic table.
   a. Write in it the symbols of the elements that you have already come across in this chapter.
   b. Label the groups and periods.
   c. Label the names of groups 1, 2, 17 and 18.
   d. Colour the metals, metalloids and non-metals different colours and include a key.
3. What is similar about all of the gases in the noble gas group of the periodic table?

Apply and analyse

4. State the name, symbol and number of protons for the element with atomic number 74.
5. Refer to the periodic table and using the information provided state the number of protons and electrons that are present in a chlorine atom.
6. Suggest an element that would have similar properties to calcium.

Evaluate and create

7. Make up a 'Guess the element' card game, finding out and using information about the first 18 elements.

Fully worked solutions and sample responses are available in your digital formats.

7.7 Making molecules

LEARNING INTENTION

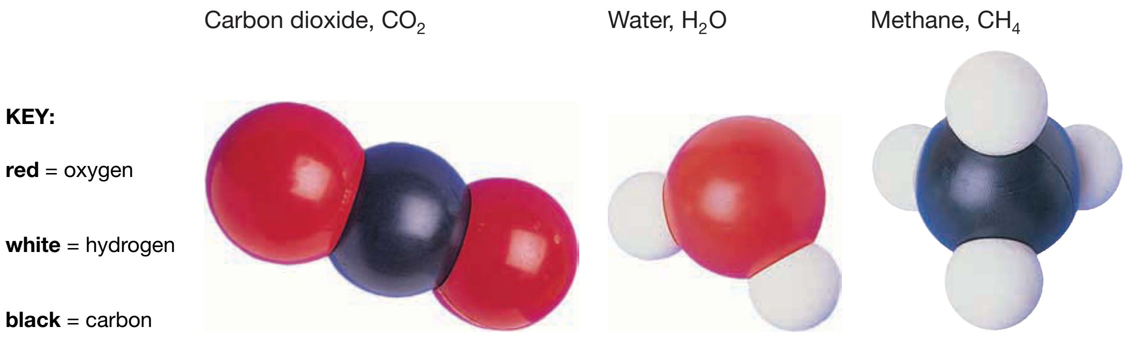
At the end of this subtopic you will be able to create models of elements, compounds and mixtures to visualise how atoms are arranged in them.

7.7.1 Bonding

The naturally occurring elements are the building blocks of everything in our world. The atoms of various elements join together in a wide variety of ways to produce many compounds. Elements and compounds can be combined in many ways to make countless mixtures.

Atoms can join, or bond, in many different ways. In some substances, atoms are joined in groups called molecules. For example, in oxygen gas, oxygen atoms are joined in groups of two. In the compound carbon dioxide, one carbon and two oxygen atoms are joined in every molecule. Atoms can join to form small or large molecules of many different shapes.

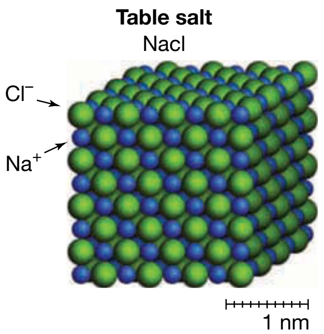
FIGURE 7.15 Models representing the molecules of some compounds



Some compounds are not made up of molecules. Instead the atoms bond by lining up one after the other. Sodium bonds to chlorine, which bonds to sodium and so on. Common table salt is an example of a substance that is bonded in this way.

A molecule consists of two or more atoms chemically joined together.

FIGURE 7.17 The atoms of common table salt bond by lining up after the other



on Resources

Video eLesson Methane (eles-2272)

elog-0135

INVESTIGATION 7.7

Modelling elements, compounds and mixtures

Aim

To make models of elements, compounds and mixtures

Materials

- LEGO® blocks that are all the same size
- Each block represents an atom of the following elements (possible colour key but others are acceptable):
  - White = hydrogen (H)
  - Red = oxygen (O)
  - Black = carbon (C)
  - Blue = nitrogen (N)
  - Green = chlorine (Cl)
  - Yellow = helium (He)

Method

Remember

- Elements contain only one type of atom.
- When two or more atoms are chemically joined (bonded) together they are called molecules. They can be the same or different atoms.
- Mixtures contain different elements and/or compounds but they are not chemically joined.

1. Draw a key showing the colours used for each element.
2. Draw the table shown in the results section to record your results.
3. Keep two of each model that you make.

Elements

4. A single block represents an atom; a LEGO® helium atom is drawn and coloured in the table.
5. Pick up a handful of yellow blocks; this represents the element helium (He), a noble gas.

6. Join two white blocks together (hydrogen atoms are found in pairs); this is a molecule of hydrogen.
7. Make a few more hydrogen molecules; these represent the element hydrogen (H_2).
8. Oxygen gas also contains atoms that are found in pairs. Make and draw an oxygen molecule (O_2).

Compounds

9. Take a black and a red block and join them together; this is a molecule of carbon monoxide. Draw this molecule in the table.
10. Make a few more carbon monoxide molecules. These represent the compound carbon monoxide.
11. Make a water molecule, H_2O. Draw it in the table. You can place the elements in any order until you learn more about molecules in later years.
12. Make a hydrogen chloride molecule, HCl. Draw it in the table.
13. Now make the following molecules and draw them in the table: CO_2, NO_2, NH_3

Extension

Make the following molecules:

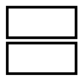
- dinitrogen monoxide (laughing gas N_2O)
- methane (natural gas, CH_4)
- benzene (in petrol, C_6H_6)

Mixtures

14. Collect the models of elements that you made but DO NOT join them together. This is a mixture of elements. A mixture of elements is shown in the table.
15. Collect the models of compounds that you made but DO NOT join them together. This is a mixture of compounds. Draw it in the table.
16. Collect a few of the models of any of the atoms or molecules that you have made but DO NOT join them together. This is a mixture. Draw it in the table.

Results

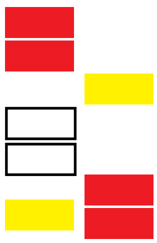
Elements

He helium atom		H_2 hydrogen molecule		O_2 oxygen molecule	

Compounds

CO carbon monoxide		H_2O water		HCl hydrogen chloride	
CO_2 carbon dioxide		NO_2		NH_3 ammonia	

Mixtures

Mixture of elements		Mixture of compounds		Mixture	

Discussion

1. Nitrogen gas is also made up of atoms in pairs.
   a. What would the formula for nitrogen gas be?
   b. What would the LEGO® model of a nitrogen molecule look like?

2. a. Name the molecule with the formula NO_2
   b. How many atoms are present in this molecule?
   c. How many elements are present in this molecule?
3. Dihydrogen monoxide is the chemical name of a familiar substance. What is it?
4. Hydrogen peroxide (found in hair bleach) contains two oxygen atoms and two hydrogen atoms. What would a LEGO® molecule of hydrogen peroxide look like?
5. How would you explain elements, compounds and mixtures to a friend using fruit as examples?

Conclusion

1. What do these models show about molecules?
2. How do these models of molecules compare with those in section 7.7.1?

7.7.2 Compounds of today and tomorrow

Polymer is the name given to a compound made of molecules that are long chains of atoms. Most polymers are made up of chains containing carbon atoms. **Plastics** are synthetic polymers, whereas cotton and rubber are examples of natural polymers. Although scientists first developed polymers in laboratories in the 1800s, it was not until after World War II that most modern polymers were invented. Modern polymers are used in food wrapping, paint, plastic 'glass', polystyrene foam for packaging and cups, banknotes cases for electronic appliances such as computers and televisions, clothing, glues, shopping bags, sports equipment and even tea bags!

polymer substance made by joining smaller identical units. All plastics are polymers.

plastic synthetic substance capable of being moulded

WHAT DOES IT MEAN?

The word polymer comes from the Greek word *polymeres*, meaning 'of many parts'.

CASE STUDY: Elements nitrogen and gold

- Nitrogen is an element. It is a clear, colourless gas made up of molecules. Each molecule is made up of a pair of atoms. Nitrogen makes up 80 per cent of the atmosphere, which means that four-fifths of each breath you take is nitrogen. Our bodies cannot use this nitrogen so we breathe it straight out again! The gases oxygen, hydrogen and chlorine also exist as molecules made up of pairs of atoms.
- Gold is the only metal element found in large amounts in its pure form, rather than bonded in compounds with other elements.

DISCUSSION

What are the advantages and disadvantages of the use of plastics in current society?

EXTENSION ACTIVITY: Nanomaterials

Why are very tiny particles called nanomaterials? Find out what they are and where they might be used.

on Resources

Interactivity Making molecules (int-0228)

eWorkbook The periodic table — atomic structure (ewbk-3104)

assess on Additional automatically marked question sets

7.7 Exercise

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Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2	Questions 3, 4	Questions 5, 6

Remember and understand

1. a. Define the term molecule.
   b. Name two elements made of molecules.
   c. Name two compounds that are made up of molecules.
2. a. What are polymers?
   b. What is the difference between a natural polymer and a synthetic polymer? State two examples of natural polymers and two examples of synthetic polymers.
3. Are all compounds made up of molecules? Explain.

Apply and analyse

4. Complete the table provided. Use the formula of each compound to work out how many elements are present and which ones they are. (The formula of a compound not only tells you which elements are present, but also indicates the ratio of atoms of the different elements. For example, in the compound NH_3 there are three hydrogen atoms for each nitrogen atom.)

TABLE Composition of different compounds

Compound	Formula	Number of elements	Names of elements
Copper sulfate	$CuSO_4$	3	Copper, sulfur, oxygen
Zinc sulfide	ZnS		
Ammonia	NH_3		
Sulfuric acid	H_2SO_4		
Hydrochloric acid	HCl		
Table salt	NaCl		

Evaluate and create

5. What is the difference between an atom and a molecule?
6. SIS Australia has led the way in the production of polymer banknotes. Find out what you can about how these notes are made.

Fully worked solutions and sample responses are available in your digital formats.

7.8 Carbon — It's everywhere

LEARNING INTENTION

At the end of this subtopic you will recognise that carbon has a number of forms and is an important element found in compounds present in all organisms.

7.8.1 That's carbon?

Carbon is a most amazing element. It is found naturally in three different forms. One form is diamond, another is graphite (the 'lead' in lead pencils), and the third is called amorphous carbon (coal, charcoal and soot). Diamond is the hardest substance known and is used to make drill tips and cutting tools. The three forms are different from each other because the carbon atoms are joined in different ways.

Carbon is found combined with other elements in a huge range of compounds. No other element forms as many different types of compounds as carbon. Carbon is found in everything from the skin of an elephant to paint on the walls!

7.8.2 The chemistry of life

All living things are made up of compounds including proteins, fats and carbohydrates. The main element in these compounds is carbon. Carbon is not found only in living things, but also in the air in carbon dioxide and under the sea in limestone. The carbon atoms in carbon dioxide were once carbon atoms in living things. The carbon atoms in living things will eventually become carbon atoms in the air or carbon atoms in limestone under the sea. Figure 7.17 shows how nature constantly recycles carbon atoms.

Plants take in carbon dioxide through their leaves and, in a process known as **photosynthesis**, use the carbon dioxide and water to make sugar. Sugar is a compound made up of carbon, hydrogen and oxygen atoms. Plants use the sugar to make other substances and for energy to grow. Animals eat plants or plant-eating animals. The carbon atoms then become part of the animals' bodies.

Carbon atoms in the bodies of living things return to the air in several ways: **respiration**, **decomposition** and **burning**.

- Respiration is a process that occurs in the cells of every living thing, from a microscopic water plant to a humpback whale. Respiration releases energy and produces carbon dioxide. The carbon dioxide released by the cells in your body is taken by your blood to your lungs. The carbon dioxide that you breathe out contains carbon atoms that were once part of your body.
- Decomposition is what happens when plant or animal material breaks down, such as in a compost heap or after something is buried. Microscopic living creatures called decomposers absorb some of the substances in the dead material and release carbon dioxide to the air by respiration.
- When substances containing carbon are burned, carbon dioxide is released. Coal, natural gas and oil are all **fuels** formed from living things, and contain carbon atoms. Fuels undergo **combustion** reactions. Combustion can be described as a reaction in which a substance reacts with oxygen gas releasing energy, often described as burning. When these fuels are burned in homes, cars, factories and power stations, carbon dioxide is released into the air. Bushfires also release carbon dioxide back to the air.

photosynthesis a series of chemical reactions that occur within chloroplasts in which the light energy is converted into chemical energy. The process also requires carbon dioxide and water, and produces oxygen, water and sugars — which the plant can use as 'food'.

respiration the chemical process that takes place in every cell to release energy. Glucose reacts with oxygen to produce carbon dioxide and water.

decomposition breaking up of a substance into smaller parts

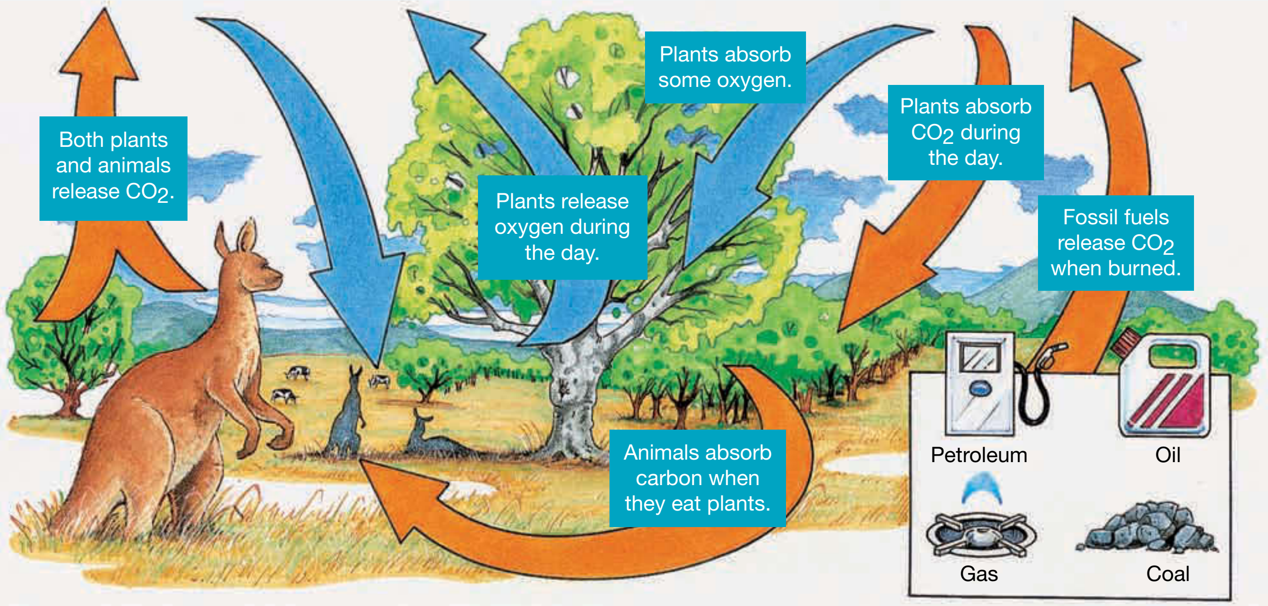
burning combining a substance with oxygen in a flame

fuels substances, such as coal, oil and natural gas, that are often used as fuels; that is, they are burnt in order to produce heat

combustion the process of combining with oxygen, most commonly burning with a flame

Carbon is found in a huge range of compounds.

FIGURE 7.17 This diagram shows how nature constantly recycles carbon atoms.



DISCUSSION

How are photosynthesis and respiration linked?

EXTENSION ACTIVITY: Carbon dioxide levels

Find out why the amount of carbon dioxide in the atmosphere is increasing.

Make fives slides summarising your findings.

elog-0136

INVESTIGATION 7.8

Carbon and its compounds

Note: Limewater becomes cloudy when carbon dioxide is added.

Aim

To investigate carbon and carbon compounds

Materials

- paper straw
- spatula
- 100 mL beaker
- 2 test tubes
- test-tube holder
- test tube with holed stopper (glass tube with rubber tubing attached)
- limewater (calcium hydroxide solution)
- sodium carbonate
- 1M hydrochloric acid
- Bunsen burner
- ‘lead’ pencil sharpened at both ends
- battery or power pack
- wires with alligator clips
- light globe

Method

Test 1

1. Half fill a 100 mL beaker with limewater. Using the straw, blow into the limewater and then discard the straw. Record your observations.

Test 2

2. a. Half fill test tube A with limewater.
   b. Place half a spatula of sodium carbonate in test tube B and quarter fill this test tube with hydrochloric acid.
   c. Place the holed-stopper (glass tube with rubber tubing attached) on test tube B and put the open end of the rubber tubing in the limewater in test tube A.
   d. Record your observations.

Test 3

3. a. Connect the Bunsen burner to the gas tap, close the air hole.
   b. Light the Bunsen burner.
   c. Hold an empty test tube over the yellow flame for a minute.
   d. Open the air hole.
   e. Hold the test tube over the blue flame for a minute.
   f. Record your observations.

Test 4

4. Use the conductivity kit to test the conductivity of the 'lead' pencil.

Results

Copy the table to record your observations of these tests.

TABLE Results of investigation 7.8

Test	Observation

Discussion

1. In test 1 was there evidence of carbon dioxide when you blew into the limewater? Where did it come from?
2. a. In test 2 was there evidence of carbon dioxide?
   b. Did it come from the hydrochloric acid or the sodium carbonate?
   c. The formula for sodium carbonate is Na_2CO_3. Name the elements present in sodium carbonate.
3. If the air hole is closed on the Bunsen burner then the methane gas is converted to carbon, which is black and is deposited on the outside of the test tube.
   a. The formula for methane is CH_4. What elements are present in methane?
   b. How many atoms are present in a molecule of methane?
   c. When the air hole is open, more oxygen is available to react and carbon dioxide is produced instead of the black carbon. What is the formula for carbon dioxide?
   d. When should an orange flame be used? Explain why.
   e. When should a blue flame be used? Explain why.
   f. Describe an experiment to test which flame is hotter: an orange flame or a blue flame.
4. Carbon is a non-metal. Why was the result of test 4 unusual?

Conclusion

Name the carbon compounds, with their formulas, examined in this investigation and describe what you found about the properties of each of them.

on Resources

assesson Additional automatically marked question sets

7.8 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3, 6, 7	Questions 4, 8, 9	Questions 5, 10, 11

Remember and understand

1. a. State the number of protons, neutrons and electrons in an atom of carbon.
   b. State the group and period where carbon is found on the periodic table.
   c. Is carbon a metal or non-metal?
2. List and describe the three different forms of the element carbon.
3. MC How do plants get the carbon that they need to make sugar?
   A. Hydrogen gas from the air
   B. Carbon dioxide in the air
   C. Carbon in the soil
   D. From other plants
4. Describe three ways in which carbon can return to the atmosphere.
5. What is respiration and where does it take place?
6. MC Some fabrics are more combustible than others. What does this mean?
   A. They are more easily stretched.
   B. They retain their shape once stretched.
   C. They are more easily ignited.
   D. They are easier to tear.

Apply and analyse

7. How do animals obtain carbon?
8. Where does the carbon come from to form limestone at the bottom of the sea?

Carbon occurs in many forms in the oceans.

Evaluate and create

9. The amount of carbon dioxide in the Earth's atmosphere is increasing. Why is this happening?
10. SIS Many different materials are used to provide heating. The table provided shows how much carbon is in some of them. The last column indicates how much heat energy (in MJ) 1 kg of each material typically provides.
    a. Draw a bar graph showing the percentage of carbon content in each material.
    b. Which is the best material for heating?
    c. Does the table indicate any relationship between the amount of carbon in a material and the amount of heat that it provides? Explain your answer clearly.

TABLE Carbon content and heat production of different heating materials

Material	Carbon content (%)	Heat production (MJ)
Wood	11	17.9
Brown coal	73	29.5
Black coal	80	35.9
Natural graphite	90	39

11. SIS Fuels can be solids, liquids or gases. Search the internet or use a library to find as many examples as possible of solid, liquid and gas fuels, and complete a table like the one provided.

TABLE Comparison of fuels in different states

	State		
	Solid	Liquid	Gas
Examples			
Uses			
Advantages			
Disadvantages			

Fully worked solutions and sample responses are available in your digital formats.

7.9 Thinking tools — Affinity diagrams

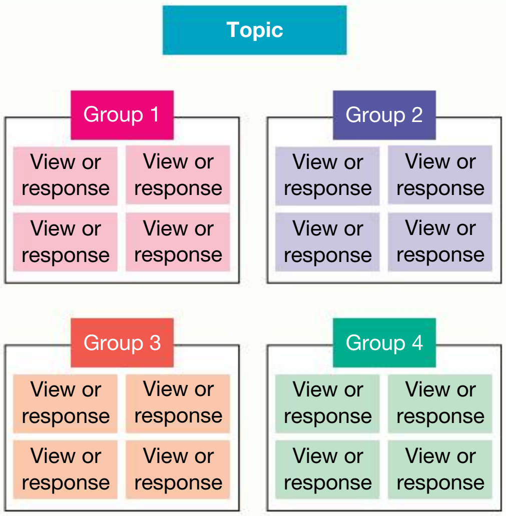
7.9.1 Tell me

What is an affinity diagram?

An affinity diagram is a useful thinking tool that allows you to become aware of both your and others' feelings and thoughts about issues. They can assist you to show what you understand about a particular topic. They graphically demonstrate the hierarchical structure of concepts related to a topic, and they also explain the links or relationships between the concepts and subtopics.

They are sometimes called 'JK method', named after its developer Jiro Kawakita.

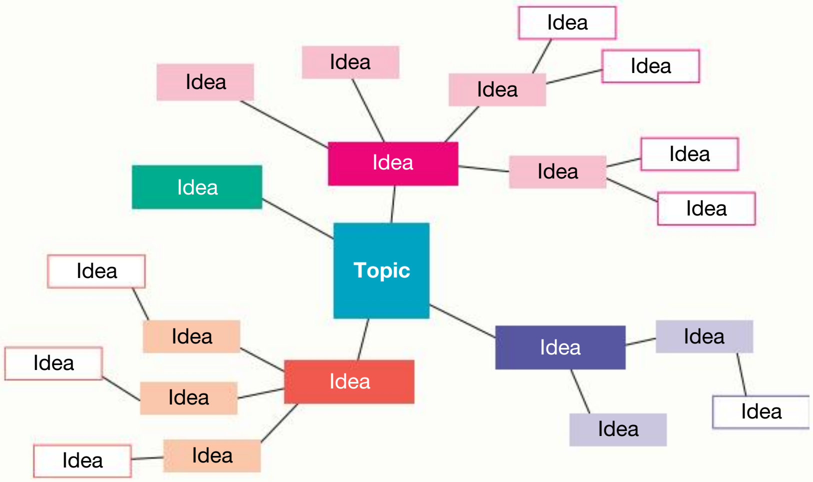
FIGURE 7.18 Affinity diagram



Comparing affinity diagrams to cluster maps

Both infinity diagrams and cluster maps organise ideas or features into groups. Related features radiate out of a cluster map; however, they are organised into boxes in affinity diagrams.

FIGURE 7.19 Cluster map



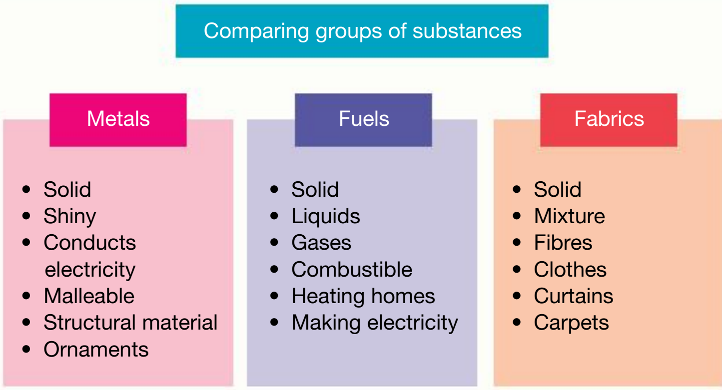
7.9.2 Show me

To create an affinity diagram:

1. Think about a topic and write any ideas you have onto small pieces of paper. You could also use software or apps to create your affinity diagram.
2. Examine your pieces of paper and put similar ideas into groups. Feel free to rearrange your groups until you are happy with them.
3. Think of names for your groups.
4. Now you are ready to draw an affinity diagram like the one shown.

The affinity diagram represents some of our knowledge about the properties and uses of metals, fuels and fabrics.

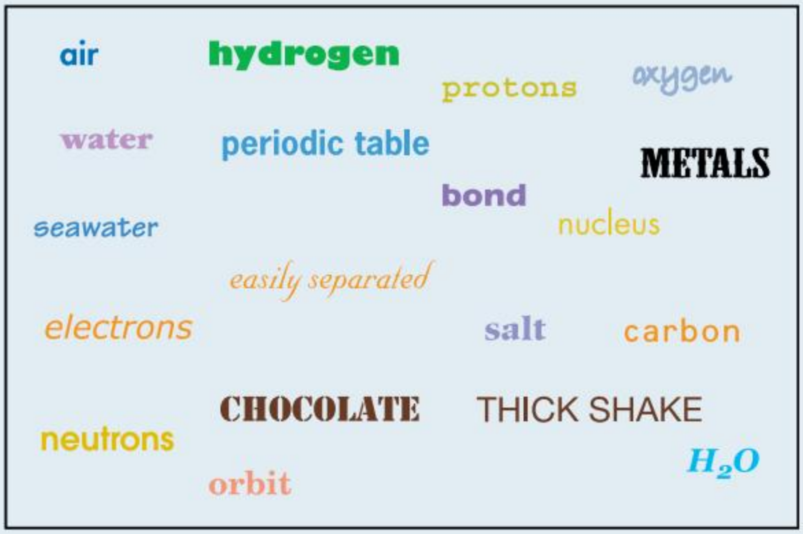
FIGURE 7.20 Affinity diagram comparing properties and uses of metals, fuels and fabrics



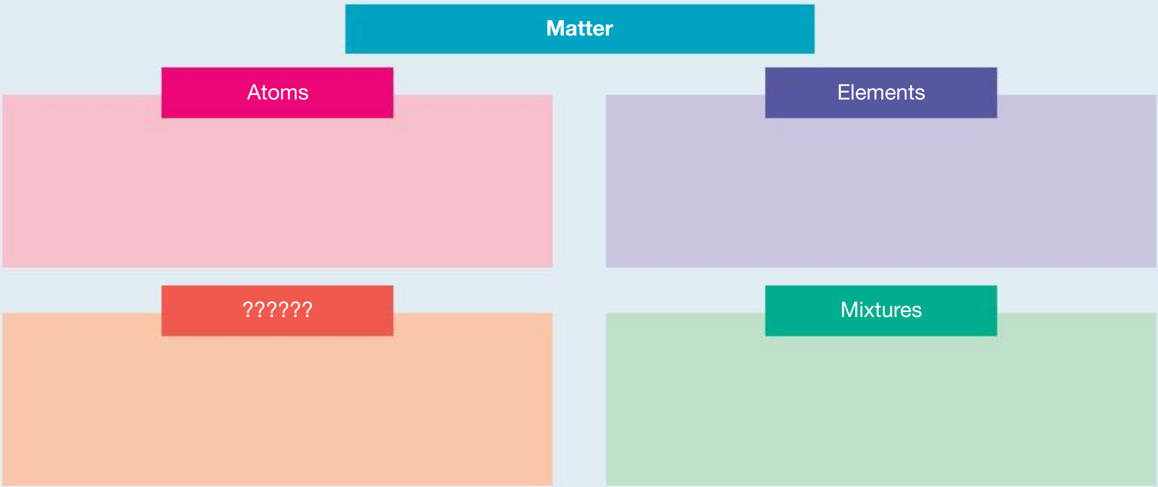
7.9.3 Let me do it

7.9 ACTIVITIES

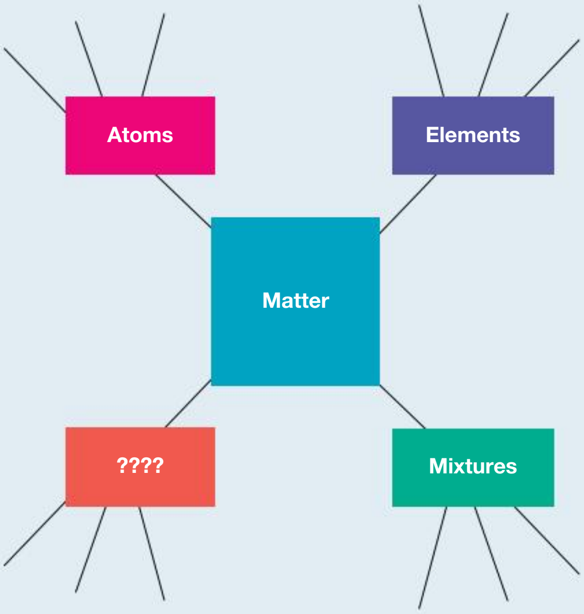
1. a. Write each of the ideas, objects or substances listed here on a small card or sticky note.



b. Arrange the ideas, objects or substances on the cards into four categories in an affinity diagram like the one provided. You will need to work out the name of the missing category.



c. Use the ideas, objects and substances from question a) to create a cluster map using the four categories as the main associations. Add as many associations as you can to the diagram. Don't forget that you can sometimes make links between the different arms of your cluster map.



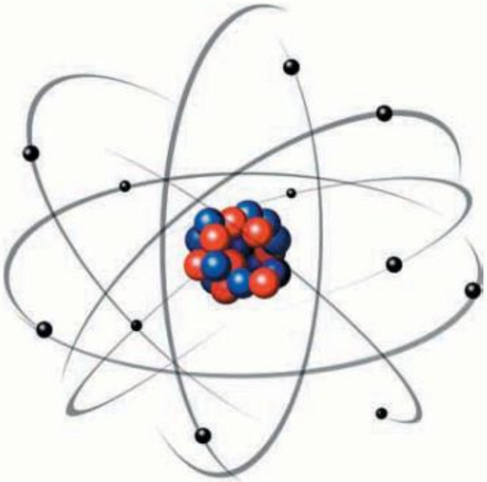
2. About 2500 years ago, when the Greek teacher Democritus suggested that all matter was made of atoms, other Greek thinkers proposed that there were four elements. These elements were earth, air, fire and water. All other substances were combinations of these four elements.
Work in a small group to create a cluster map called 'Elements' using 'Earth', 'Air', 'Fire' and 'Water' as the main associations. Add as many common substances as you can to your map.

Fully worked solutions and sample responses are available in your digital formats.

7.10 Project — *Science TV*

Scenario

In the media world, programs that combine entertainment and education are known as 'edutainment'. With the success of edutainment programs such as *Mythbusters* (SBS/7Mate), *Scope* (Network 10) and *The ExperiMentals* (ABC), it seems that science is attracting a bigger share of the television market than many network executives would have expected. Now, your local TV network — Channel 55 — has decided to jump on the 'science as edutainment' bandwagon and has announced that next year it will develop a program called *Science TV*.



To make *Science TV* more appealing to a younger audience, the developing executives of the program want it to be presented by a team of school students, who will do all of the introductions, explanations and experiments for each of the segments. It is important that the right team of students is found or the program will be canned after only a few episodes, so Channel 55 has announced that it is accepting online audition files from groups of students who think they have what it takes to be the *Science TV* stars.

Your task

Your group is going to put together a video submission that you could send to the Channel 55 developers to showcase how suitable you would be as the stars of *Science TV*.

The guidelines for the video submission from the Channel 55 website are as follows:

- The video must be between four and five minutes in length.
- The target audience of *Science TV* is between 8 and 14 years old.
- At least two people must be shown on camera.
- The video must be in the form of a chemistry segment that explains ONE of the following:
  - **A.** The big mix up: What are elements, compounds and mixtures?
  - **B.** Setting the periodic table: Why is the periodic table important?
  - **C.** Famous molecules: small and/or large.
  - **D.** Concerning carbon: How is carbon important to our lives?
- At least one experiment must be performed in the segment — the experiment must be relevant to the segment and safe to perform (i.e. no explosions and no dangerous fumes produced).

The segment should be engaging and informative. It should have an introduction (either a scenario played out or a discussion between the presenters), an experiment to either test or demonstrate an idea, an explanation of the main concepts involved and a resolution that ties back into the original scenario or discussion. Remember, the main idea is to show that science is FUN!

on Resources

ProjectsPLUS *Science TV* (pro-0090)

7.11 Review

Access your topic review eWorkbooks

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-3120	ewbk-3121	ewbk-3122

on Resources

7.11.1 Summary

Elements and atoms

- There are 92 naturally occurring elements.
- Properties describing elements include colour, texture, state at approximately 25 °C (room temperature), crystalline, lustrous, surface.
- Elements have a chemical symbol, which may be the first letter or letters of their name (e.g. C, S, N) but may also be from a Greek or Latin name (e.g. Na, K, Pb).
- Elements are usually found combined with other elements.
- Some elements are dangerous (e.g. sodium is very reactive and mercury is poisonous).
- An element is a substance made of one type of atom.
- An atom contains a nucleus, which contains protons and neutrons, and electrons move around the outside of the nucleus.
- Protons and neutrons are similar in size; electrons are much smaller.
- Protons have a positive charge, neutrons have no charge and electrons are negatively charged.
- Each chemical element is identified with a unique atomic number, which is equal to the number of protons in its nucleus.
- Elements are arranged in the periodic table in order of increasing atomic number. Elements with similar properties are arranged in vertical groups and elements are arranged in horizontal periods according to the number of electron shells in their atoms.
- Most of the elements are metals and found on the left and in the centre of the periodic table; they are separated from the non-metals by the metalloids.

Compounds and mixtures

- A compound is a substance made up of two or more different types of atoms that have been joined (bonded) together.
- The atoms in compounds are bonded very tightly together and can be separated from compounds only through a chemical reaction.
- Elements can be separated from a compound by different means including passing electricity through the compound, burning the compound or reacting the compound with other substances.
- Compounds have a huge variety of uses.
- In compounds there is a definite amount of each element present. In water, for example, there are twice as many hydrogen atoms as oxygen atoms. In mixtures, however, the amounts of each element is variable so it is not possible to write a chemical formula for mixtures.
- The properties of compounds are different from the properties of the elements that make them up.
- A mixture is a combination of substances that keep their own properties. The substances are relatively easy to separate from a mixture because of their different properties.
- Atoms can be joined (bonded) in groups called molecules, for example: water, H_2O, and carbon dioxide, CO_2. The formula shows the ratio of the atoms of each element present in the molecule.

Science as a human endeavour

- The ideas about elements and the atom have changed over time.
- Alchemists were early scientists who tried to manipulate matter, but it wasn't until about the seventeenth century that the development of the scientific method resulted in many important discoveries.

- Democritus, about 2500 years ago, proposed the existence of atoms but these ideas were not developed until Dalton in 1803 expanded on them. Rutherford proposed the idea of the nuclear atom and J.J. Thomson experimented with electrons, which he suggested existed in shells moving around the nucleus.
- New scientific discoveries and technology have impacted on our understanding of the atom, elements and compounds

7.11.2 Key terms

alchemist olden-day 'chemist' who mixed chemicals and tried to change ordinary metals into gold. Alchemists also tried to predict the future.
atomic number number of protons in the nucleus of an atom. The atomic number determines which element an atom is.
atoms very small particles that make up all things. Atoms have the same properties as the objects they make up.
bonded joined by a force that holds particles of matter, such as atoms, together
burning combining a substance with oxygen in a flame
chemical formula shows the ratio of the atoms of each element present in a molecule or compound
chemical symbol the standard way that scientists write the names of the elements, using either a capital letter or a capital followed by a lowercase letter. For example, carbon is C and copper is Cu.
combustion the process of combining with oxygen, most commonly burning with a flame
compound substance made up of two or more different types of atoms that have been joined (bonded) together
decomposition breaking up of a substance into smaller parts
electrons very light, negatively charged particles inside an atom. Electrons move around the central nucleus of an atom.
elements pure substances made up of only one type of atom
fuels substances, such as coal, oil and natural gas, that are often used as fuels; that is, they are burnt in order to produce heat
group in the periodic table of elements, a single vertical column of elements with a similar nature
hydrogen the element with the smallest atom. By itself, it is a colourless gas and combines with other elements to form a large number of substances, including water. It is the most common element in living things.
inert not reactive
investigations activities aimed at finding information
metalloids elements that have the appearance of metals but not all the other properties of metals
metals elements that conduct heat and electricity; shiny solids that can be made into thin wires and sheets that bend easily. Mercury is the only liquid metal.
mixtures a combination of substances in which each keeps its own properties
molecule two or more atoms joined (bonded) together
neutrons tiny, but heavy, particle found in the nucleus of an atom. Neutrons have no electrical charge.
noble gas elements in the last column of the periodic table. They are extremely inert gases.
non-metals elements that do not conduct electricity or heat. They melt and turn into gases easily and are brittle and often coloured.
nucleus (in biology) roundish structure inside a cell that acts as the control centre for the cell; (in chemistry) the central part of an atom, made up of protons and neutrons. Plural = nuclei.
observations information obtained by the use of our senses or measuring instruments
oxygen atom that forms molecules (O_2) of tasteless and colourless gas; it is essential for cellular respiration for most organisms and is a product of photosynthesis
periodic table a table listing all known elements. The elements are grouped according to their properties and in order of the number of protons in their nucleus.
photosynthesis a series of chemical reactions that occur within chloroplasts in which the light energy is converted into chemical energy. The process also requires carbon dioxide and water, and produces oxygen, water and sugars — which the plant can use as 'food'.
plastic synthetic substance capable of being moulded
polymer substance made by joining smaller identical units. All plastics are polymers.
protons tiny, but heavy, positively charged particle found in the nucleus of an atom
respiration the chemical process that takes place in every cell to release energy. Glucose reacts with oxygen to produce carbon dioxide and water.
scientists people skilled in or working in the fields of science; scientists use experiments to find out about the material world around them

on Resources

Digital document	Key terms glossary (doc-34763)
eWorkbooks	Study checklist (ewbk-3119) Literacy builder (ewbk-3111) Crossword (ewbk-3112) Word search (ewbk-3113)
Practical investigation eLogbook	Topic 7 Practical investigation eLogbook (elog-0145)

7.11 Exercise

learnon

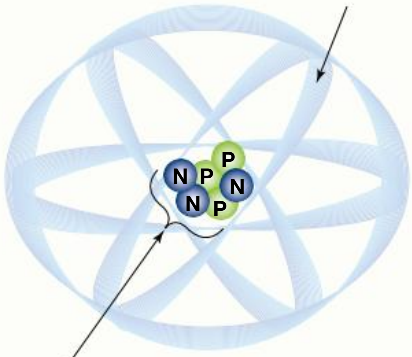
To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3, 6, 7, 8, 10, 15, 20	Questions 4, 5, 11, 12, 14, 17, 21	Questions 9, 13, 16, 18, 19, 22, 23

Remember and understand

1. Which element is shown in the diagram?



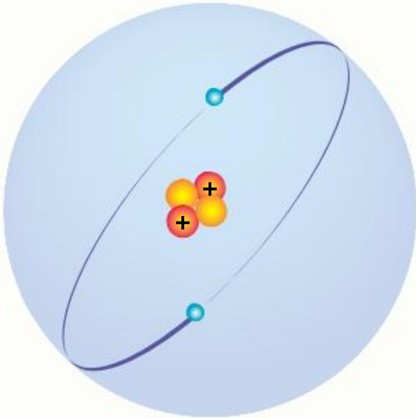
2. Complete the table provided, describing the structure of atoms.

TABLE Features of sub-atomic particles

Part of atom	Location	Size and mass (relative)	Electric charge
		Large	Positive
Neutron			
	Outside the nucleus		

3. If a neutral atom has 12 protons, how many electrons does it have?
4. What takes up most of the space in an atom?

5. MC Identify the one feature that every single atom of the element sodium has in common.
   A. Eleven electrons in the electron orbits
   B. Eleven neutrons in the nucleus
   C. Eleven protons in the nucleus
   D. Eleven protons and eleven electrons
6. What is the atomic number of each of the following elements?
   a. Hydrogen
   b. Oxygen
   c. Carbon
   d. Uranium
7. How many protons does each of the elements listed in question 6 have in its nucleus?
8. How many electrons does each of the elements listed in question 6 have in its nucleus?
9. Make a copy of the diagram of the atom given and label an electron and the nucleus. Answer the following questions.



   a. How many protons does this atom have?
   b. How many neutrons does this atom have?
   c. How many electrons does this atom have?
   d. What is the atomic number of this atom?
   e. Describe one use of the element that is made up of these atoms.
10. Complete the following table to summarise what you know about metals and non-metals.

TABLE Properties of metals and non-metals

	Metals	Non-metals
Conduct electricity well		
Conduct heat well		
Surface features		
State at room temperature		
Malleable		
Ductile		
Brittle		

11. Which of the elements iron, lead, hydrogen, oxygen, silicon, uranium, sodium and zinc are:
   a. metals
   b. metalloids
   c. non-metals?
12. a. Which element is used inside illuminated signs like the one shown?
   b. To which group in the periodic table does this element belong?

13. What event must take place in order to separate a compound into separate elements?

Apply and analyse

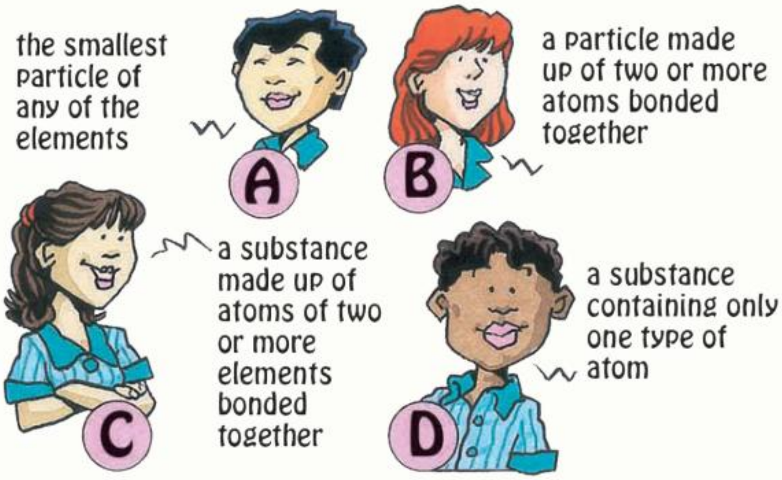
14. MC How are the molecules in polymers different from the molecules of other compounds?
   A. They are very small and consist of repeating sub-units or monomers.
   B. They are very large and consist of repeating sub-units or monomers.
   C. They consist of single elements.
   D. They consist of repeating elements.

15. Complete the table provided to indicate whether the substances listed are elements, compounds or mixtures. Also indicate why you made that decision.

TABLE Classifying substances

Substance	Element, compound or mixture	Why do you think so?
Gold		
Diamond		
Carbon dioxide		
Air		
Seawater		
Pure water		
Iron		
Ammonia		
Table salt (NaCl)		

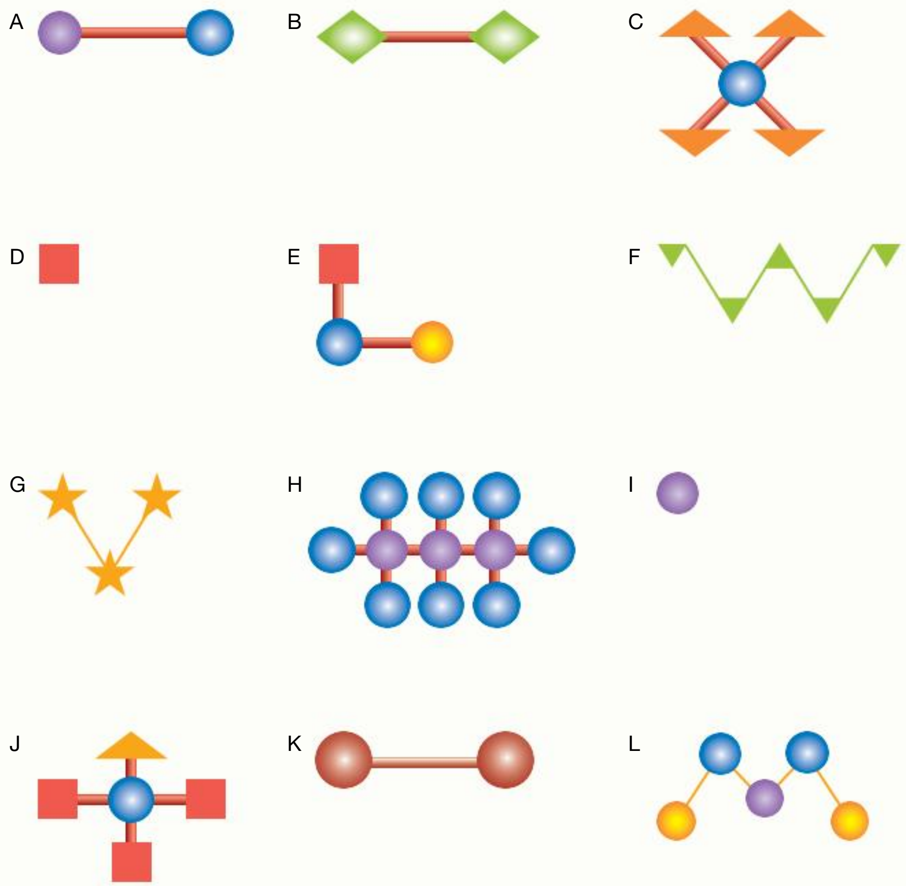
16. **MC** Why doesn't water appear in the periodic table?
 A. Water is a different kind of element.
 B. Water cannot be classified into the groups.
 C. Water is a compound.
 D. Water is naturally occurring.
17. Which of 'the bits that matter' is represented by each of the cartoons shown?



18. What do diamonds, the 'lead' in pencils and coal have in common?
19. Explain why, unlike compounds, mixtures cannot be represented by chemical formulas.
20. About 2500 years ago, Democritus suggested what all substances were made up of. In what way was Democritus' idea about substances the same as the model that scientists currently use to describe substances?
 Suggest why most thinkers of the time disagreed with Democritus.

Evaluate and create

21. Each of these diagrams below represents one of 'the bits that matter' that make up substances.



Which of the diagrams represents:

a. an atom of an element
b. a molecule of an element
c. a molecule of a compound?

22. Most of the substances around you are compounds and mixtures.
    a. What differences could be observed between a mixture of hydrogen and oxygen, and a compound of hydrogen and oxygen?
    b. Explain the difference between a compound and a mixture in your own words.
23. Respiration is a chemical reaction in which carbon dioxide is produced.
    a. Where in your body does respiration take place?
    b. What is released during respiration apart from carbon dioxide?
    c. Suggest how the carbon atoms in carbon dioxide enter your body.

Fully worked solutions and sample responses are available in your digital formats.

on Resources

eWorkbook Reflection (ewbk-3038)

teachon

Test maker

Create customised assessments from our extensive range of questions, including teacher-quarantined questions. Access the assignments section in learnON to begin creating and assigning assessments to students.

RESOURCE SUMMARY

on Resources

Below is a full list of **rich resources** available online for this topic. These resources are designed to bring ideas to life, to promote deep and lasting learning and to support the different learning needs of each individual.

7.1 Overview

eWorkbooks
- Topic 7 eWorkbook (ewbk-3106)
- Student learning matrix (ewbk-3110)
- Starter activity (ewbk-3108)

Practical investigation eLogbooks
- Topic 7 Practical investigation eLogbook (elog-0145)
- Investigation 7.1: How big is an atom? (elog-0129)

Video eLesson
- A 3D view of the structure of DNA (eles-2030)

7.2 It's elementary

eWorkbook
- How big is an atom? (ewbk-3098)

Practical investigation eLogbook
- Investigation 7.2: Checking our appearances of elements (elog-0130)

Video eLesson
- Lavoisier and hydrogen (eles-1772)

7.3 Elements: The inside story

Practical investigation eLogbook
- Investigation 7.3: Getting to know atoms (elog-0131)

Video eLessons
- The hydrogen atom (eles-2269)
- An atom of carbon (eles-2031)

Interactivities
- Democritus and the atom (int-5744)
- Diagram of the atom (int-3387)
- Periodic table (int-0758)

7.4 Compunding the situation

eWorkbook
- Pure substances and mixtures (ewbk-3100)

Practical investigation eLogbooks
- Investigation 7.4: Making a compound from its elements (elog-0132)
- Investigation 7.5: Let's collect an element (elog-0133)

Interactivity
- Hofmann voltameter (int-3389)

7.5 Types of elements

eWorkbook
- Metals and non-metals (ewbk-3102)

Practical investigation eLogbook
- Investigation 7.6: Looking for similarities (elog-0134)

Video eLessons
- Malleability (eles-2033)
- Liquid nitrogen (eles-2271)

7.6 Putting elements in order

Interactivities
- It's elementary (int-0229)
- Metals, non-metals and metalloids (int-3388)

7.7 Making molecules

eWorkbook
- The periodic table — atomic structure (ewbk-3104)

Practical investigation eLogbook
- Investigation 7.7: Modelling elements, compounds and mixtures (elog-0135)

Video eLesson
- Methane (eles-2272)

Interactivity
- Making molecules (int-0228)

7.8 Carbon – It's everywhere

Practical investigation eLogbook
- Investigation 7.8: Carbon and its compounds (elog-0136)

7.10 Project – Science *TV*

ProjectsPLUS
- *Science TV* (pro-0090)

7.11 Review

eWorkbooks

- Topic review Level 1 (ewbk-3120)
- Topic review Level 2 (ewbk-3121)
- Topic review Level 3 (ewbk-3122)
- Study checklist (ewbk-3119)
- Literacy builder (ewbk-3111)
- Crossword (ewbk-3112)
- Word search (ewbk-3113)
- Reflection (ewbk-3038)

Practical investigation eLogbook

- Topic 7 Practical investigation eLogbook (elog-0145)

Digital document

- Key terms glossary (doc-34763)

To access these online resources, log on to **www.jacplus.com.au**.

8 Chemical change

LEARNING SEQUENCE

8.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

8.1.1 Introduction

Chemical reactions are happening everywhere. Chemical reactions in your body digest food, decay your teeth and much more. Chemical reactions occur in batteries to provide electricity, in the oven when you bake a cake, in your hair when it is bleached or coloured, and in your car when it burns fuel.

In this topic we will investigate the difference between physical and chemical changes. Consider the image on the opening page of this topic. Iodine crystals are being heated, which produces a purple gas. Do you think this is a chemical change or a physical change? We will also look at different types of chemical reactions, and what can be done to make these reactions occur faster or slower.

FIGURE 8.1 Explosions are very fast chemical reactions.

on Resources

Video eLesson Reaction of magnesium ribbons in acid (eles-2571)

There are many different types of chemical reactions. In this video, a metal (magnesium) reacts with an acid (hydrochloric acid) to form hydrogen gas and a salt. But the speed at which this reaction occurs can be changed. In this video, the concentration of the reacting acid is changed. Which beaker has the more concentrated acid?

8.1.2 Think about chemical reactions

1. Why does a half-eaten apple go brown?
2. How is an explosion different from other chemical reactions?
3. Why does a spoonful of sugar dissolve more quickly than a sugar cube?
4. What makes a nail rust?
5. Why is the Sydney Harbour Bridge continually being painted?
6. What is a backdraught and what causes it?
7. What makes Lycra® so special?
8. Why is recycling so important?

8.1.3 Science inquiry

What is a chemical reaction?

Chemical reactions occur all around us every day. For example, there are thousands of chemical reactions occurring in our body every second, allowing us to breathe, digest and survive.

chemical reaction a chemical change between two or more substances in which one or more new chemical substances are produced

There are many different types of chemical reactions. Some are easy to see, such as colour changes, but others are not easy to detect such as the production of a gas.

There are many signs of chemical reactions, which allow us to know that a change in chemical structure of the elements, compounds and mixtures has occurred. It is important to know the changes in a chemical reaction and how vital chemical reactions are to our lives.

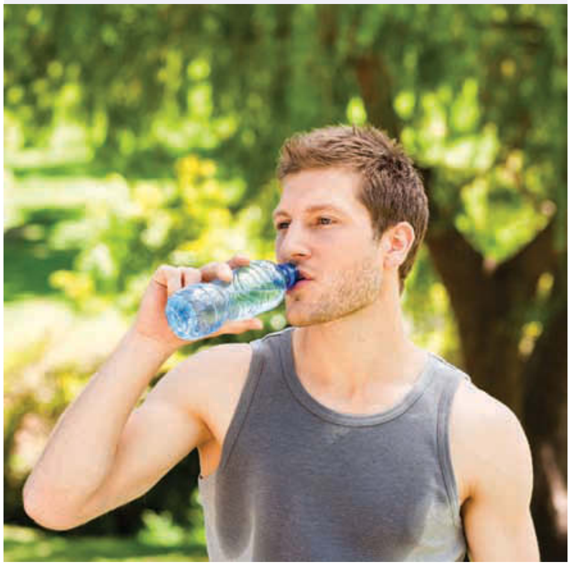
What is a chemical reaction and how do you know whether a chemical reaction has taken place?

Look at figures 8.2 and 8.3. Consider if chemical reactions are taking place in both images.

1. Write down your opinion on whether or not a chemical reaction is taking place.
2. Explain how you know if a chemical reaction has taken place.

FIGURE 8.2 The boiling liquid began as a mixture of reds, yellows and blues. After stirring, it is changing into a dangerous looking green soup.

FIGURE 8.3 Runners in long-distance races sweat heavily. Is the loss of water from skin through sweating a chemical reaction?



elog-0238

INVESTIGATION 8.1

Investigating chemical reactions

Aim

To investigate changes that occur during a chemical reaction

Materials

- Space Rocks (popping candy) or Fruit Tingles
- glow stick
- aspirin tablet
- instant icepack
- plastic cup
- well plate
- bread
- iodine solution
- yeast
- sugar
- conical flask
- water
- balloon

Method

Complete the following tasks and note down your observations.

1. Eat some Space Rocks or Fruit Tingles.
2. Crack a glow stick.
3. Carefully drop an aspirin tablet into a clear cup of water.
4. Hit an instant icepack.
5. Place a small piece of bread in a well plate. Put two drops of iodine solution onto the bread.
6. Combine a packet of yeast, 100 mL of warm water and 2 tablespoons of sugar in a 250 mL conical flask. Place the neck of a balloon over the top of the flask.

Results

TABLE Observations of investigation 8.1

Reaction	Observations
Space Rocks in your mouth	
Cracking a glow stick	
Aspirin in water	
Hitting an icepack	
Placing iodine on bread	
Combining yeast, water and sugar	

Discussion

1. Explain why each of these reactions is classed as a chemical reaction.
2. Name three signs that a chemical reaction has occurred.
3. Melting an ice cube is classed as a physical change instead of a chemical change. Explain why you think this might be the case.
4. Name three other examples of chemical reactions that you can think of.

Conclusion

Write a conclusion for this investigation. Your conclusion should state what you discovered about chemical reactions from this investigation.

on Resources

eWorkbooks Topic 8 eWorkbook (ewbk-3467)
Student learning matrix (ewbk-3477)
Starter activity (ewbk-3469)

Practical investigation eLogbook Topic 8 Practical investigation eLogbook (elog-0252)

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8.2 Physical and chemical properties

LEARNING INTENTION

At the end of this subtopic you will be able to identify the difference between the chemical and physical properties of various substances.

8.2.1 Physical or chemical properties

Thousands and thousands of different substances are used in the objects that surround you. Each substance shown in figure 8.5 has physical and chemical properties that make it useful for a particular purpose.

The properties of most substances fall into two categories — physical or chemical.

ductile capable of being drawn into wires or threads; a property of most metals

malleable able to be beaten, bent or flattened into shape

elasticity the property that allows a material to return to it original size after being stretched

FIGURE 8.4 Matter has both physical and chemical properties.

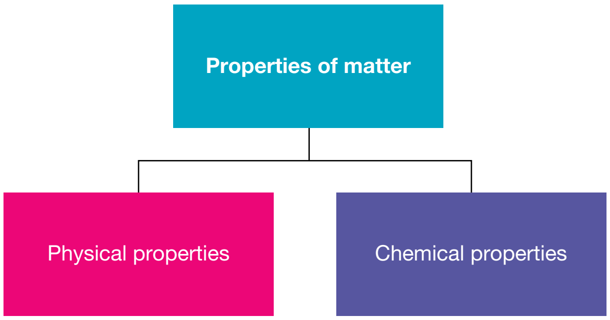

FIGURE 8.5 The objects around you are made of different substances, which make those objects useful for a particular purpose. All of the properties shown in the labels for this photo are physical properties.

Physical properties are those that you can either observe using your five senses — seeing, hearing, touching, smelling and tasting — or measure directly. Examples include colour, size, shape, texture, temperature, malleability and ductility, but there are many, many more. **Chemical properties** are those that describe how a substance combines with other substances to form new chemicals or how a substance breaks up into two or more different substances. Examples of chemical properties include **flammability**, **reactivity** and **toxicity**.

- Flammability is how easily a substance catches fire. When a substance burns, it creates new substances.
- Reactivity is how easily a substance combines with other substances to produce new substances.
- Toxicity refers to the damage caused to an organism when poisonous substances combine with chemicals in your body to produce new substances and damaging effects.

physical properties properties that you can either observe using your five senses — seeing, hearing, touching, smelling and tasting — or measure directly

chemical properties properties that describe how a substance combines with other substances to form new chemicals or how a substance breaks up into two or more different substances

flammability an indicator of how easily a substance catches fire

reactivity a measure of how likely a particular substance reacts to make new substances

toxicity the danger to your health caused when poisonous substances combine with chemicals in your body to produce new substances and damaging effects

CASE STUDY: What are potato chip bags made from?

Potato chips are delicious but to make sure they stay that way, they are packaged in complex packaging made of several layers. The packaging must be strong because it will need to be handled, but also easy enough to open. The inner layer next to the potato chips is usually a polymer, polypropylene, which locks oil in but also keeps moisture and gases, which can spoil the chips, out. Next is a layer of low-density polyethylene (LDPE), another polymer, which gives some strength. This is then coated with another layer of polypropylene. Finally, on the outside, is a layer of thermoplastic resin that can be printed and coloured.

Some manufactures are experimenting with compostable packaging that has a layer of polyactic acid polymer; but there is one drawback — these packages are much nosier to open than LDPE packaging. You would notice the difference in sound in a quiet movie theatre!

FIGURE 8.6 Why are potato chip bags pumped full of air? Why is foil often used for the packaging? Could a different material be used?

elog-0239

INVESTIGATION 8.2

Describing properties

Aim

To describe the physical properties of a variety of substances

Materials

a range of small items that might include a tennis ball, a table-tennis ball, a table-tennis paddle, a dishwashing sponge, assorted fabrics (e.g. wool from a jumper, nylon socks and stockings, polyester, cotton), a magnifying glass or lens, a roll of sticky tape, a candle, paper clips, small springs, polystyrene cups, foam rubber, aluminium foil, a clear plastic bottle of dishwashing detergent, a bottle of perfume

Method

Work in groups of three or four so that you can discuss the properties. Work on one item at a time.

Results

1. For each item, list all its physical properties that you can think of. Some items will consist of more than one substance. In those instances, list the physical properties of each substance.
2. For each physical property of each substance in the item, explain how that property makes the substance useful for its purpose.

Discussion

List tests that you could perform to discover some of the chemical properties of the substances in some of the items.

Conclusion

Write a conclusion for this investigation. Your conclusion should state what you discovered about physical properties of substances.

on Resources

eWorkbook Properties of materials (ewbk-3434)

assess on Additional automatically marked question sets

8.2 Exercise

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LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3, 4, 8	Questions 5, 7	Questions 6, 9, 10

Remember and understand

1. Recall information about physical properties to complete the following sentences.
   a. Most metals can be described as ductile and malleable. Being ductile means that a metal is able to be ______________.
   b. Being malleable means that a metal is able to be ______________.

2. Recall the two categories of properties that can be directly observed with your five senses.
3. MC Some substances have the chemical property of toxicity. This means that:
   A. there is a danger to your health when the substance combines with chemicals in your body to produce new substances and have damaging effects.
   B. there is a danger to your health when the substance combines with chemicals in your body to cause fire.
   C. the substance is very reactive and can cause fire.
   D. the substance is explosive.
4. List the properties of potato chip packaging. Compare these properties to the plastic packaging used for bags of lollies. Explain why plastic is used for lollies.
5. Identify from the following options two physical properties that you can describe using your sense of touch.
   a. Texture b. Density c. Colour d. Solubility
6. Flammability, reactivity and toxicity are three examples of chemical properties. Can you think of another one? Explain that chemical property using an example.

Apply and analyse

7. SIS Identify the properties of leather that makes a soccer ball easy to grip. How would you test which has better grip: a leather ball or a synthetic leather (PVC) ball? Describe a test you could perform.
8. SIS Complete the table listing the properties of the materials that make them suitable for their purpose.

TABLE Properties of different materials that are suitable for their purpose

	Malleable	Ductile	Able to be coated	Flexible	Adhesive	Able to be cut
Paperclip						
Sticky tape						
Aluminium foil						

9. Imagine that you are designing a spacecraft that will take astronauts to the moon and back. List the properties that the outer surface of the spacecraft would need to have. Include at least two chemical properties.

Evaluate and create

10. SIS Road bike frames for serious and competitive cyclists are made from aluminium or carbon fibre, or a combination of both. Find out:
    a. what properties both aluminium and carbon fibre have that make them suitable for the frames of road racing bikes. Create a table to summarise your findings.
    b. which properties make aluminium bikes more suitable than carbon fibre bikes for some purposes. (Note that cost is not a property!)

Fully worked solutions and sample responses are available in your digital formats.

8.3 Chemical and physical changes

LEARNING INTENTION

At the end of this subtopic you will be able to identify the difference between chemical and physical changes and how these can be described using word equations.

8.3.1 Chemical changes

When you hard-boil an egg, a **chemical change** takes place. At about 100 °C the eggwhite and yolk undergo chemical changes that alter their chemical make-up. Bonds between atoms or molecules are broken or new bonds between these particles are formed. Unlike cooling melted chocolate, which brings about another physical change, cooling the egg will not change it back to its raw state. In fact, most chemical changes are difficult to reverse.

When paper is burnt, it combines with oxygen to form ash and smoke. This is a chemical reaction, because new substances are formed. Burning gas in a Bunsen burner is also a chemical change. The methane gas burns with oxygen in the air to form two new substances: carbon dioxide and water vapour. During this chemical reaction heat is also produced.

FIGURE 8.7 Cooling a boiled egg will not change it back to the raw state.

How does a candle burn?

When you light a piece of solid wax it melts, but does not burn. If solid wax doesn't burn, how does a candle burn? Is it the string wick in the middle of the candle that burns? String will burn, but it doesn't burn like a candle does. How then does a candle burn?

When you light the wick of a candle, the wax at the top of the candle melts. The molten wax is drawn up the wick just as water soaks into a paper towel. As the liquid wax flows up the wick and gets closer to the heat of the flame it **evaporates**. The wax vapour mixes with oxygen in the air and burns.

FIGURE 8.8 The physical and chemical changes that occur when a candle burns

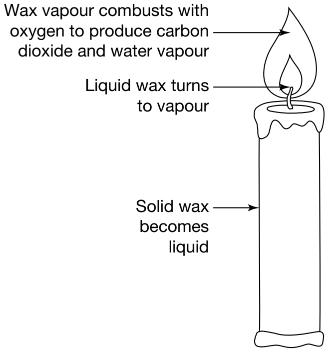
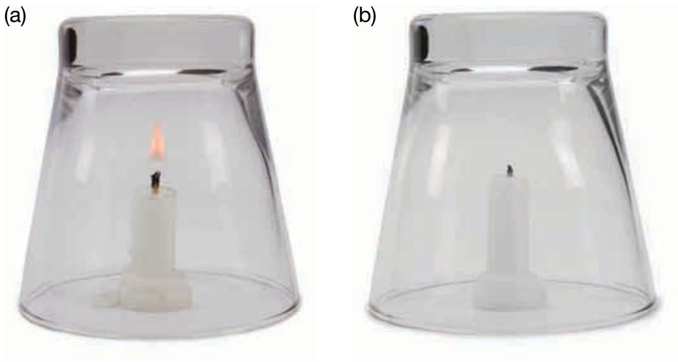


FIGURE 8.9 When a glass is placed over a burning candle **a.** Initially it continues to burn, using up the oxygen in the glass and producing carbon dioxide. **b.** A few seconds later all the oxygen is used and the candle goes out.



chemical change change that results in a new substance being formed. During a chemical change, some chemical bonds break and others form.

evaporates changes state from a liquid to a gas. Evaporation occurs only from the surface of a liquid.

elog-0240

INVESTIGATION 8.3

A burning candle

Aim

To observe and describe the changes that take place when a candle burns

Materials

- safety glasses
- candle
- jar lid
- matches
- heatproof mat

Method

1. Place a jar lid on a heatproof mat.
2. Light a candle and allow a drop of wax to drip onto the lid. Place the candle on the drop of wax and fix it to the lid.

Results

1. Observe the candle and write down as many observations of the burning candle as you can.
2. Discuss your observations with others in your group.
3. Blow out your candle and you will see a white vapour rising from the top of the wick.

CAUTION

Do not smell the vapour directly. Fan the odour to your nose with your hand.

To confirm that the white vapour is not smoke, carry out the following test: Relight the candle. Once it is burning properly, blow it out. Quickly light the top of the vapour trail. The flame should run down the vapour to the wick and relight the candle.

Discussion

1. How far is the flame from the solid wax?
2. The solid wax forms a little pool of liquid wax around the wick. Why does this happen?
3. Describe the odour of the vapour that is present after the candle is blown out.
4. Draw a diagram of a candle and its flame. Label this diagram to explain how a candle burns.
5. Explain why lighting the wax vapour causes the candle to relight.
6. Which of the observations you have made show evidence of chemical changes?

Conclusion

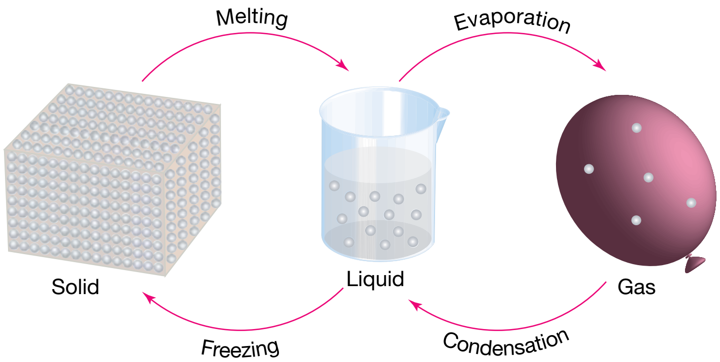
What can you conclude about the types of changes that occur when a candle burns?

8.3.2 Physical changes

If you enjoy eating chocolate you will know that it is not so easy to eat on a hot summer's day. Energy transferred from the hot air surrounding the chocolate causes it to melt. The chocolate changes **state** from solid to liquid. The chocolate's change in state is reversible. The melted chocolate can be cooled and solid chocolate will form again.

state condition or phase of a substance. The three main states of matter are solid, liquid and gas.

FIGURE 8.10 Changes of state are reversible physical changes.



These changes to the chocolate are **physical changes**. Melting, evaporation, condensation and freezing are all physical changes. Changes of state are reversible physical changes.

Changes in the shape or size of a substance are also physical changes. These are not always reversible. For example, if you drop an egg, and it breaks, its shape is changed forever. But when you stretch an elastic band, it can quickly return to its original shape when you let it go.

A physical change does not break any bonds between the atoms of a substance, nor does it create any new bonds. No new substances are formed.

FIGURE 8.11 When water is added to dried copper sulfate, it turns blue. But has a chemical reaction taken place? No reaction has occurred since the solid turns white again when dried.

8.3.3 Word equations

In a burning candle, there are both physical and chemical changes. The melting of the solid wax to form liquid wax and the evaporation of liquid wax to form wax vapour are physical changes. The burning of the wax vapour is a chemical change. The wax vapour reacts with oxygen in the air to form new substances including carbon dioxide and ash.

Using word equations to describe changes

Physical and chemical changes can be described using word equations.

Physical change: Melting chocolate can be described by the equation:

solid chocolate → liquid chocolate

Chemical change: The burning of paper can be described by the equation:

paper + oxygen → smoke + ash

on Resources

eWorkbook Changing states (ewbk-3809)

assess**on** Additional automatically marked question sets

physical changes changes in which no new chemical substances are formed. A physical change may be a change in shape, size or state. Many physical changes are easy to reverse.

8.3 Exercise

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Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 5	Questions 3, 4, 6, 9	Questions 7, 8, 10

Remember and understand

1. MC Identify the statement that describes the difference between a physical and a chemical change.
   A. During a chemical change, no bonds are broken.
   B. During a physical change, bonds are broken.
   C. During a chemical change, bonds are broken.
   D. During a physical change, the reactants do not change.
2. Describe two examples of a physical change.
3. Describe two examples of a chemical change.
4. Match the change of state with the physical change.

Change of state	Physical change
a. Change from solid to liquid	A. Freezing
b. Change from gas to liquid	B. Melting
c. Change from liquid to solid	C. Condensation
d. Change from liquid to gas	D. Evaporation

5. MC Identify which type of physical change can always be reversed by heating or cooling.
   A. Changes of the size of particles
   B. Changes of state
   C. Changes of colour
   D. Changes of shape
6. Complete the following word equations to describe the changes of state that take place when a candle burns.
   a. Solid wax → ______________________
   b. Liquid wax → ______________________
7. MC When you hard-boil an egg, the inside of the egg gets hard. Identify the most appropriate statement that describes the change that has occurred.
   A. It is a physical change as heat has been applied to the egg.
   B. It is a physical change as the egg has changed from mostly liquid to a solid.
   C. It is a chemical change as the reaction cannot be reversed.
   D. It is a chemical change as the egg has changed colour.

Apply and analyse

8. SIS Consider the observations in the table. Complete the table by classifying if the observation is a physical or a chemical change.

Observation	Physical change	Chemical change
Water freezing to form snow		
A cake cooking		
Lighting the gas on the stove		
Petrol evaporating at the petrol pump		
Lighting a match		
Steam condensing on the bathroom mirror		
Melting gold to cast gold bars		

Dynamite exploding		
Bleaching a stain		
Dissolving eggshell in ethanoic acid		

9. SIS Sort the following list so that the first step is at the top to describe the chemical change that takes place when methane burns in a Bunsen burner.
   - Carbon dioxide and water vapour produced
   - Methane enters the burner
   - Methane mixes with air
   - Methane burns in oxygen

Evaluate and create

10. SIS Create a labelled scientific diagram of a burning piece of wood showing both the chemical and physical changes occurring.

Fully worked solutions and sample responses are available in your digital formats.

8.4 Chemical reactions

LEARNING INTENTION

At the end of this subtopic you will be able to recognise that chemical reactions begin with reactants, which are changed into products. You will be able to write word equations for chemical reactions.

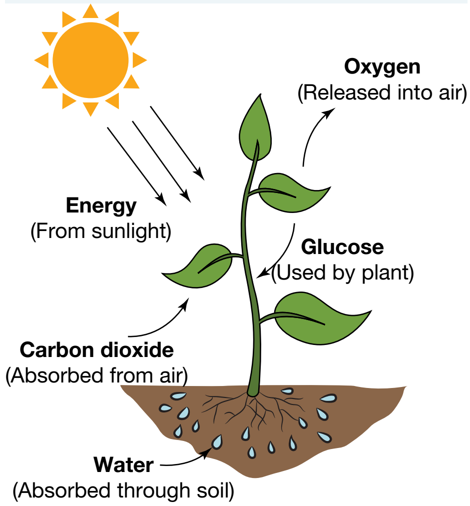
8.4.1 Chemical reaction

A **chemical reaction** is a chemical change in which a completely new substance or substances are produced.

chemical reaction a chemical change between two or more substances in which one or more new chemical substances are produced

Almost all the products you use or wear each day are made by chemical reactions. Examples include cosmetics, concrete, plastics, paper, glass, graphite, stainless steel, shampoo, fibres, food additives, margarine, medicines and many, many more.

FIGURE 8.12 Photosynthesis is the process by which plants convert light energy into chemical energy.



8.4.2 Food and chemical reactions

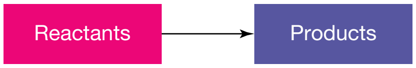
A cheese and lettuce sandwich is an incredible mixture of chemicals. Every part of it has been produced by chemical reactions. The most important chemical reaction in growing the lettuce is photosynthesis, in which the reactants are carbon dioxide and water. The products are glucose (a type of sugar) and oxygen. That chemical reaction cannot take place without light and a chemical called chlorophyll, which gives plants their green colour. In fact, none of the other components of the sandwich could be grown or produced without photosynthesis.

The substance used to make cheese is the product of a chemical reaction in which a protein in cow's milk called casein reacts with ethanoic acid when heated. Ethanoic acid is found in orange and lemon juice and is more commonly known as acetic acid or vinegar.

8.4.3 Reactants and products

The substances that you begin with in a chemical reaction are called the **reactants**; the substances that are produced are called the **products**. When you wash the dishes, a chemical reaction occurs between the detergent and the mess on the dishes. When you shampoo your hair, some of the chemicals in the shampoo react with the greasy substances on your scalp that contain dust, dirt and tiny organisms such as bacteria that can make your hair unhealthy.

FIGURE 8.13 In a chemical reaction reactants are substances that change into products.



WHAT DOES IT MEAN?

The word product comes from the Latin word *productum*, meaning 'thing produced'.

Where's the evidence?

You can usually tell whether a chemical reaction has taken place by identifying one or more of these clues:

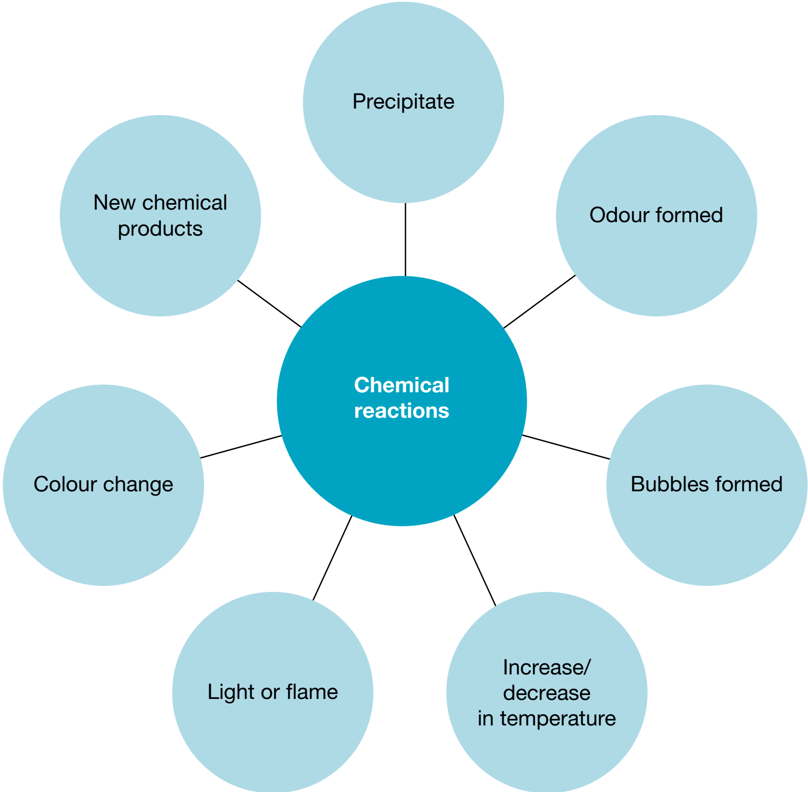
- a **precipitate** (cloudiness caused by a solid substance) appears in a liquid or gas
- an odour is detected
- bubbles appear
- there is an increase or decrease in temperature
- light is emitted or a flame appears
- there is a change in colour.

reactants chemical substances used up in a chemical reaction. Some chemical bonds in a reactant are broken during the reaction.

products new chemical substances that result from a chemical reaction

precipitate solid product of a chemical reaction that does not dissolve in water

FIGURE 8.14 Ways to identify a chemical reaction has occurred



However, the only way to be certain that a chemical reaction has taken place is to identify one or more new chemical products.

8.4.4 Chemical reaction experiments

Before you start each of the following four investigations, design a suitable table for recording your observations.

As you perform the experiments:
1. Make a note of the appearance of each of the reactants you start with.
2. Carry out the experiment and observe carefully to detect any changes that occur.
3. Describe the changes that take place and products of the reaction.

FIGURE 8.15 Safety glasses should always be worn during experiments involving chemical reactions.

on Resources

Video eLessons Precipitation (eles-2058)
Magnesium metal burning (eles-2303)
Baking and carbon dioxide (eles-2059)

elog-0241

INVESTIGATION 8.4

Heating copper carbonate

Aim

To observe and record the chemical reaction that occurs when copper carbonate is heated

Materials

- Bunsen burner, heatproof mat and matches
- safety glasses
- test tube, test-tube rack and test-tube holder
- spatula
- copper carbonate powder

Method

1. Pour two spatulas of copper carbonate into the test tube.
2. Using the test-tube holder, heat the test tube in the Bunsen burner flame. Remember to move the test tube in and out of the flame and point it away from people.
3. Stop heating when the copper carbonate has changed colour.

Results

Record your observations.

Discussion

Describe which observation provides evidence that a chemical reaction has taken place. Explain your reasoning.

Conclusion

What can you conclude about the chemical reaction that occurred in this investigation?

elog-0242

INVESTIGATION 8.5

Magnesium metal in hydrochloric acid

Aim

To observe and describe the chemical reaction between magnesium and hydrochloric acid

Materials

- heatproof mat
- safety glasses
- test tube and test-tube rack
- 1 cm piece of magnesium ribbon
- dropping bottle of 0.5 M hydrochloric acid

Method

1. Put the magnesium in the test tube.
2. Add 20 drops of hydrochloric acid to the test tube.

CAUTION

The test tube may become quite hot.

Results

Record your observations.

Discussion

Describe which observation provides evidence that a chemical reaction has taken place. Explain your reasoning.

Conclusion

What can you conclude about the reaction between magnesium and hydrochloric acid?

elog-0243

INVESTIGATION 8.6

Sodium sulfate and barium chloride

Aim

To observe and describe the chemical reaction between sodium sulfate and barium chloride

Materials

- heatproof mat
- safety glasses
- test tube, test-tube rack and test-tube holder
- dropping bottle of 0.1 M sodium sulfate solution
- dropping bottle of 0.1 M barium chloride solution

Method

1. Add 20 drops of the sodium sulfate solution carefully to the test tube.
2. Add 20 drops of the barium chloride solution carefully to the test tube.

Results

Record your observations.

Discussion

Describe which observation provides evidence that a chemical reaction has taken place. Explain your reasoning.

Conclusion

What can you conclude about the reaction between sodium sulfate and barium chloride?

elog-0244

INVESTIGATION 8.7

Steel wool in copper sulfate solution

Aim

To observe and record the chemical reaction between steel wool and copper sulfate

Materials

- heatproof mat
- safety glasses
- test tube and test-tube rack
- glass stirring rod
- 1 cm ball of steel wool
- dropping bottle of 0.5 M copper sulfate solution

Method

1. Put the steel wool in the test tube, using the glass stirring rod to push it gently to the bottom of the test tube.
2. Add copper sulfate solution to the test tube to a depth of 2 cm.

Results

Record your observations.

Discussion

Describe which observation provides evidence that a chemical reaction has taken place. Explain your reasoning.

Conclusion

What can you conclude about the reaction between a metal (steel wool) and copper sulfate?

8.4.5 Writing word equations

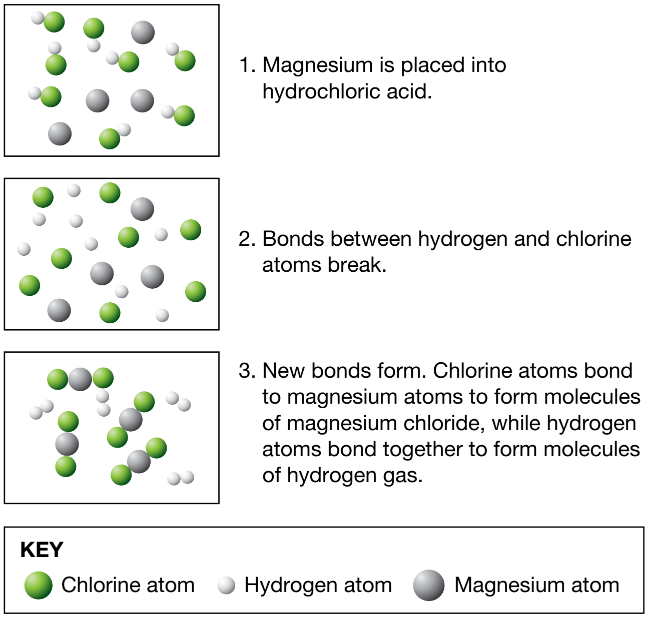
Each of the chemical reactions in investigations 8.4–8.7 can be described by a chemical word equation. In each case the reactants are on the left side of the equation and the products are on the right side.

1. When magnesium metal reacts with hydrochloric acid, hydrogen gas and magnesium chloride are formed:

magnesium + hydrochloric acid → hydrogen + magnesium chloride

eles-2294

FIGURE 8.16 Chemical reaction when magnesium is placed into hydrochloric acid



2. Heating copper carbonate forms copper oxide and carbon dioxide:

$$\textbf{copper carbonate} \xrightarrow{\text{heat}} \textbf{copper oxide + carbon dioxide}$$

Although heat is required for this chemical reaction to take place, it is not a substance and therefore is not a reactant. It is written above the arrow for this reason.

3. Sodium sulfate and barium chloride in solution react to form solid barium sulfate and sodium chloride, which remains dissolved in the solution:

sodium sulfate solution + barium chloride ⟶ solid barium sulfate + sodium chloride solution

4. Steel wool (which is made of iron) dissolves in copper sulfate solution to form iron sulfate solution and copper metal:

iron + copper sulfate solution ⟶ iron sulfate solution + copper

When writing word equations, it does not matter in which order the reactants are written and the same is true for writing the products. The word equation in the steel wool example above could also be written as:

copper sulfate solution + iron ⟶ copper + iron sulfate solution

on Resources

eWorkbooks Physical and chemical changes (ewbk-7627)
Describing chemical changes (ewbk-7628)

assess on Additional automatically marked question sets

8.4 Exercise

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LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 3, 4	Questions 2, 5, 7, 9	Questions 6, 8, 10

Remember and understand

1. Identify which of the following observations provide evidence that a chemical reaction has taken place.

Observation	Is there evidence of a chemical reaction?
a. Change in colour	
b. Heat or light produced	
c. Melting of a substance	
d. Gas produced when boiling a kettle	

e. Stretching a substance	
f. Formation of a precipitate	
g. Gas given off	

2. When magnesium metal reacts with hydrochloric acid, hydrogen gas and magnesium chloride are formed.
   a. Identify the products of this reaction.
   b. Identify the reactants in this reaction.
3. **MC** Identify which of the following is the provided 'real' proof that a chemical reaction has taken place.
   A. Production of a precipitate
   B. Formation of new products
   C. Gas formation
   D. Change in colour
4. Word equations can be very useful to represent chemical reactions.
   a. Fill in the blanks to represent the following reaction as a word equation:
   Octane gas is burnt with oxygen in a car engine to produce carbon dioxide and water.

   _____________ + oxygen gas → _____________ + water vapour

   b. **MC** Identify which word equation correctly describes the following reaction.
   Sodium metal reacts with chlorine gas to form sodium chloride.
   A. salt + chlorine gas → sodium chloride
   B. sodium gas + chlorine metal → sodium chloride
   C. sodium metal + chlorine gas → sodium chloride
   D. sodium chloride → chlorine gas + sodium metal
   c. True or false? The reaction in which hydrogen gas and oxygen gas combine to form water can be described by the word equation:

   hydrogen gas + oxygen gas → water

   d. True or false? The reaction in which zinc metal dissolves in hydrochloric acid to form hydrogen gas and zinc chloride can be represented by the word equation:

   zinc metal + hydrogen gas → hydrochloric acid solution + zinc chloride solution

5. True or false? The reaction that takes place when copper carbonate is heated is called a precipitation reaction.
6. Explain why the tomato, cheese, bread and meat in a hamburger cannot be grown or produced without photosynthesis.

Apply and analyse

7. Describe the evidence that one or more chemical reactions take place when meat is grilled.
8. **SIS** Read through investigation 8.6.
   The method requires 20 drops of each reactant. How could you test if all the barium chloride was used up in the reaction? What is your prediction?
9. **SIS** Draw a diagram (or create a model using an atom modelling kit) to show sodium metal reacting with hydrochloric acid. Remember to add a key to your diagram.

Evaluate and create

10. **SIS** Performing some chemical reactions can be dangerous. Design a safety poster for one of the experiments you have done. Be sure to list all the safety precautions. Your teacher can provide you with the relevant risk assessments for the experiment you have chosen.

Fully worked solutions and sample responses are available in your digital formats.

8.5 Reaction rates

LEARNING INTENTION

At the end of this subtopic you will be able to describe the factors that affect the rate of reaction such as the temperature, surface area, an enzyme or catalyst and the amount of a reactant.

8.5.1 Explosions

Explosions are chemical reactions that take place very quickly. Explosions also release a lot of heat, light and noise. In less than 10 milliseconds, a dynamite blast in a large mine can produce 5 billion litres of gas and release 20 billion joules of energy — enough energy to tear any rock apart.

In contrast, the chemical reactions that cause concrete to set are very slow. It can take several days for concrete to set hard. Rusting is another example of a slow chemical reaction.

The **reaction rate** is a measure of how quickly a chemical reaction occurs. How can the rate of a reaction be changed to make a slow reaction happen quickly or make a fast reaction slow down?

FIGURE 8.17 Explosions are fast chemical reactions.

WHAT DOES IT MEAN?

The word explosion comes from the Latin word *explosio*, meaning 'driven off by clapping or hooting'.

8.5.2 Speeding up a reaction with heat

Heating a substance adds energy to its particles. They move more rapidly and collide more frequently. When they collide, bonds between the particles are broken and new ones are more easily formed with the particles of other substances. Heating substances, therefore, usually causes the rate of a chemical reaction to increase.

8.5.3 Slowing down a reaction

Food 'goes off' because micro-organisms cause chemical reactions in the food, which make it rot. These chemical reactions can be slowed by lowering the temperature of the food. Imagine what life would be like without a refrigerator or freezer.

8.5.4 Catalysts and enzymes

A **catalyst** is a chemical that can speed up a chemical reaction but is still present once the reaction has finished. Catalysts are not reactants because they are not changed by the reaction. For this reason the catalyst is written above the arrow of the chemical equation.

Catalytic converters in car exhausts use a precious metal, such as platinum, as a catalyst. This enables nitrogen oxide to react with toxic gases, such as carbon monoxide, to form the less harmful carbon dioxide and nitrogen gases; this reaction would not occur in the absence of the catalyst.

reaction rate speed at which a reaction takes place

catalyst chemical that helps to start or speed up a chemical reaction

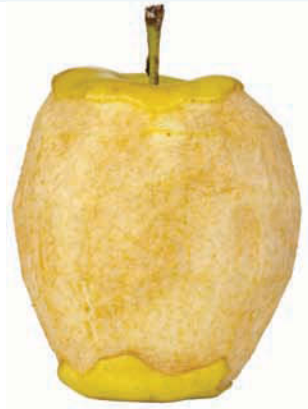
This reaction in a catalytic converter can be shown as:

$$\text{carbon monoxide} + \text{nitrogen oxide} \xrightarrow{\text{platinum}} \text{carbon dioxide} + \text{nitrogen}$$

The catalysts in living things are called enzymes. **Enzymes** in the human body help to digest the food you eat more quickly.

Apples and other fruits go brown because chemicals in them, called phenolics, react with oxygen in the air. The brown chemical products are called quinones. Enzymes in the fruit speed up the reaction.

FIGURE 8.18 Apples go brown when phenolics react with oxygen in the air. Enzymes speed up the reaction.



The chemical word equation for this reaction is:

$$\text{phenolics} + \text{oxygen} \xrightarrow{\text{enzymes}} \text{quinones}$$

8.5.5 Altering the reactants

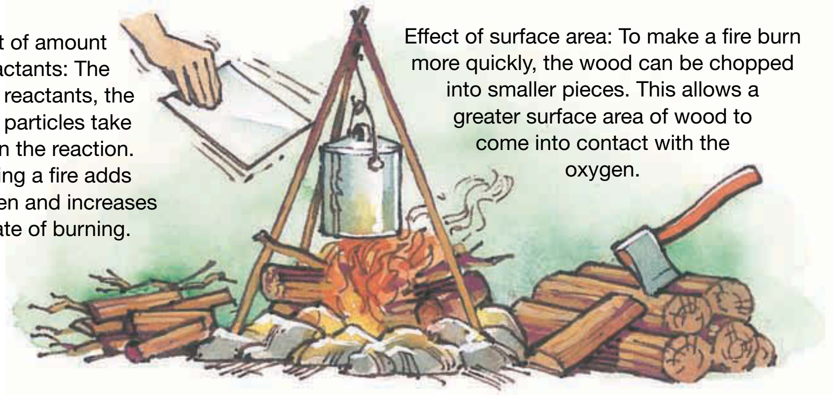
No doubt you have been in situations in which you wanted to increase the rate of a chemical reaction. Perhaps you wanted a camp fire to burn faster, a tablet to dissolve or a stain to be removed more quickly. What would you do in each case to make the reaction faster?

One solution is to add more reactant. In the case of the camp fire you can add more wood, or more oxygen by fanning the fire. To make the stain disappear more quickly, you could add more bleach.

Another solution is to increase the surface area of the reactants so that they can mix more easily. In the case of the camp fire, you can chop the wood or use smaller pieces of twigs and leaves. To help the tablet dissolve, you could crush it.

FIGURE 8.19 Granular sugar dissolves faster than a sugar cube because it has a larger surface area.

FIGURE 8.20 The effects of amount of reactants and surface area on the rate of reaction



enzymes special chemicals that speed up reactions but are themselves not used up in the reaction

SCIENCE INQUIRY SKILLS: Heating a test tube

When heating substances in a test tube, as in investigation 8.8, it is important to act safely.

- Use a test-tube holder to hold the test tube at the top.
- Point the test tube away from yourself and anyone else.
- Slowly move the test tube in and out of the middle of the blue flame of the Bunsen burner.
- Do not let the contents of the test tube bubble out; stop heating when you see this is likely.
- Allow the test tube to cool in a test-tube rack.

FIGURE 8.21 It is important to act safely when heating substances in test tubes.

elog-0245

INVESTIGATION 8.8

The effect of temperature on a reaction

Aim

To investigate the effect of temperature on the rate of a chemical reaction

Materials

- safety glasses
- marble chips
- test tube, test-tube holder and test-tube rack
- dropping bottle of 1 M hydrochloric acid
- Bunsen burner
- heatproof mat
- matches

Method

1. Carefully slide one or two marble chips to the bottom of the test tube.
2. Add 1 M hydrochloric acid to half-fill the test tube.
3. Observe the reaction.
4. Now gently heat the test tube and observe the reaction.

Results

Has a chemical reaction occurred? Describe the evidence that you observed.

Discussion

1. What effect did heating the test tube have on the rate of this reaction?
2. In this chemical reaction, the calcium carbonate that makes up the marble chips reacts with the hydrochloric acid to produce calcium chloride, water and carbon dioxide gas.
   a. List the reactants.
   b. List the products.
   c. Write a word equation for this chemical reaction.
3. Suggest a different method of increasing the rate of reaction.

Conclusion

Do you think a valid conclusion could be that the marble chips become smaller as the reaction progresses and so the reaction goes faster? Give your opinion of the validity of this conclusion.

Write a different conclusion for this investigation.

SCIENCE AS A HUMAN ENDEAVOUR: UV light at the dentist

Have you ever had a composite resin filling in your tooth? The dentist uses blue light or ultraviolet (UV) radiation to set this type of filling. The visible or UV light speeds up the reactions that cause the materials in the filling to harden. Without the UV light, you would be waiting for hours for this type of filling to set.

FIGURE 8.22 UV light can speed up the setting of a composite resin filling.

on Resources

Interactivity Reaction rates (int-0230)

elog-0246

INVESTIGATION 8.9

Changing the rate of reaction

Aim

To investigate the factors that affect the rate of chemical reactions

Materials

- safety glasses
- spatula
- heatproof mat
- 0.5 M hydrochloric acid
- test tubes and test-tube rack
- 1 M hydrochloric acid
- white chalk
- measuring cylinder
- mortar and pestle

Method

Hydrochloric acid reacts with chalk to produce carbon dioxide gas, water and calcium chloride.

1. Place a small amount of chalk in a test tube and add enough 0.5 M hydrochloric acid to cover it. Observe the chemical reaction.
2. Discuss with your partner how you could use this reaction to demonstrate one of the hypotheses listed.
   - Increasing the concentration or amount of reactants will speed up a chemical reaction.
   - Increasing the surface area of reactants will speed up a chemical reaction.
   - Decreasing the concentration or amount of reactants will slow a chemical reaction.
3. Design your experiment and write down the method.
4. Perform the experiment.

Results

1. Predict the results you would expect to obtain that would support the hypothesis you chose.
2. Record your results.

Discussion

1. Did your prediction prove to be true? Explain.
2. How could you improve on the investigation you performed?

Conclusion

Prepare a report of your findings.

on Resources

Interactivity Time Out: Reactions (int-0759)

eWorkbook Speeding up reactions (ewbk-3438)

assess on Additional automatically marked question sets

8.5 Exercise

learn on

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Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 4, 5, 6	Questions 2, 3, 7, 9	Questions 8, 10, 11, 12

Remember and understand

1. **MC** The rate of a reaction is a measure of:
   A. the type of reactants used.
   B. how many products are produced.
   C. how quickly the reaction happens.
   D. the number of observable changes.
2. Identify which of the following are different methods of changing the rate of a reaction.

Method	Does it impact the rate of reaction?
a. Heating	
b. Adding more products	
c. Increasing the time that the reaction has to occur	
d. Cooling	
e. Adding a catalyst	
f. Changing the container	
g. Adding more reactants	
h. Increasing the surface area of the reactants	

3. Explain how heating increases the rate of a reaction.

4. MC A catalyst is a substance that:
   A. stops a reaction from occurring.
   B. increases the rate of a chemical reaction.
   C. decreases the rate of a chemical reaction.
   D. increases time needed for a chemical reaction.
5. State how you know that a catalyst is not a reactant.
6. MC Identify the statement that defines an enzyme.
   A. A chemical that prevents a chemical reaction from occurring
   B. A catalyst found in living things
   C. A chemical that can produce toxicity in the body
   D. A reactant in many biological processes

7. State if a refrigerator stops food from rotting or if it slows down the rotting. Explain your answer.
8. Identify the main reason for adding catalysts to washing powders.
9. Identify which will dissolve more quickly: a sugar cube or the same amount of granulated sugar on a teaspoon.

Apply and analyse

10. SIS Choose one of the hypotheses in investigation 8.9 (that you have not used) and design an experiment for it. Predict your results.
11. SIS List the variables that will need to be controlled to investigate if a piece of chalk takes longer to react with an acid than the same amount of crushed chalk.

Evaluate and create

12. Choose one of the investigations you have performed in this subtopic or topic and consider how you could improve your experimental method.

Fully worked solutions and sample responses are available in your digital formats.

8.6 Corrosion

LEARNING INTENTION

At the end of this subtopic you will be able to recognise that corrosion breaks down metals and be able to describe the processes of surface protection and galvanising to prevent corrosion.

8.6.1 Rusting and corrosion

Rusting is an example of **corrosion**. Corrosion is a chemical reaction that occurs when substances in the air or water around a metal 'eat away' the metal and cause it to deteriorate.

There are many examples of corrosion: silver tarnish; the green film that forms on copper or brass objects; and, the most common one, the rusting of iron. Corrosion causes enormous damage to buildings, bridges, ships, railway tracks and cars.

8.6.2 Rust

Rust is the flaky substance that forms when iron corrodes. Iron reacts with water and oxygen in the air to form iron oxide and other iron compounds that make up the familiar red–brown substance known as rust.

rusting the corrosion of iron

corrosion a chemical reaction between air, water or chemicals in the air or water with a metal, which causes the metal to wear away

rust a brown substance formed when iron reacts with oxygen and water

Rusting is a slow chemical reaction that can be represented by the following word equation:

iron + water + oxygen → rust

Even strong buildings and bridges that are made from steel, an alloy of iron, are weakened by rusting. The Sydney Harbour Bridge, for example, is continually painted to protect it from moisture and the air, which would cause its steel girders to rust. Ships and cars are also constructed largely of steel. Despite the strength of steel, it needs to be protected from the corrosive effects of the environment.

FIGURE 8.23 The Sydney Harbour Bridge is continually painted to protect it from moisture and the air, which would cause its steel girders to rust.

elog-0247

INVESTIGATION 8.10

Observing rusting

Steel wool is made from iron. You can observe rusting of the iron in steel wool by performing the following experiment.

Aim

To observe and describe the rusting of steel wool

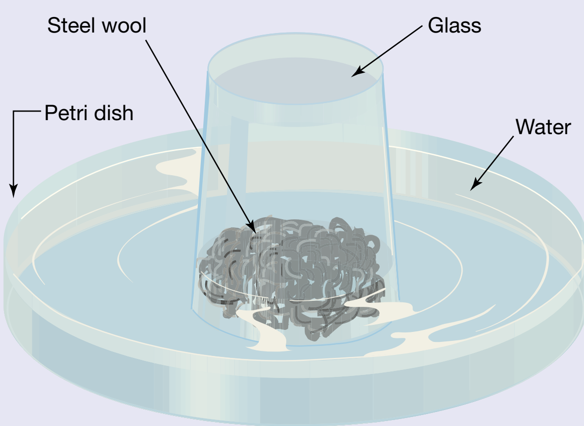
Materials

- Petri dish
- water
- steel wool (without any soap)
- small glass
- permanent marker

Method

1. Pour some water into the Petri dish.
2. Place the steel wool in the middle of the Petri dish.
3. Cover the steel wool by placing the glass over it upside-down.
4. Mark the level of the water on the outside of the glass with a permanent marker.
5. Leave for several days, adding water as required to keep the level at the mark on the glass.

Observing the rusting of iron



Results

Construct a table to record your observations over several days.

Discussion

1. What did you observe about the level of water inside the glass? Can you explain why this happened?
2. Write down a word equation for the chemical reaction that occurred inside the glass.

Conclusion

What can you conclude about the rusting of steel wool?

8.6.3 Speeding up rusting

Some substances in the environment make rusting happen much more quickly. One of the most effective of these is salt. Steel dinghies that are used in the ocean rust much faster than those that are used only in fresh water. This is because the salt in the seawater speeds up the reaction between oxygen in the air and the iron in the steel.

Some chemicals released from factories also increase the rate of rusting. A CSIRO study conducted in Melbourne found that rusting rates were high near airports and sewage treatment plants.

Rusting is much slower in dry environments such as deserts, where the rainfall is nearly zero and there is very little water vapour in the air.

FIGURE 8.24 In the Mojave Desert of Southern California, hundreds of unused aircraft are stored out in the open air. Due to the dry air, rusting occurs extremely slowly. As a result, some of the aircraft are still structurally sound after being exposed in the open air for about 20 years.

elog-0248

INVESTIGATION 8.11

Investigating the corrosion of different metals

Aim

To investigate the corrosion of a variety of metals

Materials

- small strips of a range of metals such as copper, aluminium, zinc and magnesium
- sandpaper
- other equipment approved by your teacher

Method

Design and carry out an investigation to study the resistance of a selection of different metals to corrosion. Ensure that appropriate variables are controlled. Before commencing, clean the metal strips with sandpaper to ensure that any coatings already caused by corrosion are removed.

Results

Write a report on your investigation that includes your aim, method, results (including a table), discussion and a clear conclusion listing the metals in order of resistance to corrosion, from most resistant to least resistant. Include the answers to the questions below in your discussion.

Discussion

1. Identify the independent and dependent variables in your investigation.
2. Name the variables that you controlled.
3. Suggest how you might be able to improve or speed up the investigation.

Conclusion

What can you conclude about corrosion of different metals?

8.6.4 Rust protection

The layer of rust that forms on an iron object flakes off the metal, allowing air and moisture to get through to the iron below. This causes more rusting to occur and eventually the iron becomes a heap of rust. It is important to protect iron and steel from corrosion, especially if they are part of a bridge or the hull of a ship.

FIGURE 8.25 This wrecked car has rusted quickly because of its proximity to the sea.

There are several ways to protect iron and steel from rusting. One way is to prevent oxygen or moisture from contacting the metal. This is called **surface protection**. The metal can be protected by coating it with paint, plastic or oil. If the surface protection becomes scratched or worn off, the metal below can be attacked by moisture and oxygen, and rusting will occur. Examine the painted surface of an old car. Wherever the paint has chipped off you will find that corrosion has occurred and rust can be seen.

Another way to protect iron from rusting is to coat it with a layer of zinc. This is called **galvanising**. Zinc is a more reactive metal than iron, and in the presence of moisture and oxygen the zinc layer corrodes, leaving the iron unaffected. Many roofing materials and garden sheds are made from galvanised iron. You can also buy galvanised nails.

surface protection coating over a metal surface to prevent corrosion
galvanising protecting a metal by covering it with a more reactive metal that will corrode first

elog-0249

INVESTIGATION 8.12

Rusting and salt water

Aim

To investigate the effect of salt water on the rate of rusting

Materials

- test tubes and test-tube rack
- measuring cylinder
- iron nails
- water
- salt (sodium chloride)

Method

1. Design an experiment to test the effect of the saltiness of water on the time taken for an iron nail to rust.
2. Propose a hypothesis.
3. Discuss your experiment design with a partner. You will need to consider which conditions must be kept the same and which condition will be varied.
4. You will need to set up a control test tube. Find out what the purpose of a control is.
5. Write down your method. It should be clear enough for someone else to follow without any help.

Results

Construct a table in which to record your observations over the next few days.

Discussion

1. Describe the effect of salt on the time taken for the nail to rust.
2. Was your hypothesis supported?
3. Outline how your results compare with those of others in your class.

4. Write a report of your findings. Include in your report the aim, materials, method, results and conclusion for your investigation.

Conclusion

Does salt water affect the rate of rusting?

8.6.4 Rusting can be useful

Not all rusting is bad. You can buy hand warmers, which are commonly used by skiers and campers, from pharmacies. These packages will produce heat when you shake them. The contents of the packet include powdered iron, water, salt and sawdust. When the packet is shaken vigorously, the iron rusts quickly, which produces heat.

HOW ABOUT THAT!

City councils face problems caused by the action of dogs on metal lampposts. The corrosive properties of the dogs' urine rusts the steel of the lampposts a few centimetres above the ground.

EXTENSION: Corten steel

Sometimes rust can protect the surface of steel. This steel alloy sculpture is made from Corten steel. It is a specially designed alloy that is designed to rust over a period of weeks or months to build up a dense protective layer of rust. The rust layer is densely packed and does not let air or water through it, so further rusting cannot occur once the protective layer has rusted. As well as in sculptures, this type of steel can be seen used in modern buildings, garden fences and edging.

FIGURE 8.26 A Corten steel sculpture

Resources

eWorkbook Rusting (ewbk-3439)

assesson Additional automatically marked question sets

8.6 Exercise

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Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 4, 5, 7	Questions 3, 8	Questions 6, 9, 10

Remember and understand

1. MC Identify the statement that describes corrosion.
   A. A physical change in the composition causing the solid to break down
   B. A chemical reaction with a metal and other substances that causes the metal to deteriorate
   C. A chemical reaction between a fuel and oxygen that produces heat
   D. A chemical reaction with only one reactant that causes the breakdown of a metal
2. MC Identify the statement that describes rusting.
   A. A physical change from solid iron to liquid iron
   B. A chemical reaction between iron and carbon dioxide
   C. A physical change from solid iron to gaseous iron
   D. A chemical reaction between iron, water and oxygen that produces rust
3. State which of the following substances can be used for surface protection of metals.

Substances	Provide surface protection of metals?
a. Paint	
b. Water	
c. Oil	
d. Oxygen gas	
e. Plastic	

4. a. Complete the sentence. Galvanised iron is iron covered with a layer of ________________.
   b. What advantage does galvanising iron have over iron that is not galvanised?
5. Explain how galvanising protects iron from rusting when the zinc coating corrodes more quickly than the iron.
6. Explain why the powdered iron inside hand warmers used by skiers and campers rust much more quickly than an iron nail.

Apply and analyse

7. Explain why rusting occurs faster in coastal regions than in areas further away from the sea.
8. SIS If you have access to an old car, survey it carefully and record all its rust spots. If you do not, then carefully observe the rusty car in figure 8.25. Why are some parts of the car more likely to rust?
9. SIS Corrosion is found in many places. Survey your school for rust spots. Write a report about your findings.
10. SIS Aluminium corrodes quite quickly, yet it is used to make soft-drink cans. Write a hypothesis about why aluminium cans are not corroded by the drinks they store. Make sure that your hypothesis can be scientifically tested.

Fully worked solutions and sample responses are available in your digital formats.

8.7 Combustion

LEARNING INTENTION

At the end of this subtopic you will be able to identify that one type of oxidation reaction is combustion, which is the reaction of fuels with oxygen to produce heat, carbon dioxide and water vapour.

8.7.1 Oxidation reactions

Burning is a chemical reaction; it is also known as combustion. It involves the combination of oxygen with a fuel and always produces heat and gases. Reactions that involve combination with oxygen are examples of **oxidation** reactions.

There are many other oxidation reactions. The rusting of iron to form iron oxide is an oxidation reaction. Rusting could correctly be described as a very slow type of burning reaction.

burning combining a substance with oxygen in a flame

oxidation chemical reaction involving the loss of electrons by a substance

fossil fuel substance, such as coal, oil and natural gas, that has formed from the remains of ancient organisms. Coal, oil and natural gas are often used as fuels; that is, they are burnt in order to produce heat.

8.7.2 Burning fossil fuels

When a **fossil fuel** reacts with oxygen, heat is produced, along with carbon dioxide and water vapour. Fossil fuels are fuels formed from the remains of living things. Petrol, natural gas, coal, wood and even paper are fossil fuels.

The production of carbon dioxide from the burning of fossil fuels is a major source of greenhouse gas emissions, which are a major contributor to climate change.

If combustion of fuels occurs when there is not enough oxygen, carbon monoxide or solid carbon (soot) can also be formed.

FIGURE 8.27 An oxyacetylene torch is used in construction work.

The oxyacetylene torch

To obtain temperatures as high as 3000 °C — hot enough to melt iron and weld metals — acetylene fuel is mixed with pure oxygen in an oxyacetylene torch.

acetylene + oxygen → carbon dioxide + water

The car engine

Petrol or gas car engines work by the combustion of petrol or gas in the cylinders. A mixture of air and fuel is drawn into each cylinder and ignited by a spark from the spark plug. The fuel reacts rapidly with oxygen in the air. The resulting explosion pushes the piston, which turns the drive shaft. The products of the reaction, carbon dioxide and water vapour leave the car engine through the exhaust pipe.

EXTENSION: The danger of backdraughts

A backdraught occurs when a fire in a closed room dies down because it has been starved of oxygen, but flammable gases continue to stream out of the hot materials in the room. When a door to the room is opened, air is quickly drawn inside, restoring the supply of oxygen and allowing the fire to reignite. The resulting fire consumes all the flammable gases in a few seconds and produces sufficient heat to ignite any remaining materials in the room. This is very dangerous to firefighters.

Rocket fuels

Liquid and solid fuels are used in the NASA rocket program. When these fuels are burnt, they provide sufficient thrust to place a rocket in orbit hundreds of kilometres from Earth. Liquid hydrogen and liquid oxygen react to power the rocket's main engines. The only product of this reaction is water; it does not produce pollution, unlike the burning of fossil fuels. For this reason, hydrogen is being investigated as an alternative fuel source on Earth.

hydrogen + oxygen → water

Most of the thrust required to place the rocket in its desired orbit comes from chemical reactions in the solid fuel, which is located in the solid rocket boosters. In space, liquid fuel such as hydrazine is oxidised to produce an enormous volume of gas. As the gas is released, the rocket is thrust forward. By controlling the direction of the thrust, it is possible to steer the rocket.

FIGURE 8.28 Oxidation reactions provide the thrust to launch a rocket.

elog-0250

INVESTIGATION 8.13

Burning paper

Aim

To observe and record the combustion of paper

Materials

- safety glasses
- Bunsen burner, heatproof mat and matches
- tongs
- gas jar
- limewater
- paper
- deflagrating spoon

Method

1. Place 10 mL of limewater in the bottom of the gas jar.
2. Put a ball of scrunched-up paper into the deflagrating spoon.
3. Light the paper and lower it into the gas jar.
4. When burning has stopped, remove the deflagrating spoon and cover the jar.
5. Shake the gas jar and observe the colour of the limewater.

Results

What happened to the limewater?

Discussion

1. What gas was given off by the burning paper?
2. Which other substance or substances were produced by the reaction?

Conclusion

Write a conclusion for this investigation.

on Resources

eWorkbook Combustion (ewbk-7389)

assess on Additional automatically marked question sets

8.7 Exercise

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LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 3, 5	Questions 2, 4, 6, 7	Questions 8, 9, 10, 11, 12

Remember and understand

1. MC Identify the statement that describes what 'burning' means.
   A. A physical change that produces a gas by evaporation
   B. A chemical reaction between a fuel and carbon dioxide that produces heat and gases
   C. A chemical reaction between a fuel and oxygen that produces heat and gases
   D. A chemical reaction between a fuel and heat that produces gases
   E. A physical change in which heat is applied to produce gases
2. Identify which of the following are evidence that burning is a chemical reaction.

Evidence	Evidence of chemical reaction?
a. Change of state	
b. Release of heat	
b. Only two products	
d. Production of gases	
e. Bubbles are produced	

3. What is a fossil fuel? List three examples of fossil fuels.
4. a. MC What type of reaction is burning?
      A. Reduction
      B. Corrosion
      C. Oxidation
      D. Catalyst
   b. Write the word equation for each of the following parts i to iii.
      i. The reaction of acetylene with oxygen to make a flame hot enough to weld metals together

      ____________ + oxygen → ____________

      ii. The reaction of oxygen and petrol or gas in a car engine that produces a hot gas, which causes the movement of the piston, the drive shaft and the wheels of the car

      ____________ + fuel vapour → carbon dioxide + water

      iii. Energy is released by the reaction of hydrogen and oxygen that produces the thrust necessary to get rockets into orbit.

      ___________ → water

5. Is rusting an example of burning? Explain your response.

6. Select the correct substances to complete the word equation.

fuel + ____________ → ____________ + water vapour

7. Identify which of the following are names given to chemical reactions in which fuels react with oxygen.

Chemical reaction	Chemical reaction in which fuel reacts with oxygen?
a. Burning	
b. Corrosion	
c. Combustion	
d. Oxidation	
e. Catalysis	

Apply and analyse

8. Space agency scientists are constantly searching for better rocket fuels. List the properties that are i desirable and ii undesirable.

9. SIS The following table shows the heat of combustion per kilogram of certain fuels.

TABLE Energy generated per kilogram of fuel

Fuel	Heat value (MJ per kg)
Methane	50
Petrol	44
Natural gas	42
LPG	46
Diesel fuel	42

a. Use the data in the table to make a bar chart of the fossil fuels.
b. Identify which of the fossil fuels in your bar chart produces the most amount of heat per kilogram.
c. Explain why this fossil fuel is not used to power cars in Australia.

Evaluate and create

10. SIS Suggest why in most buildings we have thick fire doors that have to remain closed.
11. A student conducts a experiment in which they burn magnesium in the presence of oxygen. At the end of this experiment, the compound magnesium oxide is produced.
    a. How do you know that a chemical reaction has taken place?
    b. Write a word equation for the chemical reaction.
    c. Would this reaction be classed as a combustion reaction? Justify your response.
12. SIS Read through investigation 8.13. How could you establish that the limewater did not react with another substance in order to turn milky? Design an investigation to show that limewater reacts with carbon dioxide to turn a milky colour.

Fully worked solutions and sample responses are available in your digital formats.

8.8 Plastics and fibres

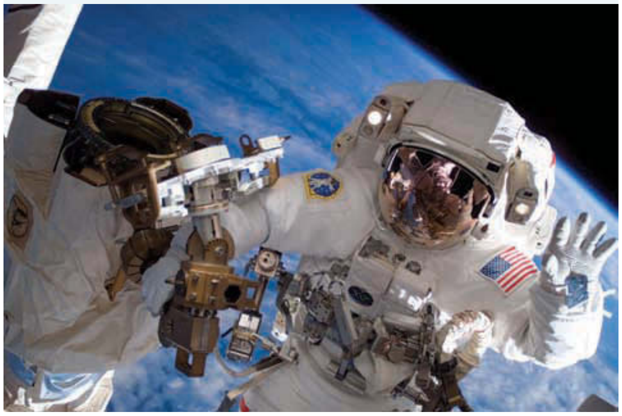
LEARNING INTENTION

At the end of this subtopic you will be able to describe examples of how plastics and fibres or their blends can be developed for a particular purpose.

8.8.1 Plastics

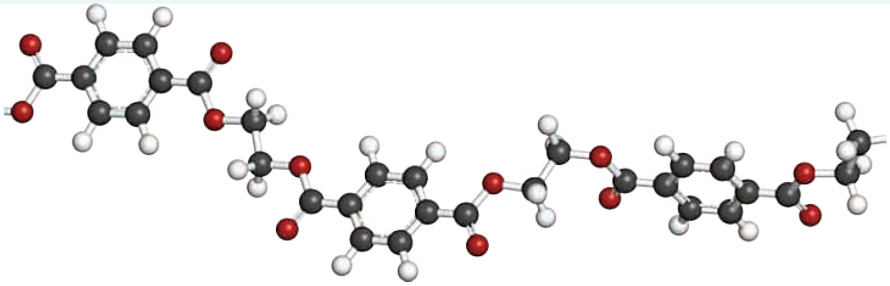
The scientists and engineers who develop new plastics for spacesuits that allow astronauts to walk in space need a knowledge of chemistry to create materials that are strong, light and heat resistant. Developing new materials for a particular purpose requires an assessment of the required properties and an understanding of chemical reactions.

FIGURE 8.29 The spacesuits worn by astronauts when they are walking in space contain many layers of materials developed by scientists and engineers.



Metals, paper and ceramics have been used for thousands of years. But plastics have been around for less than 100 years. Plastics are synthetic (manufactured) materials that can be easily moulded into shape. Some plastics are flexible and soften when they are heated. They can be easily moulded into products such as milk and fruit juice containers, rubbish bins, spectacle lenses, electrical insulation and laundry baskets. Others are quite hard and rigid. These plastics are used to make items such as toilet seats, electrical switches, bench tops and outdoor furniture. Most plastics are the products of chemical reactions with crude oil, from which petrol and bitumen are also produced, as the main reactant.

FIGURE 8.30 Plastics are made from chains of molecules and are also called polymers (poly means 'many'). This chain of molecules has two repeated units.



WHAT DOES IT MEAN?

The word plastic comes from the Greek word *plastikos*, meaning 'able to be moulded'.

CASE STUDY: Plastic currency

Australia was the first country in the world to use only plastic notes for currency. The notes are more difficult to forge and last much longer than the old paper notes.

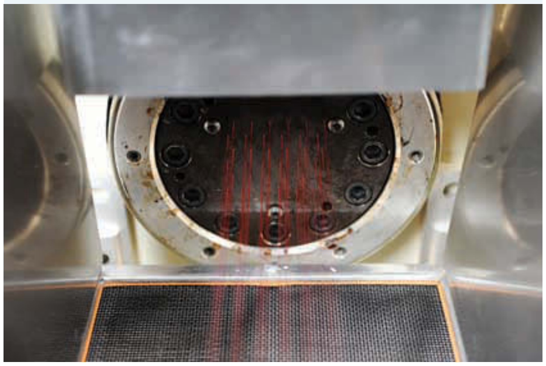
8.8.2 Fibres

Until the development of nylon in 1938, just in time to make parachutes for World War II, the world relied almost completely on fabrics made from **natural fibres** such as wool, cotton, linen and silk.

Animal-based products include wool from sheep and silk from silkworms. Cotton is derived from cotton bushes and linen comes from flax plants. Today, it would be impossible to provide clothing and bedding for the world's population with purely natural fibres because of the amount of land and water that would be needed for crops and sheep.

Synthetic fibres such as those used in compression sports gear have many desirable qualities that natural fibres lack, including easy care, colour-fastness and light weight.

FIGURE 8.31 Synthetic fibres form when soft plastic is forced through the holes of a spinneret.



Of the many synthetic fibres, the most widely used are **nylon** and **polyester**. Synthetic fibres are made by pushing softened plastic materials through tiny holes in a nozzle called a **spinneret**, which looks a little like a shower head.

EXTENSION: Biomimicry

Biomimicry is the imitation of designs found in nature to solve human problems using technology. The spinneret used to make synthetic fibres is an example of biomimicry. The spinneret gets its name from the organ used by spiders to spin their webs. Liquid silk flows through the spider's spinneret. It hardens into a fibre as it passes through. Most spiders have six spinnerets.

natural fibres fibres that form naturally; that is, they have not been made by humans. Natural fibres include wool and silk from animals and cotton from plants.

nylon synthetic fibre. The monomers are joined by the elimination of water molecules at the joins.

polyester synthetic fibre. The monomers are joined together by the elimination of water molecules at the joins.

spinneret device like a nozzle with small holes through which a plastic material passes, forming threads, also the organ used by spiders to create their webs

on Resources

Video eLesson The future of clothing (eles-0859)

SCIENCE INQUIRY SKILLS: Variables

In a fair test such as the one you will develop in investigation 8.14, it is important to control and measure variables. For a test to be fair the variables must be controlled. For example, if the elasticity of different fibres was being tested, the fibres should all be the same length and thickness. The fibres should all be tested in the same way; for example, they should be joined to a testing frame in the same way and the load or force used to test them be applied for the same time and at the same rate.

elog-0251

INVESTIGATION 8.14

Testing fibres

Aim

To observe and describe the properties of a range of fibres

Materials

a range of threads of different fibres, for example cotton, polyester, wool, nylon, rayon, uniformly sized fabric samples made from different fibres or blends of fibres and equipment decided upon by the group

Method

Work in groups of three or four to complete this investigation.

1. Start by listing the properties of either the fabric samples or the fibres that can be tested by experiments. Some examples to help get you started include flammability, elasticity and the ability to absorb water.

Devise an experiment that will allow you to compare one property of threads of either different fibres or different fabric samples.

2. Make a list of the equipment you will need.
3. Have your experiment plan and equipment list checked by your teacher.

CAUTION

Obtain your teacher's approval before carrying out any tests. Synthetic fibres or blends should be burned only in a fume cupboard.

Results

1. Carry out your experiment and keep a record of your measurements and observations.
2. Write a report about your experiment.

Discussion

1. List the variables that you were able to control in your experiment.
2. Identify any variables that you didn't feel the need to control.
3. Identify the most useful properties of each of the fibres or fabrics that you tested.
4. Suggest at least one improvement that you could make to your experiment.

Conclusion

What can you conclude about the combustibility of different fabric samples?

8.8.3 Blends

Many of today's fabrics are made from blends of natural and synthetic fibres to make the best of the properties of each fabric in the blend. A blend of polyester and cotton is commonly used for shirts and dresses. The cotton helps keep the wearer cool, while the polyester reduces creasing.

Rayon is shiny, easy to dry and cool in summer. On the 'down' side it has low **durability** and is not **elastic**. Elasticity describes the ability of a material to return to its original size and shape after being stretched. Rayon is neither a natural nor a synthetic fibre. To make it, cellulose fibres from spruce and eucalyptus trees are mixed with chemicals that soften them. The mixture is then passed through a spinneret.

8.8.4 Lycra

When you watch the feats of Olympic athletes, cyclists, skiers and skaters, it's almost certain that they are wearing Lycra. Lycra is not a fabric. Lycra is the registered trademark of a synthetic fibre called spandex. Spandex was invented in 1958. Spandex is lightweight, durable, retains its shape and fits snugly. It even pulls moisture away from the wearer's skin. Spandex is very elastic. It can be stretched to up to seven times its normal length and spring back to its initial length when released. Spandex is always blended with other fibres. As little as 2 per cent of this material in a blend makes a difference to the properties of the fabric. Lycra suits usually consist of between 3 per cent and 10 per cent spandex.

durability the quality of lasting, not easily being worn out

elastic describes a material that is able to return to its original size after being stretched

Each fibre, whether natural or synthetic, has advantages and disadvantages. Some of these are outlined in table 8.1.

TABLE 8.1 Advantages and disadvantages of fibres

Fibre	Advantages	Disadvantages
Wool	• Warm in cold weather • Crease resistant • Burns slowly • Retains its shape well	• Shrinks when washed • Turns yellow in sunlight
Cotton	• Absorbs moisture • Soft • Cool in hot weather	• Creases easily • Burns quickly
Nylon	• Dries quickly • Light • Strong • Elastic	• Builds up static electricity • Melts rather than burns
Polyester	• Dries quickly • Crease resistant • Resistant to many chemicals	• Builds up static electricity • Melts rather than burns

DISCUSSION

Working collaboratively, or independently, make a list of at least ten items in your houses made from plastic. Imagine that they could no longer be made from plastic! For each item, think about the most important properties that item must have and discuss which other material could be used to make them.

on Resources

assesson Additional automatically marked question sets

8.8 Exercise

learnON

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3, 4, 5, 7	Questions 6, 8, 9, 11, 13	Questions 10, 12, 14, 15

Remember and understand

1. MC Which single property do all plastics have?
   A. Flexible
   B. Can be moulded
   C. Rigid
   D. Cannot be moulded
2. From which substance found beneath the ground are most plastics made?
3. MC Identify the source where all natural fibres come from.
   A. Plants or animals
   B. Plants only
   C. Animals only
   D. Soil
4. MC Identify which of the following options explains why woollen clothing is popular in winter whereas cotton clothing is popular in summer.
   A. Wool is cool on warm days, but cotton allows heat and moisture to be trapped against the body in cold weather.
   B. Wool is warm on cold days, but cotton allows heat and moisture to escape from the body in hot weather.
   C. Wool is cool on cold days, but cotton allows heat and moisture to be trapped against the body in cold weather.
   D. Wool is warm on warm days, but cotton allows heat and moisture to escape from the body in cold weather.
5. State the reason cotton and polyester blends are so commonly used for shirts and dresses.
6. Describe what a spinneret is used for.
7. Which fibre does Lycra clothing always contain?
   A. Spandex
   B. Nylon
   C. Elastane
   D. Polyester
8. Most plastics are not biodegradable. Metals and glass are also not biodegradable.
   a. What does biodegradable mean?
   b. If non-biodegradable rubbish cannot be recycled, what happens to it?

Apply and analyse

9. State which properties make plastic more suitable for use in outdoor furniture than:
   a. wood
   b. metal?
10. Identify which properties of plastic banknotes make them more suitable than the old paper ones.

11. Which of the following are properties of nylon? For each property you identify, explain what makes it suitable to be used as parachute material in World War II.

Properties	Properties suitable for making parachutes
a. Light but strong	
b. Strong and heavy	
c. Shrinks when washed	
d. Elastic	
e. Burns quickly	
f. Waterproof and dries quickly	
g. Builds up static electricity	

12. Explain why rayon is neither a natural fibre nor a synthetic fibre.
13. Describe how the properties of a pure cotton fabric would change by blending it with spandex.

Evaluate and create

14. SIS Examine the table provided showing some advantages and disadvantages of natural and synthetic fibres.

Fibre	Advantages	Disadvantages
Wool	• Warm in cold weather • Crease resistant • Burns slowly • Retains its shape well	• Shrinks when washed • Turns yellow in sunlight
Cotton	• Absorbs moisture • Soft • Cool in hot weather	• Creases easily • Burns quickly
Nylon	• Dries quickly • Light • Strong • Elastic	• Builds up static electricity • Melts rather than burns • Turns yellow in sunlight

a. Which of the materials would burn slowly if it were exposed to flames?
b. Deduce one advantage and one disadvantage of synthetic materials over natural materials.
c. Deduce one disadvantage that one natural material and one synthetic material both have in common.

15. SIS Choose one of the properties in investigation 8.14 (one that you haven't investigated) and decide on the equipment you would use to investigate it.

Fully worked solutions and sample responses are available in your digital formats.

8.9 Recycling

LEARNING INTENTION

At the end of this subtopic you will be able to identify the types of plastics that are easily recycable and those that are more difficult. You will also understand how glass, metal and paper products can be sorted and recycled in a recycling facility.

8.9.1 Recycling and landfill

The material that you throw out as household rubbish is buried in landfill tips.

The food scraps that make up almost half of your household rubbish are biodegradable. They will be broken down by microbes and other decomposers in the soil such as worms. Chemical changes take place when these organisms digest the scraps, returning nutrients to the soil. You can use compost bins or compost heaps to allow this to happen in your own backyard. Even paper and cardboard break down fairly quickly in the soil.

However, materials such as plastic, glass and metals take hundreds or even thousands of years to break down. The properties of these materials allow them to be **recycled**.

FIGURE 8.32 Look closely at this photo. This is not garbage. All these things can be recycled, including cardboard, paper, egg cartons, steel cans, plastic and glass.

8.9.2 Packaging

Just about everything you buy at the supermarket comes in a package. Even if it doesn't, you usually put it in a bag to take it home. The type of packaging needed depends on the properties of the product inside. For example, you cannot package tomato sauce in a paper bag. The most commonly used materials in packaging are paper (or cardboard), plastic, metal and glass. For a consumer, it is not just the properties of the packaging that are important. At least two questions should be asked when you make a choice about buying a product:

- Is the packaging recyclable?
- Is the packaging biodegradable?

If the packaging is glass, aluminium or steel, it is probably recyclable, which can save energy and water. If it is a plastic bottle, it is also likely to be recyclable. If the packaging is not recyclable, think about whether it is **biodegradable**; that is, can it be broken down by natural chemical reactions in the bodies of worms or other small **organisms** that live in the soil? Plastics, metals and glass are not biodegradable. If they are thrown out with other household rubbish such as food waste, they end up in rubbish tips and will not break down. This creates the need for more rubbish tips. Of course, there is a limit to how much land can be used for rubbish tips in or near major towns and cities.

Paper is mostly biodegradable. Paper packaging that has been contaminated by food or oils, however, cannot be recycled. But at least when it gets to the rubbish tip it can be broken down in the soil. If you have a choice, choose items with packaging that is either recyclable or biodegradable.

recycled reuse an unwanted substance or object for another purpose

biodegradable describes a substance that breaks down or decomposes easily in the environment

organisms living things

8.9.3 Recycling plastics

There are two very good reasons for recycling plastics:

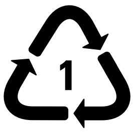
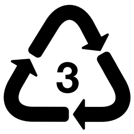
- Plastics are non-biodegradable. That is, they are not broken down naturally by micro-organisms. Plastics add thousands of tonnes of new rubbish to the environment every year.
- Plastics are made from oil — a resource that is expensive and dwindling. This is a chemical reaction. The continued production of new plastic is not **sustainable**. Recycling plastics is usually a physical change involving heat.

Household waste contains many different types of plastic, which need to be separated. The plastics industry has introduced a code system to help consumers identify recyclable plastics. The symbols shown on the next page make the sorting of plastics before recycling easier and cheaper. Some plastics are more easily recycled than others because of differences in the structure of the chains of molecules of which they are made.

FIGURE 8.33 The symbols shown make the sorting of plastics before recycling easier.

sustainable describes the concept of using the Earth's resources so that the needs of the world's present population can be met, without damaging the ability of future populations to meet their needs

TABLE 8.2 Different types of plastic and their potential to be recycled

Symbol	Use of plastic and potential to be recycled
 PETE	PET or PETE (polyethylene terephthalate) is used to make plastic soft-drink bottles. Most commonly known as PET, this plastic is recycled to make carpet fibre and flower tubes. Empty PET bottles completely and remove the lids before placing them in a home recycling bin. The lids are recyclable, but their small size makes the sorting process awkward.
 HDPE	HDPE (high-density polyethylene) is used to make plastic milk and fruit juice bottles. This plastic is recycled to make bottles, crates, pipes, wheelie bins and playground equipment. Empty HDPE bottles completely and remove the lids before placing them in a home recycling bin.
 V	Polyvinyl chloride, more commonly known as PVC, is used to make pipes, fencing and bottles containing substances other than food. It is not easily recycled and can be dangerous to your health and the environment. PVC bottles can be placed in your home recycling bin as long as the lids are removed. They are separated from the more easily recyclable plastics and sent to a separate plant for processing.

4 LPDE	LPDE (low-density polyethylene) is used to make wash bottles and other containers. These are recyclable and can be placed in your recycling bin. LPDE is also used to make supermarket plastic bags, which should not be placed in your home recycling bin. These bags interfere with the automatic sorting machines in recycling plants. They can be collected together and taken to a soft plastic recycling drop off bin. These are usually located at the entrance to major supermarkets. It is best to avoid using them by using reusable bags for shopping.
5 PP	PP (polypropylene) is used in synthetic fibres to make clothing, industrial fibres, car batteries, bumper bars and other car parts. Although these products are not appropriate for your recycling bin, polypropylene can be recycled for use in carpet, furniture, white goods and even polymer bank notes. Most car workshops, scrap metal dealers and service stations will accept used car batteries for recycling.
6 PS	Polystyrene is a very light plastic used in solid form to make plastic cutlery and toys. In its softer foam form, it is used for disposable drinking cups and packing materials. Polystyrene products should not be placed in home recycling bins. The lightness of polystyrene foam makes it difficult to sort and recycle. Although all polystyrene can be recycled, it is a very expensive process.
7 OTHER	Other plastics, including nylon, fibreglass and polycarbonate, are not generally recycled and should not be placed in your home recycling bin.

8.9.4 Recycling glass

About 45 per cent of the glass packaging used in Australia is recycled. Used glass bottles, known as **cullet**, are collected and melted down in a furnace to produce new products. This is a physical change. The overall energy saving is only 8 per cent of that used in making new glass. This is because of the high cost of collecting and melting down the bottles. In some countries, milk is sold in bottles that can be sterilised and reused up to 50 times before they need melting down, which saves a large amount of energy.

8.9.5 Recycling paper and cardboard

Over a million tonnes of paper, about a third of our annual consumption, is recycled in Australia. Paper is made out of fibres of the chemical cellulose and is relatively easy to recycle. Waste paper is first mixed with water to separate the fibres. Additives such as ink and adhesives are then removed, producing low-quality fibres that can be used to make cardboard and other products. Steam rollers are used to improve the quality of the finished paper. Recycling paper reduces the amount of new paper needed, saving millions of trees.

8.9.6 Recycling metals

Metals such as steel and aluminium are easily recycled as long as they can be cheaply separated from other rubbish. Steel cans, aerosol containers, jar lids and bottletops can be recycled. The recycling of aluminium cans saves huge amounts of energy. Twenty aluminium cans can be recycled with the same amount of energy needed to produce just one new can.

cullet used glass

ACTIVITY: Design your own waste disposal system

Your group is responsible for preparing a report on ways to improve the household waste management and disposal for the shire of Green Valley.

The shire currently collects rubbish from its 134 500 ratepayers using large green bins that are emptied by compactor trucks. The rubbish is taken to the local tip and used as landfill, at a cost to the council of $60 per tonne. The tip is nearing capacity and will be closed within 12 months. Waste paper is collected separately by a private recycling company.

Your report could be produced in written form or as audio or video. It should address the following issues:

1. How will the shire encourage each household to produce less waste?
2. Is recycling too costly?
3. If recycling occurs, will recyclable wastes such as plastics, glass and metals be separated at a disposal station after collection, or collected in separate containers from households?
4. What measures will be used to encourage households to use compost bins?
5. How will the shire dispose of rubbish when the landfill site closes?

8.9.7 Sorting out recyclables

The separation of the items in your recycling bin relies on differences in their physical properties including size, weight, magnetic properties and even colour. For example, items of different weights can be separated using blasts of air or a centrifuge that works like the spin dryer of a washing machine. Steel can be separated from other metals by a large magnet.

Special recycling programs

There are separate recycling programs for some products that cannot be placed in home recycling bins. These recycling programs are generally used to collect products containing substances that would endanger the environment or the community if they were dumped in landfill tips. For example, printer cartridges can be placed in recycling boxes at many Australia Post outlets and retail stores that sell computers and printers. Mobile phones can be left at most mobile phone outlets for recycling. Use the **Recycling** weblink in your Resources tab to find out where computers and other electronic equipment, white goods such as fridges and washing machines, corks, light globes and many other items are collected for recycling. This site also provides information about how to dispose of chemical wastes from home, school or industry. Oil, paints and unused medicines should not be placed in rubbish bins or flushed down the sink.

FIGURE 8.34 This compost bin is made from recycled polypropylene (PP). The compost decreases in volume as it breaks down. Almost 50 per cent of domestic waste in Australia is suitable for composting.

8.9.8 You can make a difference

The three-bin collection system used by many city and shire councils throughout Australia makes it very easy for you to make a difference to the environment by recycling.

For example recycling paper:

- reduces the amount of energy needed to produce new paper
- prevents tonnes of greenhouse gases from entering the atmosphere from manufacturing new paper
- saves the many litres of water used in paper production; less water is used in recycling it.

Resources

Weblink Recycling

assesson Additional automatically marked question sets

8.9 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3, 4, 5, 6, 8	Questions 7, 9, 11	Questions 10, 12, 13, 14, 15

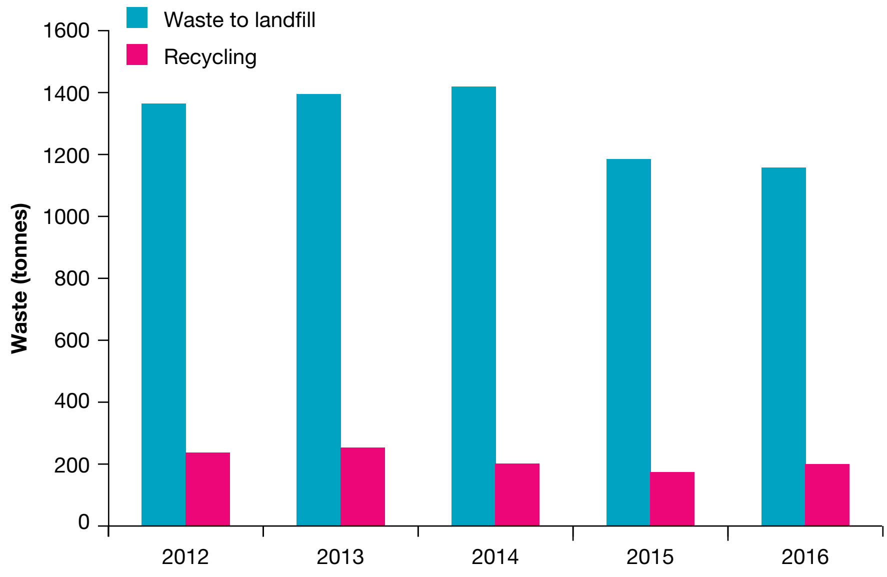
Remember and understand

1. MC How are biodegradable substances different from those that are not biodegradable?
   A. Non-biodegradable waste can be broken down by catalysts in a factory.
   B. Biodegradable waste cannot be broken down by decomposers.
   C. Biodegradable waste cannot be broken down by catalysts in a factory.
   D. Biodegradable waste can be broken down by decomposers.
2. Recall and state where the chemical changes that break down biodegradable waste take place.
3. Identify two of the main benefits of recycling plastics.
4. MC Why are plastics such as PET now identified by a code?
   A. To identify how long plastics can be used for
   B. To identify which plastics can be heated
   C. To identify which plastics can be recycled
   D. To identify which plastics are safe for food items
5. True or false? Cullet is a type of plastic. Explain your response.
6. MC The first part of the process of recycling paper involves mixing it with water. What is the major purpose of mixing the paper with water?
   A. To begin the chemical reaction that breaks down paper
   B. To cause a change of state from solid to liquid
   C. To increase the effect of temperature
   D. To weaken the forces between the fibres
7. List three problems associated with the disposal of waste in landfill sites.
8. Tue or false? Only a small amount of energy is saved when glass is recycled. Explain your response.
9. List two benefits of recycling aluminium.
10. Ink is removed from paper when it is recycled. Is the combination of ink and paper a compound or a mixture? Explain your answer.

Apply and analyse

11. SIS The following graph shows the amount of waste going to landfill compared to the amount of waste that is recycled.

Waste disposal 2012–2016



From this graph:

a. Identify which method of dealing with waste has been the least used in the years from 2012 until 2016.

b. Describe the general trend in waste going to landfill

12. SIS If a plastic-bag manufacturer claimed that the bags it produced were biodegradable, what evidence would you need to be satisfied that the claim was correct?

Evaluate and create

13. a. What factors influence the decision as to whether it is worth the trouble of recycling a resource?

b. SIS Which of these factors can be investigated scientifically?

14. SIS Research and report on what different alternatives to plastics are currently being developed.

15. SIS Current projects include making roofing tiles from milk bottle tops. Investigate ways that plastics are being recycled in imaginative ways and share your findings.

Fully worked solutions and sample responses are available in your digital formats.

8.10 Thinking tools — Target maps

8.10.1 Tell me

What is a target map?

A target map is a very useful thinking tool that can assist you to identify (target) which concepts are relevant to the topic and what concepts are not relevant to the topic. They are sometimes called circle maps.

Why use a target map over a single bubble map?

Similar to single bubble maps, target maps identify and describe the subtopics and concepts that relate to the topic of content. However, single bubble maps do not separate the relevant material from the non-relevant material

FIGURE 8.35 Target map

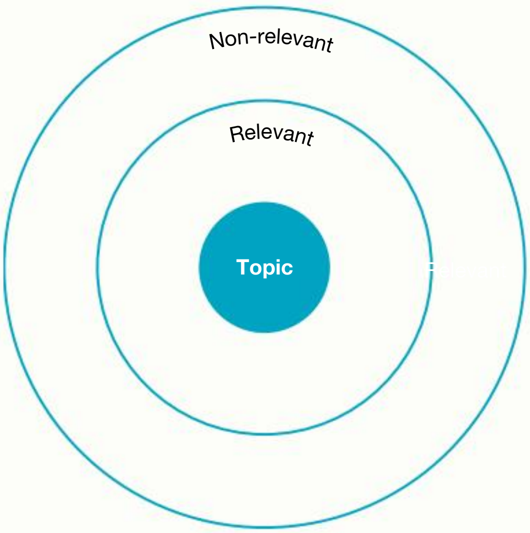
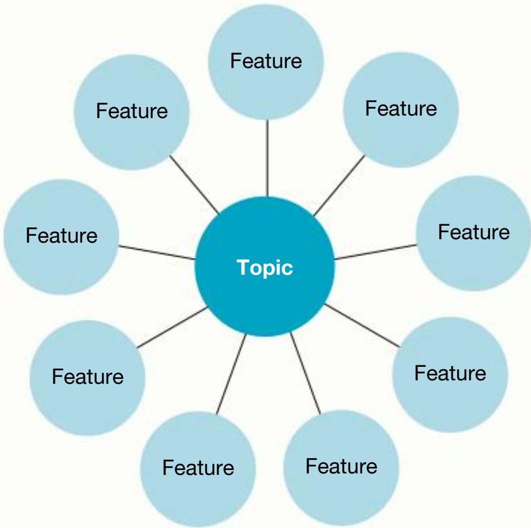


FIGURE 8.36 Single bubble map



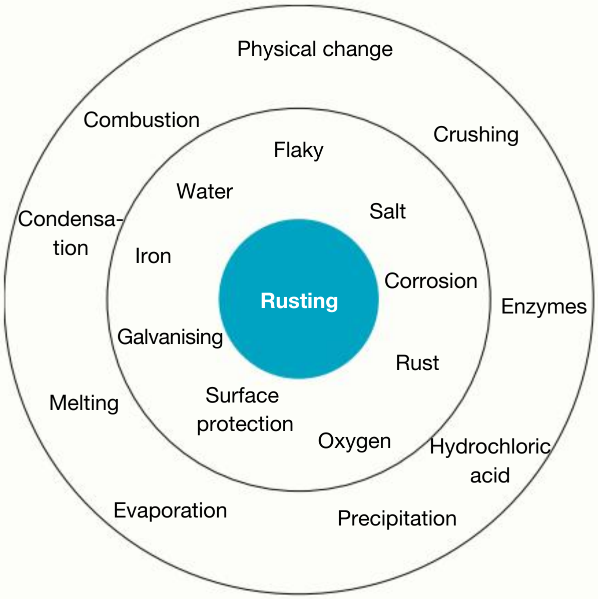
8.10.2 Show me

To create a target map:

1. Draw three concentric circles on a sheet of paper.
2. Write the topic in the centre circle.
3. In the next circle, write words and phrases that are relevant to the topic.
4. In the outer circle, write words and phrases that are not relevant to the topic.

The example given shows a single bubble map of the methods of rusting.

FIGURE 8.37 Target map of rusting



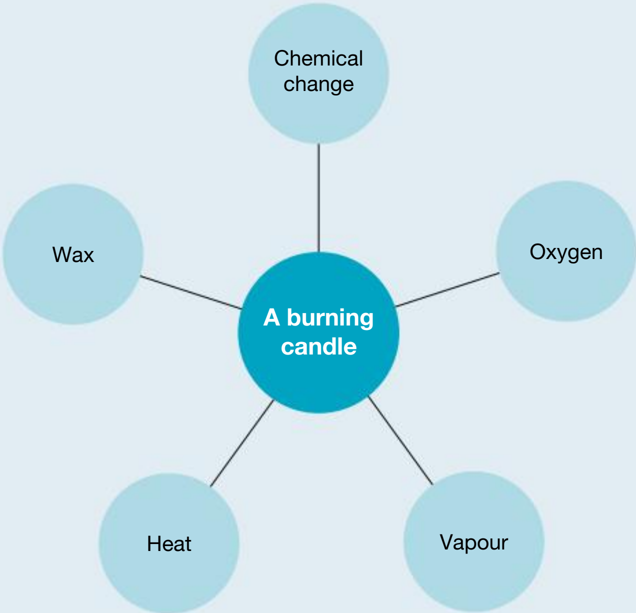
8.10.3 Let me do it

8.10 ACTIVITIES

1. Construct a target map about physical change. Use each of the words shown in your target map.

Melting	Burning	Precipitate
Evaporation	Condensation	Explosion
Reactant	Stretching	Catalyst
Rusting	Freezing	

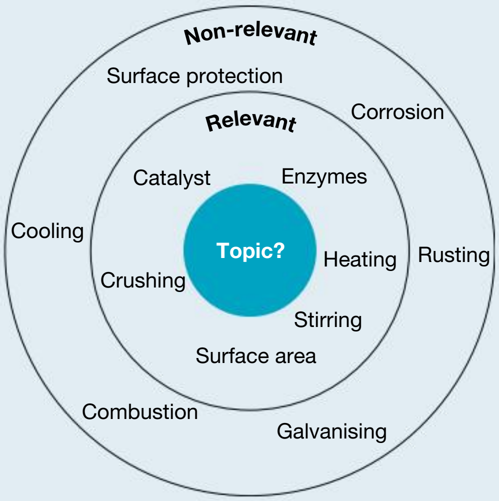
2. The single bubble map shown identifies some of the ideas associated with a burning candle.
   a. Draw your own single bubble map about the topic 'a burning candle', adding as many additional bubbles as you can.
   b. Construct a single bubble map that identifies clues that provide evidence that a chemical reaction has taken place.



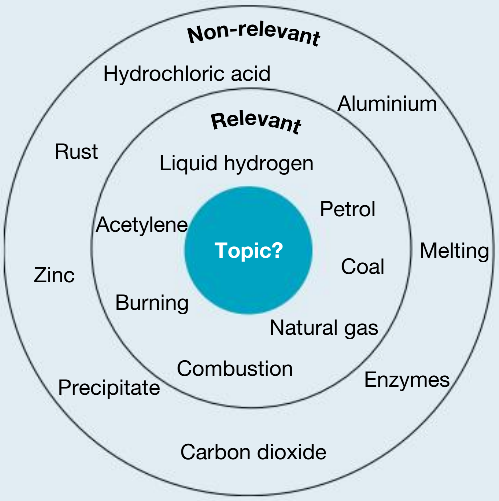
3. a. Form small groups, or work independently, to brainstorm as many single words as you can that are associated with chemical reactions.
   b. Use your brainstorm list to create a team single bubble map about chemical reactions.
   c. Compare your list with those of other teams and then work together to construct a class single bubble map about chemical reactions.

4. Which topic would be the most appropriate for the target maps shown?

a.



b.



5. Create a target map about recycling.

Fully worked solutions and sample responses are available in your digital formats.

8.11 Review

Access your topic review eWorkbooks

Topic review level 1	Topic review level 2	Topic review level 3
ewbk-3451	ewbk-3452	ewbk-3453

on Resources

8.11.1 Summary

Physical and chemical properties

- Physical properties can either be observed or measured directly.
- Chemical properties are those that describe how a substance combines with other substances to form new chemicals or how a substance breaks up into two or more different substances.
- There are many chemical properties including flammability, reactivity and toxicity.

Chemical and physical changes

- Chemical change results in a new substance being formed; some chemical bonds break and others form.
- Evaporation is a change of state from a liquid to a gas.
- During physical changes no new chemical substances are formed.
- Word equations for both physical changes and chemical changes have the starting substances on the left and the final substances on the right, separated by an arrow.

Chemical reactions

- A chemical reaction is a chemical change in which a new substance or substances are produced.
- Photosynthesis is a chemical reaction that life depends on. Carbon dioxide and water react with energy from the Sun to form glucose and oxygen.
- Reactants are the chemical substances used up in a chemical reaction.
- The substances that are produced in a chemical reaction are called products.
- Evidence of a chemical reaction occurring includes bubbles, odour, change in temperature, a precipitate, light or flame, and colour change.
- When writing word equations, it does not matter in which order the reactants or products are written.

Reaction rates

- The rate of a reaction may be changed by altering the temperature, size of particles, strength of reactants, the amount of reactants or the addition of a catalyst or enzyme.

Corrosion

- Rusting is an example of corrosion, which is a chemical reaction that occurs when substances in the air or water around a metal cause it to deteriorate.
- Rusting can be avoided using galvanising or surface protection.

Combustion

- Reactions that involve combination with oxygen such as burning are examples of oxidation reactions.
- When fossil fuels are combusted with oxygen, the products are heat, carbon dioxide and water, according to the reaction:

fossil fuel + oxygen → carbon dioxide + water

- The production of carbon dioxide from burning fossil fuels is a major contributor to greenhouse gas emissions and climate change.

- Rocket fuels rely on the combustion of hydrogen and oxygen to produce energy and water according to the reaction:

$$\textbf{hydrogen + oxygen} \rightarrow \textbf{water}$$

Plastics and fibres

- Plastics are polymers produced from a series of monomers.
- Natural fibres include wool and silk from animals and cotton from plants.

Recycling

- Recycling involves reusing an unwanted substance or object for another purpose.
- Biodegradable substances break down or decompose easily in the environment.

8.11.2 Key terms

biodegradable describes a substance that breaks down or decomposes easily in the environment
burning combining a substance with oxygen in a flame
catalyst chemical that helps to start or speed up a chemical reaction
chemical change change that results in a new substance being formed. During a chemical change, some chemical bonds break and others form.
chemical properties properties that describe how a substance combines with other substances to form new chemicals or how a substance breaks up into two or more different substances
chemical reaction a chemical change between two or more substances in which one or more new chemical substances are produced
corrosion a chemical reaction between air, water or chemicals in the air or water with a metal, which causes the metal to wear away
cullet used glass
ductile capable of being drawn into wires or threads; a property of most metals
durability the quality of lasting, not easily being worn out
elastic describes a material that is able to return to its original size after being stretched
elasticity the property that allows a material to return to it original size after being stretched
enzymes special chemicals that speed up reactions but are themselves not used up in the reaction
evaporates changes state from a liquid to a gas. Evaporation occurs only from the surface of a liquid.
flammability an indicator of how easily a substance catches fire
fossil fuel substance, such as coal, oil and natural gas, that has formed from the remains of ancient organisms. Coal, oil and natural gas are often used as fuels; that is, they are burnt in order to produce heat.
galvanising protecting a metal by covering it with a more reactive metal that will corrode first
malleable able to be beaten, bent or flattened into shape
natural fibres fibres that form naturally; that is, they have not been made by humans. Natural fibres include wool and silk from animals and cotton from plants.
nylon synthetic fibre. The monomers are joined by the elimination of water molecules at the joins.
organisms living things
oxidation chemical reaction involving the loss of electrons by a substance
physical changes changes in which no new chemical substances are formed. A physical change may be a change in shape, size or state. Many physical changes are easy to reverse.
physical properties properties that you can either observe using your five senses — seeing, hearing, touching, smelling and tasting — or measure directly
polyester synthetic fibre. The monomers are joined together by the elimination of water molecules at the joins.
precipitate solid product of a chemical reaction that does not dissolve in water
products new chemical substances that result from a chemical reaction
reactants chemical substances used up in a chemical reaction. Some chemical bonds in a reactant are broken during the reaction.
reaction rate speed at which a reaction takes place
reactivity a measure of how likely a particular substance reacts to make new substances
recycled reuse an unwanted substance or object for another purpose
rust a brown substance formed when iron reacts with oxygen and water

rusting the corrosion of iron
spinneret device like a nozzle with small holes through which a plastic material passes, forming threads, also the organ used by spiders to create their webs
state condition or phase of a substance. The three main states of matter are solid, liquid and gas.
surface protection coating over a metal surface to prevent corrosion
sustainable describes the concept of using the Earth's resources so that the needs of the world's present population can be met, without damaging the ability of future populations to meet their needs
toxicity the danger to your health caused when poisonous substances combine with chemicals in your body to produce new substances and damaging effects

on Resources

Digital document	Key terms glossary (doc-31828)
eWorkbooks	Study checklist (ewbk-3444) Literacy builder (ewbk-3445) Crossword (ewbk-3446) Word search (ewbk-3447)
Practical investigation eLogbook	Topic 8 Practical investigation eLogbook (elog-0252)

8.11 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 5, 8, 14, 16, 18	Questions 2, 6, 7, 11, 12, 13, 15, 20	Questions 3, 4, 9, 10, 17 ,19, 21

1. Match the substances on the left to the list of properties on the right.

Substances	Properties
a. Glass	**A.** Flexible, biodegradable
b. Metal	**B.** Transparent, unreactive, strong
c. Plastics	**C.** Malleable, ductile, good electrical conductor
d. Paper	**D.** Mouldable, light, strong

2. Physical properties are those that you can observe or measure using your senses or measuring instruments. Chemical properties are those that describe how a substance combines with other substances. True or false? Explain your response.

3. Match the property on the left to its meaning on the right.

Property	Meaning
a. Ductile	A. Able to be rolled or beaten into sheets
b. Reactive	B. Substances that can damage living things when taken into the body
c. Malleable	C. Readily combines chemically with other substances
d. Lustrous	D. Lets light through without scattering
e. Toxic	E. Temperature at which a solid changes into its liquid form
f. Transparent	F. Able to be drawn into wires
g. Melting point	G. Shiny

4. Determine whether each of the following scenarios is a chemical change or physical change. Then write the correct reactants and products to complete the word equation for the reaction.
   a. The wax on a burning candle melts.
      This is a ______________ change.
      ______________ → ______________
   b. The wax vapour at the top of a candle wick burns with oxygen to produce carbon dioxide, water vapour and heat.
      This is a ______________ change.
      wax vapour + ______________ → ______________ **+ water**
   c. Calcium carbonate is dissolved by hydrochloric acid to form calcium chloride, water and carbon dioxide gas.
      This is a ______________ change.
      solid calcium carbonate + ____________ → ____________**+ carbon dioxide gas + water**
   d. Hydrogen gas explodes with oxygen gas to form water.
      This is a ______________ change.
      __________________ → __________________

5. MC How do you know that toasting bread and the rusting of a nail is not a physical change?
   A. A new colour is produced
   B. A new chemical has been formed
   C. A gas is produced
   D. Heat is produced
6. Catalysts are sometimes added to the reactants in a chemical reaction to speed up a reaction.
   a. What is a catalyst?
   b. When a word equation is written to describe a chemical reaction, catalysts are not included as either reactants or products. Why is this so?
7. When a lead nitrate solution is added to a potassium iodide solution, a chemical reaction takes place. A bright yellow solid appears. It is the compound lead iodide. Another compound, potassium nitrate, remains in the solution and is not visible.
   a. MC Which of the following are the reactants in the reaction? Select all possible answers from the options given.
      A. Lead nitrate
      B. Lead iodide
      C. Potassium iodide
      D. Potassium nitrate
      E. Water
   b. MC Which of the following are the products in the reaction? Select all possible answers from the options given.
      A. Lead nitrate
      B. Lead iodide
      C. Potassium iodide
      D. Potassium nitrate
      E. Water

c. The yellow lead iodide will eventually settle to the bottom of the flask.
What 11-letter word beginning with ‘p’ is given to a substance that behaves like the lead iodide?

d. MC Which of the following is the chemical word equation for the reaction?
A. lead iodide + potassium iodide → lead nitrate + potassium nitrate
B. lead nitrate + lead iodide → potassium iodide + potassium nitrate
C. lead iodide + potassium nitrate → lead nitrate + potassium iodide
D. lead nitrate + potassium iodide → lead iodide + potassium nitrate

8. The chemical word equation for rusting is:

iron + water + carbon dioxide → rust (iron oxide)

True or false? Justify your response.

9. SIS For each of the reactions provided, match the way that the reaction could be made to happen more quickly.

Reaction	How to speed up the reaction
a. Burning a pile of dry leaves	A. Leaving it in a warm place
b. Cooking potatoes	B. Placing it in a salty environment
c. Dissolving marble chips in acid	C. Fanning the fire to increase the amount of oxygen
d. Making an iron nail go rusty	D. Cutting them into smaller pieces
e. Milk going sour	E. Heating the acid

10. Some chemical reactions can be destructive. Write down three examples of harmful chemical reactions.

Apply and analyse

11. Children’s steel swing sets in beachside towns and suburbs rust much faster than those further from the coast.
a. Explain why this happens.
b. Suggest two methods of slowing down or preventing the rusting of steel swing sets.

12. The oxyacetylene torch shown is used to melt metals to allow them to be joined together.
a. MC What type of chemical reaction takes place in the oxyacetylene torch?
A. Corrosion reaction
B. Combustion reaction
C. Addition reaction
D. Rusting reaction

b. MC What is the evidence in the photo that suggests a chemical reaction has taken place?
A. A bright light and small sparks are being produced.
B. The photo is mostly dark.
C. The welder is wearing gloves.
D. The welder is wearing a face shield.

13. Just as chemicals can be grouped or classified, so can chemical reactions. Match the chemical reactions on the left to the type of reaction on the right.

Chemical reaction	Type of reaction
a. The corrosion of iron	A. Combustion
b. The reaction of substances with oxygen	B. Rusting
c. Burning	C. Oxidation

14. This illustration shows a camper boiling water in a billy over a camp fire.

a. State the three physical changes that are shown in the image.
b. Identify which chemical change is shown taking place.
c. List two ways in which the chemical reaction taking place has been sped up.

15. Which two properties of the plastic used to make light switches and power points make it right for the job?
16. MC What is the difference (other than their properties) between natural and synthetic fibres?
A. Natural fibres are made from plants whereas synthetic fibres are made from animals.
B. Natural fibres are made from plants or animals whereas synthetic fibres are made from crude oil.
C. Natural fibres are made from animals whereas synthetic fibres are made from plants.
D. Natural fibres are made from crude oil whereas synthetic fibres are made from plants or animals.
17. Classify whether each of the fibres listed are natural, synthetic, or a combination of both.

Fibre	Synthetic	Natural	Combination
Nylon			
Cotton			
Rayon			
Lycra			
Wool			
Polyester			

18. Explain how synthetic fibres, such as nylon, are made.
19. Match the substances on the left to the properties that would be essential for their packaging.

Substances	Properties of packaging
a. Pool chemicals	A. Gas tight, strong, chemically resistant to the drink
b. Eggs	B. Airtight, opaque to light
c. Soft drink	C. Resistance to the chemicals inside, opaque to light
d. Peanuts	D. Lightweight, strong, rigid

Evaluate and create

20. SIS Some plastic containers are marked with this symbol.

a. MC Which two of the following substances would you expect to find in bottles made from this type of plastic?
   A. Wine
   B. Soft drink
   C. Eggs
   D. Milk

b. MC What two things should you do before placing bottles made from this type of plastic in a recycling bin?
   A. Fill up with water.
   B. Empty the contents.
   C. Remove the lids.
   D. Screw on the lids.

c. MC Which two of the following are uses for this type of plastic after it has been recycled?
   A. Carpet fibres
   B. PETE cannot be recycled
   C. Paper
   D. Glass bottles
   E. Flower tubes

21. SIS Describe the 'three-bin system' used by many cities and shires in Australia, and explain how it helps the environment.

Fully worked solutions and sample responses are available in your digital formats.

on Resources

eWorkbook Reflection (ewbk-3038)

teachon

Test maker
Create customised assessments from our extensive range of questions, including teacher-quarantined questions. Access the assignments section in learnON to begin creating and assigning assessments to students.

RESOURCE SUMMARY

on Resources

Below is a full list of **rich resources** available online for this topic. These resources are designed to bring ideas to life, to promote deep and lasting learning and to support the different learning needs of each individual.

8.1 Overview

eWorkbooks
- Topic 8 eWorkbook (eles-3467)
- Student learning matrix (ewbk-3477)
- Starter activity (ewbk-3469)

Practical investigation eLogbooks
- Topic 8 Practical investigation eLogbook (elog-0252)
- Investigation 8.1: Investigating chemical reactions (elog-0238)

Video eLesson
- Reactions of magnesium ribbons in acid (eles-2571)

8.2 Physical and chemical properties

eWorkbook
- Properties of materials (ewbk-3434)

Practical investigation eLogbook
- Investigation 8.2: Describing properties (elog-0239)

8.3 Chemical and physical changes

eWorkbook
- Changing states (ewbk-3809)

Practical investigation eLogbook
- Investigation 8.3: A buring candle (elog-0240)

8.4 Chemical reactions

eWorkbooks
- Physical and chemical changes (ewbk-7627)
- Describing chemical changes (ewbk-7628)

Practical investigation eLogbooks
- Investigation 8.4: Heating copper carbonate (elog-0241)
- Investigation 8.5: Magnesium metal in hydrochloric acid (elog-0242)
- Investigation 8.6: Sodium sulfate and barium chloride (elog-0243)
- Investigation 8.7: Steel wool in copper sulfate solution (elog-0244)

Video eLessons
- Precipitation (eles-2058)
- Magnesium metal burning (eles-2303)
- Baking and carbon dioxide (eles-2059)
- Magnesium and hydrochloric acid (eles-2294)

8.5 Reaction rates

eWorkbook
- Speeding up reactions (ewbk-3438)

Practical investigation eLogbooks
- Investigation 8.8: Reaction rates (elog-0245)
- Investigation 8.9: Changing the rate of reaction (elog-0246)

Interactivities
- Reaction rates (int-0230)
- Time Out: Reactions (int-0759)

8.6 Corrosion

eWorkbook
- Rusting (ewbk-3439)

Practical investigation eLogbooks
- Investigation 8.10: Observing rusting (elog-0247)
- Investigation 8.11: Investigating the corrosion of different metals (elog-0248)
- Investigation 8.12: Rusting and salt water (elog-0249)

8.7 Combustion

eWorkbook
- Combustion (ewbk-7389)

Practical investigation eLogbook
- Investigation 8.13: Burning paper (elog-0250)

8.8 Plastics and fibres

Practical investigation eLogbook
- Investigation 8.14: Testing fibres (elog-0251)

Video eLesson
- The future of clothing (eles-0859)

8.9 Recycling

Weblink
- Recycling

8.11 Review

eWorkbooks

- Topic review Level 1 (ewbk-3451)
- Topic review Level 2 (ewbk-3452)
- Topic review Level 3 (ewbk-3453)
- Study checklist (ewbk-3444)
- Literacy builder (ewbk-3445)
- Crossword (ewbk-3446)
- Word search (ewbk-3447)
- Reflection (ewbk-3038)

Practical investigation eLogbook

- Practical investigation eLogbook (elog-0252)

Digital document

- Key terms glossary (doc-31828)

To access these online resources, log on to **www.jacplus.com.au**.

9 Sedimentary, igneous and metamorphic rocks

LEARNING SEQUENCE

9.1 Overview

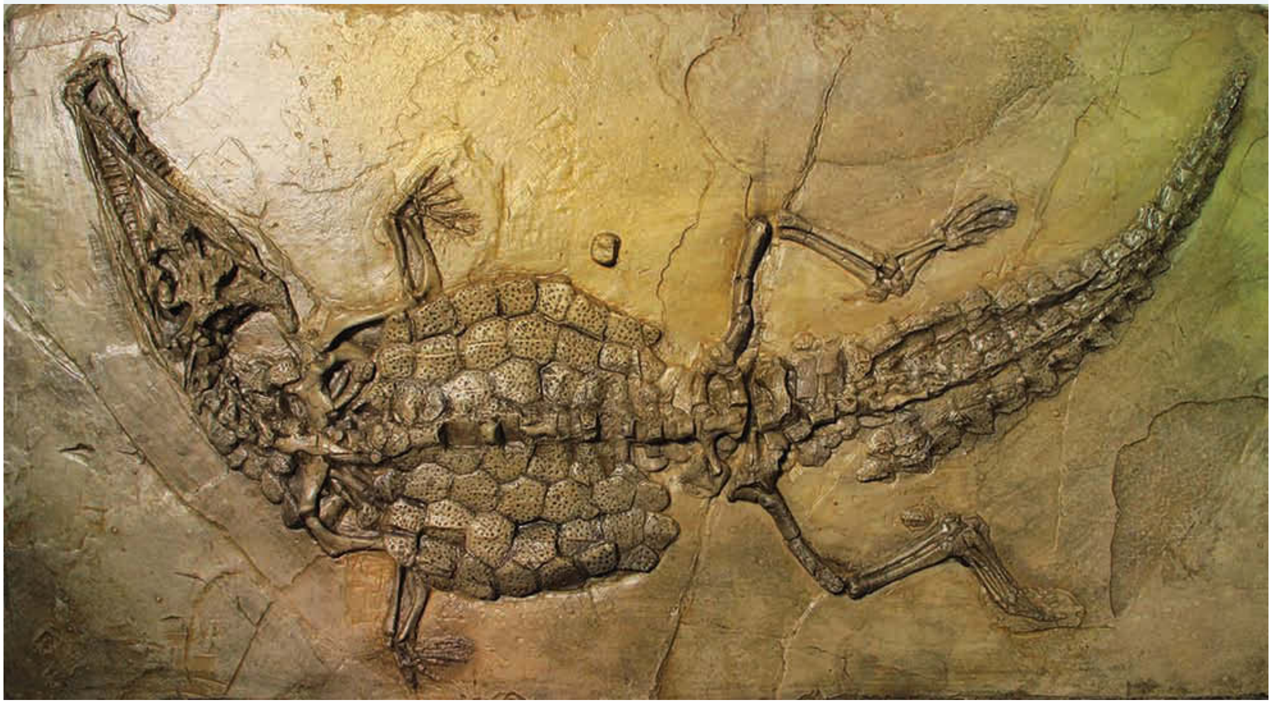
Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the concepts covered in this topic.

9.1.1 Introduction

The Earth's surface is constantly changing. Volcanoes and earthquakes can cause quick changes, but most of the changes to the Earth's surface happen slowly. Rocks on and below the surface of the Earth are the records of these natural events. A geologist is a scientist who learns to read each type of rock, much like reading a chapter in a book, to discover the chapters of Earth's history. An important record held in the rocks includes the evolution of life.

Locked in the limestone rocks of Cerin, France, is a fossil of the *Crocodilaemus robustus*, an extinct reptile similar to crocodiles. The rocks suggest that it lived in a near-tropical lagoon environment about 160 million years ago, long before humans were around. It was a small reptile, only 60 centimetres long, with long back legs that probably made walking on land easier. The strong plated armour on its abdomen and tail protected it, but also made it a slower swimmer. If you visit Cerin today, you won't see a lagoon or a living *Crocodileimus robustus* because the Earth's surface is continually changing and life has evolved with it. The best way to learn about the past is to look at the rocks, and know the past is a tool to predicting the future.

FIGURE 9.1 Fossil *Crocodilaemus robustus* that lived 160 million years ago



9.1.2 Think about rocks

1. Which rock is light enough to float on water?
2. Which rocks are formed from the remains of living things?
3. What do butterflies, frogs, werewolves and metamorphic rocks have in common?
4. How do we know what living things that have not existed for millions of years looked like, how they walked and what they ate?
5. How can whole skeletons of animals be fully preserved for millions of years?
6. What can you learn from a dinosaur footprint?
7. Why did the dinosaurs vanish from the Earth 65 million years ago?

9.1.3 Science inquiry

Rock types

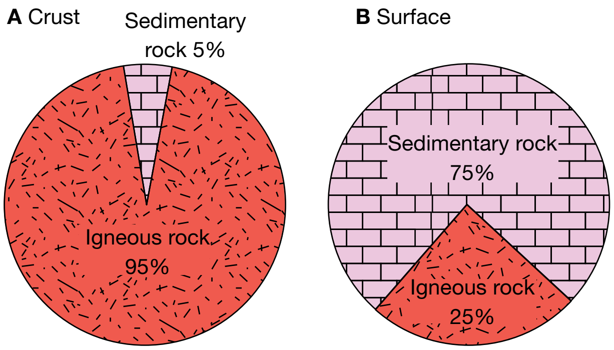
Rocks are classified as either igneous, sedimentary or metamorphic. Each of these names provides a clue to how the rocks within the type formed. For example, the word igneous comes from the Latin word *ignis*, meaning 'fire'. That is, these rocks have formed from the cooling and hardening of fiery hot, melted rock. As a class discuss the following questions.

1. The word sediment comes from the Latin word *sedere*, meaning 'settle', or 'sit'. What could this imply about how sedimentary rocks form?
2. The word *meta* is Greek for 'change' and *morpho* means 'form'. What could this imply about how metamorphic rocks form?

Further to your answers above, consider figure 9.2, which illustrates the distribution of rocks in the crust (the top layer that averages 6–35 km thick) and the surface of Earth. In these charts, metamorphic rocks are included within the rocks that they were formed from. That is, metamorphic rocks derived from sedimentary rocks are included in the sedimentary rock total.

3. Igneous rocks, or metamorphic rocks derived from igneous rocks, account for 95 per cent of all rocks in the Earth's crust; sedimentary rocks account for 5 per cent. However, when we look at just the Earth's surface, sedimentary rocks make up 75 per cent. What does this tell you about the nature of igneous and sedimentary rocks?

FIGURE 9.2 The distribution of rocks in the crust and across the surface of Earth



Bathroom rocks

When you last used the bathroom, you probably weren't thinking about rocks. After all, what does a bathroom have to do with rocks? But where did the materials to make the shower recess come from? What about the taps and pipes that deliver the water? Where do the materials to make tiles come from? And what about the toothpaste? The answers to all of these questions lead back to rocks. For example, metals are extracted from rocks and are used to make the steel taps.

Work in small groups to research and answer the following questions.

4. What materials are mirrors made from?
5. What metal is primarily used to make bathroom taps? Where do we get the metal?
6. What are bathroom tiles and the toilet basin made from?
7. List some building materials that are:
   a. made directly from rocks
   b. not made directly from rocks but can be traced back to rocks.

FIGURE 9.3 Taps, tiles, glass and even mirrors. Where do the materials needed to produce these come from?

on Resources

eWorkbooks	Topic 9 eWorkbook (ewbk-5034) Student learning matrix (ewbk-5036) Starter activity (ewbk-5037)
Practical investigation eLogbook	Topic 9 Practical investigation eLogbook (elog-0610)
learnon	Access and answer an online Pre-test and receive **immediate corrective feedback** and **fully worked solutions** for all questions.

9.2 Rocks and minerals

LEARNING INTENTION

At the end of this subtopic you will be able to define a geological mineral and recognise that they have unique chemical and physical properties, and how they differ from rocks.

9.2.1 What's in a rock?

Firstly, let's make sure we know what a rock is. To call something a rock, it needs to be a naturally occurring, coherent collection of minerals, organic material and/or glass.

- Naturally occurring: must be formed by natural process; it is not manufactured
- Coherent: holds together; for example, form cliffs
- Collection of minerals, organic matter and/or glass: some rocks only contain a collection of one type of mineral, some contain several different minerals, some are entirely made of glass and some are composed of large volumes of organic matter (for example, coal).

Never confuse rocks and minerals. Minerals are to rocks as letters are to words.

DISCUSSION

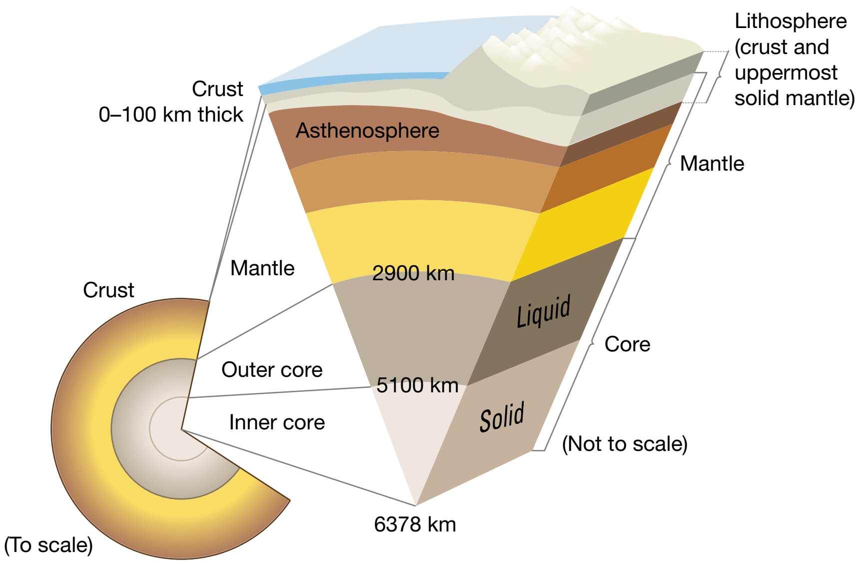
Discuss whether these items are considered a rock or not. Be sure you can explain your answer.

- Footpath cement
- Benchtop granite
- Bricks
- Bathroom marble
- Garden soil

How rocks are formed

The rocks we can see have formed in the Earth's **lithosphere** (figure 9.4), which includes the Earth's crust and the top part of its mantle. Rocks are classified into one of three groups based on how they formed: **igneous**, **sedimentary** or **metamorphic rocks** (table 9.1).

FIGURE 9.4 The rocks we can see have formed in the Earth's lithosphere.



lithosphere the outermost layer of the Earth, includes the crust and uppermost part of the mantle

igneous rock formed when hot, molten rock cools and hardens (solidifies)

sedimentary rocks formed through the deposition and compaction of layered sediment

metamorphic rocks formed from the change (alteration) of pre-existing rocks in response to increasing temperature and/or pressure conditions

TABLE 9.1 The thee types of rocks and how they formed

Igneous rocks	Sedimentary rocks	Metamorphic rocks
If the right temperature and pressure conditions are met, rocks can partially melt into **magma**. New rocks are formed when magma gets close to the surface and slowly *cools and solidifies*. Some of that red-hot magma breaks through the Earth's crust to form fiery volcanoes, releasing **lava** to cool quickly on the surface or even underwater.	When rocks are exposed on the surface, the presence of water, air and life help to both physically and chemically break them down. This is called **weathering**. New rocks can form as **erosion** and **deposition** create layers of **sediments**; this can include the remains of living things that are hardened by *compaction* as more and more layers of sediment are added.	Rocks can be buried to great depths, where the higher temperatures (greater than 200 °C) and pressures can cause the rock to change form. Both the mineral type and appearance can change. The change happens in the solid state; meaning there is no melting. We can see these rocks because they get brought back up to the surface.

magma a very hot mixture of molten rock and gases, just below the Earth's surface, that has come from the mantle

lava molten rock flowing on the surface

weathering the physical or chemical break down of rocks on the surface

erosion the wearing away and removal of soil and rock by natural elements, such as wind, waves, rivers and ice, and by human activity

deposition the settling of transported sediments

sediment material broken down by weathering and erosion that is moved by wind or water and collects in layers

9.2.2 Minerals

Most rocks are made up of substances called **minerals**. A mineral is any naturally occurring solid substance with a definite chemical composition and crystal structure.

FIGURE 9.5 Quartz is one of the most common minerals in the Earth's crust.

Chemical composition

Elements found naturally in their uncombined, pure form are also minerals. These elements, called **native elements**, include diamonds (pure carbon) and gold.

Most minerals in rocks are **compounds**, where one or more elements bond together. For example, the mineral calcite is the combination of one calcium (Ca), one carbon (C) and three oxygen atoms (O) to make calcium carbonate ($CaCO_3$). Calcite is the primary mineral found in the rock's limestone and marble.

The most common group of minerals is the **silicates**, in which elements bond to oxygen (O) and silicon (Si). This is because oxygen and silicon are the most abundant elements in the Earth's crust. The mineral quartz (figure 9.5) is a simple silicate (SiO_2); whereas, clay is a complex silicate ($Al_4Si_4O_{10}(OH)_8$).

Wherever you go, a specific type of mineral will have the same chemical composition. The colours and shapes may change a little, which tells us more about how they were formed and provides clues about the past.

Crystal structure

The elemental atoms that join to form minerals create regular geometric shapes called **crystals**. The crystal shape reflects the organisation of the atoms inside. The physical environment around them can also impact the crystal structure, where additional pressure or compaction will force the structure to be more closely packed.

The size of crystals depends on how fast they form and how much space is available. If a crystal forms quickly, do you think it would be smaller or bigger? Smaller, because it had less time to grow.

mineral a naturally occurring, inorganic and solid substance with a defined chemical formula and an ordered arrangement of atoms

native elements elements found uncombined in the Earth's crust

compounds substance made up of two or more different types of atoms that have been joined (bonded) together

silicates group of minerals consisting primarily of SiO_4^{2-} combined with metal ions, forming a major component of the rocks in the Earth's crust

crystal geometrically-shaped substance made up of atoms and molecules arranged in one of seven different shapes. The elements that make up a crystal and the conditions present during the crystal's growth determine the arrangement of atoms and molecules and the shape of the crystals.

The quartz crystals in figure 9.5 have had a lot of time and space to grow. Quartz, one of the most common minerals, consists of hexagonal-shaped crystals of silicon dioxide (SiO_2) that make it look like a six-sided column with a six-sided pyramid at both ends.

EXTENSION: Are diamonds forever?

Although graphite (which can be found in some of your pencils) and diamonds are both minerals with pure carbon as their chemical composition, they are physically very different. Graphite is soft enough to leave behind traces when rubbed on paper, and diamonds are the hardest minerals on Earth. In fact, diamonds are so hard they are used to drill into rocks.

If they are made of the same element why do they display such different properties? They formed under different pressure conditions. To get the crystal structure of a natural diamond, carbon crystals have to form under pressures that are only reached deeper than 150 km into the Earth. This is one of the reasons they are so rare here on the surface. The bad news is that at the surface where the pressure is much less, diamonds are slowly changing back to graphite — very, very slowly.

FIGURE 9.6 Natural graphite form

FIGURE 9.7 Faceted diamond, created by grinding a diamond on a spinning lap

on Resources

Interactivity Crystals (int-5338)

Weblink Mexico giant crystal cave

DISCUSSION

Is table salt a mineral? Think carefully about your answer and suggest reasons for and against classifying it as a mineral. How about ice that forms on car windows during a freezing winter night?

Identifying minerals

Although colour might seem to be the quickest way to identify a mineral, it is not reliable. Many different minerals have similar colours. Some samples of the same mineral can have different colours due to small impurities. For example, quartz can be colourless like glass, or may be pink, violet, brown, black, yellow, white or green. Therefore, we must use a combination of properties to identify minerals.

Additional mineral properties include the following.

- The **lustre** of a mineral describes the way that it reflects light. Minerals could be described as metallic or non-metallic, with non-metallic expanding with options such as dull, pearly, waxy, silky or glassy.
- The **streak** is the colour of a powdery mark left by a mineral when it is scraped across a hard surface, such as an unglazed white ceramic tile.
- The **hardness** of a mineral can be determined by trying to scratch one mineral with another. The harder mineral leaves a scratch on the softer mineral.

lustre appearance of a mineral caused by the way it reflects light. A mineral can appear glassy, waxy, metallic, dull, pearly, silky

streak colour of a mineral as a fine powder, found by rubbing it onto an unglazed white ceramic tile

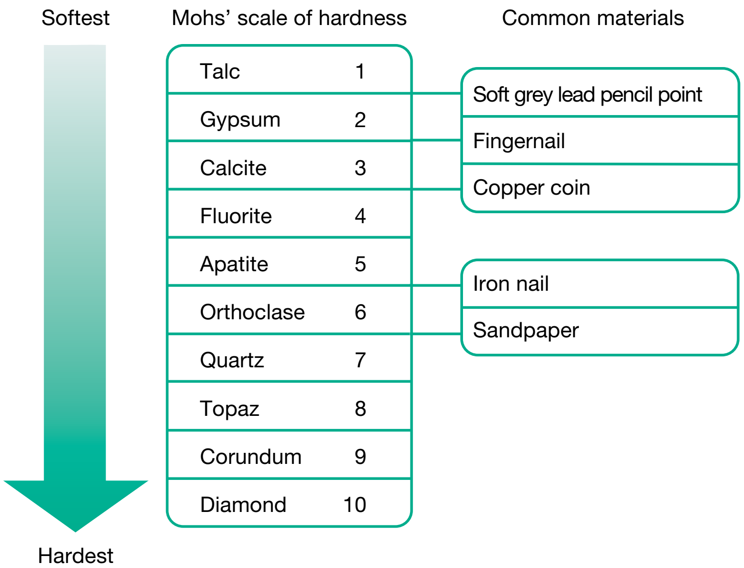
hardness a measure of how difficult it is to scratch the surface of a solid material, hardness can be ranked using Moh's scale

Minerals generally have no 'fingerprint' or single property that sets them apart from others; therefore, we tell them apart by identifying a combination of physical properties.

Friedrich Mohs' scale of hardness is a numbered list of ten minerals ranked in order of hardness. Higher numbers correspond to harder minerals. The hardness of a mineral is determined by comparing it with the minerals or common materials in the Mohs' scale. For example, a mineral that can be scratched by quartz but not by orthoclase has a hardness between 6 and 7.

Figure 9.8 shows that some more common materials can also be used to determine the hardness of a mineral.

FIGURE 9.8 Moh's scale for testing the hardness of minerals



elog-0612

INVESTIGATION 9.1

Identifying mineral properties

Aim

To observe the properties of a range of minerals

Materials

- mineral kit
- common materials to substitute for unavailable Mohs' scale minerals
- hand lens
- white ceramic tile

Method

1. Construct a table like the one in the results section to record your observations as you work through the following steps for each mineral.
2. Write down the mineral name and describe the colour and lustre.
3. Use the magnifying glass to look closely at the mineral and describe the shape and size of its crystal(s).
4. Scrape the mineral across the unglazed side of a white ceramic tile. Record the colour of the streak.
5. Use Mohs' scale minerals or the common materials (figure 9.8) to estimate the hardness of the mineral by trying to scratch it. An approximate range, such as 5–6, is sufficiently accurate.

Results

Complete your table for each mineral to present your results. Remember to add a title to your table.

Mineral	Colour	Lustre	Crystal shape and size	Streak	Hardness

Discussion

1. How similar were some of your minerals? Note two minerals that were close but had one or two different properties.
2. Other than those already described, what additional properties of minerals could be used to identify them?
3. If two unlabelled mineral samples have the same colour and lustre, can you be sure that they are the same mineral? Explain how you would find out.

Conclusion

What can you conclude about the properties across a range of minerals?

on Resources

eWorkbook Identifying and classifying minerals (ewbk-5023)

assess on Additional automatically marked question sets

9.2 Exercise

learn on

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 6, 9	Questions 3, 4, 7, 10, 14	Questions 5, 8, 11, 12, 13

Remember and understand

1. Rocks are naturally forming, coherent combinations of what potential three substances?
2. In which part of the Earth are most of the rocks we see formed?
3. List the three ways in which rocks can form.
4. What is a mineral?
5. What is a native element? List two examples.
6. What is the largest group of minerals called and what are they based on?
7. What is the approximate hardness on Mohs' scale (to the nearest whole number) of a mineral that can be scratched by sandpaper but not by an iron nail?
8. List at least five properties that you could observe to help you identify an unknown mineral.

Apply and analyse

9. Explain the difference between a rock and a mineral.
10. A mineral can be scratched by a copper coin but not by a fingernail. You know that the mineral is quartz, fluorite or calcite. Which is it?
11. You have two samples, each of a different mineral, but no other equipment to test them for hardness. How could you tell which mineral is harder?
12. You have found a rock with tiny minerals in it and you would like to identify them. How could you go about testing the physical properties to help you identify the mineral?

Evaluate and create

13. SIS A geologist has been hired to find some haematite iron ore. They are walking the field in search of it and find lots of rocks. In order to determine whether or not the rocks contain haematite, they look for a sample with a dark colour and metallic lustre. They then pick up the sample to see how heavy it is. If it is dark coloured with a steel grey metallic lustre, and very heavy, they call it haematite.
    a. Reflect on the method the geologist used to identify the mineral. Is anything missing?
    b. How reliable is their claim that the sample contains haematite?
    c. What could you do to improve the conclusion?
14. SIS Find out how crystals can be artificially grown and then grow a crystal garden.

Fully worked solutions and sample responses are available in your digital formats.

9.3 Mining for metals

LEARNING INTENTION

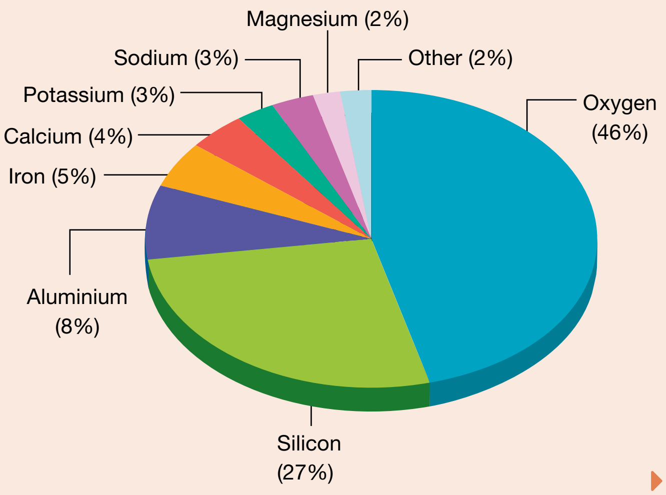
At the end of this subtopic you will be able to describe that minerals containing metals can be mined from the Earth's surface but that this process relies on many steps that involve knowledge of the geology, the environmental impact of the mining activity, processing of the ore and rehabilitation once the mining is complete.

SCIENCE AS A HUMAN ENDEAVOUR: Mining minerals in Australia

Metals play an important part in our lives every day. The phone you use to chat with your friends has several metal components, wires and lithium batteries. You use metal cutlery to eat food. The bus, car, bike or scooter you rode to school is made from metal.

The metal elements used to make these things are found in minerals within rocks in the Earth's crust. The pie chart in figure 9.9 shows that almost three-quarters of the Earth's crust (by weight) is made up of the non-metals oxygen and silicon. Most of the metal elements combine with other elements to form compounds. They commonly combine with oxygen, silicon or other non-metals, like sulfur.

FIGURE 9.9 The elements in the Earth's crust. The metal elements are relatively rare compared with oxygen and silicon.



Minerals containing metals of value that can be extracted for profit are called **ore minerals**. It takes a lot of time, effort and money to get the rocks that contain the ore minerals out of the ground, separate the ore from the waste rock and extract the metal element from the ore mineral. The **mining** of an ore can take place only if enough of it is found concentrated at a single location. This makes the potential of finding ore very different from one place to another.

The mining industry makes a major contribution to Australia's economy. Apart from the profits that go to shareholders in mining companies and to the government in taxes, the mining industry employs many thousands of Australians. Scientists and engineers are involved at every stage of the mining process.

Mineral exploration

Finding minerals below the Earth's surface, where you can't see them, is an expensive business. Geologists use their knowledge of sediments, rocks and minerals, and the clues they provide, to help them predict where precious ores are likely to be found.

Geologists make use of satellites equipped with cameras, radar and other sensors to search for geological features that are likely to contain high concentrations of ores. The magnetic properties of large bodies of rocks containing some minerals, like haematite iron ore, can be detected from aircraft or by geological surveyors on the ground.

Minerals in the crust breakdown in rain and running water, and get washed into creeks and rivers. A chemical analysis of the soils, sediments and surface water of lakes and streams can provide evidence of the presence of minerals in the area. Samples of soil and rocks are taken using portable equipment.

On average, only one in one thousand sites that are sampled is eventually mined.

If there is sufficient evidence of useful mineral deposits that might be worth mining, a licence must be obtained before any clearing is done or heavy drilling equipment is brought in. Helicopters are sometimes used to bring in heavy equipment to protect sensitive ecosystems. The drilling allows mining companies to have a very detailed examination of what lies beneath the surface. Mining companies are required by law to clean up exploration drill sites and ensure they are left as they were found.

You can't start until …

In the past, mining was often carried out without considering its long-term effect on the environment and the people who lived and worked in the area. Today, however, an **environmental impact statement (EIS)** must be prepared before a mining operation can commence. An EIS outlines how the mining company intends to manage all environmental aspects of the proposed mine. It also outlines how the land will be **rehabilitated** or reconstructed, so that it can be used again after the mining is completed.

The environmental impact statement, along with any other relevant information, is studied by the government before permission to proceed is granted.

The EIS reports on:

- existing flora, fauna and soils
- existing towns and roads in the area
- proposed new towns, roads and other developments
- how the new development might affect the local community and environment
- alternative plans to complete the development that might have less impact on the environment
- measures that will be put in place to monitor and control air, water and noise pollution during the project and while rehabilitation is undertaken
- rehabilitation proposals for the area.

Taking out the ore mineral

To obtain ore from the ground, it is often necessary to remove large amounts of rocks and soil. The way this is done depends on how close the ore deposit is to the surface. If it is close to the surface, first the vegetation and topsoil are removed. Then waste rock from beneath the topsoil, called **overburden**, is removed. The removed topsoil and overburden are used to fill areas that have already been mined, or are left in a pile to restore the newly mined area when mining is completed. This method of mining is called **open-cut mining**.

ore mineral a mineral from which a valuable metal can be removed for profit

mining the process of removing natural resources from the Earth

environmental impact statement (EIS) study of the possible effects of a planned project on the environment

rehabilitated restored to its previous condition

overburden waste rock removed from below the topsoil. This rock is replaced when the area is restored.

open-cut mining mining that scours out soil and rocks on the surface of the land

If the ore deposits are deep below the surface, miners use **underground mining**. This mining method is more dangerous and expensive than open-cut mining. Shafts and tunnels are dug up to four kilometres into the ground to reach the rocks containing the ore. The development of open-cut and underground mining is overseen by mining engineers.

underground mining mining that uses shafts and tunnels to remove rock from deep below the surface

Getting the metal

Obtaining the metal element takes place in two stages:

1. Mineral extraction separates the ore mineral from the rock taken from the ground. This involves crushing, grinding and washing the rock to separate the wanted minerals from the unwanted waste rock.
2. Metal extraction separates the desired metal element from the ore mineral. This always involves chemical reactions. The nature of these reactions depends on a number of factors, including the chemical composition of the ore mineral. Chemical engineers and metallurgists are involved in the design of this process.

Rehabilitation

Before mining of a new site begins, seeds of the natural vegetation of the area are collected so that seedlings can be cultivated at a later stage. The seedlings are grown in special nurseries until they are mature enough to return to the site of the mine.

During open-cut mining, the overburden (the material removed from the site to expose the mineral ore or coal) is used to fill holes left from earlier stages of the mining operation. Fresh topsoil is used to cover the overburden to ensure that new vegetation will grow. The soil surface is shaped to fit in with the surroundings, fertilised and sown with seeds or planted with seedlings. Care is taken to shape the new surface to prevent the newly sown soil from being eroded or washed away by wind or rain.

FIGURE 9.10 Resurfacing and replanting a former open-cut iron mine on Koolan Island, Western Australia

DISCUSSION

In a small group, discuss and list:

a. the factors a mining company should consider when it decides whether or not to start a mining project
b. the different tasks that scientists and engineers might perform from the beginning of mining exploration until mining rehabilitation is complete
c. some advantages to mining
d. some disadvantages to mining.

Compare the lists of your group with those of others in your class. Finally, debate as a class whether or not Australia should continue to mine.

elog-0613

INVESTIGATION 9.2

Searching without disturbing

Aim

To model the search for minerals below the ground

Materials

- a tray of sand
- 10 paperclips
- blindfold (optional)
- compass
- paper and clipboard-ruler

Method

1. Find a partner. Each of you should then draw identical maps of the sand tray. Use a ruler to construct a grid on each map. Label the grids across the top and down the side (e.g. A–J across the top, 1–15 down the side). Each grid should consist of at least 100 equal-sized rectangles or squares.
2. Without showing your partner, hide the paperclips in the tray of sand and mark the location of the 10 clips on your map.
3. Your partner's task is to locate the 10 paperclips and mark them on the map without disturbing the sand. You might wish to set a time limit.
4. Swap roles and repeat the steps above.

Results

1. What property of the paperclips allowed them to be located?
2. Record where and how many you found onto your grid map.

Discussion

1. How could your predictions of the location be checked with a pencil?
2. What was your success rate?
3. After checking, can the sand be restored to its initial condition?

Conclusion

What can you conclude about searching for hidden metals?

on Resources

assesson Additional automatically marked question sets

9.3 Exercise

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Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 5, 8	Questions 3, 6, 9, 10	Questions 4, 7, 11

Remember and understand

1. Where are ore minerals found?
2. Where in the Earth's crust are the metal elements found?
3. Describe the method of open-cut mining for removing mineral ores from the ground.
4. Outline the two stages involved in obtaining a metal element from rock.
5. What is an EIS?
6. Outline the information that is included in an EIS.
7. How do mining companies rehabilitate the land used for mining?
8. Explain why it is important to recycle metals as much as possible.

Apply and analyse

9. The most common element in the Earth's crust is oxygen. This element is a gas except at extremely low temperatures. In what form is oxygen found in the Earth's crust?

Evaluate and create

10. In a table like the one provided, make a list of the benefits and disadvantages of mining.

TABLE Benefits and disadvantages of mining

Benefits	Disadvantages

11. Discuss reasons for and against allowing mining to take place in Australia's national parks.

Fully worked solutions and sample responses are available in your digital formats.

9.4 Igneous — the 'hot' rocks

LEARNING INTENTION

At the end of this subtopic you will be able to describe the type of environments that igneous rocks form in and how they can be classified according to their composition and texture.

9.4.1 Melting rock

There are places around the Earth where physical conditions allow rocks to partially melt deep underground. The molten rock underground is called **magma**, and it rises slowly towards the surface. If the magma breaks through and flows onto the surface it is then called **lava**. Rocks that form from the cooling of magma below the surface or lava on the surface are called igneous rocks.

magma a very hot mixture of molten rock and gases, just below the Earth's surface, that has come from the mantle

lava molten rock flowing on the surface

The appearance of all igneous rocks depends on two major factors:

1. how quickly the lava or magma cooled
2. what substances it is made of.

WHAT DOES IT MEAN?

The word igneous comes from the Latin word *ignis*, meaning 'fire'. The words ignite and ignition also come from the same Latin word.

EXTENSION: Is the interior of the Earth all liquid?

At the Earth's surface, rock begins to melt when heated between 800 and 1000 °C, and will be completely melted at about 1200 °C. However, if you put a rock under pressure, it becomes stronger and requires a higher temperature to melt. This is why the interior of the Earth is mostly hot solid material and not all molten rock, despite the fact that temperatures of greater than 1000 °C exist.

The physical conditions required to melt rock would be:

1. adding so much heat that it overcomes the pressure
2. releasing pressure from a hot rock
3. adding fluids, like water.

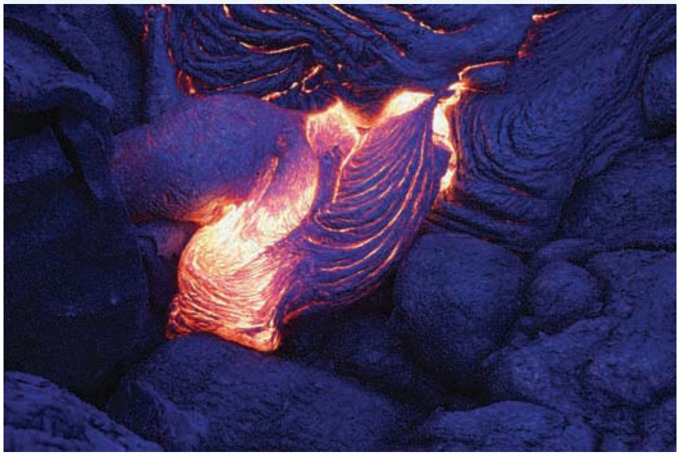
Releasing pressure and adding fluids lower the melting temperature. Magma is generated only where one or more of these conditions are met.

9.4.2 Extrusive rocks

Lava is released from erupting volcanoes at temperatures of 1000 °C or more. At that temperature, flowing lava could take hours to weeks to cool down and become solid rock. However, if lava is ejected into the air from explosive volcanoes it cools almost instantly. The lava erupting from underwater volcanoes on the ocean floor also cools quickly.

Igneous rocks that form from the cooling of red-hot lava above the Earth's surface are classified as **extrusive**. Igneous rocks that form from lava spilling from underwater volcanoes are also classified as extrusive rocks. Features of extrusive rocks are summarised in table 9.2.

FIGURE 9.11 Red-hot lava flowing on the surface. The cooling of lava causes a crust to form that can shift with the continued movement of underlying lava, creating a ropey look.



extrusive igneous rock that forms when lava cools above the Earth's surface

basalt a dark, igneous rock with small crystals formed by fast cooling of hot lava. It sometimes has holes that once contained volcanic gases.

TABLE 9.2 Features of extrusive igneous rocks

Crystal size	Rock colour
The size of crystals in extrusive igneous rocks is generally very small because of how fast the lava cools. When it cools quickly, there is not enough time for large crystals to form.	Colours range from black to grey, white or even red. The colour reflects the types of minerals that have formed. Generally, the dark rocks are rich in iron (Fe) and magnesium (Mg) minerals. The lighter coloured rocks contain more minerals that are richer in silicon (Si).

Basalt and rhyolite

Basalt is a common extrusive rock that is dark coloured with small mineral crystals. You may be able to see some of the small crystals, but most require a magnifying tool. If basalt forms from lava cooling in cold ocean water, the crystals will be even smaller and only visible under a microscope. Why do you think that is so?

When rocks are heated up they expand, and when they cool down they contract (shrink). The basalt in figure 9.12 (and in the image opening this topic) formed from a cooling basalt lava flow. During cooling, the new rock contracts and this can form vertical columns of basalt. Beware of these columns on a cliff, as they can topple over.

FIGURE 9.12 When basalt flows cool, they can form hexagonal columns.

Rhyolite is another common extrusive rock. It also has generally small crystals, but, unlike basalt, it is light coloured. The lighter colour means it has more silica-rich minerals. More silica-rich minerals makes the lava sticky and harder to flow — a term called **viscosity**. A good example of different viscosities is honey verses water. Water flows over a table easily (low viscosity), but honey poured over the same table will move a lot slower (high viscosity). Because the rhyolite lava is viscous, it does not travel far from the volcano. Basalt has a lower viscosity and can flow further from a volcano.

FIGURE 9.13 Rhyolite is an extrusive igneous rock that is light coloured.

rhyolite a light-coloured extrusive igneous rock with a similar mineral composition to granite but with smaller crystals

viscosity a measure of a fluid's resistance to flow

scoria a dark, igneous rock formed from basalt lava that cools quickly and full of holes that once contained gas

pumice a glassy, pale igneous rock that forms when frothy rhyolite lava cools in the air. Pumice often floats on water as it is very light and full of holes that once contained gas.

Scoria, pumice and obsidian

Some violent volcanic eruptions shoot out lava filled with gas. The lava cools very quickly while it is still in the air and traps the gas inside. Rocks that form this way are full of holes from where the gas was trapped. Two examples of this type of rock are **scoria** and **pumice**.

TABLE 9.3 Features of explosive igneous rocks

Scoria	Pumice
Scoria is a dark (black, reddish-brown, or grey) volcanic rock full of holes. The darker colour is because it contains more iron. It is usually found closer to the volcano's crater.	Pumice is a pale-coloured volcanic rock. It is very light because it is mostly made of glass and full of holes. Pumice floats on water and sometimes washes up on beaches.
	

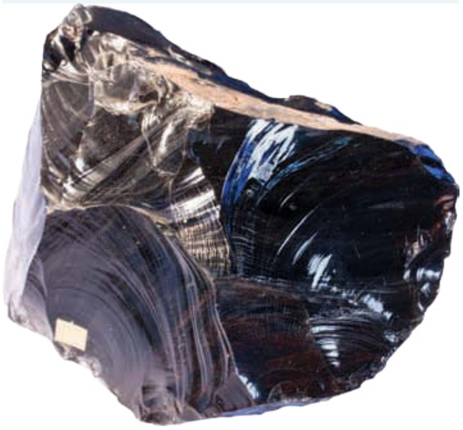
Obsidian is a smooth, black rock that looks like glass because it is a natural volcanic glass. It is formed when silica-rich lava cools almost instantly. Glass is not a mineral because, as it cools so quickly, it does not have a crystal structure.

Although obsidian is usually dark in colour like basalt, obsidian is extremely rich in silica and mostly glass, like pumice. Its dark colour is due to a high amount of impurities caught in the glass.

on Resources

Video eLesson Volcanoes (eles-0130)

FIGURE 9.14 The glassy extrusive igneous rock called obsidian



9.4.3 Intrusive rocks

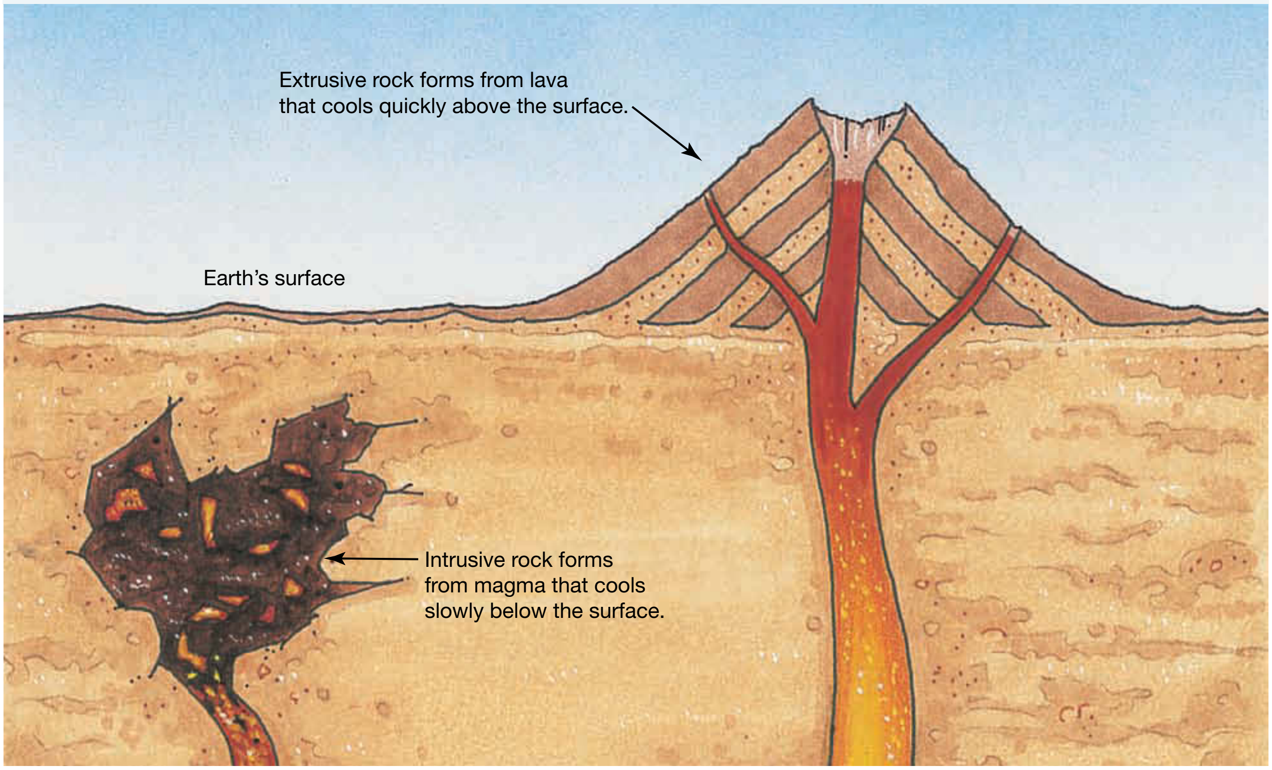
Igneous rocks can also form as magma cools 5–30 kilometres below the surface of the Earth. Those that form below the surface are called **intrusive**. They cool very slowly (thousands of years or more) and become visible only when the rocks and soil above them are removed by erosion. Intrusive rocks (sometimes called plutonic rocks) have larger crystals than extrusive rocks because the crystals had more time to grow. Large bodies of intrusive rock are called **batholiths**; they can stretch over distances of up to 100 kilometres.

obsidian a black, glassy rock that breaks into pieces with smooth shell-like surfaces

intrusive igneous rock that forms when magma cools below the Earth's surface

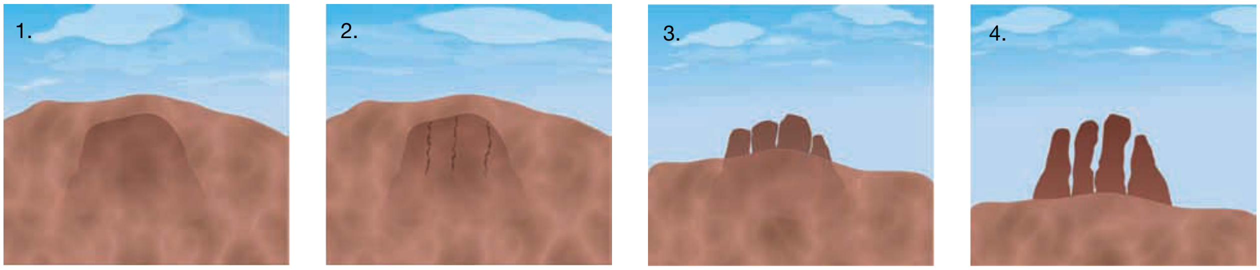
batholiths intrusive rock mass that measures more than 100 kilometres across

FIGURE 9.15 Igneous rocks can form below or above the Earth's surface. Where they form will determine the speed of cooling and thus the crystal size.



int-5337

FIGURE 9.16 If a batholith is exposed to the environment, it will start to wear away along the cracks, which can leave large rounded boulders balancing on the surface. Over time, the batholith may break down completely. The breakdown of rocks is called weathering.



Granite and gabbro

Two common intrusive igneous rocks are **granite** and **gabbro**. The crystals in both form over long periods of time and grow large enough to be easily seen without magnification. Being able to see the individual crystals makes it easier to identify the type of minerals present.

granite a light-coloured intrusive igneous rock with mineral crystals large enough to see

gabbro a dark-coloured intrusive igneous rock with a similar mineral composition to basalt but with larger crystals

TABLE 9.4 Features of intrusive igneous rocks

Granite	Gabbro
Granite is a light-coloured intrusive rock with silica-rich minerals. The crystals found in granite are a mixture of white, pink, clear to grey, and black minerals. These are (in order of most abundant to least): • *feldspar* (white and pink) • *quartz* (clear to grey) • *mica* (black).	Gabbro is a dark-coloured intrusive rock with minerals rich in iron (Fe) and magnesium (Mg). It looks mostly black, but if you look close enough, you will see some white and green. These are (in order of most abundant to least): • *pyroxene* (black) • *feldspar* (white) • *olivine* (green).
	

elog-0614

INVESTIGATION 9.3

Does fast cooling make a difference?

Aim

To investigate the effect of the cooling rate on the size of crystals

Materials

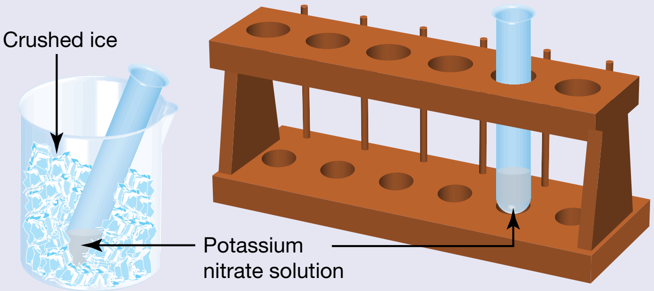
- freshly made saturated solution of potassium nitrate
- potassium nitrate
- spatula
- 250 mL beaker
- 3 test tubes and test-tube rack
- test-tube holder
- Bunsen burner, heatproof mat and matches
- crushed ice
- safety glasses
- hand lens

CAUTION

Safety glasses must be worn during this experiment.

Method

1. Half-fill a beaker with crushed ice.
2. Quarter-fill a clean test tube with saturated potassium nitrate solution. Add a spatula of potassium nitrate.
3. Gently heat the solution over a Bunsen burner flame until the added potassium nitrate has dissolved or until the solution starts to boil.
4. Pour half the warm solution into one clean test tube, and then the remaining half into another.
5. Place one test tube in the beaker of crushed ice and the other test tube in the rack to cool.
6. When crystals have formed in each test tube, examine them with a hand lens.
7. Cool one solution quickly and the other one slowly.



Results

1. Draw a labelled diagram of some crystals in each test tube, concentrating on their shape and size.
2. Which test tube contained the larger crystals: the one that cooled quickly or the one that cooled slowly?

Discussion

1. Which type of igneous rock would you expect to have the larger crystals: those that cool slowly underground or those that cool quickly on the surface?
2. Why do safety glasses need to be worn during this experiment?

Conclusion

What can you conclude about cooling rates and crystal size?

9.4.4 Useful igneous rocks

Igneous rocks can sometimes host valuable ore minerals but they are also used in several other ways, as summarised in table 9.5.

abrasive a property of a material or substance that easily scratches another

TABLE 9.5 Uses of igneous rocks

Igneous rocks	Example of modern uses
Basalt	Blocks have been used as a decorative building material. It is also commonly crushed and used for road base, asphalt and concrete.
Scoria	A reddish-brown or grey rock that can be crushed and used in garden paths or as a drainage material around pipes.
Pumice	Powdered pumice is used in some **abrasive** cleaning products.
Granite and gabbro	Commonly used in building due to their strength and beauty. Granite or gabbro that has been polished to give it a glossy finish are also used for grave headstones, benchtops and statues or other monuments.

DISCUSSION

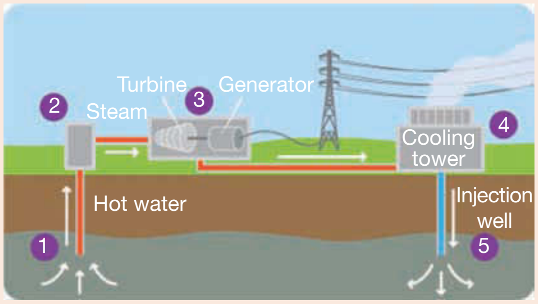
Locate a building, statue or memorial in your area that is made from granite. Describe the granite in the structure, and suggest why it was the chosen material.

SCIENCE AS A HUMAN ENDEAVOUR: Renewable geothermal energy in Australia

Geothermal energy is heat contained within the Earth. Australia has great potential for geothermal energy to be used for generating electricity (figure 9.17). Geoscience Australia has calculated that there is sufficient energy contained within the Australian crust around hot rock systems, that if only one per cent of the resource were used, it would provide 26 000 years worth of electricity.

geothermal energy using heat from the Earth as a energy source

FIGURE 9.17 How heat from the Earth can be used to generate electricity

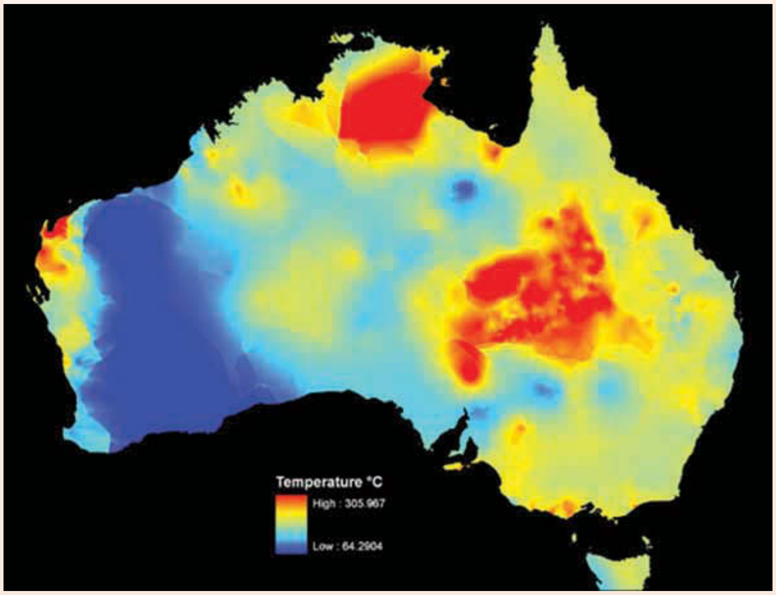


1. Hot water is pumped from deep underground through a well under high pressure.
2. When the water reaches the surface, the pressure is dropped, which causes the water to turn into steam.
3. The steam spins a turbine, which is connected to a generator that produces electricity.
4. The steam cools off in a cooling tower and condenses back to water.
5. The cooled water is pumped back into the Earth to begin the process again.

The hot rock systems in Australia are normally associated with bodies of granite rock at 3–5 kilometres depth, which contain unusually high concentrations of the naturally radioactive elements uranium (U), thorium (Th) and potassium (K). The radioactive decay of these elements generates heat that is insulated by the rocks above them. Figure 9.18 is a model of the temperature of the crust at 5 kilometres depth. The thicker the insulating layer, the hotter the temperature. For the system to be complete as a geothermal energy source, there also needs to be a fluid circulating through the rock above to transport heat to the surface.

While significant hot rock systems have been identified, there is no present commercial production of geothermal energy in Australia.

FIGURE 9.18 Modelled crustal temperature at 5 kilometres depth



- How would exploration be conducted to find these hot rock systems?
- According to the modelled crustal temperatures at 5 kilometres depth, where are the potential 'hot rock' systems?
- What sort of challenges are limiting access to this substantial renewable energy source?

on Resources

eWorkbook Igneous rocks (ewbk-5024)

assess on Additional automatically marked question sets

9.4 Exercise

learn on

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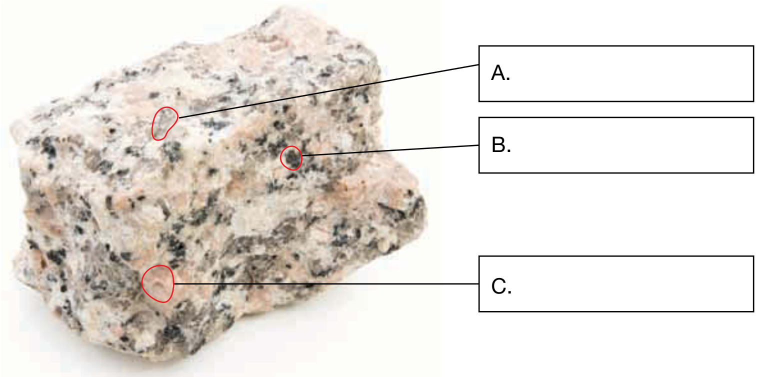
Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3, 4	Questions 5, 6, 7, 8	Questions 9, 10, 11, 12

Remember and understand

1. How do igneous rocks form?
2. Distinguish between the ways extrusive and intrusive igneous rocks are formed.
3. What do the varying colours of igneous rocks represent?
4. What causes the frothy (holey) appearance of pumice and scoria?

5. Label the three minerals found in granite.



6. Describe two major differences between the appearance of granite and basalt.

Apply and analyse

7. Why are the crystals in basalt that formed under water smaller than those in basalt that formed on the ground?
8. Batholiths form well below the ground. Explain how they become visible on the Earth's surface.
9. Explain how you would decide that an igneous rock formed from a volcanic eruption.
10. Rhyolite is an extrusive rock that contains the same minerals as granite. In what ways would you expect it to be different from granite?

Evaluate and create

11. **SIS** Geologists like to use classification tables to identify relationships between different rock types and their properties.

TABLE Igneous rock classification table

	Silica rich	Iron and magnesium rich
Extrusive		
Intrusive		

a. Complete this igneous-rock classification table by adding the names: basalt, granite, rhyolite and gabbro into their proper locations.
b. Where would scoria, pumice and obsidian go?
c. What could you add to your table to include these rocks and identify what makes them different?

12. If you came across an igneous rock that had a mixture of large crystals surrounded by small crystals, suggest how it may have formed.

Fully worked solutions and sample responses are available in your digital formats.

9.5 Sedimentary — the 'deposited' rocks

LEARNING INTENTION

At the end of this subtopic you will be able to describe how sedimentary rocks are formed and classified, and that they form in layers that record time and changes to the Earth's surface.

9.5.1 Weathered, eroded, deposited and lithified

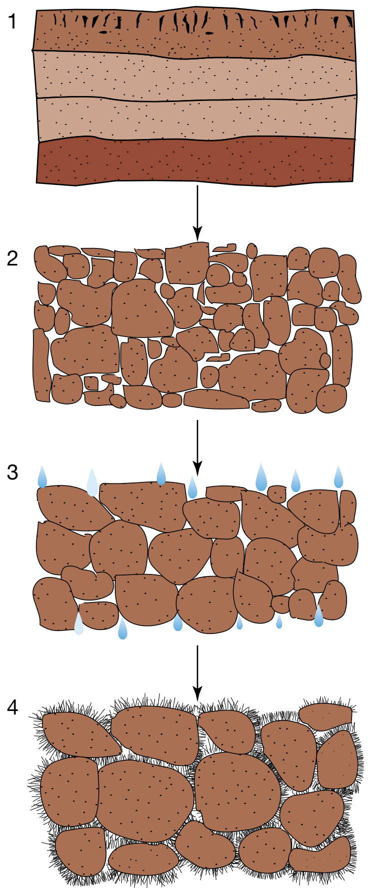
Rocks that are formed from weathered, eroded, deposited and lithified sediments are called sedimentary rocks. Each of these processes are described below.

- Rocks exposed on the surface are physically or chemically broken down by weathering as the rocks are exposed to the atmosphere, water and living things.
- The weathered particles are then transported by wind, running water, waves or flowing glacial ice as sediment. This process is called **erosion**.

erosion the wearing away and removal of soil and rock by natural elements, such as wind, waves, rivers and ice, and by human activity

- When the agents of erosion slow down or stop moving, their capacity to transport sediments reduces and the sediments settle onto the surface. This settling is called deposition. Deposits of dead plants and animals are also sediments.
- Sediments will deposit one on top of another, which creates layers, or beds. As beds continue to deposit, the individual sediments are packed closer together by compaction. Water can also seep around the sediment and leave behind newly formed mineral crystals that cement the sediment together. Compaction and cementation help to **lithify** the beds into rock (figure 9.19).

FIGURE 9.19 Lithify — turning sediments into rock



Deposition environments

Sand deposited by the wind forms sand dunes, especially in coastal areas where sand is picked up and blown inland until it is stopped by obstacles such as rock or vegetation.

A fast-moving river is likely to carry with it sand, gravel and smaller particles. As it slows down on its path to the sea, the river loses energy and will deposit along the river channel. The larger particles, such as gravel and sand, settle first. By the time the river reaches the sea, it is usually travelling so slowly that the very fine silt and mud particles begin to settle to help form **deltas**.

During floods when rivers break out of their channels, sediments are deposited on flat, open land alongside the river. These plains are called **floodplains**.

lithify to transform sediment into rock

deltas a landform created by the deposition of sediment at the end of a river as it enters a body of water

floodplain flat, open land beside a river where sediments are deposited during floods

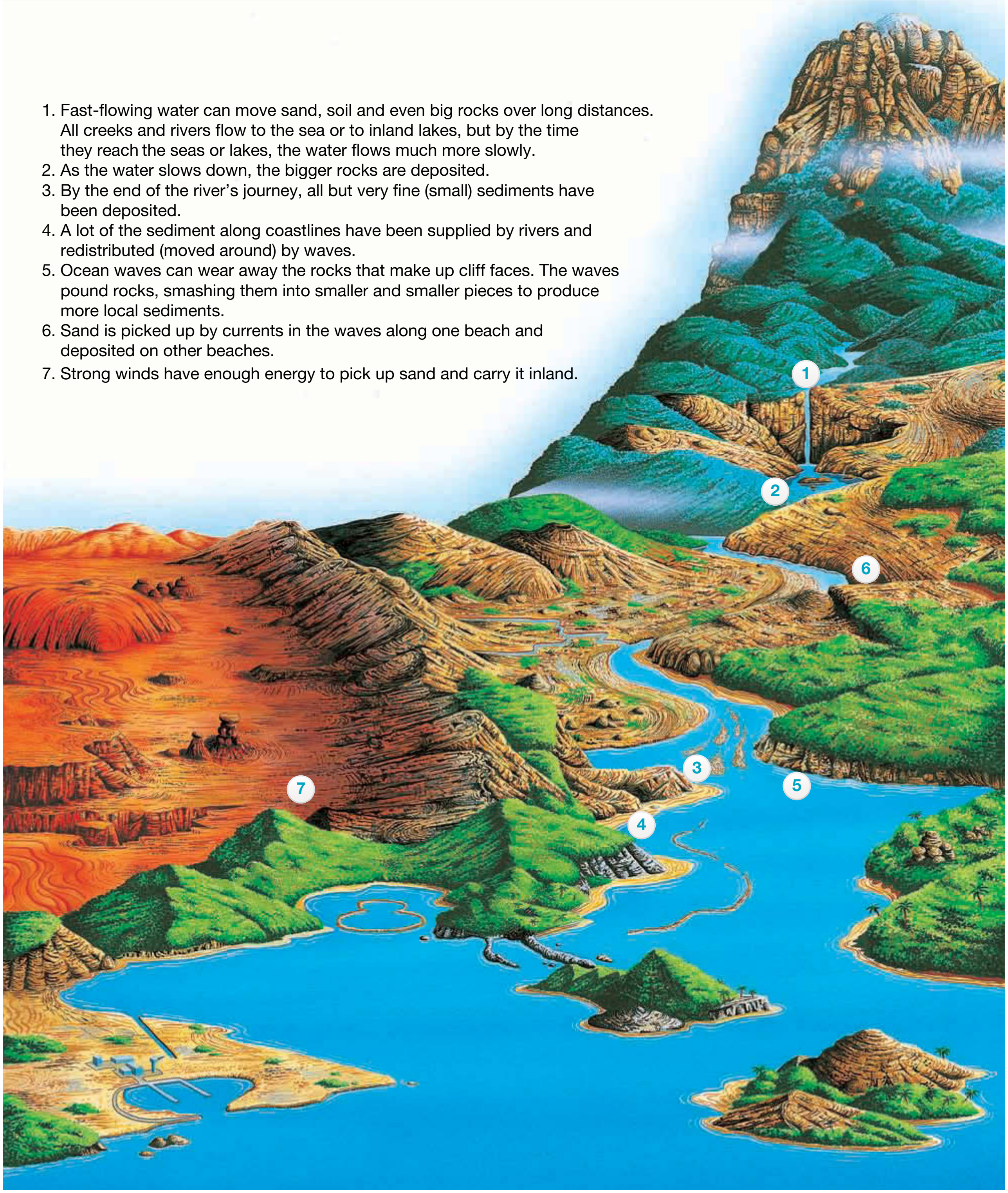
In the coldest regions of the Earth, especially at high altitudes, bodies of ice called **glaciers** slowly make their way down slopes. They generally move between several centimetres and several metres each day. Being solid, glaciers can push boulders, rocks, gravel and smaller particles down the slope. As the glacier melts it can deposit these sediments to form long hills along the margins of the glacier. These long hills are called **moraines**.

glaciers large bodies of ice that move down slopes and push boulders, rocks and gravel

moraine a long hill made out of sediments deposited by a glacier

int-5339

FIGURE 9.20 Most sedimentary rocks are formed from weathered rock that has been transported and deposited by moving water (rivers and ocean).



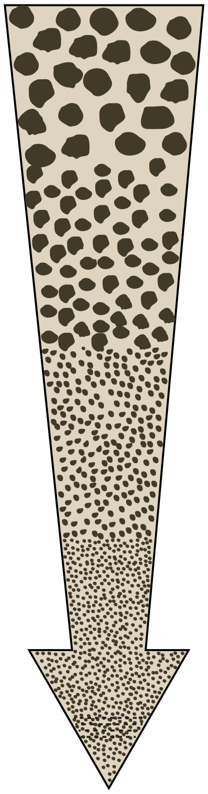
DISCUSSION

A common and fun activity on a warm summer day or weekend is to go to the beach, but where does all that sand come from? Is it a deposition environment? As a class, or in small groups, discuss where you think the sediment on beaches comes from. Consider if all beaches have the same size and type of sediment.

9.5.2 Clastic sedimentary rocks

Types of sedimentary rocks are classified by their grain size. The most common type are clastic sedimentary rocks, which are made of fragments/sediments of weathered and eroded pre-existing rocks. These fragments are known as clasts.

TABLE 9.6 Names of sedimentary rocks are based on their grain size.

Sediment clast size	Clastic sedimentary rock names
	**Conglomerate** contain large clasts surrounded by sediments of different sizes, all cemented together.
	Sandstone is formed from grains of sand that have been cemented together.
	Siltstone is smaller than sand, but slightly larger and not as soft as those in mudstone.
	Mudstone and **shale** are formed from finer grains of sediment deposited by calm water in the form of mud. Shale shows tiny layers of clay (represented by short horizontal lines), where as mudstone is a thicker bed of clay.

conglomerate sedimentary rock containing large particles of various sizes cemented together

sandstone a sedimentary rock with medium-sized grains. The sand grains are cemented together by silica, lime or other salts.

siltstone a sedimentary rock with a particle size between that of sandstone and mudstone

mudstone a fine-grained, sedimentary rock without layering

shale a fine-grained sedimentary rock formed in layers by the consolidation of clay

on Resources

Interactivity Clastic sedimentary rocks (int-5340)

WHAT DOES IT MEAN?

Conglomerate is formed from sediments that might be deposited by a fast-flowing or flooded river. The word conglomerate comes from the Latin word *conglomerare*, meaning to 'roll together'.

FIGURE 9.21 A conglomerate sedimentary rock

elog-0615

INVESTIGATION 9.4

Sediments and water

Aim

To investigate the order in which different sediments are deposited

Materials

- mixture of garden soil, gravel, sand and clay
- large jar with lid
- watch or clock

Method

1. Before commencing this experiment, form your own hypothesis about the order in which the different types of particles will settle. Give reasons for your hypothesis.
2. Draw a diagram to illustrate your hypothesis.
3. Place enough of a mixture of garden soil, gravel, sand and clay in a large jar to quarter-fill it.
4. Add enough water to three-quarter fill the jar and place the lid on firmly. Shake the jar vigorously.
5. Put the jar down and watch carefully as particles begin to settle. Note the time taken for each layer of sediment to settle completely.
6. Leave the jar for a day or two. Then compare your observations of the jar with your diagram.

Results

Record your answers to the following tasks to present your results:

1. Draw a labelled diagram showing clearly any layers that form. Identify the layers if you can.
2. Which type of sediment settled first?
3. Where are the other particles of sediment while the first layers are settling?
4. Which sediments settled after a day or two?

Discussion

1. Why did the last sediments take so long to settle?
2. Was your hypothesis supported by your observations?
3. What is the relationship between the size of sediment particles and the time taken to settle?

Conclusion

What can you conclude about the order that different sediments will deposit?

9.5.3 Sedimentary rocks from living things

Limestone is a sedimentary rock that is formed from deposits of the remains of sea organisms such as algae, brachiopods and corals. The remains of some of these organisms are still visible within limestone, while others are microscopic. The skeletal hard parts of these dead animals contain calcium carbonate (the mineral calcite). When the organisms die, fragments of their skeletons deposit as sediments and are cemented together over a period of time.

limestone a sedimentary rock formed from the remains of sea organisms. It consists mainly of calcium carbonate (calcite).

FIGURE 9.22 Limestone is made from sea-based sediments of living things. Colours can range from white and tan to red and dark grey.

FIGURE 9.23 Coal is formed form the remains of dead plants.

Coal is sedimentary rock formed from the remains of dead plants that are buried by other sediments. In dense swamps, layers of dead trees and other plants build up on the wet floor. If these layers are covered with water before rotting is completed, they can be buried by other sediments. The weight of the sediments above compacts the partially decayed plant material. Over millions of years the compaction and heating squeezes out the water, forming coal.

coal a sedimentary rock formed from dead plants and animals that were buried before rotting completely followed by compaction and some heating

CASE STUDY: Chalk

Chalk is a sedimentary rock. It is similar to limestone, but not as hard. Chalk is formed from very fine grains of calcium carbonate that separate from sea water and settle to become a white, muddy sediment on the sea floor. The sediment hardens over time to form chalk. This process takes millions of years. The remains of shellfish and other sea animals are also found in the sediment that forms chalk, but most of these remains are microscopic.

FIGURE 9.24 The white cliffs of Dover that overlook the English Channel are composed of chalk.

9.5.4 Chemical sedimentary rocks

Some sedimentary rocks form when water evaporates and leaves behind precipitated mineral crystals that can be compressed and buried by other sediments. **Rock salt** is an example of a rock formed in this way. It forms from residues of salt that remain after the evaporation of water from salt lakes or dried-up seabeds and can form beds that are hundreds of metres thick.

rock salt a sedimentary deposit formed when a salt lake or seabed dried up. The sediments are made of sodium chloride (halite).

9.5.5 Rocks in layers

Layers of sedimentary rock are often clearly visible in road cuttings and cliffs, as seen in the spectacular cliffs of the Grand Canyon (figure 9.25). Not only do the layers help you identify them as sedimentary rock, but they are also records of time, with the bottom layers older than the top layers.

FIGURE 9.25 The Grand Canyon is a spectacular example of exposed sedimentary rock layers that have been cut into by erosion of a fast-flowing river.

When fossils are found in sedimentary rock, the layer they are found in can be used to work out how old the fossil may be.

on Resources

Interactivity Sedimentary rock layers (int-5341)

As seen in the Grand Canyon, sedimentary rock layers are originally deposited flat (horizontal). However, layers of sedimentary rocks can be compressed by the same forces below the Earth's surface that form mountains. Those forces can bend and tilt the rock layers into incredible folds (figure 9.26).

FIGURE 9.26 These layers of limestone formed on the ocean floor and were originally horizontal, but have since been bent and folded by large mountain-building forces.

9.5.6 Useful sedimentary rocks

TABLE 9.7 Uses of sedimentary rocks

Sedimentary rock	Example modern uses
Sandstone, limestone and shale	Sandstone and limestone are often used as external walls of buildings. These sedimentary rocks are well suited to carving into bricks of any shape. Shale can be broken up and crushed to make bricks.
Limestone	Limestone is broken up to produce a chemical called lime. Lime is used to make mortar, cement and plaster, and is also used in the treatment of sewage and on gardens to neutralise acid in the soil.
Rock salt	Rock salt is used on roads and driveways in very cold areas to combat ice.
Coal	Coal is another useful sedimentary rock. It is used as a non-renewable fuel and burned in electric power stations to boil water. The steam is then used to drive the turbines that produce electricity. In some countries, coal is burned in home heaters, although this can cause air-quality problems. Coal is a non-renewable energy source because it is not replenished within our lifetime; in fact, it has taken millions of years to form a layer of coal.

elog-0616

INVESTIGATION 9.5

Identifying sedimentary rocks

Aim

To use a key to identify a variety of sedimentary rocks

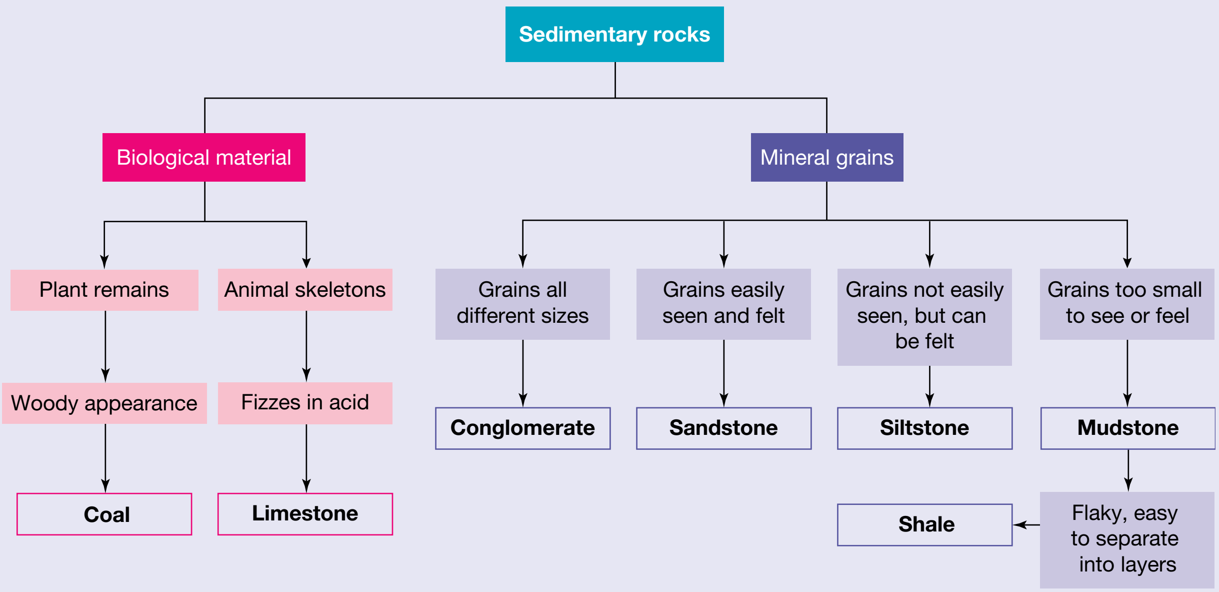
Materials

- several examples of unlabelled sedimentary rocks, including limestone
- dropping bottle of dilute hydrochloric acid

Method

1. Use the key in figure 9.27 to identify the samples of sedimentary rocks you have been given.
2. To do the acid test, just add one drop of dilute hydrochloric acid onto the sample and wipe off with a clean paper towel.

FIGURE 9.27 Flowchart to identify sedimentary rocks



Results

Design a table to record your answers for each step in identifying each sample, particularly the name at the end.

Discussion

1. How many of the unlabelled rocks did you confidently identify?
2. Which of the rock samples were the most difficult to identify, or which are you least confident about?
3. Discuss why it was difficult and how the key might be improved.

Conclusion

What can you conclude about identifying sedimentary rocks?

on Resources

eWorkbook Sedimentary rocks (ewbk-5026)

assess on Additional automatically marked question sets

9.5 Exercise

learnON

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Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3, 8, 11, 12	Questions 4, 5, 9, 13, 16	Questions 6, 7, 10, 14, 15

Remember and understand

1. From what are all sedimentary rocks formed?
2. List in order the process of forming a sedimentary rock.
3. What are clastic sediments before they eventually form a clastic sedimentary rock?
4. As a flooded river slows down, which particles are likely to settle first: gravel, sand or fine clay?
5. Explain, with the aid of a diagram, how sediments lithify and become a sedimentary rock.
6. Clastic sedimentary rocks formed from weathered pieces of other rock are classified based on what characteristic?

7. Explain how a floodplain is created.
8. In which type of sedimentary rock would you most likely find embedded seashells?
9. How is coal formed?

Apply and analyse

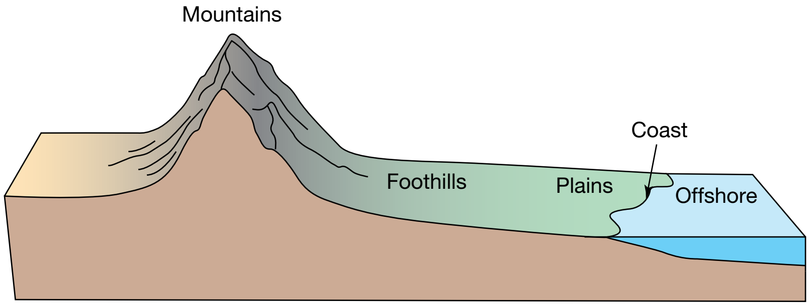
10. Explain why sedimentary rocks are found in layers.
11. Explain why limestone and coal are sometimes referred to as 'biological rocks'.
12. A road cutting reveals a layer of sandstone beneath a layer of mudstone. Between them is a much thinner layer of conglomerate.
    a. Which layer would have formed from sediments beneath the sea?
    b. Which layer would have formed while the area was flooded by a swollen, fast-flowing river?
    c. Which layer would have formed while the area was near a delta and coastline?
    d. Which layer was formed most recently?

Evaluate and create

13. What type of sediment would you expect to find on the bed of the Yarra River in Melbourne?
14. SIS A geologist collects a sedimentary rock sample, shown in the figure. They classify the rock by using the figure 9.27 in investigation 9.5. First, they decide it is a sedimentary rock because it came from a layered rock outcrop. Next, they observed that the sample is missing fossils, so they claim that it must contain mineral grains, not biological material. Then, they observe that the grain sizes are the same and small, but still easily seen and felt. In conclusion, they call this rock a sandstone.
    a. The rock was correctly classified as sandstone. Identify two correct applications in the method used to identify the rock.
    b. Is there a step they could have used to gather more information?

A sedimentary rock sample

15. **SIS** Create a model illustrating how the clast size for sediment deposits would change in a classic path from mountain to coastline to just offshore.



16. What do peat, brown coal and black coal have in common? How are they different from each other?

Fully worked solutions and sample responses are available in your digital formats.

9.6 Metamorphic — the 'changed' rocks

LEARNING INTENTION

At the end of this subtopic you will be able to describe how some common types of metamorphic rocks form, and what clues they provide to past environments.

9.6.1 Stability and change

So far, we have had rocks melt and solidify, some even blasted out of a volcano to solidify on the surface. On the surface, rocks weather and erode, where sediment ends up depositing and lithifying over time. What on earth is going to happen next?

The Earth never stops changing. As rocks are put under new conditions (like increasing temperature and/or pressure with deep burial or during a mountain-building event) it can 'morph' right into another kind of rock — a **metamorphic rock**.

WHAT DOES IT MEAN?

The word metamorphic comes from the Greek words *meta*, meaning 'change', and *morph* meaning 'form'.

This change occurs because every mineral forms in a specific set of physical conditions. When those conditions change, the mineral changes physically and/or chemically to be stable under the new set of conditions. All of this change can happen without melting and is called **metamorphism**.

- A physical shift can occur when the mineral rotates into a new orientation.
- A chemical shift can occur when either the mineral breaks down to form new minerals or crystal structures realign — such as we saw in the formation of diamonds in section 9.2.2.

9.6.2 Metamorphic rocks

Rocks pushed deep below the Earth's surface are buried under the weight of the rocks, sediments and soil above them. They are also subjected to higher temperatures with depth. On average, the temperature increases by about 25 °C for every kilometre below the surface. Added heat and pressure can change the type and appearance of the minerals in rocks.

metamorphic rocks formed from the change (alteration) of pre-existing rocks in response to increasing temperature and/or pressure conditions

metamorphism the process that changes rocks by extreme pressure or heat (or both)

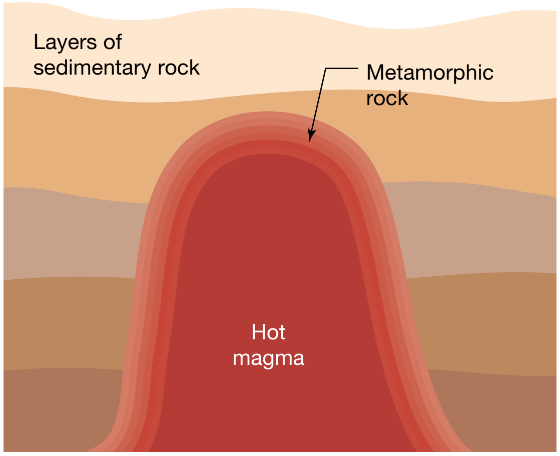
The changes that take place during the formation of metamorphic rocks depend on:

- the type of original rock, sometimes called the 'parent' rock
- the amount of heat to which the original rock is exposed
- the type and amount of pressure added to the rock
- how quickly the changes take place.

The higher the amount of heat and/or pressure, or the longer a rock is exposed to metamorphism, the greater the change will be. This is called a metamorphic grade, where a low-grade rock has experienced less change than a highest graderock.

Rocks do not always need to be buried to great depths to experience metamorphism. Figure 9.28 shows how rocks can be changed by the high temperatures that result from contact with hot magma. The metamorphic rocks around the body of magma are baked by the heat escaping the cooling magma body. Where would you expect to find the high-grade metamorphic rocks?

FIGURE 9.28 The formation of metamorphic rock by contact with hot magma



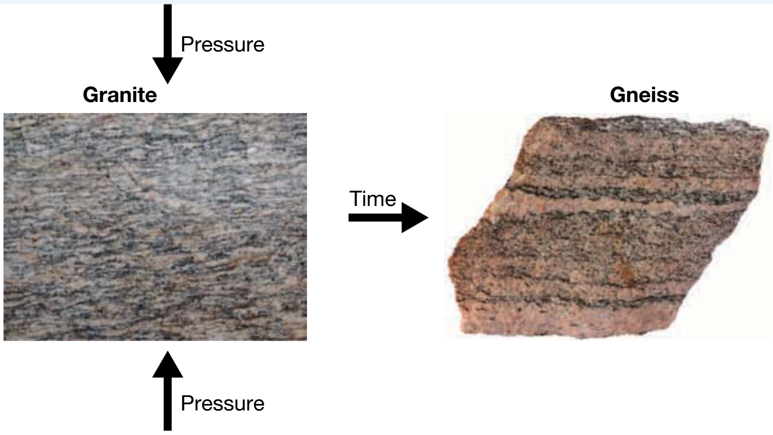
Types of metamorphic rocks

Shale is a common type of sedimentary rock. It is made of tiny clay particles that can be scratched with your fingernail and it comes in tiny layers that crumble easily. However, when shale is exposed to heat and pressure, the minerals begin to change, and the rock hardens to form the low-grade metamorphic rock called **slate**. Slate doesn't look much different from shale, in that it can still split into thin layers, but the rock is much harder. Give it more time and higher conditions, it will continue to morph into a high-grade rock called *schist*.

FIGURE 9.29 When shale is exposed to heat and pressure it becomes slate.

Metamorphic rocks that are mainly the result of great pressure can often be identified by bands of light and dark colours. These bands are evident in the sample of **gneiss** (pronounced 'nice'), pictured in figure 9.30. Gneiss is formed mainly as a result of great pressure applied to the igneous rock of granite.

FIGURE 9.30 When granite is exposed to high pressure it becomes gneiss.



slate a fine-grained metamorphic rock formed as a result of moderate heat and pressure on shale

gneiss a coarse-grained metamorphic rock with light and dark bands formed mainly as a result of great pressure on granite

Marble forms when limestone is put under heat and pressure. It contains the same calcite minerals as limestone; although, they generally grow larger with metamorphism. If the limestone has minerals other than calcite in it, the marble will have a swirling colour effect.

marble a metamorphic rock formed as a result of great heat or pressure on limestone

FIGURE 9.31 Marble quarry in Italy. Marble forms from the metamorphism of limestone.

Common examples of the formation of metamorphic rocks are summarised in table 9.8.

TABLE 9.8 How some common metamorphic rocks are formed

'Parent' rock	Condition of metamorphism	Metamorphic rock
Shale (sedimentary)	Mainly low pressure ⇒	Slate
Sandstone (sedimentary)	Mainly heat ⇒	Quartzite
Limestone (sedimentary)	Mainly heat ⇒	Marble
Granite (igneous)	Mainly high pressure ⇒	Gneiss

CASE STUDY: Rocks in your pool table

Have you ever tried to lift one end of a pool table and noticed how incredibly heavy it is? Pool tables are very heavy and difficuilt to move because the flat surface under the felt is not wood as you may have thought — it's actually made of slate. Because of its natural hardness and flat face, slate makes an ideal even surface!

on Resources

Interactivity Metamorphic rocks (int-5343)

Clues from metamorphic rocks

We do not actually see metamorphism, because it takes place entirely underground. This makes metamorphic rocks the most mysterious of the three rock groups. However, the nature of metamorphic rocks above and below the ground can provide clues about the history of an area.

Think about why the presence of quartzite or marble high in a mountain range would suggest that the area was once below a shallow sea. The presence of slate might suggest that the area was once the floor of a still lake or deep ocean. These original rocks were either deeply buried, or exposed to magma, or pushed and pulled during a mountain-building event to transform them into new rock.

9.6.3 Useful metamorphic rocks

The unique hardness and ability to split into thin layers has historically made slate useful as roofing or flooring material. **Quartzite** is also very hard and has been used for building materials.

Marble's softness and beautiful appearance make it suitable for sculpting. It is used for carving statues as well as tiles and columns for walls and floors of buildings (inside and outside). It is usually highly polished. Ground-up marble can also be used in toothpaste, pharmaceuticals, agriculture mixtures, cosmetics, paper and paint.

The sedimentary rocks from which marble and slate are formed could not be used for many of these purposes.

quartzite an extremely compact and hard metamorphic rock consisting essentially of quartz

elog-0617

INVESTIGATION 9.6

Rocks — the new generation

Aim

To examine and compare a selection of metamorphic rocks and their corresponding 'parent' rocks

Materials

- labelled samples of granite, gneiss, limestone, marble, sandstone, quartzite, shale and slate hand lens

Method

1. Try to sort the rocks into pairs of 'parent' rock and corresponding metamorphic rock. Use the descriptions and examples in this subtopic if you have trouble pairing the rocks.
2. Examine each pair of rocks with a hand lens. Take particular note of grain or crystal size and banding.
3. If necessary, re-sort the rocks into different pairs.

Results

Complete the table provided by noting the similarities and differences between the 'parent' and metamorphic rock of each pair.

TABLE Comparing 'parent' and metamorphic rocks

'Parent' rock	Metamorphic rock	Similarities	Differences	Main cause of metamorphism
Shale				
	Gneiss			
Sandstone				
	Marble			

Discussion

1. Why is the term ‘parent’ used to describe the original rock before metamorphosis?
2. Use the last column of your table to suggest whether the main cause of metamorphism was heat or pressure.
3. Is there a pattern to the rock’s appearance that could help you determine that pressure was a main cause of metamorphism?
4. Suggest an idea or two about why or how the metamorphic layering and banding could form.

Conclusion

What can you conclude about metamorphic rocks and their ‘parent’ rocks?

DISCUSSION

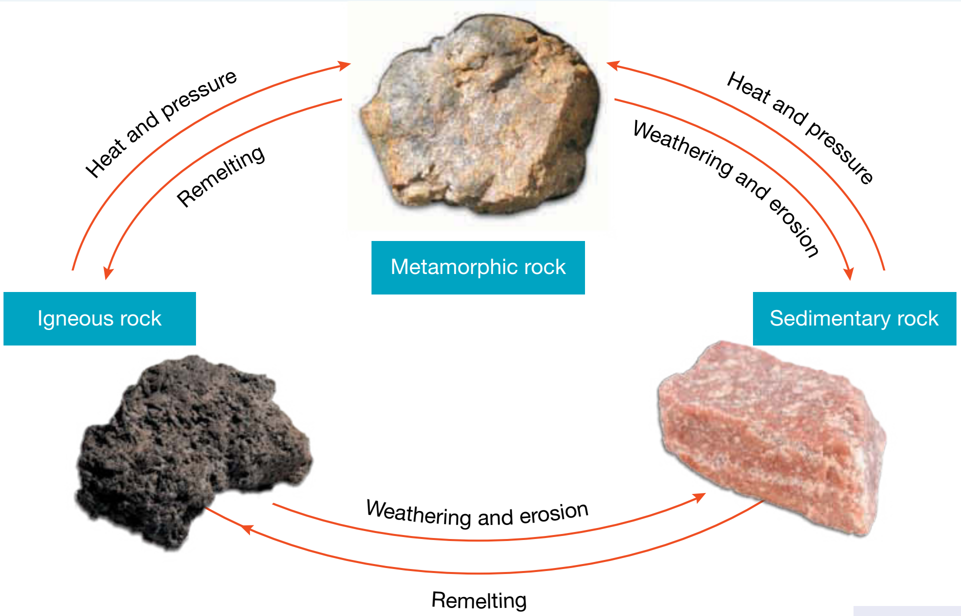
Some have argued that black coal is actually more of a metamorphic rock than a sedimentary rock. Discuss why this may be, and what you would call it.

9.6.4 The rock cycle

The **rock cycle** in figure 9.32 describes how rocks can change from one type to another. Weathering, erosion, heat, pressure and remelting are processes that help change rocks. The rock cycle is different from other cycles because there is no particular order in which the changes happen, and it generally takes a long time to make the complete change.

Some rocks have been unchanged on Earth for millions of years and may not change for millions more. Some rocks change a bit quicker (but still slowly), especially near regions of the Earth’s crust that are pushing, pulling or twisting.

FIGURE 9.32 The processes of melting, metamorphism by increased heat and pressure, as well as weathering and erosion over time will change rocks from one type to another. This is called the rock cycle.



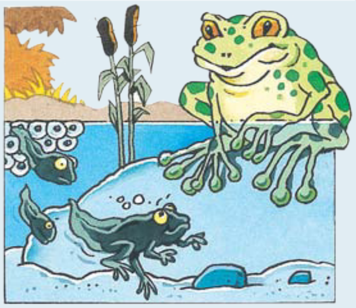
rock cycle a cycle of processes that rocks experience in the Earth’s crust as they constantly change from one type to another

DISCUSSION

A tadpole grows into a frog, female frogs lay eggs, and eventually more tadpoles emerge from the eggs. That's a life cycle.

Some of the changes in rocks can be described as cycles too. Weathered rock is moved by erosion and the particles form sediments, which can be cemented together to form sedimentary rocks, which in turn may eventually change into metamorphic rocks. Once those rocks are exposed at the surface the weathering starts all over again. A complete cycle normally takes millions of years, but sometimes never takes place at all. Why?

FIGURE 9.33 There are many cycles in nature. Some happen faster than others.



on Resources

Interactivity Metamorphic rocks (int-0234)

eWorkbooks Metamorphic rocks (ewbk-5028)
The rock cycle (ewbk-5030)

assess on Additional automatically marked question sets

9.6 Exercise

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Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 4, 6, 13	Questions 3, 5, 7, 9, 12, 14, 16	Questions 8, 10, 11, 15

Remember and understand

1. What can cause rocks to change form and become metamorphic rocks?
2. Describe the visual differences between gneiss and granite.
3. What causes granite to be transformed into gneiss?
4. Slate is commonly used in floor and patio tiles. Why?
5. Rocks are classified into three groups. Identify which of the groups a metamorphic rock can form from.
6. If a sandstone is subjected to increased temperature and pressure during a mountain-building event, what metamorphic rock will form?
7. Why is limestone referred to as the 'parent' rock of marble?
8. Describe the environments where you would expect to find metamorphic rocks forming?

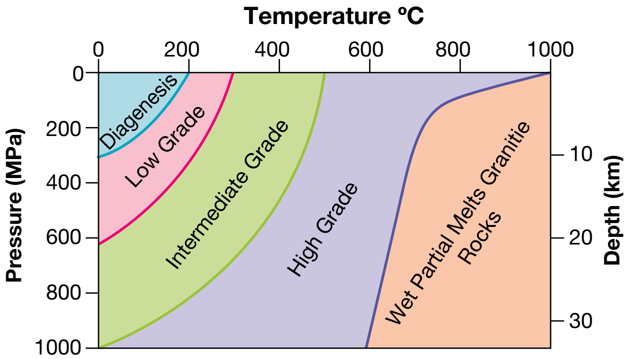
Apply and analyse

9. Metamorphic rocks are generally formed deep below the surface of the Earth. However, they are often found above the ground — even high in mountain ranges. How can this be so?
10. Why do geologists classify rocks?
11. If a rock gets so hot that it melts completely, it does not become a metamorphic rock. Explain why.
12. What is the progression of rock types if the steps in the rock cycle are as follows?
    Melting and cooling → erosion and deposition → burial with increased temperature and pressure

Evaluate and create

13. Why is the rock cycle important?
14. SIS Consider the figure that shows the different grades of metamorphism in rocks. As the pressure and/or temperature changes, the minerals in the rock become unstable, break down and form new minerals. The growth of particular minerals indicates that a grade boundary on this graph has been crossed.

Grades of metamorphism in rocks



a. What are the relationships between temperature, pressure, depth and metamorphic grade?
b. What is the temperature range for a low-grade rock found at a depth of 10 km?
c. What are geologists using to recognise the difference between low- and high-grade metamorphic rocks?
d. Suggest a definition for diagenesis and find out how it differs from lithification.

15. SIS A geologist finds an outcrop of marble near an outcrop of granite. Knowing how both granite and marble form, answer the following questions.
a. Suggest an idea that explains this relationship.
b. How could you test your idea?
16. Devise a 'buildings trail' in your city or town to locate buildings made of different kinds of rock. Draw a map to show the location of the buildings and the type of rock used in constructing them.

Fully worked solutions and sample responses are available in your digital formats.

9.7 Rock technology

LEARNING INTENTION

At the end of this subtopic you will be able to describe how development of Stone Age tools required knowledge of rock types and how Aboriginal and Torres Strait Islander peoples created tools for many specific purposes using their knowledge of different rock types.

SCIENCE AS A HUMAN ENDEAVOUR: Rocks as specialised tools

Rock technology began about two million years ago when early humans started using rocks to make simple chopping tools. This was the beginning of the period known as the **Stone Age**. For the great civilisations of Asia, Europe and North Africa, the Stone Age ended around 3000 BC with the discovery of bronze, an **alloy** of copper and tin.

The most commonly used resource in the Stone Age was a fine-grained sedimentary rock called **flint**. When flint breaks, it leaves a razor-sharp edge, so it was ideal for making sharp tools like knives, axes and spearheads.

Stone Age a prehistoric time when weapons and tools were made of stone, bone or wood

alloy a mixture of a metal with a non-metal or another metal

flint a fine-grained sedimentary rock that leaves a very sharp edge when broken

FIGURE 9.34 The use of chipping one rock with another to make the desired shape

FIGURE 9.35 Flint arrowheads were attached to wooden shafts with twine or animal sinews.

Small tools were made by striking tool stones like flint or the glass-like igneous rock obsidian with harder stones, such as quartzite, a metamorphic rock. To remove large flakes from the tool stone, a sharp blow was delivered by the harder rock. If the tool stone was struck correctly, a flake sheared from it. This process is called **percussion flaking**. The toolmaker continued to remove flakes from the stone until the desired shape was obtained. The flakes were then used to make tools such as knife blades, scrapers and engravers.

percussion flaking a process in which tool stones, such as flint or obsidian, were struck with harder stones, such as quartzite, to shear large flakes off until it was a desired shape

Larger items such as axeheads and spearheads were made with a combination of techniques, such as percussion flaking, grinding stones against each other and chiselling against the edge of a stone with tools made of bone or wood.

Indigenous ingenuity

Aboriginal and Torres Strait Islander peoples were still using Stone Age tools when Europeans began to settle in Australia in 1788. They were highly skilled at working with stone. In fact, Indigenous Australians were the first people to use ground edges on cutting tools and to grind seed.

FIGURE 9.36 Hand axes made and used by the Ngadjonji people of the tropical rainforests of northern Queensland

Their stone axes and other sharp tools were used to cut wood, shape canoes, chop plants for food, skin animals and make other tools out of stone or wood. The sharpened stones were often attached to wooden handles with twine from trees or with animal sinews.

Grinding stones are slabs of stone used with a smaller, harder top stone to grind seeds such as corn and wheat, berries, roots, insects and many other things to prepare food for cooking. Leaves and bark were sometimes ground to make medicines. Aboriginal people also used grinding stones to grind various types of soil and rock to make the powders used to paint shields and other wooden implements with traditional patterns.

Grinding stones were rough and usually made from sandstone, basalt with large crystals or quartzite. The smaller top stone was usually a hard, smooth river pebble.

The tools and the type of stone used to make them varied from group to group, depending on the location. Aboriginal people were skilled at making good use of the available resources. Apart from grinding stones, axes and other cutting tools, they made items such as bowls, cups and food graters out of stone.

FIGURE 9.37 An Aboriginal grinding stone with a top stone, or muller. The grinding stone is 40 cm long, 35 cm wide and 10 cm high. It is made from sandstone. The top stone is a hard, smooth river pebble.

FIGURE 9.38 A food grater made from stone by the Ngadjonji people of northern Queensland

on Resources

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9.7 Exercise

learn on

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3	Questions 4, 5, 8	Questions 6, 7

Remember and understand

1. List one example of each of the following types of rock that were used in the Stone Age to make tools.
   a. Igneous
   b. Sedimentary
   c. Metamorphic
2. Which alloy replaced stone to make tools when the Stone Age ended?
3. What role did animal sinews play in tool making by Indigenous Australians?
4. List three different uses of grinding stones.

Apply and analyse

5. What properties of flint made it so useful during the Stone Age?
6. Suggest how the process of percussion flaking got its name.
7. List some properties that you would look for when selecting a suitable top stone for a grinding stone.

Evaluate and create

8. Research and report on a range of tools and other devices made from rocks or other natural materials that Aboriginal and Torres Strait Islander peoples used in their daily lives.

Fully worked solutions and sample responses are available in your digital formats.

9.8 Geologic history

LEARNING INTENTION

At the end of this subtopic you will be able to identify the relationships between rocks and the clues they contain as to how and when they formed, including the fossil record.

9.8.1 Clues in rocks

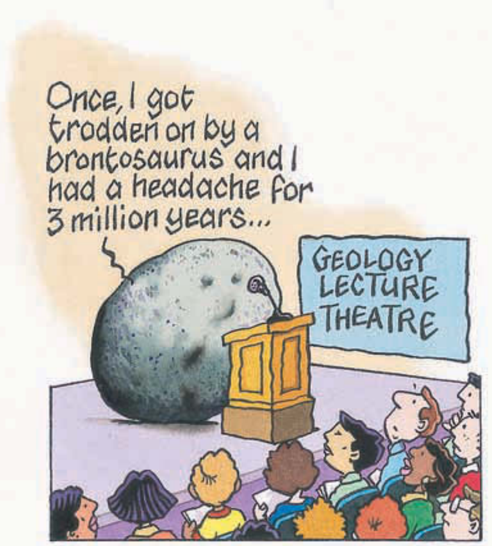
If only rocks could talk! They would have so much to say. They would tell us about the Earth's history — about prehistoric creatures whose fossils lie within them, about explosive volcanoes, earthquakes, flooded rivers that washed them away and about what it is like inside the Earth.

Although rocks can't talk, geologists are able to read them to answer questions such as:

- How has the Earth's climate changed over millions of years?
- When did the Himalayas form?
- What was the first signs of life?
- What caused the extinction of the dinosaurs?

The clues lie in the appearance of the rocks, the minerals they contain, and how they are layered or located next to one another. There are also clues in fossils. A **fossil** is evidence of living things preserved in rocks.

FIGURE 9.39 Rocks tell the history of the Earth.



9.8.2 Geologic history

Over very long periods of time, rivers change their course, mountains form where seas once existed and the climate changes. As these changes take place, different layers of sediment can be deposited at the same location. Some layers will be thicker than others, but the layer below will have been deposited before the one on top. Sudden events that occurred in the area of deposition, such as erupting volcanoes or landslides, are also recorded in the sediment layers.

Sedimentary rocks, which are formed by the hardening of the different layers of sediments, provide many clues about the order in which events took place. Slow movements caused by the forces beneath the surface can tilt, break, curve and push up the layers. This will disturb the pattern of layers and mark their occurrence in the record. Reading sedimentary rocks is particularly important to interpreting a geologic history of the Earth.

fossil any remains, impression, or trace of an animal or plant of a former geological age; evidence of life in the past

A geologic history uses the concept of **relative age** to interpret an order to events. The relative age of a rock simply indicates whether it was formed before or after another rock.

Principles of relative age

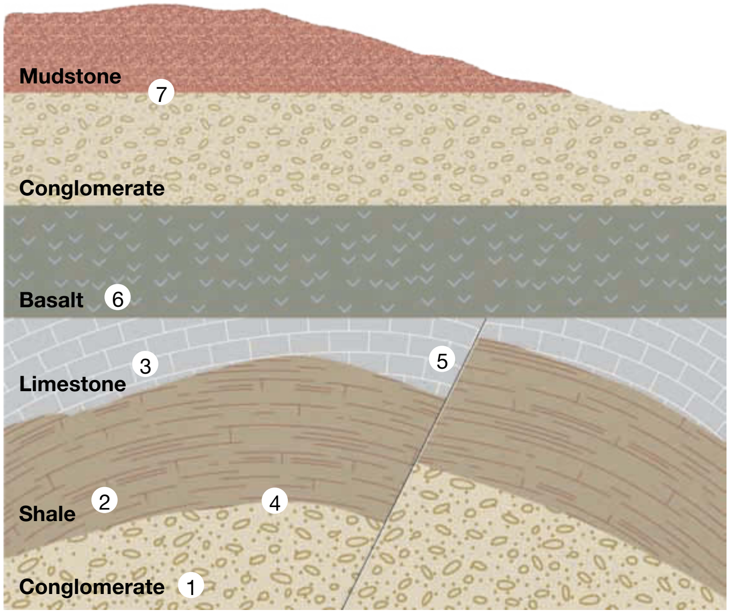
- A layer of sedimentary rock is older than the rocks above it and younger than those below it.
- Layers of sedimentary rock were originally deposited and lithified as horizontal layers. Thus, if you see bent or broken layers, the bending or breaking event must have happened after deposition.
- A time of weathering and erosion can remove layers, disturbing the surface. This results in a time gap in the record but can also be a fresh start for a younger sequence to deposit on top.

The relative ages of some igneous rocks and metamorphic rocks can be determined in the same way.

int-0233

FIGURE 9.40 Illustrated side-view of a portion of the crust. It highlights the relationships of rock layers relative to one another, which can be used to propose a geologic history.

7. These layers were deposited last. They have started to weather and erode.
6. A long period of weathering and erosion left the layer of limestone with a flat surface. When a volcano then erupted nearby, lava from the volcano cooled to form basalt on the flat surface.
5. A sudden event such as an earthquake has occured to break the layers of rocks like this. This event took place after the lower layers were folded. A break like this is called a fault.
4. A slow event has caused the lower levels to buckle. This is called folding. Folding can occur when rock layers are under pressure from both sides.
3. The third event to occur was deposition of limestone. It tells us that there were probably marine organisms present in the area during this time.
2. This is the second layer deposited. Shale is a fine-grained rock that is deposited in a quiet environment — such as a swamp, lake or slow-flowing part of a river.
1. Conglomerate was deposited first in this rock sample. This layer was deposited by a glacier or an active environment — such as a very fast-flowing river.



DISCUSSION

The present is a key to the past. As a class, or in a small group, discuss how much time you think it took to complete the sequence of events in figure 9.40? What observations of the modern world can we use to judge how quickly geologic events occur?

It's all relative

Fossils provide a way of finding out how living things have changed over time. Evidence of the very oldest living things is buried within the deepest and oldest layers of rock. Scientists who study fossils are called **palaeontologists**.

Since it is almost certain that a layer of sedimentary rock is older than the rocks above it and younger than those below it, it can be assumed that the fossils in lower layers are older than those in the layers above. By comparing fossils found in rocks in different areas, including different continents, it is possible to compare the relative age of rocks throughout the world.

relative age the age of a rock compared with the age of another rock

palaeontologist a scientist who studies fossils

FIGURE 9.41 Fossils provide clues about life in the past. This is a fossil of an ancient fish.

9.8.3 How fossils form

The remains of most animals and plants decay or are eaten by other organisms, leaving no trace behind. However, if the remains are buried in sediments before they disappear, they can be preserved, or fossilised. Fossils can form in several ways.

The hard parts of plants and animals are more likely to be preserved than the softer parts. Wood, shells, bones and teeth can be replaced or chemically changed by minerals dissolved in the water that seeps into them. Fossils are most commonly formed in this way (**permineralization**) and are the same shape as the original remains but are made of different chemicals. Petrified wood and fossil dinosaur bones are two examples of fossils formed by permineralization.

Animal bones and shells can be preserved in sediments or rock for many years without changing. The types of bones, shells and other remains found in the layers of sedimentary rock provide clues about the environment, behaviour and diets of ancient animals.

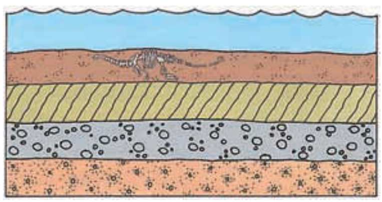
permineralization the most common method of fossilisation, in which minerals fill the cellular spaces and crystallise. The shape of the original plant or animal is preserved in great detail.

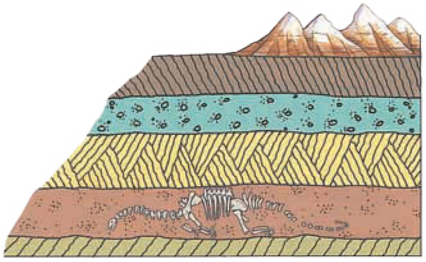
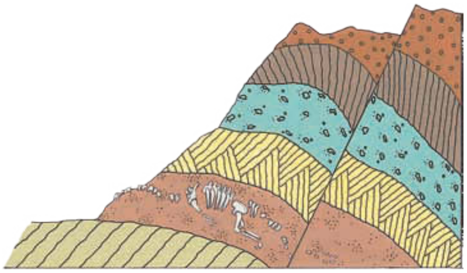
carnivores animals that eats other animals

scavengers animals that eat dead plant and animal material

int-5342

Dinosaurs preserved in rock

1. After the death of a dinosaur, its body would usually be eaten by meat-eating animals (**carnivores** or **scavengers**). Its bones would be crushed or weathered, leaving no remains. If, however, the remains of a dinosaur were buried in sediment, the bones could be preserved.	
2. If a dinosaur died near a muddy swamp, shallow lake or riverbed, its remains sank in the mud or were washed into a river in a flood. The bones were quickly buried in sediment.	

3. Over millions of years, more layers of sediment were deposited on top of the buried remains. Chemicals that dissolved in the water that seeped into the remains changed their colour and chemical composition. The shape, however, was preserved. The sediments were gradually transformed into sedimentary rock.	
4. The layers of rock containing the fossilised remains were pushed upwards, bent and tilted by forces beneath the Earth's surface. Weathering and erosion by the wind, sea, rivers or glaciers might expose one or more of the bones or teeth. If the exposed fossils were discovered before being buried again, palaeontologists might discover the remains.	

Whole bodies

Sometimes, fossils of whole organisms, including the soft parts, are preserved. Such fossils are rare and valuable. Insects that became trapped in the resin of ancient trees (the fossilised resin is called amber) have sometimes been wholly preserved (figure 9.42). Similarly, if the remains of animals or plants are frozen and buried in ice, they can be fully preserved.

Whole bodies of ancient woolly mammoths (including skin, hair and internal organs) have been found trapped in the ice of Siberia and Alaska (figure 9.43). Whole bodies and preserved skulls of animals can even reveal evidence of their last meal before death. Scientists collect DNA from these remains and compare the DNA sequences to those of modern elephants. Could we one day clone a woolly mammoth?

FIGURE 9.42 These insects were trapped in the resin of a tree millions of years ago.

FIGURE 9.43 An ancient woolly mammoth. Whole bodies of these ancient animals have been discovered in the ice of Siberia and Alaska.

Making an impression

The remains of animals or plants sometimes leave a dark impression, or imprint, in hardened sediments or newly formed rock (figure 9.44). The dark imprint is carbon, a reminder that the imprint came from a once-living thing.

It is also possible for remains trapped in rock to dissolve and be broken down; this leaves behind an empty space in the shape of the fossil. The depression is called a **mould**.

Leaving just a trace

Some fossils only provide signs of the presence of animals, not the animal itself, and are called **trace fossils**. A trace fossil can be a footprint, trail or burrow. Footprints preserved in rock can provide clues about ancient animals, including dinosaurs, and how they lived. By studying the shape, size and depth of footprints, hypotheses can be made about the size and weight of extinct animals as well as how they walked or ran.

FIGURE 9.44 The imprint of a leaf from an ancient fern left in stone

DISCUSSION

How complete is the fossil record?

Having just learned about the various ways a fossil is formed, discuss what parts of organisms are most likely to be preserved in the fossil record, and what external conditions are required for those parts to be preserved.

With your responses in mind, consider then, what percentage of life today would actually become part of the modern fossil record? Are there any plants or animals that you think are very unlikely to create a fossil? What does this tell you about how complete our fossil record is?

9.8.4 Earth's living history

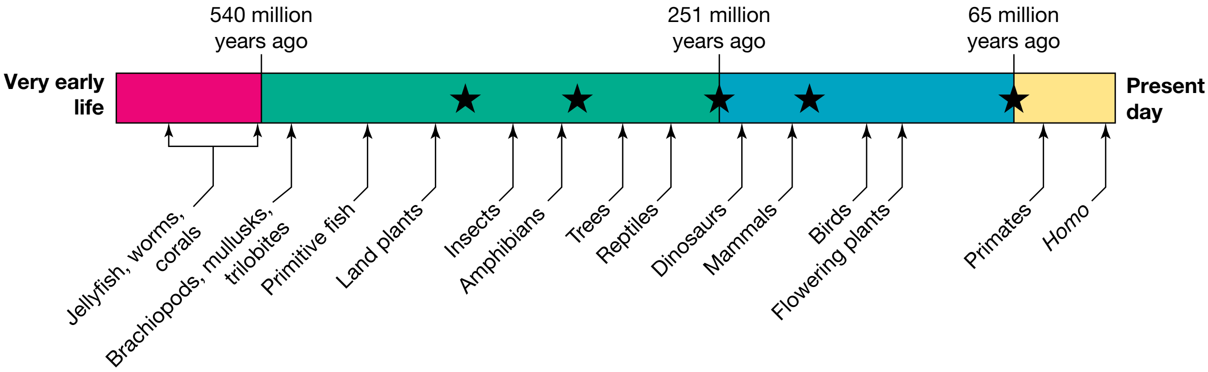
Despite the fossil record being incomplete, every fossil found helps to piece together the history of life on Earth. The oldest undisputed fossils are from rocks dated around 3.5 billion years ago in Western Australia. The fossils are photosynthetic single-celled organisms that formed features called *stromatolites*. They would have helped to introduce free oxygen into the atmosphere!

Fossils from the Ediacaran Period (636 to 541 million years ago) were the first multicellular forms, with soft bodies like jellyfish or worms. Because the Ediacaran fauna did not have hard parts, they were not well preserved. However, after the Ediacaran Period, the rock record explodes with an abundance of fossils because organisms evolved with hard body parts like claws, scales, shells and bones. Early life was dominated by marine organisms, but both animals and plants slowly grew in abundance and complexity on land.

mould cavity in a rock that shows the shape of the hard parts of an organism

trace fossils fossils that provide evidence, such as footprints, that an organism was present when the rock was formed

FIGURE 9.45 A summary of Earth's living history for the last 600 million years, marking the first fossil records and mass extinction events (stars)



The last 540 million years has seen five **mass extinctions**, where large volumes of life disappear from the rock record. The most significant of these was around 251 million years ago, which saw the extinction of over 80 per cent of all species, including the trilobites (figure 9.46). Palaeontologists have placed most of the divisions of geologic time at points in the fossil record where there are major changes in the type of organisms observed in the rocks.

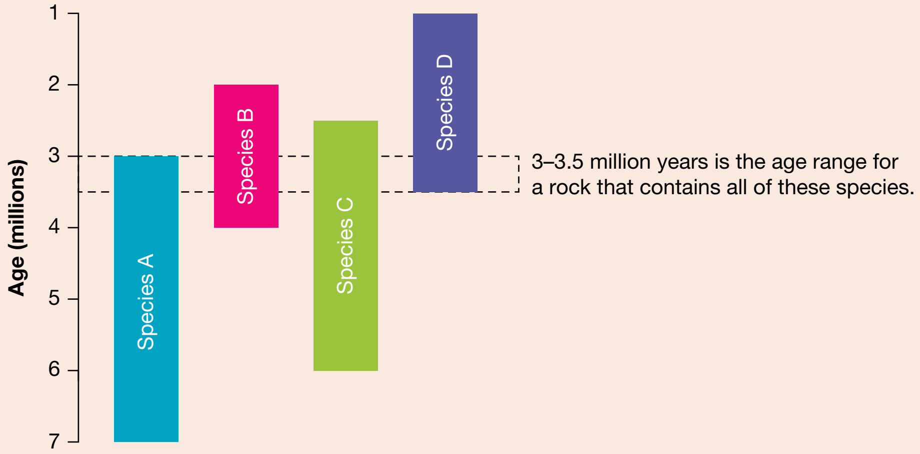
FIGURE 9.46 Trilobites were some of the first organism with hard parts preserved in the fossil record but are not found in any rocks younger than 251 million years.

mass extinction an event where a large amount of life in the fossil record no longer continue

SCIENCE AS A HUMAN ENDEAVOUR: Fossils help to date rocks

If the rock we are studying has several types of fossils in it, and we can assign time ranges to those fossils, we might be able to narrow the age range of the rock. First, we evaluate the age range for each fossil, then determine the overlap in age between fossils. The overlap is the age, or time period, of the rock sample.

FIGURE 9.47 When a rock is found containing multiple fossils, the overlap of the fossil age ranges can narrow down the age of the rock.



Resources

- **eWorkbook** Geologic history (ewbk-5032)
- **Weblink** How many mass extinctions have there been?
- **assesson** Additional automatically marked question sets

9.8 Exercise

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3, 8, 11	Questions 4, 5, 9, 12, 14, 16	Questions 6, 7, 10, 13, 15, 17

Remember and understand

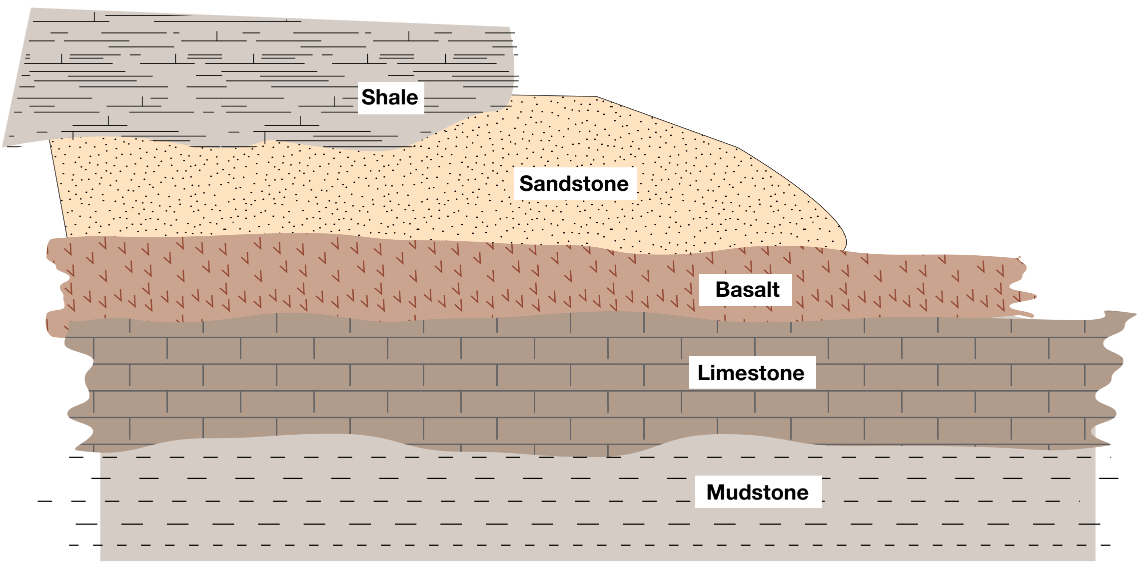
1. Explain why some layers of sedimentary rock are tilted, even though the sediments that formed them were originally laid in horizontal beds.
2. What does a palaeontologist study?
3. What rock group is most likely to have fossils?
4. What clues about life in the past do fossils provide?
5. Under what circumstances can whole ancient living things be preserved as fossils?
6. Describe trace fossils and how are they useful.
7. What is the difference between a cast and a mould?
8. List the information about dinosaurs that can be obtained from fossils.
9. Fossils of dinosaurs form when their remains are buried deep under many layers of rock. Explain why fossils are often discovered on the surface.
10. Describe four ways an animal or plant can be fossilised.

Apply and analyse

Use figure 9.48 to answer questions 11–13.

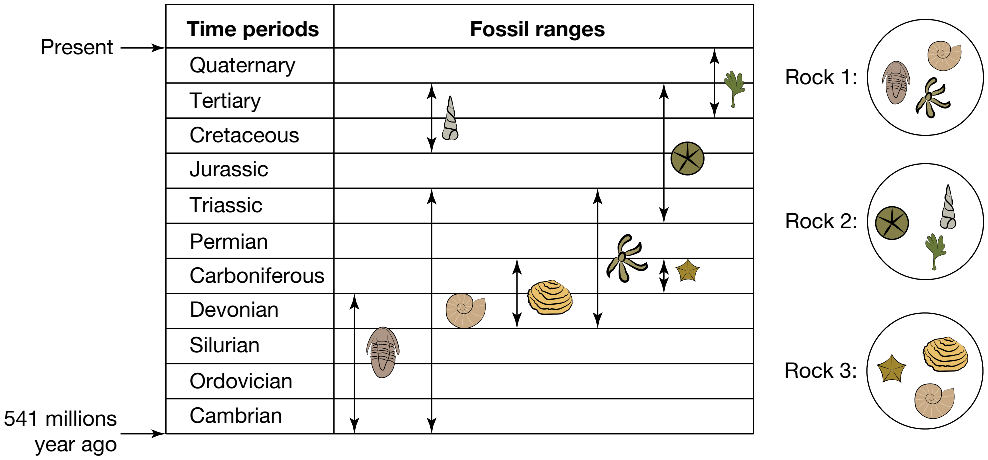
11. A road cutting reveals the layers of rock shown in figure 9.48. Which of the rocks in the cutting is:
    a. the oldest rock
    b. the youngest rock
    c. evidence of volcanic activity?
    d. Why are some layers in the diagram thicker than others?

FIGURE 9.48 Layers of rock exposed by a road cutting



12. Which rocks would you most likely find the fossil of:
a. a seashell
b. the leaf of a fern usually found in swamps?
13. If a fault cuts and displaces the mudstone, limestone and basalt layers in figure 4.48:
a. What is the relative age of the basalt and the fault?
b. What is the relative age of the sandstone and the fault?
14. SIS Explain why the hard parts of plants and animals are more likely to be preserved than the softer parts.
15. SIS Using the fossil age ranges (arrows) in figure 9.49, determine the time period of the three rocks shown.

FIGURE 9.49 Fossil age ranges 541 million years ago to present



16. Even an animal's droppings can become fossilised. Use the internet or books to research and report on the following.
a. Which animal was responsible for a huge fossilised dropping found in Canada in 1998?
b. How long was the dropping?
c. What can palaeontologists find out from it?
17. Find out how the actual age of a rock in years is determined. This actual age is known as the absolute age.

Fully worked solutions and sample responses are available in your digital formats.

9.9 Questioning and predicting the extinction of dinosaurs

LEARNING INTENTION

At the end of this subtopic you will understand what fossils teach us about the dinosaurs, and the scientific questions and predictions concerning why they went extinct.

9.9.1 Delving into dinosaurs

It is about 65 million years since the last non-flying dinosaurs existed on the Earth.

- What did they look like?
- What colour were they?
- How fast could they move?
- How did they behave?
- What did they eat?

Palaeontologists use fossils to try to answer all of these questions and more!

Not just a pile of bones

Dinosaur fossils are not all bones. They may include the following.

- *Fossilised teeth:* The shape of the teeth and the way they are arranged provide vital clues about the diets of dinosaurs. Flat-surfaced grinding teeth would have belonged to a dinosaur with a plant diet. Sharp-pointed teeth suited to tearing flesh would have belonged to a meat-eating dinosaur.
- *Footprints:* Dinosaur footprints have been preserved in rock. Footprints from a single dinosaur provide clues about its size and weight. They also indicate whether the dinosaur walked on two legs or four, and how its weight was spread. The distance between footprints enables palaeontologists to estimate how fast the dinosaur moved. Footprints also provide clues about the behaviour of dinosaurs and whether they lived in herds or alone.
- *Impressions* of skin may be left in mud that has hardened.

FIGURE 9.50 Human hand compared to a three-toed dinosaur footprint

on Resources

Video eLesson A palaeontologist (eles-2054)

Close-up of an Edmontosaurus femur being excavated by a paleontologist.
Notice the flakes and layers of sedimentary rock being removed.

9.9.2 What happened to the dinosaurs?

Between about 65 and 250 million years ago, dinosaurs were the most successful animals on Earth. In fact, those years are known as 'the age of the dinosaurs'. Dinosaurs thrived and dominated the land while mammals lived in their shadow. Fossil evidence indicates that the last of the dinosaurs died about 65 million years ago.

Two of the inquiry skills that geologists and other scientists use are questioning and predicting. The question of how the dinosaurs died out has intrigued scientists for many years. In answering this question, scientists use scientific knowledge to make 'predictions' about what happened many millions of years ago.

9.9.3 Solving the dinosaur riddle

There are several lines of thought about the extinction of the dinosaurs. Scientists and others argue about whether the end of the dinosaurs was sudden or gradual. Scientists do generally agree that the riddle of the dinosaur extinction remains unsolved. Palaeontologists and other scientists continue to look for clues that might provide the final solution.

The asteroid theory

The most widely accepted solution to the dinosaur riddle is that an asteroid collided with the Earth around 65 million years ago.

The asteroid's impact threw billions of tonnes of dust into the air, blocking out sunlight and plunging the Earth into darkness for two or three years.

- Plants stopped growing but their seeds remained intact.
- The temperature dropped.
- The large plant-eating dinosaurs would have died quickly of starvation.
- The meat-eating dinosaurs would probably have died next, having lost their main food supply but surviving for a while by eating smaller animals.
- Many smaller animals would have survived by eating seeds, nuts and rotting plants.

FIGURE 9.51 Dust from a colliding asteroid could have blocked out sunlight for two or three years.

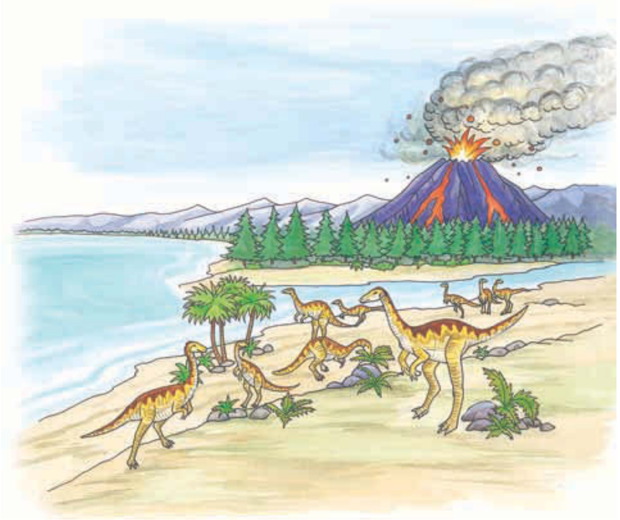
As the debris began to settle and sunlight filtered through the thinning dust clouds, many of the plants began to grow again. The surviving animals continued to live as they did before the impact. The surviving mammals were no longer competing with dinosaurs for food. It was the beginning of the age of mammals.

The volcano theory

The June 1991 eruption of Mount Pinatubo in the Philippines showed that ash and gases from volcanoes could reduce average temperatures all over the world. The average global temperatures during 1992 and 1993 were almost 0.2 °C less than expected. While this is not a large drop in temperature, the size of the eruption of Mount Pinatubo was much smaller than those of many ancient volcanoes.

The ash from a large volcano could have the same effect on sunlight and the Earth's temperature as an asteroid impact. If there was an unusually large amount of volcanic activity about 65 million years ago, the extinction of the dinosaurs could be explained. The largest known volcanic eruption occurred about 251 million years ago in what is now Siberia. It is believed that many types of marine animals became extinct at about the same time.

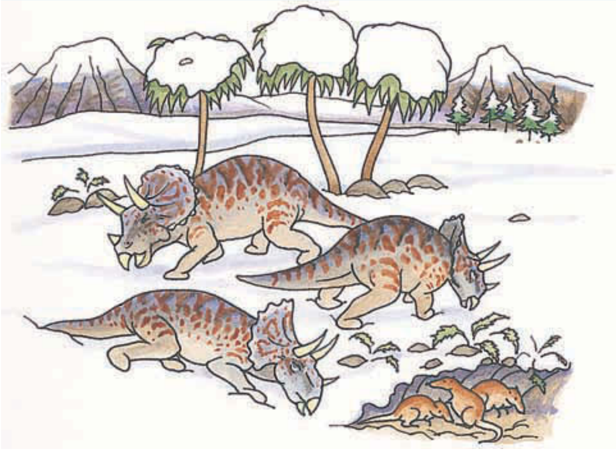
FIGURE 9.52 Huge volcanic eruptions could have caused a global cooling.



The cooling climate theory

The gradual cooling of the Earth's climate due to changes in the Sun's activity or Earth's orbit around the Sun could have caused the extinction of the dinosaurs. Dinosaurs, with no fur or feathers, had less protection from cold weather than mammals and birds. The larger dinosaurs would have found it very difficult to shelter from the cold conditions. Many smaller animals could burrow below the ground or shelter in the hollow trunks of trees or in caves. Many mammals and birds would have been able to migrate to warmer regions closer to the equator.

FIGURE 9.53 Could global climate change have killed the dinosaurs?



EXTENSION: Cold-blooded or warm-blooded?

Until recently, it was believed that dinosaurs were **ectothermic**. Ectothermic animals have body temperatures that depend on the temperature of their surroundings. As the surrounding temperature decreases, their body temperature decreases, and they become less active.

Mammals are **endothermic**. Endothermic animals are able to maintain a constant body temperature that is usually above that of their surroundings. They are able to remain warm and active in lower surrounding temperatures.

If dinosaurs were in fact ectothermic, a cooler climate would have made it more difficult for them to compete with other animals for food. However, many scientists now believe that dinosaurs may have been endothermic. The question of whether dinosaurs were cold-blooded or warm-blooded needs to be answered before the riddle of the dinosaurs can be solved.

ectothermic describes an animal whose body temperature is determined by its environment

endothermic describes an animal that requires heat input to maintain its body temperature

The emerging plants theory

During the Cretaceous period (140 million to 65 million years ago), new types of plants began to appear. Flowering plants evolved, competing with the more primitive plants such as ferns for nutrients, water and sunlight. The plant-eating dinosaurs did not eat flowering plants. According to this theory, as their traditional food supply became more scarce, the plant-eating dinosaurs could not survive, and the meat-eating dinosaurs that preyed on them starved as well.

FIGURE 9.54 The evolution of flowering plants may have wiped out much of the plant-eating dinosaurs' main food source.

The declining oxygen theory

During the 'age of the dinosaurs' the amount of oxygen in the atmosphere was higher than it is today — 10 to 14 per cent more. This meant that despite the dinosaurs having large bodies and muscles, they could get away with having small lungs.

Around 95 million years ago, the oxygen levels appear to drop rapidly to the 21 per cent we have today. It is possible that the decline in available oxygen was quicker than evolution could take place, and the dinosaur's biology did not cope with the lower levels of oxygen.

CASE STUDY: Australian megafauna

The name megafauna means 'big animals' and is a general term used to describe a group of large land animals that appeared millions of years after the dinosaurs became extinct. The megafauna were at their largest and most widespread during the last 2.5 million years. In Australia, the megafauna were unique, including giant marsupials such as the diprotodon. The diprotodon is often referred to as a giant wombat with a nose like a koala. It was about the size of a two-ton white rhinoceros.

Most of the Australian megafauna became extinct around 45 000 years ago. Scientists have been debating the causes of the extinction for decades. Some claim the animals could not have survived changes in climate, which would have changed landscapes from wooded eucalyptus to arid and sparsely vegetated. Others have suggested the animals were hunted to extinction by Australia's earliest immigrants who had colonised most of the continent by 50 000 years ago. Perhaps it is the combination of the two.

FIGURE 9.55 An illustration of some of the Australian megafauna that inhabited Australia some 45 000 years ago. The diprotodon is in the top centre.

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9.9 Exercise

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To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3, 6, 7, 11	Questions 4, 8, 9, 12, 14	Questions 5, 10, 13, 15

Remember and understand

1. When did a mass extinction take place that included the loss of most dinosaurs?
2. How is the shape of a fossil tooth helpful for understanding how a dinosaur lived?
3. What is the most widely accepted theory to explain the extinction of the dinosaurs?
4. Why would smaller animals be more likely to survive the effects of an asteroid impact or large volcanic eruption than larger animals?
5. What is the difference between an ectothermic animal and an endothermic animal?

Apply and analyse

6. In what ways were the dinosaurs different from mammals?
7. How could volcanic eruptions affect life throughout the whole world?
8. How could meat-eating dinosaurs be endangered by the evolution of new types of plants?
9. SIS The boundary that marks the extinction of the dinosaurs is known as the K-T boundary. When scientists sampled this boundary across the world, they found that it had a much higher concentration of iridium than normal. Iridium is rare on Earth's surface.
   a. Of all the theories presented, which theory does this finding best support?
   b. Are there any patterns to the iridium concentrations that would help convince you even further?
10. SIS Explain how it is possible to use preserved animal footprints to form hypotheses about:
   a. whether the animal lived alone or in herds
   b. the way that the animal walked
   c. the weight of the animal
   d. the walking or running speed of the animal.

Evaluate and create

11. Which group of animals benefited the most as a result of the extinction of the dinosaurs?
12. List as many weaknesses as you can in each of the five theories about the dinosaur extinction presented.
13. Which theory of the extinction of the dinosaurs do you think is most likely to be correct? Explain your answer.
14. Imagine what it would have been like 65 million years ago if an asteroid plunged into the Earth. Write a story about the first 24 hours after the impact.
15. Which animals and plants do you think would be most likely to survive if an asteroid struck central Australia now? Explain your answer.

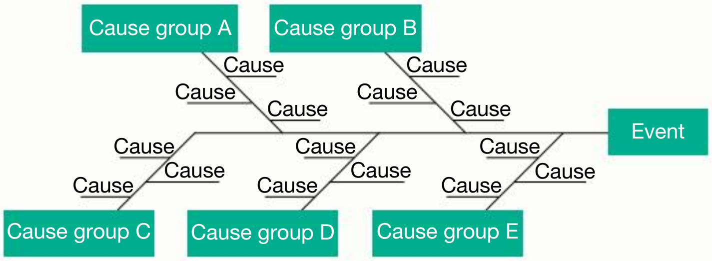
Fully worked solutions and sample responses are available in your digital formats.

9.10 Thinking tools — Fishbone diagram and tree maps

9.10.1 Tell me

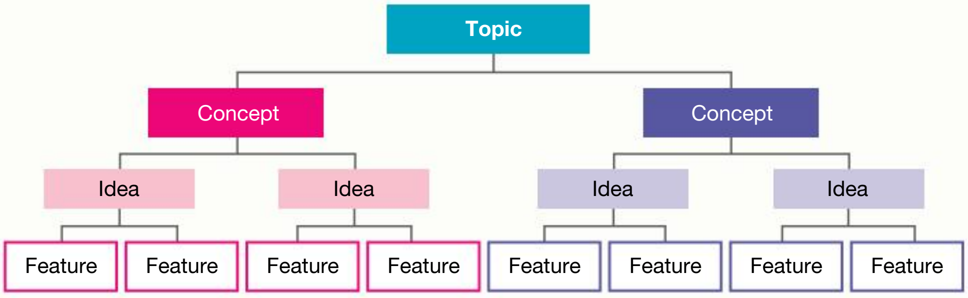
A fishbone diagram is a useful thinking tool, when you are trying to determine or understand what could have caused something to happen. They show visually the reasons for what is happening or has happened. They are sometimes called cause-and-effect analysis or Ishikawa diagrams.

FIGURE 9.56 A fishbone diagram



Similar to fishbone diagrams, a tree map divides ideas into groups or categories. However, fishbone diagrams always categorise causes, but tree maps do not.

FIGURE 9.57 A tree map



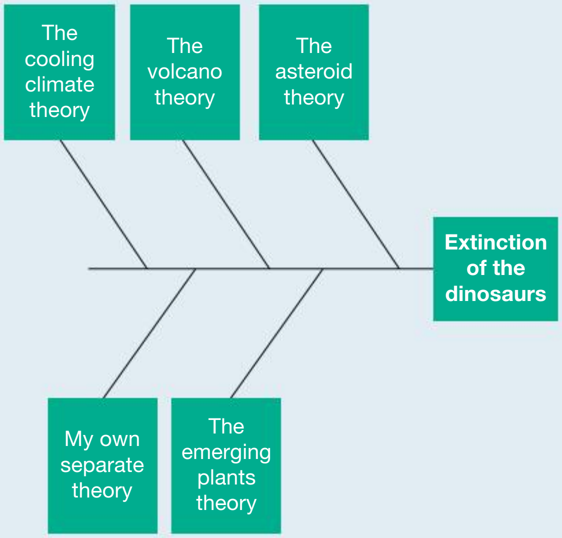
9.10.2 Show me

1. Think of an event of which you do not know the causes.
2. Brainstorm as many possible causes as you can for this event.
3. In pairs, or teams of four, organise your list of causes into groups.
4. Write the event that you are analysing as the 'fish's head' of a fishbone diagram. Your groups of causes then become the main 'bones' of the diagram, one bone for each group.
5. Write the title for each of your groups of causes on its relevant 'fishbone'.
6. Write the causes on the smaller 'fishbones' that are joined to the sides of the main bones. (You can attach causes to more than one bone or group of causes.)

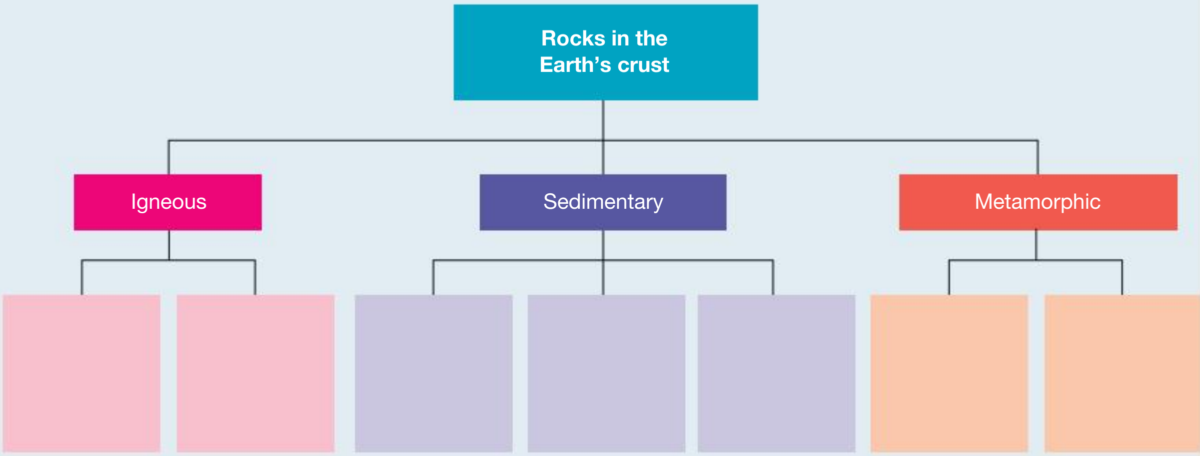
9.10.3 Let me do it

9.10 ACTIVITIES

1. Create a fishbone diagram that shows the possible causes of the extinction of the dinosaurs. Use the one provided as a template, adding the smaller 'bones' and causes yourself. Four of the theories discussed in this subtopic are already on the template. Include a separate theory of your own on the diagram. It could be a combination of the four other theories, or something completely different.



2. Working with a partner, copy the tree map given onto A3 paper and complete it to represent the three main classes of rock found in the crust. Add further branches below the existing ones if you can.



3. Create a fishbone diagram to represent the formation of rocks. Use the cause categories listed, and add any others that you think should be included.
   Cause categories:
   - weathering
   - erosion
   - volcanoes
   - pressure
   - heat

Fully worked solutions and sample responses are available in your digital formats.

9.11 Review

Access your topic review eWorkbooks

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-5046	ewbk-5048	ewbk-5050

on Resources

9.11.1 Summary

Rocks and minerals

- A mineral is any naturally occurring solid substance with a definite chemical composition and crystal structure.
- The physical properties of a mineral, such as colour, lustre, streak, hardness and shape, are controlled by the:
  - elements present
  - environment they formed in.
- A combination of physical properties is used to identify a mineral.
- A rock is a naturally occurring, coherent collection of minerals, organic material and/or glass.
- Rocks are classified into three groups based on how they formed: igneous, sedimentary and metamorphic.
- Some rocks may contain valuable ore minerals.
- The process obtaining metals from ore minerals includes:
  - exploration
  - environmental impact studies
  - mining
  - metal extraction
  - mine rehabilitation.

Igneous — the 'hot' rocks

- Rocks that form from the cooling and solidification of magma or lava are called igneous rocks.
- The appearance of igneous rocks depends on the:
  - cooling environment (intrusive or extrusive)
  - types of minerals or glass substances present.
- Igneous rocks that formed in an extrusive environment will have small mineral crystals or volcanic glass because it solidified quickly (days to weeks) on or near the surface.
  - Basalt is dark coloured, with minerals rich in iron and magnesium.
  - Rhyolite is light coloured, with more silica-rich minerals.
  - Scoria is like basalt but with lots of holes from trapped gas.
  - Pumice also has a lot of holes, but is made of glass and can float on water.
  - Obsidian is a dark and dense volcanic glass.
- Igneous rocks that formed in an intrusive environment will have large mineral crystals because it solidified slowly (thousands of years) underground.
  - Granite is light coloured, like rhyolite but with visible crystals.
  - Gabbro is dark coloured, like basalt but with visible crystals.
- Igneous rocks can be useful because they may contain ore minerals or they can be used as building material.
- Granite bodies underground can be a source of renewable geothermal energy.

Sedimentary — the 'deposited' rocks

- Sedimentary rocks form by weathering, erosion, deposition, and lithification of sediments on the surface.
- Lithification can occur by:
  - long periods of compaction
  - quick cementing.

- Clastic sedimentary rocks are made of weathered fragments of pre-exiting rocks and are named based on clast size.
  - From largest to smallest: conglomerate, sandstone, siltstone, mudstone/shale
  - Mudstone and shale are soft because they are mostly clay minerals.
- Biological sedimentary rocks are made of fragments of living things.
  - Limestone is the most common and is made from the calcite skeletal remains of warm shallow sea animals.
  - Coal is made from the sediment remains of swamp plants that have been buried and heated for millions of years.
- Rock salt and gypsum are examples of chemical sedimentary rocks, which form when water evaporates, and minerals grow from the solution.
- Sedimentary rocks come in layers, as records of changing surface conditions. The lower layers are older than the top layers.
- There are many modern uses for sedimentary rocks, such as gravels and lime in concrete, and coal as a non-renewable fossil fuel.

Metamorphic — the 'changed' rocks

- Metamorphic rocks form when pre-existing rocks are put under increased temperature and pressure.
  - The rock changes to become more stable to the new conditions.
- The degree and type of metamorphism is determined by the:
  - original rock (parent rock)
  - amount of pressure or temperature change
  - length of time.
- Some of the common metamorphic rocks are slate, quartzite, marble and gneiss.
  - Apply low pressure to shale to form slate that splits into thin sheets.
  - Apply high pressure to granite to form gneiss with light and dark bands.
  - Apply higher temperatures to limestone to form marble.
  - Apply higher pressure or temperature to sandstone to form quartzite.
- Each type of metamorphic rock is a clue to the original rock as well as the amount of temperature or pressure change that caused the metamorphism.
- Metamorphic rocks like slate, quartzite and gneiss are hard and can be used as building material or percussion tools.
- Marble is softer and easier to carve into sculptures.
- Geologists refer to the constant and slow change of rocks from one type to another over time as the 'rock cycle'.

Geologic history

- Rock types and their relationships to one another are used to interpret past environments and events.
- Principles of relative age help to interpret these rocks or events as either older or younger than another.
- Fossils in sedimentary rocks are recorded and compared across the world to help with determining rock age.
- Fossils of plant or animal bodies can form by:
  - per mineralization
  - whole-body preservation
  - imprints.
- Hard parts of plants and animals are likely to be better preserved than soft parts.
- The fossil record is incomplete, making the finding and addition of any new fossil records important to building the history of life on Earth.
  - Complexity of life on Earth exploded 541 million years ago and continues today.
  - There have been five mass extinction events in the past 600 million years.

Questioning and predicting the extinction of dinosaurs

- Dinosaurs dominated the Earth from 65 to 250 million years ago.
- Palaeontologists use dinosaur bones as well as fossilised teeth, footprints and skin impressions to question and predict dinosaur:
  - size and weight
  - walking style

- diet
- social behaviour.

- Fossil evidence indicates that the last of the dinosaurs died about 65 million years ago.
- Scientific questioning and predicting skills have helped to develop several theories as to why the dinosaurs went extinct.
  - Asteroid impact
  - Large volcanic eruptions
  - Global climate cooling
  - Evolution of flowering plants
  - Decreasing oxygen levels
- The most widely accepted theory is that an asteroid collided with Earth.

9.11.2 Key terms

abrasive a property of a material or substance that easily scratches another
alloy a mixture of a metal with a non-metal or another metal
basalt a dark, igneous rock with small crystals formed by fast cooling of hot lava. It sometimes has holes that once contained volcanic gases.
batholiths intrusive rock mass that measures more than 100 kilometres across
carnivores animals that eats other animals
coal a sedimentary rock formed from dead plants and animals that were buried before rotting completely followed by compaction and some heating
compounds substance made up of two or more different types of atoms that have been joined (bonded) together
conglomerate sedimentary rock containing large particles of various sizes cemented together
crystal geometrically-shaped substance made up of atoms and molecules arranged in one of seven different shapes. The elements that make up a crystal and the conditions present during the crystal's growth determine the arrangement of atoms and molecules and the shape of the crystals.
deltas a landform created by the deposition of sediment at the end of a river as it enters a body of water
deposition the settling of transported sediments
ectothermic describes an animal whose body temperature is determined by its environment
endothermic describes an animal that requires heat input to maintain its body temperature
environmental impact statement (EIS) study of the possible effects of a planned project on the environment
erosion the wearing away and removal of soil and rock by natural elements, such as wind, waves, rivers and ice, and by human activity
extrusive igneous rock that forms when lava cools above the Earth's surface
flint a fine-grained sedimentary rock that leaves a very sharp edge when broken
floodplain flat, open land beside a river where sediments are deposited during floods
fossil any remains, impression, or trace of an animal or plant of a former geological age; evidence of life in the past
gabbro a dark-coloured intrusive igneous rock with a similar mineral composition to basalt but with larger crystals
geothermal energy using heat from the Earth as a energy source
glaciers large bodies of ice that move down slopes and push boulders, rocks and gravel
gneiss a coarse-grained metamorphic rock with light and dark bands formed mainly as a result of great pressure on granite
granite a light-coloured intrusive igneous rock with mineral crystals large enough to see
hardness a measure of how difficult it is to scratch the surface of a solid material, hardness can be ranked using Moh's scale
igneous rock formed when hot, molten rock cools and hardens (solidifies)
intrusive igneous rock that forms when magma cools below the Earth's surface
lava molten rock flowing on the surface
limestone a sedimentary rock formed from the remains of sea organisms. It consists mainly of calcium carbonate (calcite).
lithify to transform sediment into rock

lithosphere the outermost layer of the Earth, includes the crust and uppermost part of the mantle
lustre appearance of a mineral caused by the way it reflects light. A mineral can appear glassy, waxy, metallic, dull, pearly, silky
magma a very hot mixture of molten rock and gases, just below the Earth's surface, that has come from the mantle
marble a metamorphic rock formed as a result of great heat or pressure on limestone
mass extinction an event where a large amount of life in the fossil record no longer continue
metamorphic rocks formed from the change (alteration) of pre-existing rocks in response to increasing temperature and/or pressure conditions
metamorphism the process that changes rocks by extreme pressure or heat (or both)
mineral a naturally occurring, inorganic and solid substance with a defined chemical formula and an ordered arrangement of atoms
mining the process of removing natural resources from the Earth
moraine a long hill made out of sediments deposited by a glacier
mould cavity in a rock that shows the shape of the hard parts of an organism
mudstone a fine-grained, sedimentary rock without layering
native elements elements found uncombined in the Earth's crust
obsidian a black, glassy rock that breaks into pieces with smooth shell-like surfaces
open-cut mining mining that scours out soil and rocks on the surface of the land
ore mineral a mineral from which a valuable metal can be removed for profit
overburden waste rock removed from below the topsoil. This rock is replaced when the area is restored.
palaeontologist a scientist who studies fossils
percussion flaking a process in which tool stones, such as flint or obsidian, were struck with harder stones, such as quartzite, to shear large flakes off until it was a desired shape
permineralization the most common method of fossilisation, in which minerals fill the cellular spaces and crystallise. The shape of the original plant or animal is preserved in great detail.
pumice a glassy, pale igneous rock that forms when frothy rhyolite lava cools in the air. Pumice often floats on water as it is very light and full of holes that once contained gas.
quartzite an extremely compact and hard metamorphic rock consisting essentially of quartz
rehabilitated restored to its previous condition
relative age the age of a rock compared with the age of another rock
rhyolite a light-coloured extrusive igneous rock with a similar mineral composition to granite but with smaller crystals
rock cycle a cycle of processes that rocks experience in the Earth's crust as they constantly change from one type to another
rock salt a sedimentary deposit formed when a salt lake or seabed dried up. The sediments are made of sodium chloride (halite).
sandstone a sedimentary rock with medium-sized grains. The sand grains are cemented together by silica, lime or other salts.
scavengers animals that eat dead plant and animal material
scoria a dark, igneous rock formed from basalt lava that cools quickly and full of holes that once contained gas
sedimentary rocks formed through the deposition and compaction of layered sediment
sediment material broken down by weathering and erosion that is moved by wind or water and collects in layers
shale a fine-grained sedimentary rock formed in layers by the consolidation of clay
silicates group of minerals consisting primarily of SiO_4^{2-} combined with metal ions, forming a major component of the rocks in the Earth's crust
siltstone a sedimentary rock with a particle size between that of sandstone and mudstone
slate a fine-grained metamorphic rock formed as a result of moderate heat and pressure on shale
Stone Age a prehistoric time when weapons and tools were made of stone, bone or wood
streak colour of a mineral as a fine powder, found by rubbing it onto an unglazed white ceramic tile
trace fossils fossils that provide evidence, such as footprints, that an organism was present when the rock was formed
underground mining mining that uses shafts and tunnels to remove rock from deep below the surface
viscosity a measure of a fluid's resistance to flow
weathering the physical or chemical break down of rocks on the surface

Resources

Digital document Key terms glossary (doc-34957)

eWorkbooks Study checklist (ewbk-5039)
Literacy builder (ewbk-5040)
Crossword (ewbk-5042)
Word search (ewbk-5044)

Practical investigation eLogbook Topic 9 Practical investigation eLogbook (elog-0610)

9.11 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 19, 26, 27	Questions 10, 12, 13, 14, 15, 20, 21, 23, 28	Questions 16, 17, 18, 22, 24, 25, 29, 30, 31, 32, 33

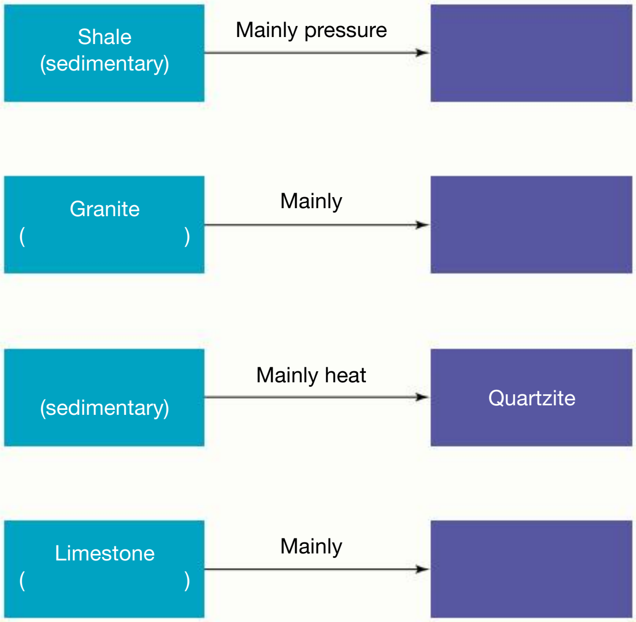
Remember and understand

1. What are the three requirements needed to call something a rock?
2. The rocks formed in the Earth's lithosphere are grouped into which three groups based on how the rock was formed?
3. How are all igneous rocks formed?
4. Explain the difference between the ways in which extrusive igneous rocks and intrusive rocks are formed.
5. List three examples of extrusive igneous rocks.
6. What is the difference between basalt and rhyolite?
7. What clues does the size of the mineral crystals in an igneous rock provide about how the rock was formed?
8. What are sediments?
9. Explain why some layers of sedimentary rocks are tilted or bent.
10. Describe the three different sediment types that can compact and cement to form sedimentary rocks.
11. What is a 'parent' rock?
12. Describe two ways in which igneous and sedimentary rocks can be transformed into metamorphic rocks.
13. Complete the table to summarise what you know about igneous, sedimentary and metamorphic rocks.

TABLE Summary of rock types

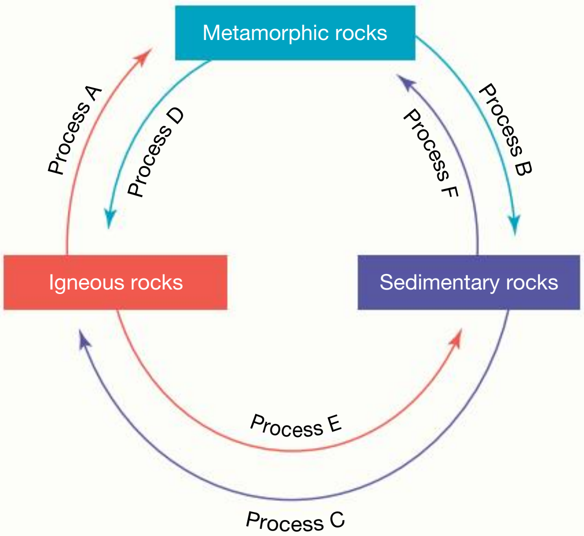
Class of rock	How it is formed	Special features	Example	Uses
Igneous				
Sedimentary				
Metamorphic				

14. Complete the diagram of parent rocks and their rock type on the left, and the common metamorphic rocks they form, on the right.



15. Explain why the mineral crystals in granite are larger than those in basalt.
16. How does applying pressure change the appearance of the rock?
17. The changes that lead to the formation of the three main groups of rocks can be drawn as a cycle, as shown in the figure.
Which of processes A–F involve:
a. weathering and erosion
b. heat and pressure
c. remelting and cooling?
18. What characteristic of minerals do the following terms describe?
a. Lustre
b. Streak
c. Hardness
19. What mineral property does Mohs' scale provide an approximate measure of?
20. Which sedimentary rock was the most important material for tool making in the Stone Age? What properties made it so useful?
21. Not all fossils are the actual remains of living things. Name and describe two types of fossils that are not preserved remains.
22. Of the several ways a fossil can form, which is the most common?

Rock formation cycle



Apply and analyse

23. SIS Suggest a way of testing that a rock sample is limestone.
24. SIS While studying sedimentary rocks in a railway cutting, a geologist discovers a layer of graded bedding, which features larger sized clasts at the bottom and the gradual decrease in size towards the top. How could the graded bedding have been made?
25. SIS If you were given a sample of two different minerals:
a. how could you tell which one had the greater hardness
b. which one would you prefer to make a road out of?

26. In the Stone Age, tools were made by a process called percussion flaking.
   a. Describe the process of percussion flaking.
   b. Which property of the rock used to make the tool must be different from those of the stone from which the tool is formed?
27. What is the most common element in the Earth's crust?
28. One factor that determines the way in which ore minerals are mined is their depth. Compare the mining processes used for ores located near the surface with those used for ores located deeper in the Earth's crust.
29. The mining industry provides employment for many Australians. Make a list of occupations that are involved in the mining industry. (*Hint*: Think about what happens before, during and after mining is undertaken.)

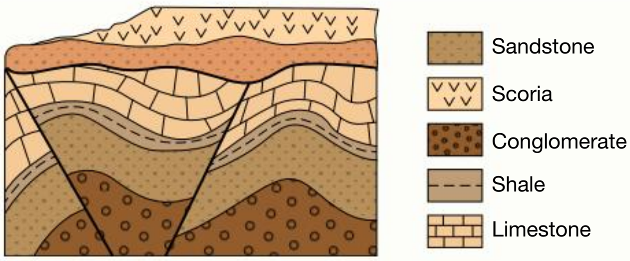
Evaluate and create

30. According to many geologists, parts of Antarctica are rich in mineral resources, similar to those found in Australia. Use a two-column table to list reasons these mineral resources should be mined and why they should not be mined.
31. **SIS** Imagine that the set of fossilised dinosaur footprints as shown in the figure were found in a layer of sedimentary rock.
   a. Use the footprints to write a description of what might have happened millions of years ago.
   b. Compare your interpretation of the footprints with others.
   c. Does each person interpret the evidence in the same way?
   d. If there are differences of opinion about what happened, is there any way of knowing who is right?
   e. List as many differences as you can between the two types of dinosaurs making these footprints.

Fossilised dinosaur footprints

32. The figure is a sketch of some rock layers and their relationships as seen from a cliff face of a canyon.

Cross-section through a rock sequence



a. What is the oldest rock?
b. What is the youngest rock?
c. What sort of event does the youngest rock suggest?
d. Which feature represents a period of weathering and erosion?
e. Is the period of weathering and erosion younger or older than faulting?
f. SIS Which layer in the diagram would most likely have fossils?
g. Normally, old layers of rock are found below younger layers. Sometimes, however, younger layers are found beneath older layers. Can you identify a spot on the diagram where this has happened?

33. SIS This photograph shows dinosaur footprints that have been preserved in rock at Gantheaume Point near Broome.
a. What type of fossil is it?
b. Why is it classified as a fossil even though it could be described as a dent in a rock?
c. Have all dinosaur footprints been preserved? Why have these been preserved for hundreds of millions of years?
d. What can be learned about the features of the dinosaur that left these footprints?
e. What forms of evidence, apart from preserved footprints, can be used to gather knowledge about dinosaurs?

This dinosaur footprint has been preserved in rock for hundreds of millions of years at Gantheaume Point near Broome.

Fully worked solutions and sample responses are available in your digital formats.

on Resources

eWorkbook Reflection (ewbk-3038)

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Test maker
Create customised assessments from our extensive range of questions, including teacher-quarantined questions. Access the assignments section in learnON to begin creating and assigning assessments to students.

RESOURCE SUMMARY

on Resources

Below is a full list of **rich resources** available online for this topic. These resources are designed to bring ideas to life, to promote deep and lasting learning and to support the different learning needs of each individual.

9.1 Overview

eWorkbooks
- Topic 9 eWorkbook (ewbk-5034)
- Student learning matrix (ewbk-5036)
- Starter activity (ewbk-5037)

Practical investigation eLogbook
- Topic 9 Practical investigation eLogbook (elog-0610)

9.2 Rocks and minerals

eWorkbook
- Identifying and classifying minerals (ewbk-5023)

Practical investigation eLogbook
- Investigation 9.1: Identifying mineral properties (elog-0612)

Interactivity
- Crystals (int-5338)

Weblink
- Mexico giant crystal cave

9.3 Mining for metals

Practical investigation eLogbook
- Investigation 9.2: Searching without disturbing (elog-0613)

9.4 Igneous — the 'hot' rocks

eWorkbook
- Igneous rocks (ewbk-5024)

Practical investigation eLogbook
- Investigation 9.3: Does fast cooling make a difference? (elog-0614)

Video eLesson
- Volcanoes (eles-0130)

Interactivity
- The weathering of a batholith (int-5337)

9.5 Sedimentary — the 'deposited' rocks

eWorkbook
- Sedimentary rocks (ewbk-5026)

Practical investigation eLogbooks
- Investigation 9.4: Sediments and water (elog-0615)
- Investigation 9.5: Identifying sedimentary rocks (elog-0616)

Interactivities
- Weathering (int-5339)
- Clastic sedimentary rocks (int-5340)
- Sedimentary rock layers (int-5341)

9.6 Metamorphic — the 'changed' rocks

eWorkbooks
- Metamorphic rocks (ewbk-5028)
- The rock cycle (ewbk-5030)

Practical investigation eLogbook
- Investigation 9.6: Rocks — the new generation (elog-0617)

Interactivities
- Metamorphic rocks (int-5343)
- Metamorphic rocks (int-0234)

9.8 Geologic history

eWorkbook
- Geologic history (ewbk-5032)

Interactivities
- Relative age of rocks (int-0233)
- Formation of a fossil (int-5342)

Weblink
- How many mass extinctions have there been?

9.9 Questioning and predicting the extinction of dinosaurs

Video eLesson
- A palaeontologist (eles-2054)

9.11 Review

eWorkbooks

- Topic review Level 1 (ewbk-5046)
- Topic review Level 2 (ewbk-5048)
- Topic review Level 3 (ewbk-5050)
- Study checklist (ewbk-5039)
- Literacy builder (ewbk-5040)
- Crossword (ewbk-5042)
- Word search (ewbk-5044)
- Reflection (ewbk-3038)

Practical investigation eLogbook

- Topic 9 Practical investigation eLogbook (elog-0610)

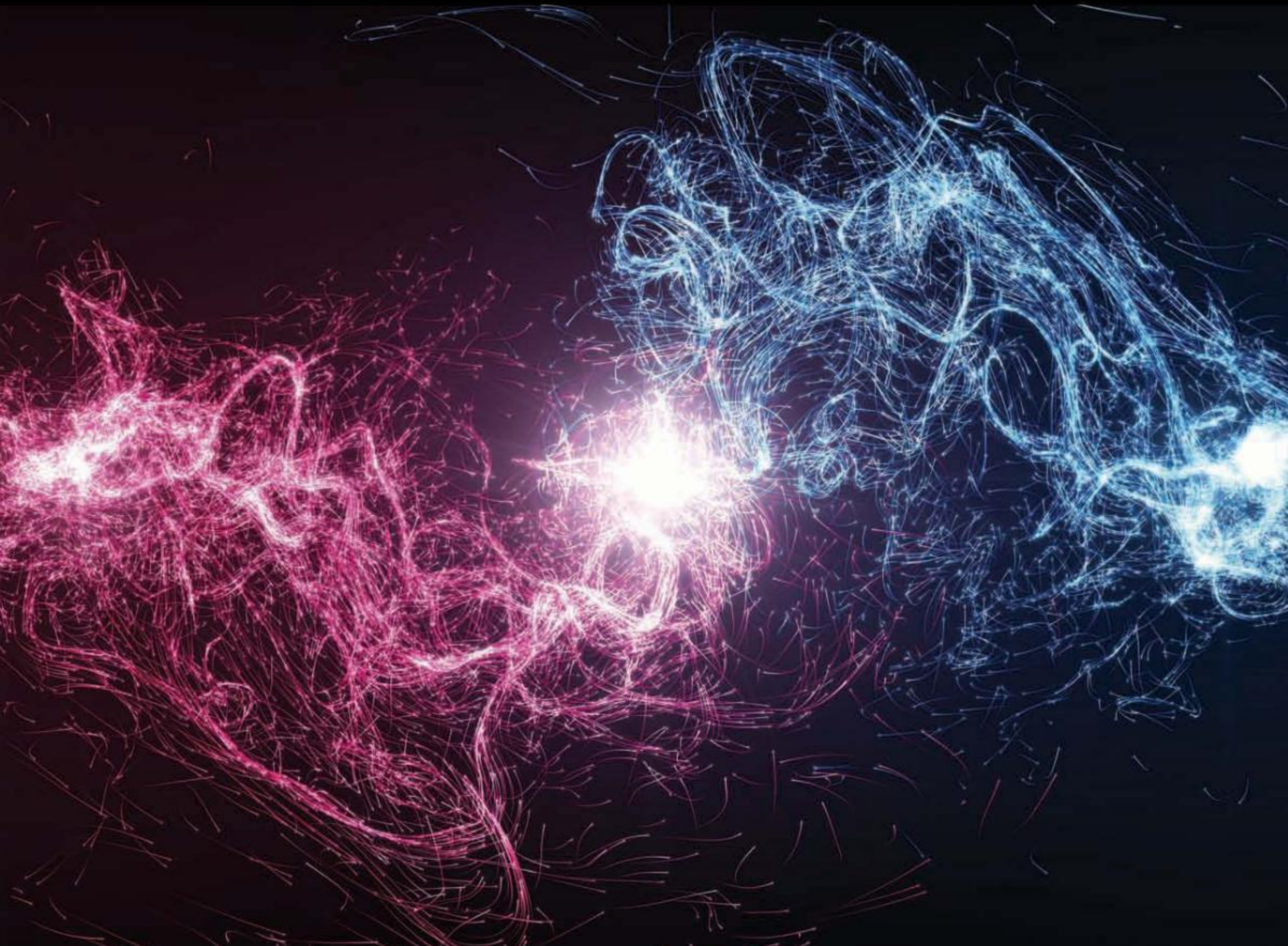
Digital document

- Key terms glossary (doc-34957)

To access these online resources, log on to **www.jacplus.com.au**.

10 Energy

LEARNING SEQUENCE



10.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

10.1.1 Introduction

A fireworks display is one of the most spectacular energy transformations; you can not only see it but also hear, feel and smell it. When fireworks are ignited, the energy stored in the substances inside them (potential energy) is quickly transformed into movement (kinetic energy), light energy, sound energy and thermal energy (more commonly called heat). Energy that is stored is known as potential energy.

FIGURE 10.1 Fireworks are a spectacular display of energy transformation.

on Resources

Video eLesson Energy transformations (eles-2677)

Watch the video of energy transformations to visualise the conversion between potential energy and kinetic energy as an object moves along a rollercoaster.

10.1.2 Think about energy

1. Which type of energy do you find in chocolate?
2. When you drop a tennis ball to the ground, why doesn't it return to its initial height?
3. How much electrical energy is wasted as heat by an incandescent light globe?
4. How does ceiling insulation keep your house warmer in winter?
5. How do glow-in-the-dark stickers work?
6. Why does your image look different in a mirror?
7. How is a rainbow formed?
8. What creates the unique sound when a didgeridoo is played?

10.1.3 Science inquiry

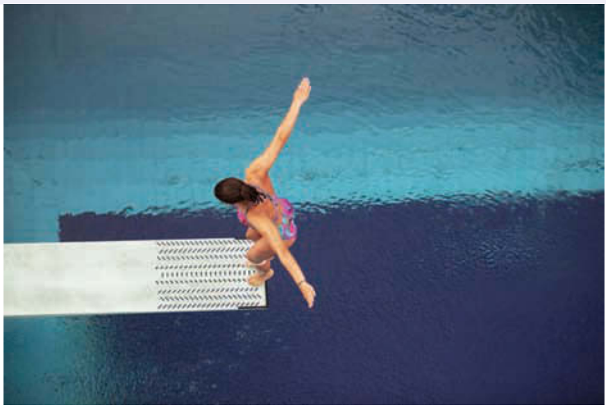
Potential energy and kinetic energy

All substances and objects possess **potential energy**, but until it is transformed into other types of energy you will not be able to see it. For example the energy stored in fireworks only becomes apparent when it explodes, transferring the stored energy into light, heat and sound. When a diver dives from a platform or diving board, the energy stored in them because of their height above the ground is transformed to **kinetic energy** they gain on the way down. The energy stored in the stretched string of a bow is transformed into the kinetic energy of the arrow when it is released.

potential energy energy that has the potential to do work and so the energy is 'stored', such as gravitational energy, elastic energy and chemical energy

kinetic energy energy due to the motion of an object

FIGURE 10.2 Potential energy is all around us. Examples include elastic potential energy in bows and the gravitational potential energy we transform into kinetic energy when we dive off a diving board.



1. Complete table given. One example has been completed for you.

TABLE Releasing and transforming energy of different objects

Object	What to do to release the stored energy	Potential energy is transformed into ...
Torch battery	Switch it on	electrical energy and light energy
Chocolate		
Petrol		
Dynamite		
Olympic diver on platform		
Match		
Stretched elastic band		

2. Answer the following questions about the wind-up toy shown.
   a. Where is the energy stored when it is wound up?
   b. What do you have to do to allow the stored energy to be transformed into different forms?
   c. Name two forms of energy into which the potential energy is transformed.
   d. From where does the energy come that allows the user to wind up the toy?

Resources

eWorkbooks Topic 10 eWorkbook (ewbk-5158)
Student learning matrix (ewbk-5160)
Starter activity (ewbk-5161)

Practical investigation eLogbook Topic 10 Practical investigation eLogbook (elog-0639)

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10.2 Different forms of energy

LEARNING INTENTION

At the end of this subtopic you will be able to describe the different forms that energy can take, and be able to classify them as potential energy or kinetic energy.

10.2.1 What is energy?

Energy is a word that you sometimes use to describe how active you feel. Sometimes you don't seem to have any energy. At other times you feel like you have enough energy to do just about anything. Energy is defined as 'the ability to do work'. That is, it is the ability to make something observable happen.

We know that:
- all things possess energy — even if they are not moving
- energy cannot be created or destroyed. This statement is known as the **Law of Conservation of Energy**. It means that the amount of energy in the universe is always the same.
- energy can be transferred to another object (e.g. from a cricket bat to a ball) or transformed into a different form (e.g. from electrical into sound)
- energy can be stored.

The SI unit of energy is the joule (J).

10.2.2 Types of energy

All forms of energy can be classified as either potential energy or kinetic energy. Potential energy is the energy related to position. Kinetic energy is the energy of a moving object.

Many forms of kinetic energy, such as light, sound and thermal energy are very easily observed. Potential energy has the 'potential' to make something happen, so is not easily observed until it is transformed into another type of energy.

Law of Conservation of Energy
a law that states that energy cannot be created or destroyed

TABLE 10.1 Types of energy

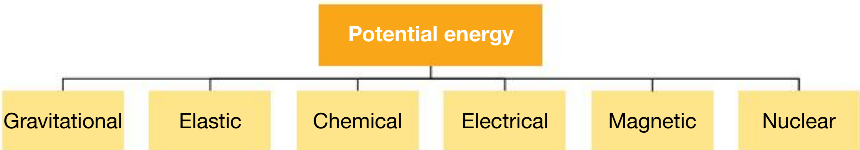
Potential energy (stored energy that, when released, is converted to forms of kinetic energy)	Kinetic energy (often converted from potential energy, these are more easily observed by our senses)
Gravitational (potential energy of an object elevated above the ground) 	Kinetic (energy possessed by objects that are moving) 

Elastic (energy stored by an elastic object that is stretched, such as a spring or rubber band) 	Heat (energy that causes objects to gain temperature) 
Chemical (energy stored in chemicals that is released as heat, sound, light or other forms of energy in a chemical reaction) 	Light (energy that may be released, for example when an object is hot or by a nuclear reaction in a star) 
Nuclear (energy stored in the nucleus of atoms that can be released slowly, such as in a nuclear reactor, or quickly, such as in a nuclear explosion) 	Sound (energy carried by vibrating particles and detected by the ear) 
Electrical (energy provided by the movement of electrons or build-up of electric charge.) 	Magnetic (energy stored in magnets or metals placed in a magnetic field) 

10.2.3 Potential energy

Potential energy is the energy associated with the position of an object. Potential energy can be a result of stretching or squashing an object, lifting an object above the ground, or keeping unlike charges apart.

FIGURE 10.4 Types of potential energy



Gravitational potential energy

Gravitational potential energy is the result of gravity. All objects are attracted to the Earth; the heavier the object and the further the object is from Earth, the stronger the attraction.

When an object is lifted above the ground or moved away from the Earth's surface, it has the potential to fall back to the Earth's surface as soon as it is released, hence it is said to have gravitational potential energy. The heavier the object and the further it is from Earth, the more gravitational potential energy it has.

FIGURE 10.3 Gravitational energy is converted into kinetic energy when we fall.

Elastic potential energy

When the shape of an object is changed, it gains or loses elastic potential energy. A good example of this is a sling shot. When the rubber band is pulled back, it gains elastic potential energy. The more the band is stretched, the more elastic potential energy it gains. While the rubber band is held stretched, it maintains its elastic potential energy that has the potential to make something happen as soon as it is released.

FIGURE 10.5 The stretched rubber in a slingshot stores elastic potential energy.

Chemical potential energy

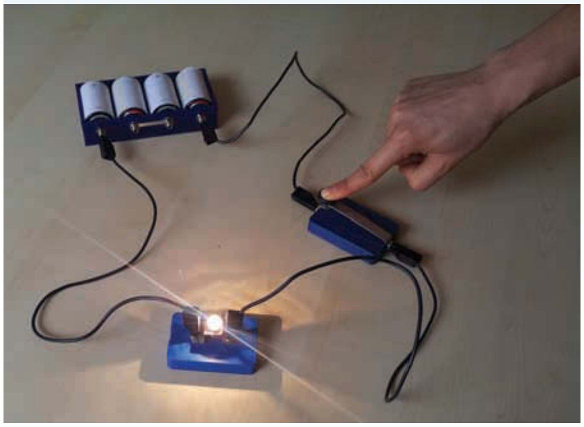
An object is said to have chemical potential energy when the chemicals inside it have the potential to react and make something happen. One example of this is a battery. When the two terminals of a battery are connected, a chemical reaction takes place that results in the flow of electricity. Another example is the chemical energy in food and drinks. When eaten or drunk, food and drink release their stored chemical energy to our body so that we have energy to do things.

FIGURE 10.6 The chemical potential energy in foods and drinks is converted into the energy that we use to power our muscles.

Electrical potential energy

All substances are made up of positive and negative charges. When opposite charges are separated, they are said to have electrical potential energy, because as soon as they are released they are attracted together again. As the charges come together again, they release their electrical potential energy into other forms of energy. If this takes place in an electrical circuit, the stored electrical potential energy is released to the connecting wires and components of the circuit, such as a light globe.

FIGURE 10.7 Electric potential energy causes electricity to flow through the circuit shown, providing power to the light.



Magnetic potential energy

Magnetic fields provide another form of potential energy, called magnetic potential energy. It is easy to understand magnetic potential by playing around with some magnets. If you hold two magnets so that they are attracted to each other you will feel the pull of the magnets attempting to reach each other. If released the magnetic potential energy will cause them to accelerate together.

Nuclear potential energy

The energy stored in the nucleus of atoms is called nuclear potential energy, because if the nuclei can be made to split or combine, a huge amount of energy has the potential to be released. There are four types of nuclear reactions that can take place: **fission**, **fusion**, **nuclear decay** and **transmutation**. Fission involves splitting a heavy nucleus into two or more smaller nuclei, releasing a huge amount of energy in the process. Fusion involves two or more lighter nuclei coming together to make one heavier nucleus. Nuclear decay involves an unstable **isotope** of a particular **element** spontaneously transforming into a new element. Transmutation refers to when an element is bombarded with high energy neutrons in an attempt to convert it to another element.

fission the process whereby a large nucleus splits into smaller fragments releasing large amounts of energy

fusion the process whereby two small nuclei combine to form a larger nuclei releasing large amounts of energy

nuclear decay the spontaneous decay of unstable nuclei to a new nucleus

transmutation the process whereby a nucleus is bombarded with high energy neutrons in an attempt to convert it to another element

isotope atoms of the same element that differ in the number of neutrons in the nucleus

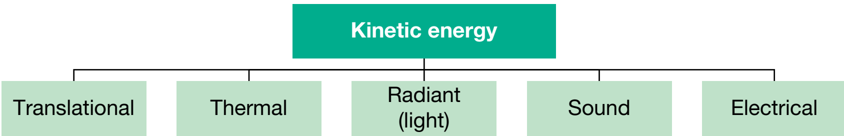
element pure substance made up of only one type of atom

FIGURE 10.8 The amount of nuclear potential energy that is released in nuclear reactions is so large it causes enormous explosion like this one.

10.2.4 Kinetic energy

Kinetic energy exists in many different forms. All kinetic energy involves movement, whether it be movement of objects that we see every day, the vibration of particles as thermal energy or other forms such as sound, light or electrical energy.

FIGURE 10.9 Types of kinetic energy



Translational kinetic energy

Any object that is moving has translational kinetic energy. The heavier an object and the faster it travels, the more translational kinetic energy it possesses. There are some obvious examples of translational kinetic energy, such as a person walking, a ball rolling, or a car driving, but some forms of kinetic energy are less obvious.

FIGURE 10.10 The blades in wind turbines contain large amounts of translational kinetic energy when they rotate.

Thermal energy

Thermal energy is more commonly known as heat, although more specifically, heat is defined as the transfer of thermal energy, which flows from hotter objects to cooler objects. Thermal energy transfer can occur as a result of the movement of atoms, molecules or ions within a solid, liquid or gas. This type of transfer is a form of kinetic energy because it requires the movement of particles. However, thermal energy can also occur as a result of radiation, even without the presence of particles, such as between the Sun and the Earth, and in outer space. We experience heating when thermal energy is transferred into our body from an object or substance with a higher temperature. Cooling is experienced when thermal energy is transferred out of your body to an object or substance with a lower temperature. If you touch a cold object with your hand, such as an ice block, thermal energy moves from your hand to the ice block. If you touch a hot object, such as a pan on the stove, thermal energy moves from the pan to your hand.

FIGURE 10.11 When you touch a cold object you transfer thermal energy to it, heating it slightly.

Radiant energy

Radiant energy is the energy of **electromagnetic waves**. The light that we can see with our eyes are electromagnetic waves with particular frequencies in the **visible spectrum**, which is only one part of a broader **electromagnetic spectrum**. Not all light can be seen with our eyes. Examples of radiant energy include light from the Sun, light bulbs, lamps, torches and flames, x-rays, radio waves and microwaves. Radiant energy is classified as a form of kinetic energy as waves (and/or particles) carry radiation from one source to another.

FIGURE 10.12 Hot objects release radiant energy in the form of light.

electromagnetic waves waves of electromagnetic radiation, light being just one example

visible spectrum different colours that combine to make up white light; they are separated in rainbows

electromagnetic spectrum complete range of wavelengths of energy radiated as electric and magnetic fields

Sound energy

Sound involves the vibration of particles in the air, or another medium. It is therefore a form of kinetic energy. A sound source, such as an instrument or our voice, vibrates, causing the nearby particles in the air to vibrate. We are able to hear some sounds because our ear can detect the vibration of particles and send a message to our brain which tells us the type of sound we are hearing.

FIGURE 10.13 The strings on a guitar vibrate, sending sound waves through the air.

Electrical energy

Electrical energy can be a form of both potential energy and kinetic energy. When electric charges are moving through a circuit, it is a form of kinetic energy called electricity. Electricity is used to power most of your favourite devices, such as your television, your smart phone and your computer. When electric charges are separated they possess potential energy that will be converted into other forms once it reaches a critical amount. An example of this is in lightning, whereby a charge imbalance builds up to the point where it is cannot be sustained, leading to a lightning strike that converts the electric potential energy into thermal energy, light and sound.

FIGURE 10.14 Electrical energy powers all electrical devices such as this tablet.

on Resources

Video eLesson Energy in disguise (eles-0063)

assess on Additional automatically marked question sets

10.2 Exercise

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Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 3, 4, 7	Questions 2, 6, 8	Questions 5, 9, 10

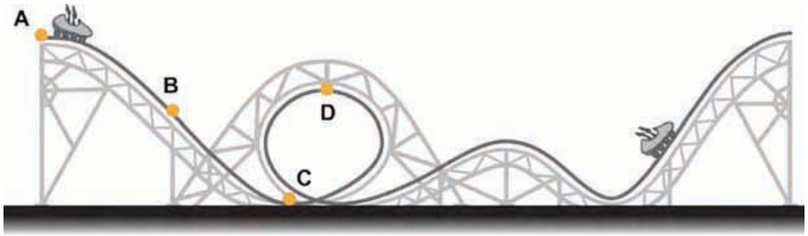
Remember and understand

1. State the Law of Conservation of Energy.
2. Classify the following as examples of potential energy or kinetic energy:
   - An athlete running
   - A spring being squashed
   - Sound coming from a speaker
   - A sky diver about to jump from an aeroplane
   - The light emitted from a globe
3. List five types of potential energy.

Apply and analyse

4. Are the following true or false? Justify your response.
   a. As a ball is thrown up into the air, it gains more gravitational potential energy the higher it moves.
   b. Elastic energy is a type of kinetic energy.
   c. Only springs and rubber bands can have elastic potential energy.
   d. Sound is a type of kinetic energy.
   e. Fusion is the process of splitting the nucleus.
5. Identify four types of energy that are present during a lightning strike.
6. How can you tell that a high diver has gravitational potential energy?

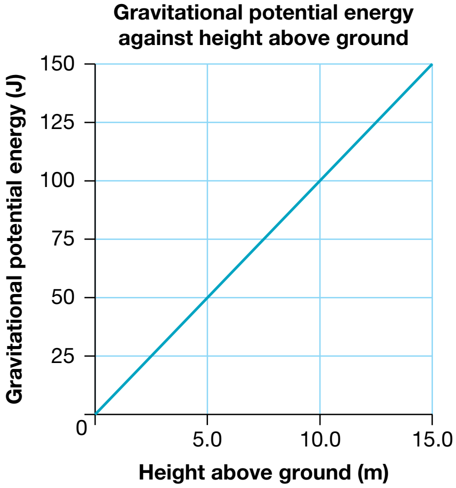
7. Consider points A, B, C and D on the roller-coaster in the diagram.



At which point does the roller-coaster have the greatest gravitational potential energy?

Evaluate and create

8. SIS Create a poster that illustrates the different forms of energy found in a moving car. Include a diagram of a car with arrows and labels indicating where different forms of energy exist.
9. SIS For one whole day, keep a tally of the number of times you come across each of the different forms of energy. Present your results in a bar chart.
10. SIS The graph shows the relationship between gravitational potential energy (J) against height above the ground (m) of a 1 kg ball thrown into the air.
    a. How much gravitational potential energy does the ball have when it is 10 m above the ground?
    b. At what height above the ground is the ball when it has 75 J of gravitational potential energy?
    c. Describe the relationship between height and gravitational potential energy shown in this graph.
    d. If gravitational energy is directly proportional to the mass of an object, sketch a graph showing the gravitational potential energy versus height for a ball with mass 2 kg thrown into the air.



Fully worked solutions and sample responses are available in your digital formats.

10.3 Transforming energy

LEARNING INTENTION

At the end of this subtopic you will be able to describe energy transformations using flow diagrams, explain why sometimes energy appears to be lost, and calculate the efficiency of an energy converting device.

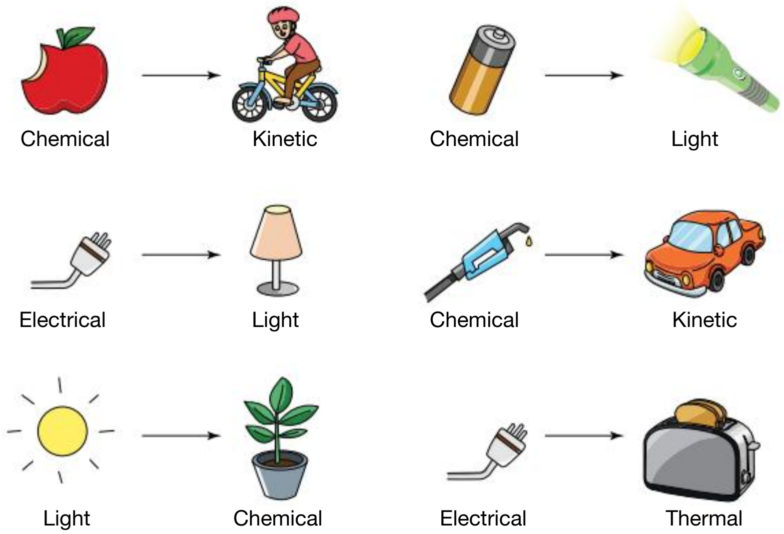
10.3.1 Energy can be transformed

Energy can change from one form to another; we call this an energy transformation or an energy conversion. Sometimes energy transformations result in something happening that we can see with our eyes; other times the result of an energy transformation may not be so obvious.

Examples illustrating some everyday energy transformations are shown in figure 10.15.

- The chemical energy stored in food is transformed into kinetic energy in the body when you move.
- Electrical energy is transformed into light when a lamp is plugged into a power point.
- Light from the Sun is transformed into chemical energy by plants via a process called photosynthesis.
- Chemical energy stored in batteries is transformed into light when a torch is switched on.
- Chemical energy stored in petrol is transformed into kinetic energy when a car is moving.
- Electrical energy is transformed into thermal energy when a toaster is switched on.

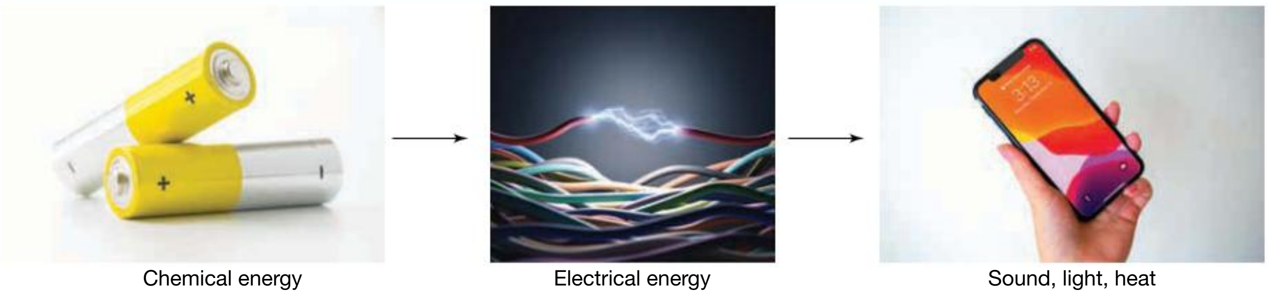
FIGURE 10.15 Examples of different energy transformations, or energy conversions



10.3.2 Energy flow diagrams

Energy flow diagrams are a visual way to show the energy transformations occurring in a system. In an energy flow diagram, an arrow is drawn from the energy input to the useful energy output (see figure 10.16).

FIGURE 10.16 An example of the energy transformations occurring in a mobile phone are shown in the flow diagram.



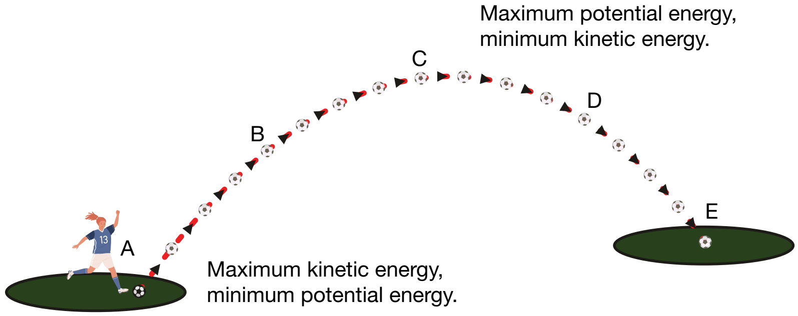
It is usual for there to be more than one energy output, but only the useful forms of energy are listed in energy flow diagrams. In the example given, heat would not usually be listed as it is not a useful form of energy for a mobile phone. Minor energy outputs that are not useful are known as by-products.

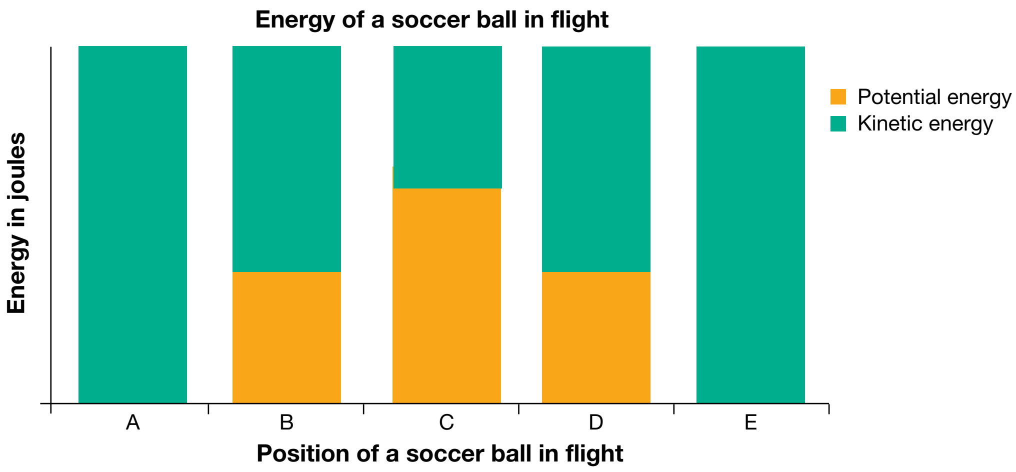
10.3.3 Falling objects

As an object falls from a height, its gravitational potential energy is converted to kinetic energy. When the object reaches the ground, all its gravitational potential energy has been transformed to kinetic energy.

In figure 10.17, notice that at position A, where the ball has just been kicked, the ball has no potential energy because it is on the ground — all its energy is kinetic.

FIGURE 10.17 The energy transformations of a soccer ball in flight





When the ball reaches position B, some of its kinetic energy has been converted to potential energy as it rises above the ground.

At position C, the ball reaches its highest point. The gravitational potential energy reaches its maximum; however, because the ball is still moving horizontally it still has some kinetic energy.

At position D, some of its potential energy is converted back to kinetic energy as the ball falls.

When the ball reaches position E, all of the ball's energy has been converted back in to kinetic energy, and the ball hits the ground at its maximum speed.

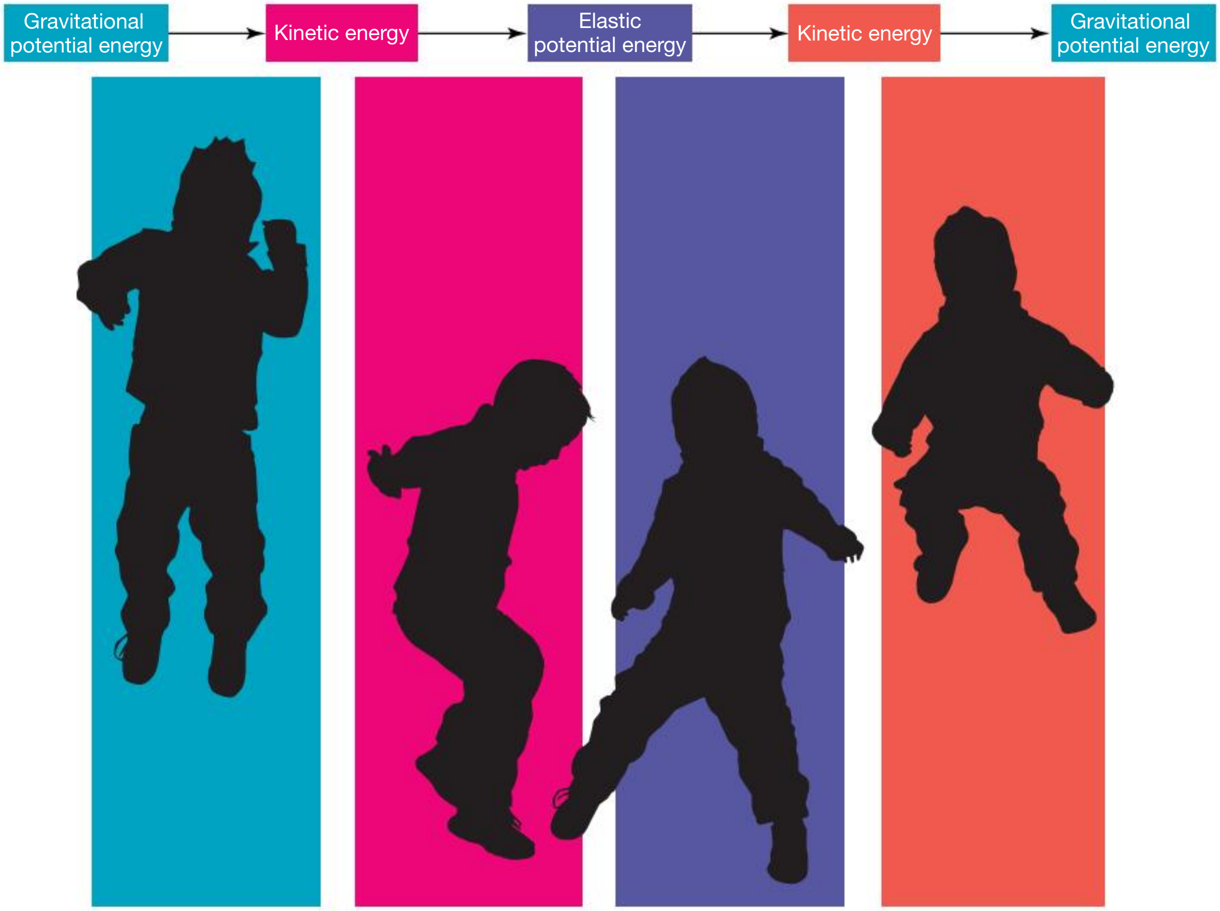
Notice that although the ball has different amounts of potential and kinetic energy at each position, the total amount of energy is the same at each position. The ball never gains or loses energy, it simply transforms kinetic energy to potential energy and then back again. Thus, we say that the energy is conserved.

Next, consider the energy transformations involved in bouncing on a trampoline (figure 10.18). As the person jumping falls towards the trampoline, some of their gravitational potential is converted to kinetic energy. When they reach the trampoline mat, their gravitational potential and kinetic energy are converted to elastic potential energy stored in the springs. Then, as the person jumps back up into the air, the elastic potential energy is converted back into kinetic and gravitational potential energy.

on Resources

Interactivity Coaster (int-0226)

FIGURE 10.18 Energy conversions that occur when bouncing on a trampoline



1 At the very top of a jump, the bouncer is momentarily stopped — he has no kinetic energy. But he does have gravitational potential energy due to his height above the trampoline. As the force of gravity pulls the bouncer down, some of his potential energy is transformed into kinetic energy.

2 As the bouncer strikes the trampoline, his kinetic and gravitational potential energy are transferred to the trampoline's surface and springs. The energy is momentarily stored in the springs. It is called elastic potential energy.

3 At this point, the bouncer pushes off the trampoline. The elastic potential energy is transformed back into kinetic energy and some gravitational potential energy.

4 As the bouncer rises again, his kinetic energy is transformed into gravitational potential energy again. At the top of the jump, the bouncer has no kinetic energy, just gravitational potential energy.

10.3.4 Solar cells

A solar cell, or photovoltaic cell, is a device that converts light energy from the Sun into electrical energy. When light from the Sun strikes the thin semiconductor layer in the solar cell, electrons are knocked free from their atoms. If the solar cell is connected to an electrical circuit, the free electrons flow through the circuit creating electricity that can be used to power devices. Energy can also be stored in the solar cell for later use, for example at night when there is little light. The most efficient solar cells designed for home use convert around 20 per cent of the energy arriving from the Sun into useful energy.

Several solar cells can be connected together to form a photovoltaic module, more commonly known as a solar panel. Multiple modules can then be wired to form an array. You may have seen an array of solar panels on the roof of a house (figures 10.19 and 10.20).

FIGURE 10.19 Solar arrays are made up of modules, which are made up of cells.

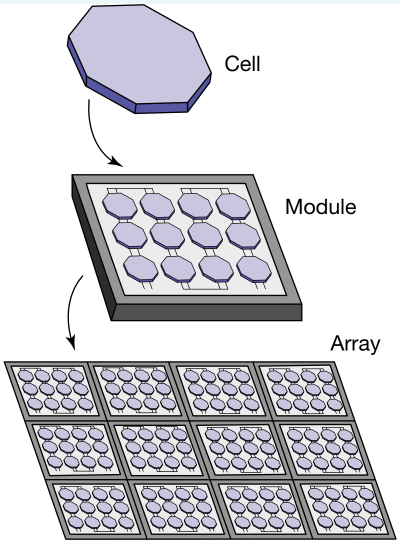


FIGURE 10.20 Solar arrays are often placed on roofs to provide cheap sustainable energy.

10.3.5 Energy 'loss'

Every electrical appliance you use, whether powered by batteries or plugged into a power point, converts electrical energy into other forms of energy. Most of that energy is usually converted into useful energy; but some is converted into forms of energy that are wasted or not so useful. But all of the electrical energy is converted — that's the Law of Conservation of Energy in action. None of the wasted energy is actually lost, it is just transformed into less useful forms of energy. Table 10.2 shows some examples of energy conversion by electrical appliances.

TABLE 10.2 Energy conversion by appliances

Appliance	Electrical energy usefully converted to …	Electrical energy wasted …
Microwave oven	thermal energy of food	heating air in the oven, plates and cups etc.
Television	light and sound	heating the television and the surrounding air
Hair dryer	thermal energy and kinetic energy of air	as sound
Electric cooktop	thermal energy of food	as light and heating the surrounding air

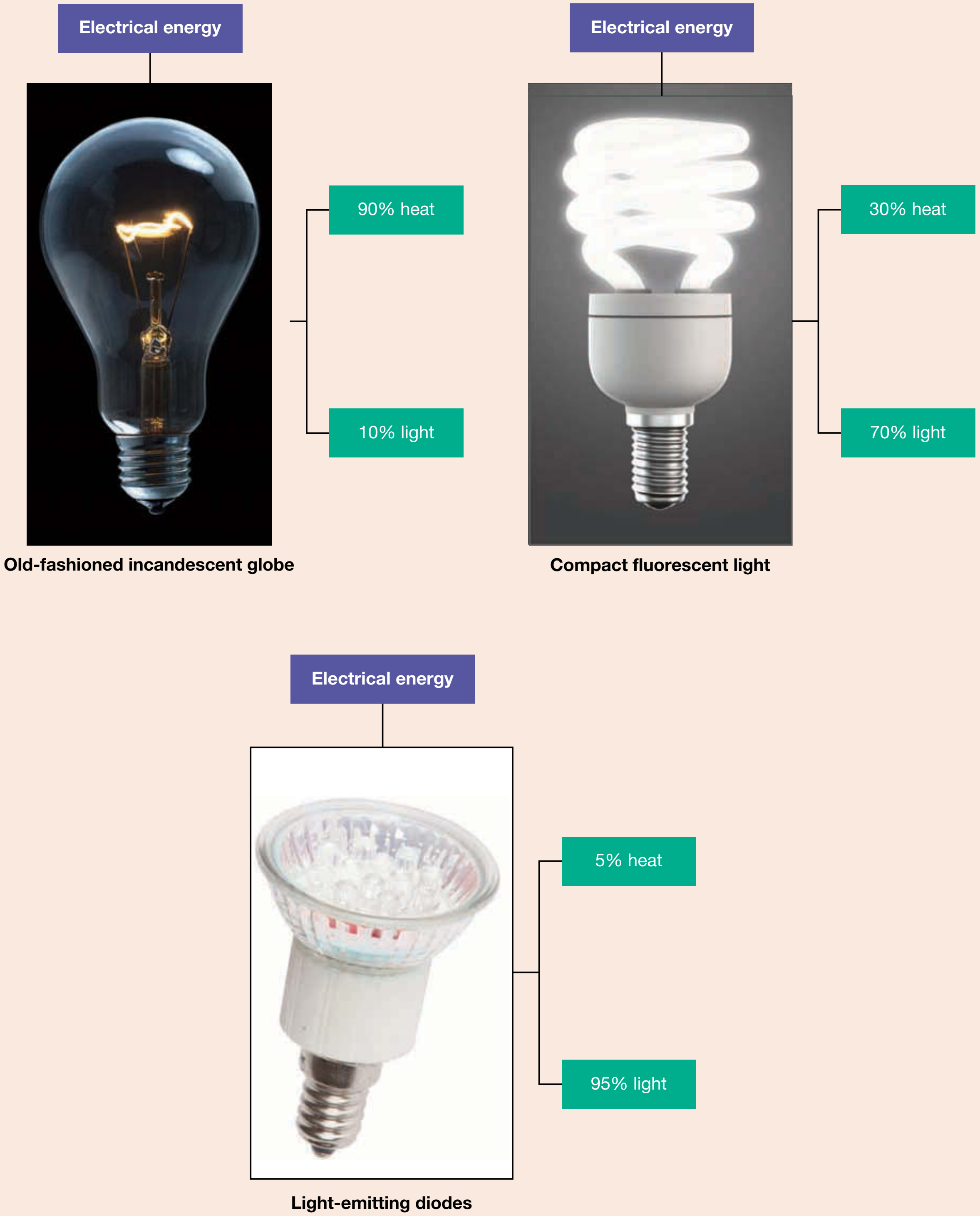
This loss of useful energy is also apparent when you step on the brake pedal in a car — not all the energy you transfer to the pedal is used to stop the car. Much of it is lost in the brakes; it is converted to thermal energy and is released to the surrounding air as heat. The same applies to using the brakes of a bicycle. Also, when you drop a tennis or cricket ball it never bounces back to its original height because some energy is lost as heat. On a larger scale it is seen in power stations, where the fuel, falling water, solar energy or any other energy source is used to produce electricity; some of the energy of the source is transformed to heat, warming the power equipment, the surrounding air and the water used as coolant. The 'loss' of useful energy is unavoidable.

Some types of lighting waste more energy than others. Old-fashioned incandescent light bulbs convert more energy to wasted heat than to light. They emit light only when the filament inside gets white hot. Fluorescent lights and LEDs (light-emitting diodes) waste substantially less energy. Almost all of the electrical energy is converted to light, so you use much less energy to produce the same amount of light than you would using an incandescent bulb.

CASE STUDY: Comparing the energy efficiency of light bulbs

In old-fashioned incandescent light bulbs, electricity passes through a thin filament in the bulb filled with nitrogen or argon gas, causing it to glow white hot. The light is a useful form of energy, but about 90 per cent of the electrical energy is wasted as heat. Compact fluorescent lights (CFLs) offer a more energy-efficient form of lighting, but LEDs are even more efficient.

FIGURE 10.21 LEDs are much more efficient than the alternatives. Note that the figures quoted are approximate.



10.3.6 Efficiency

The **efficiency** of a car, light bulb, gas heater, power station, solar cell or any other energy converter is a measure of its ability to provide useful energy.

Efficiency is usually expressed as a percentage, and can be calculated using the following formula:

$$\text{Efficiency} = \frac{\text{useful energy output}}{\text{energy input}} \times 100\%$$

The efficiency of the incandescent light globe in figure 10.21 is 10 per cent because 10 per cent of the total electrical energy input is usefully transformed into light. The efficiency of the compact fluorescent light is 70 per cent, and the LED light is 95 per cent efficient.

The efficiency of every device that uses fossil fuels is very important for the environment and life on Earth. Scientists and automotive engineers are constantly working on methods of reducing fuel consumption by:

- increasing the efficiency of burning petrol and other fossil fuels such as diesel by reducing the amount of energy wasted as heat
- changing the external design of cars to reduce the amount of energy needed to overcome air resistance
- searching for alternative fuels such as ethanol that can be produced from sugar cane and grain crops.

efficiency the fraction of energy supplied to a device as useful energy

DISCUSSION

- Should it be mandatory to use energy-efficient devices?
- Outline at least one reason efficiency is important for devices that use fossil fuels.
- Are solar-powered cars a realistic alternative to cars that run on fossil fuels or biofuels such as ethanol? What criteria would you use to evaluate this?

on Resources

Video eLesson The Australian–International Model Solar Challenge (eles-0068)

eWorkbooks Skateboard flick cards (ewbk-5148)
Types of energy (ewbk-5150)

assess on Additional automatically marked question sets

10.3 Exercise

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Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 4, 7	Questions 3, 5, 8, 10, 13	Questions 6, 9, 11, 12

Remember and understand

1. Complete the table listing the useful energy and the wasted energy converted by the following devices.

TABLE The useful energy and the wasted energy converted by the devices

Device	Source of energy	Energy usefully converted to …	Forms of energy wasted
A torch			
A wind-up toy			
A pop-up toaster			
A gas cooktop			
A car engine			

2. Outline at least three reasons efficiency is important for devices that use fossil fuels.
3. If a stretched rubber band has 12 J of elastic potential energy, and 9 J of kinetic energy is produced when the band is released:
   a. what is its percentage efficiency
   b. where has the 'lost' 3 J of energy gone?
4. A friend tells you that a light globe transforms 60 J of electric potential energy into 100 J of light. Is she correct? Why or why not?

Apply and analyse

5. An object is dropped from a height of 20 m. At a point during its fall towards the ground, it has 15 J of gravitational potential energy and 5 J of kinetic energy.
   a. What is the total amount of energy of the ball at any time during its flight?
   b. How much gravitational energy did the ball have before it was dropped?
   c. How much kinetic energy will the ball have just before it hits the ground (assuming it is 100 per cent efficient)?
6. When a tennis ball is bounced on the ground, it never returns to its original height.
   a. Does this break the Law of Conservation of Energy? Explain your answer.
   b. Why has the ball not reached its original height after the bounce? Explain with the aid of an energy flow diagram.
   c. Will the ball have the same amount of gravitational potential energy when it reaches the maximum height of its path after the bounce, compared to when it was originally dropped? Explain.
7. **SIS** A student investigating the energy of a skateboarder in a half pipe records the following data. Fill in the missing values.

TABLE The change in energy of a skateboarder in a half pipe

Position of skateboarder	Gravitational potential energy (J)	Kinetic energy (J)	Total energy (J)
Top of half pipe	600	0	
Part way down		200	600
Bottom of half pipe		600	
Part way up	300		
Top of half pipe			

8. Suggest some methods that drivers could use to increase the fuel efficiency of their vehicles.

Evaluate and create

9. The energy we get from eating a piece of fruit starts from the Sun! Describe the energy transformations involved in this process using a flowchart.
10. A catapult like the one in figure 10.22 was used by the Romans more than 2000 years ago to attack castles, cities and invading armies.The long arm was held in its usual vertical position with rope twisted around its base in what is known as a torsion bundle (figure 10.23). The arm was pulled back towards the ground using a second rope so that the bucket could be loaded with a missile. This causes the torsion bundle to twist more tightly. When the arm was released, the torsion bundle quickly untwisted and it returned to its vertical position, releasing the missile from the bucket at high

speed towards the target. The missiles fired included rocks, burning tar and even human corpses. Use flowcharts to show:

a. the energy transfers that take place during the loading and firing of the missile
b. the energy transformations that take place from the time that the missile is loaded until the time that the missile finds its target.

FIGURE 10.22 A Roman catapult

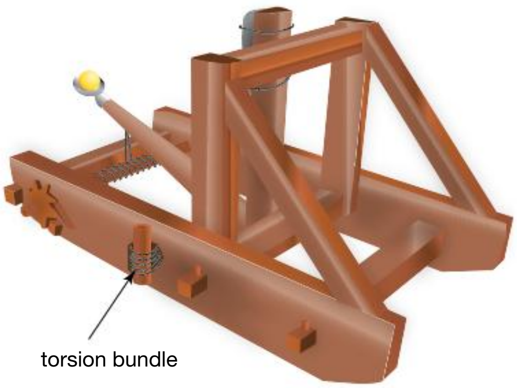
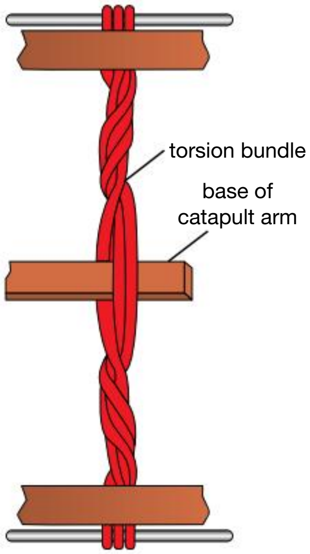


FIGURE 10.23 The torsion bundle



11. **SIS** Create a poster-sized flowchart to show the energy transformations that take place to produce lightning and thunder. (Think first about how the clouds become electrically charged during an electrical storm.)
12. **SIS** Waterwheels have been used in the past (and are still being used) to convert the energy of moving water to other useful forms of energy. Research and report on one example of the use of a water wheel. In your report, use flowcharts to illustrate the transformations and transfers of energy that take place.
13. **SIS** Are solar-powered cars a realistic alternative to cars that run on fossil fuels or biofuels such as ethanol? Find out what scientists, engineers and members of the public have contributed to the design of solar-powered vehicles.

Fully worked solutions and sample responses are available in your digital formats.

10.4 Transferring energy

LEARNING INTENTION

At the end of this subtopic you will be able to describe how energy can be transferred from one object or place to another when a force causes movement or by heating and cooling.

10.4.1 From object to object

Energy transfer from one object to another object is usually easy to observe because one or both objects slow down, speed up or change direction. A transfer of energy to or from an object can also cause it to start or stop spinning. Some examples of energy transfer from object to object are explained here.

- When the golfer in figure 10.24 swings his club, energy is transferred from his body to the club. When the club strikes the ball, most of its energy is transferred to the ball to make it move. The ball gains both kinetic energy and gravitational potential energy as a result of the transfer. It might also spin. In this case the force on the ball is supplied by the club.
- When we lift an object into the air, we are transferring energy from our body to the object in the form of additional gravitational potential energy. When we throw a boomerang, we transfer energy from our body to the boomerang in the form of kinetic and gravitational potential energy. In both cases the force is supplied by your body.
- In an electrical circuit, chemical energy in the cell or battery is transferred to electric charge, causing it to move around the circuit. The force causing the movement is the electrical force of attraction between opposite electric charges. The electrical energy of the moving electric charge is then transformed in a load such as a light globe or smart phone.

FIGURE 10.24 Energy transfers from your muscles into the club and finally into the ball in a golf swing.

10.4.2 Heat

If you accidentally touch a hotplate you'll find out quickly — and painfully — that heat travels from warm objects to cooler objects.

It is the rapid transfer of energy into your hand that causes the pain. Sports people sometimes use ice baths to assist with injury. The body heat is transferred quickly to the cold ice. If you touch something that has the same temperature as your hand, you won't feel any sensation of heat transfer into or away from your hand.

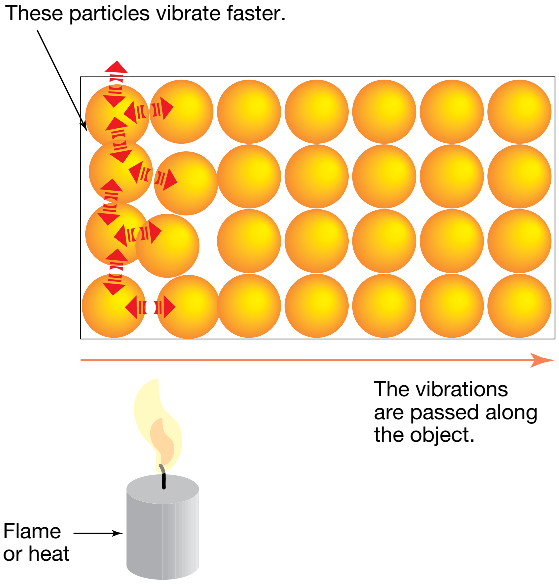
Heat is energy in transit from an object or substance to another object or substance with a lower temperature. Heat can move from one place to another in three different ways — by conduction, convection or radiation.

conduction transfer of heat through collisions between particles

Conduction

If you've ever picked up a metal spoon that has been left in a hot saucepan of soup you will know that heat moves along the spoon and up to the handle. This is an example of **conduction** of heat. Metals are very good conductors of heat. Like all substances, metals are made up of tiny particles. The particles in all solid substances are vibrating (see figure 10.25). Of course, you can't see the vibrations because the particles are far too small to see — even with a microscope. When you heat a section of a solid object, its temperature increases. The particles vibrate faster and bump into each other, transferring some of their energy to neighbouring particles when they collide. The vibrating and transferring of energy continues from particle to particle, transferring energy along the object until the whole object is hot.

FIGURE 10.25 Conduction of heat occurs as a result of vibrating particles.



Not all solids conduct heat at the same rate. Metals, for example, are much better conductors than most other solids. Some solid substances are very poor conductors of heat. Glass, wood, rubber and plastic are all poor conductors of heat, and are called **insulators**. Many metal saucepans have plastic or wooden handles for this reason.

insulator a material that is a poor conductor of heat

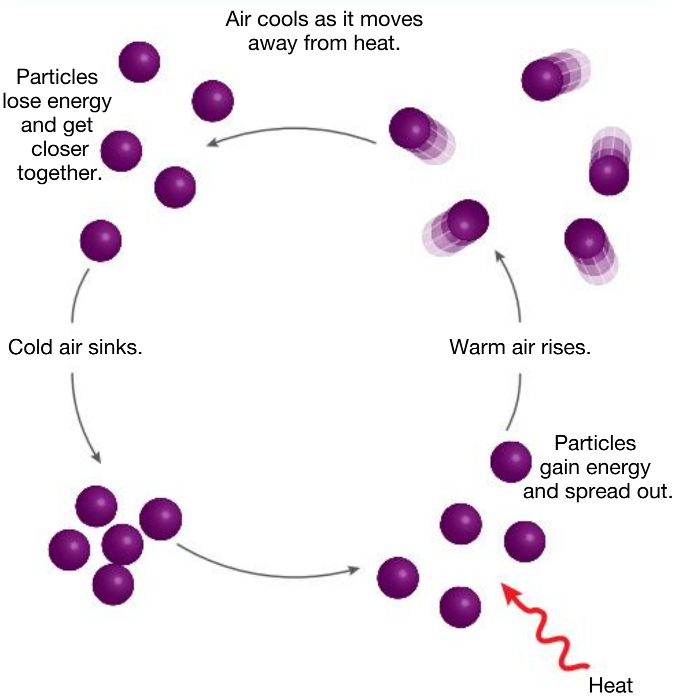
convection transfer of heat through the flow of particles

Convection

The particles that make up solids are close to each other and held together tightly. They can vibrate faster only when heated. However, in liquids and gases the particles are further apart and can move around. So when they are heated, rather than the vibration passing between particles, the particles themselves can move. Heat can travel through liquids and gases by a process called **convection**.

Figure 10.26 shows how convection takes place. Heat causes the particles of air to gain energy, move faster and spread out. This warmer air is less dense than the air around it, so it rises. As it rises it begins to cool. The particles lose some of the energy gained, slow down and move closer together. This cooler air is denser than the air around it, so it falls. The whole process then starts again, creating a pattern of circulation called a convection current.

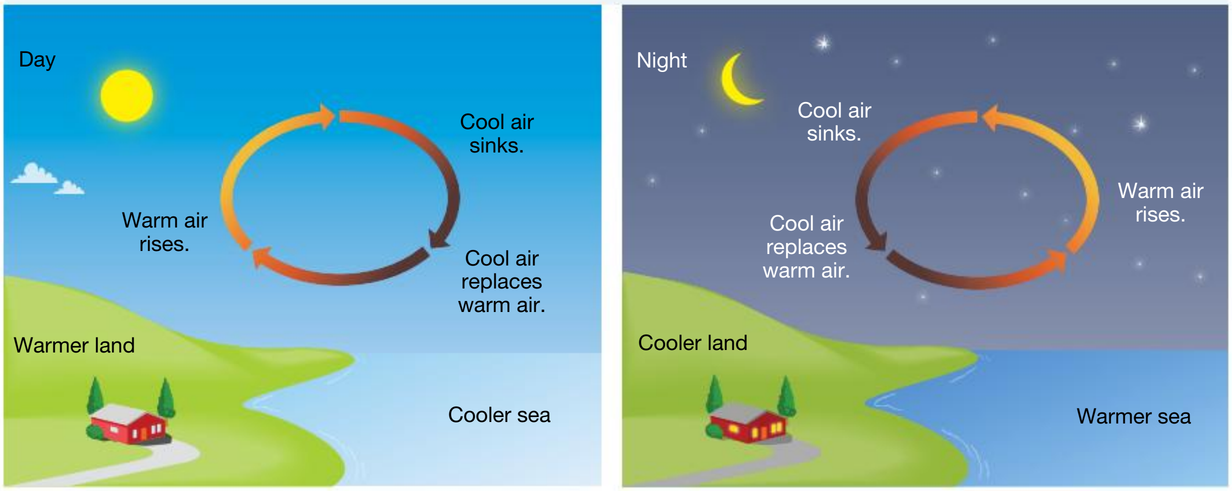
FIGURE 10.26 Modelling heat transfer in air by convection



Gas wall heaters create convection currents with the aid of a fan that pushes warm air out near floor level so that it heats the entire room as the air rises. The gentle breezes at seashore are formed by convection of air currents (see figure 10.27). The warm air above the land rises up and the cool air over the sea takes its place, producing the sea breeze in the daytime. At night, as the sea is warmer than the land, the roles of land and sea changes and convection of air produces the land breeze.

int-5346

FIGURE 10.27 Sea breezes caused by convection currents

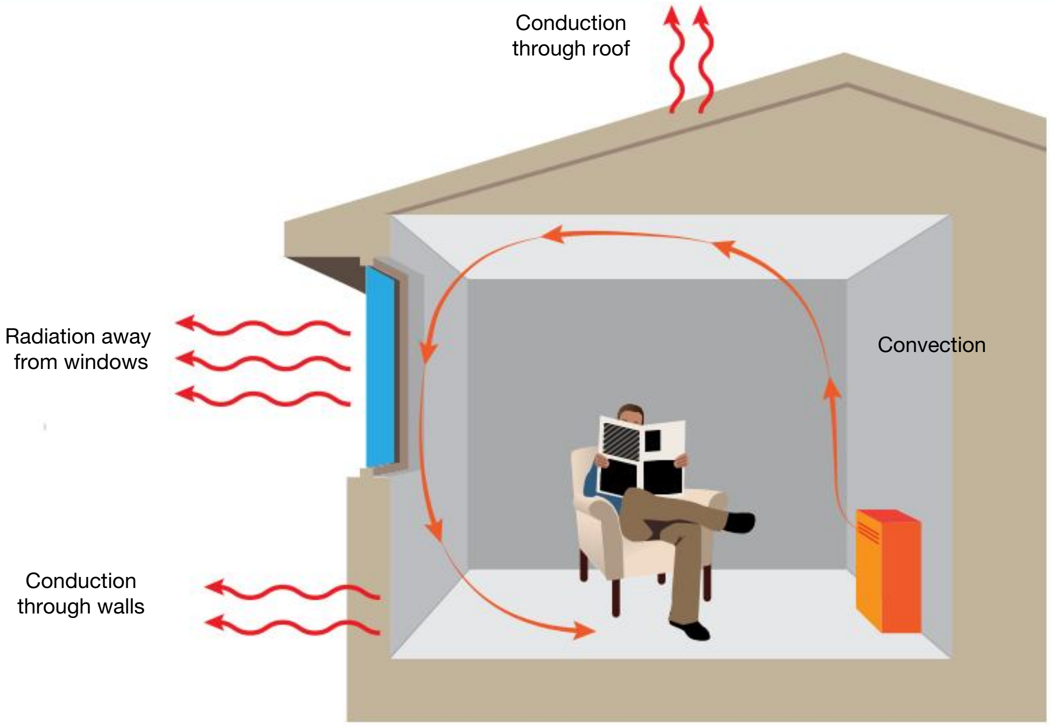


Radiation

Heat from the Sun cannot reach Earth by either conduction or convection because there are not enough particles in space to transfer heat by moving around or passing on vibrations. Heat from the Sun reaches Earth by **radiation**. Heat transferred in this way is called **radiant heat**. Heat transfer by radiation is much faster than heat transfer by conduction or convection, and does not require any contact between the heat source and the heated object, as is the case with conduction and convection.

FIGURE 10.28 A camp cookout — heat is transferred by radiation, conduction and convection.

FIGURE 10.29 The transfer of heat in a house by conduction, convection and radiation



Resources

Interactivity A hot-water system (int-3399)

Video eLesson Convection currents (eles-2056)

radiation emission of energy as electromagnetic waves

radiant heat heat transferred by electromagnetic radiation

elog-0641

INVESTIGATION 10.1

Moving particles

Aim

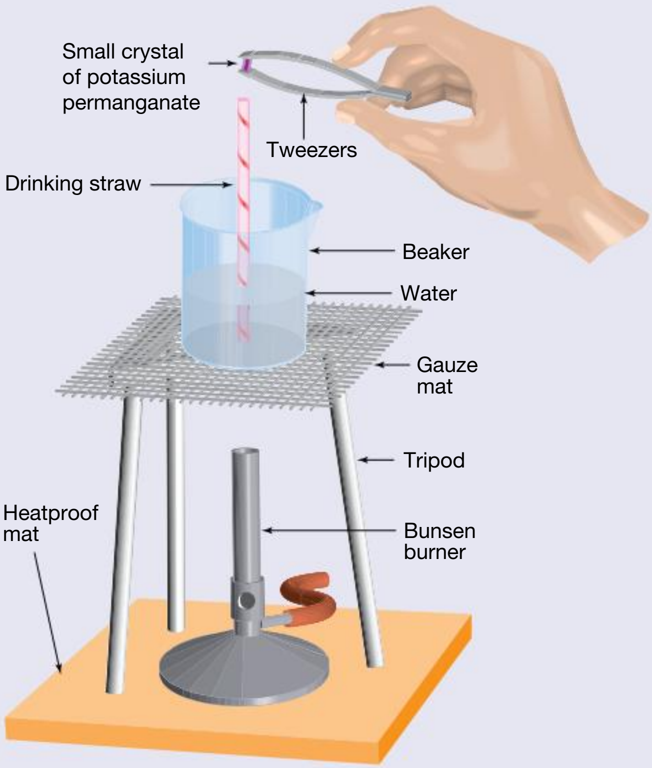
To model convection currents in a liquid

Materials

- 250 mL beaker
- tweezers
- single small crystal of potassium permanganate
- drinking straw
- Bunsen burner
- heatproof mat
- tripod and gauze mat
- matches
- water

Method

1. Fill the beaker with water and place it on a gauze mat and tripod.
2. Use the tweezers to drop a crystal of potassium permanganate down the drinking straw into the water at the bottom of the beaker.
3. Slowly remove the straw, taking care not to disturb the water.
4. Light the Bunsen burner and turn it to a blue flame. Be sure not to disturb the beaker.



Results

Draw a diagram to show the movement of colour through the beaker. This will show the currents within the beaker.

Discussion

1. Explain why the colour moved in the way it did.
2. Is this experiment successful at modelling convection? Explain why or why not.

Conclusion

What can you conclude about modelling convection currents in a liquid?

Transmission, absorption and reflection

When radiant heat strikes a surface, it can be **reflected**, **transmitted** or **absorbed** (figure 10.30). Most surfaces do all three; some surfaces are better reflectors, others are better absorbers and some transmit more heat.

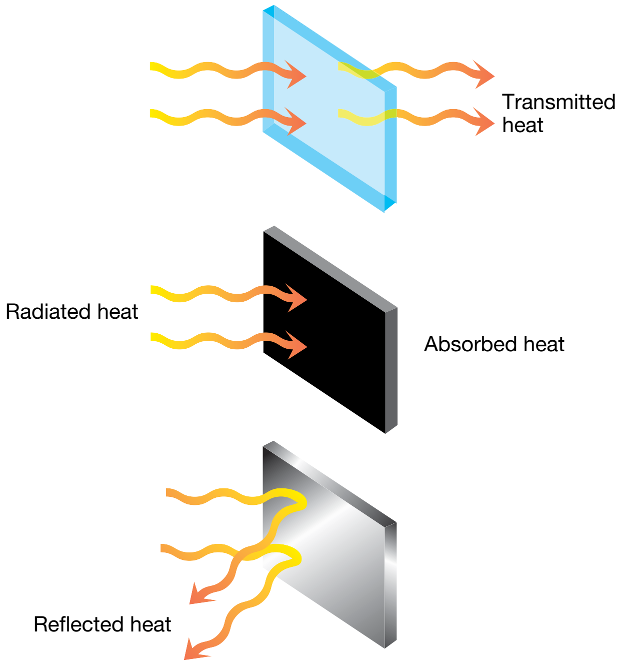
reflected bounced off

transmitted passed through something, such as light or sound passing through air

absorbed taken in

int-3400

FIGURE 10.30 How different surfaces are affected by radiant heat.



Transmitted radiant heat
Clear objects, like glass, allow light and radiant heat to pass through them. The temperature of these objects does not increase quickly when heat reaches them by radiationn.

Absorbed radiant heat
Dark-coloured objects tend to absorb light and radiant heat. Their temperatures increase quickly when heat reaches them by radiation.

Reflected radiant heat
Shiny or light-coloured surfaces tend to reflect light and radiant heat away. The temperature of these objects does not change quickly when heat reaches them by radiation.

on Resources

assess on Additional automatically marked question sets

10.4 Exercise

learn on

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Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 5, 6	Questions 3, 4, 8, 10	Questions 7, 9, 11

Remember and understand

1. What are the two methods by which energy can be transferred?
2. When a girl kicks a soccer ball, energy from her body is transferred to the soccer ball. Which two useful forms of energy does the soccer ball gain as a result?
3. Complete the table.

TABLE Heat transfer by conduction, convection and radiation

Type of heat transfer	Describe briefly how heat moves	Substances in which heat moves in this way
Conduction		
Convection		
Radiation		

4. What is an insulator? Name three different materials that can act as insulators.
5. Heat can travel through empty space (e.g. between the Sun and Earth). How does the heat move?
6. What three things can happen to radiated heat when it arrives at any surface?

Apply and analyse

7. Conduction occurs in solid materials like metals but is not an effective way of transferring heat in liquids and gases. Explain why this is so.
8. When you hold a mug of coffee or hot soup, your hands feel warm. How is the heat transferred to your hands?

Evaluate and create

9. Draw a diagram to show how air-conditioners push cool air out near the ceiling to create convection currents that cool rooms in hot weather.
10. **SIS** Investigate how evaporative and refrigerated air-conditioners work and compare the advantages and disadvantages. Write a report summarising your findings.
11. **SIS** How quickly do things cool? The rate at which substances cool is determined by many factors. A cup of hot chocolate will cool more rapidly than the same cup filled with thick vegetable soup. The material in the cup is one variable that affects how quickly cooling takes place. The size of the container, the temperature around the outside of the container, and the type of container are other variables that affect the rate of cooling.
Choose one variable to investigate. All other variables must remain the same so that the test is fair. If, for example, you decide to investigate the effect of the shape of the cup, you must make sure that nothing but the shape changes. The two or three shapes of cup you choose to investigate would need to contain the same amount of liquid, start at the same temperature, be made from the same materials, and be in the same surroundings.
    a. Write down the aim of your investigation and state your hypothesis.
    b. List the set of steps that you will follow for your method.
    c. Decide what equipment is needed and make a list of it.
    d. Decide how your results will be recorded and draw up any necessary tables.
    e. Check your method and equipment list with your teacher before beginning.
    f. Use your results to write a conclusion. State whether your hypothesis was supported.

Fully worked solutions and sample responses are available in your digital formats.

10.5 A costly escape

LEARNING INTENTION

At the end of this subtopic you will be able to use your knowledge of energy transfer to suggest ways to keep your house warm in winter and cool in summer.

SCIENCE AS A HUMAN ENDEAVOUR: Saving energy and staying warm

Knowledge of how heat moves from a warm place to a cooler place can help you to save on the energy that is used to heat and cool your home.

Using less energy for heating and cooling also conserves valuable resources such as coal and natural gas that are used to generate electricity.

In winter, heat leaves the inside of a warm, cosy home by conduction, convection and radiation. New homes are designed to reduce heat losses by all three methods. However, there are also measures that occupants can take to reduce heat losses (and the bills that go with them).

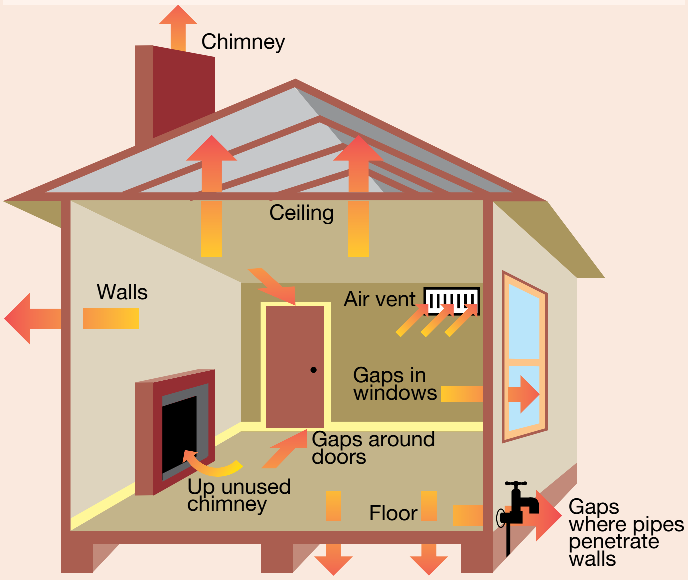
Using the Sun

The direction that a house faces, positioning of windows and skylights, and the types of trees planted around the house all affect the amount of sunlight and radiated heat that enter a home. **Deciduous** trees planted near north-facing windows allow radiated heat from the Sun through in winter but block it out in summer.

Insulation

Heat loss by conduction occurs through the ceiling, walls, windows and floor (see figure 10.31). Since air is a very poor conductor of heat, materials containing air reduce heat loss. However, if the air is free to circulate, it can move away, taking heat with it. The best insulators, therefore, are those that contain air that is restricted from moving. Woollen clothes, birds' feathers and animal fur are all good insulators because they restrict heat loss by both conduction and convection.

FIGURE 10.31 Heat can escape from many different places.



Some ways in which insulation is used in the home include:

- ceiling insulation such as fibreglass batts and loose rockwool that can be blown in. These materials contain pockets of air that provide insulation, and reduce the loss of warm air from the roof by convection.
- cavity wall insulation — a foam that can be sprayed in between the inside and outside walls
- heavy curtains, which trap a still layer of air between them and windows
- double glazing — the use of two sheets of glass in windows with a narrow gap of air between them
- cavity bricks, which have holes in them. The still air in the holes reduces heat loss by conduction and convection.

Do you feel a draught?

Preventing draughts is the easiest way to reduce heat loss in winter. There are many products available from hardware stores designed to seal small cracks and gaps to stop draughts. Draughts from chimneys and exhaust fans are difficult to control, but some exhaust fans have automatic shutters that close when the fan is not in use. Chimneys may have a metal plate to seal off air when there is no fire alight.

Radiation

A warm house radiates heat in all directions. Heat loss by radiation can be reduced with shiny foil that reflects radiated heat. Foil can be added to insulation in the ceiling and is also used in external walls.

on Resources

Interactivity A thermos flask (int-3401)

eWorkbook A costly escape (ewbk-5152)

deciduous trees and shrubs that lose their leaves and become dormant during winter

elog-0642

INVESTIGATION 10.2

Investigating insulators

Aim

To investigate the insulating ability of a range of materials

Materials

- 6 empty soft drink cans
- 6 thermometers
- polystyrene foam, or foam drink can holder
- newspaper
- foam rubber
- woollen cloth
- hot water
- cottonwool
- measuring cylinder
- sticky tape (to tape on the materials)

Method

1. Suggest a hypothesis for this investigation.
2. Surround each can except one with a different material.

(a) Plain (b) Newspaper (a few layers) (c) Woollen cloth (d) Cotton-wool (e) Foam drink can holder (f) Foam rubber

3. Copy the table from the results section into your workbook to record your measurements.
4. Measure out and pour 100 mL of hot water into each of the cans.
5. Measure the temperature of the water in each can. Repeat the measurement of temperature every 5 minutes for 20 minutes.

Results

1. Complete the table provided.

TABLE Temperature of water in cans (°C)

Can covering	Time (minutes)				
	0	5	10	15	20
None					
Newspaper					
Woollen cloth					
Cottonwool					
Foam can holder					
Foam rubber					

2. Draw a bar graph that will allow you to compare the drop in temperature of the water in the cans after 20 minutes.

Discussion

1. Which covering appears to be the most effective insulator?
2. Which one or more of the three methods of heat transfer does the most effective insulator reduce?
3. Use your data to suggest a good container for a mug of hot chocolate.
4. Why was one can left without a covering?
5. Are your conclusions reliable? Discuss the difficulties encountered in making sure that the comparison of insulators was fair.
6. Was your hypothesis supported?

Conclusion

Summarise your findings and state whether your hypothesis was supported or not.

on Resources

assesson Additional automatically marked question sets

10.5 Exercise

learnon

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Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 3, 5	Questions 2, 6, 7	Questions 4, 8, 9

Remember and understand

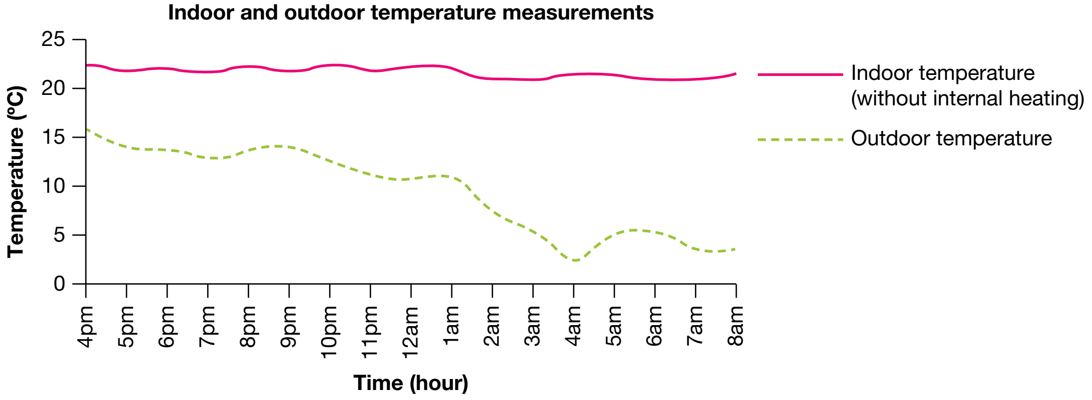
1. What property makes a material a good insulator?
2. Installing insulation in the ceiling reduces which methods of heat transfer?
3. What is the cheapest way of reducing heat losses from your home in cold weather?

Apply and analyse

4. Foil placed in ceilings and walls is often referred to as 'insulation'. Is this term appropriate? Explain your answer.
5. What are convection currents? Draw a diagram to show how they move heat around a room.
6. Homes with central heating that are built on concrete slabs have heating ducts in the ceiling because they cannot be installed in the floor.
   a. What is the disadvantage in having ducts in the ceiling?
   b. Suggest a way of overcoming this disadvantage.
7. Loose clothing is recommended on hot days as it allows body heat to escape. Explain why loose clothing is better than close-fitting clothing for this purpose.
8. SIS Investigate how a thermos flask keeps its contents warm. What features of a thermos flask reduce heat loss by:
   a. conduction
   b. convection
   c. radiation?

Evaluate and create

9. **SIS** The temperature inside and outside a house was taken over a 16-hour period. The results are shown in the graph.



a. At what time was it coldest outside?
b. Describe the outside temperature during the 16 hours.
c. Do you think the house was insulated? Give reasons for your answer.
d. Construct a graph similar to the one provided by recording the temperature inside and outside your house over a period of time (without using any internal heating such as a heater).

Fully worked solutions and sample responses are available in your digital formats.

10.6 Light

LEARNING INTENTION

At the end of this subtopic you will be able to distinguish between incandescent and non-incandescent light sources and describe the different ways in which light can behave when it meets a substance. You will also be able to identify visible light as part of a larger electromagnetic spectrum.

10.6.1 The Sun

Like all stars, the Sun changes some of the energy stored inside it into light energy. A burning candle converts some of the chemical energy stored in wax into light energy. Some living things are also able to change chemical energy stored in their bodies into light energy.

Without light from the Sun, the world would be in darkness. Plants would not grow and no other life on Earth would exist. However, light makes up only a very small fraction of the energy that comes to us from the Sun.

Light travels through space at about 300 000 kilometres per second, taking almost 10 minutes to get here.

10.6.2 Sources of light

The Sun is not the only source of light. Any objects or substances that give off their own light are said to be **luminous**. Examples of some other sources of light are shown in figure 10.32.

Most of the light sources shown are **incandescent**, which means they emit light because they are hot. The Sun and all other stars, light bulbs and flames are incandescent. Other sources, such as fluorescent tubes, the paint on the hands and numerals of clocks and watches, fireflies, glow-worms and some deep-sea fish, emit light without getting hot — they are not incandescent. Living things that emit light without heat are referred to as **bioluminescent**.

luminous releasing its own light
incandescent describes objects that emit light when they are hot
bioluminescent describes living things that release light energy

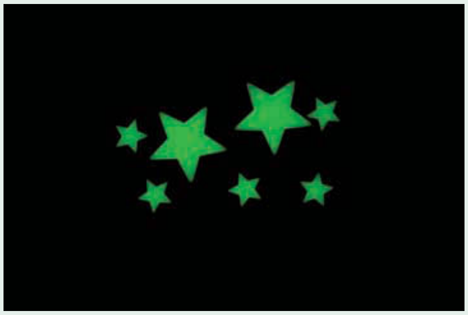
FIGURE 10.32 Each of the light sources shown here is luminous.

FIGURE 10.33 The angler fish, living in darkness about 4000 metres below the ocean surface, uses a luminous lure to attract its prey.

Most things that you see are not luminous; they do not emit their own light. We see **non-luminous** objects because light from luminous objects is reflected from them. Light from luminous objects, such as the Sun, light globes or fluorescent tubes, strikes them and is reflected into your eyes. The Moon is not a luminous object; its surface simply reflects light from the Sun.

EXTENSION: Glow in the dark

Glow-in-the-dark stickers are made with a chemical called phosphor, which absorbs light energy. Phosphor then slowly releases this extra energy as a single colour — usually green. Because the light energy is released more slowly than it is absorbed, the sticker releases green light for quite a long time. This process is called phosphorescence.



on Resources

Video eLesson Bioluminescent click beetle (*Pyrophorus* sp.) (eles-2678)

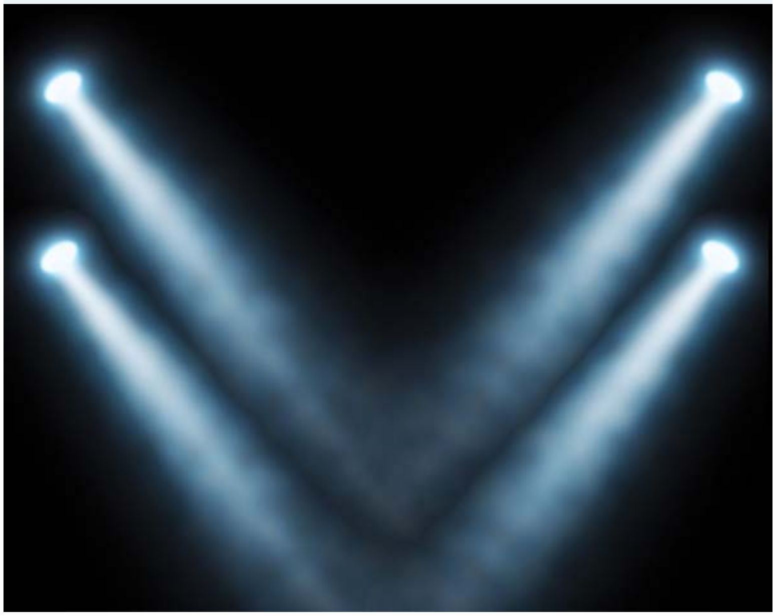
10.6.3 Seeing light

Light can be seen when looking at a luminous object, or when looking at an object that reflects light into your eyes. Light is not normally visible between its source and any surface that it strikes (figure 10.34). You can see a beam of light only if there are small particles in its path. The light is then **scattered** in many directions by the particles, some of it reaching your eye.

non-luminous describes objects that do not emit their own light, but can be seen by reflected light

scattered describes light sent in many directions by small particles within a substance

FIGURE 10.34 Light beams are visible only when there are particles in the air to scatter the light into your eyes. Light from a spotlight can be seen if there is smoke or fog in the air.



on Resources

Video eLesson Crookes radiometer (eles-2679)

elog-0643

INVESTIGATION 10.3

Observing a radiometer

A radiometer consists of four vanes, each of which is black on one side and silver on the other. The vanes are balanced on a vertical support so that they can turn with very little friction. The mechanism is encased inside a glass bulb from which air has been pumped out, making it almost a vacuum.

Aim

To observe the effect of sunlight on a radiometer

Materials

- radiometer

Method

1. Put the radiometer in direct sunlight. Record your observations.
2. Put it in the shade. Record your observations again.

Results

1. What did you observe when the radiometer was in direct sunlight?
2. What did you observe when the radiometer was in the shade?

Discussion

1. What effect does sunlight have on a radiometer?
2. How does this experiment demonstrate that sunlight is a form of energy?
3. Research a scientific theory to explain the effect of sunlight on the radiometer.

Conclusion

What happens to a radiometer when it is placed in direct sunlight? Explain this effect.

elog-0644

INVESTIGATION 10.4

Seeing the light

Aim

To observe and explain the scattering of light

Materials

- moderately dark room
- torch or projector
- matches

Method

1. Shine the torch or projector on a nearby wall.
2. Light and blow out a match, so that the smoke falls between the light source and the wall.

Results

Record your observations.

Discussion

1. Can you see the light beam between the light source and the wall without the smoke?
2. What changes when the smoke is present?
3. Explain what happens to the light from the source to make it visible.

Conclusion

Why can a light beam only be seen when there are particles between its source and a surface?

WHAT DOES IT MEAN?

The word absorb comes from the Latin word *sorbere*, meaning 'to suck in'.

10.6.4 When light meets a substance

When light energy travels from one substance to another, three things can happen to it.

1. It can be transmitted; that is, the light energy can travel through the substance. For example, light is transmitted through clear glass.
2. It can be absorbed; that is, the light energy can be transferred to particles inside the substance. For example, the tinted glass in many cars contains a substance that absorbs some of the light energy passing through it.
3. It can be reflected from the surface of the substance or reflected (scattered) by small particles inside the substance. For example, light is reflected from opaque objects like a piece of wood and scattered by particles of water in fog. This is how you are able to see them.

FIGURE 10.35 You can't see the people in this car because most of the light energy coming from inside the car is absorbed by the tinted glass.

10.6.5 The visible spectrum

Light reaching us from the Sun is known as white light. Household lighting and torches are almost always designed to produce white light. By observing a rainbow, you can see that white light consists of many different colours. This set of colours is called the **visible spectrum**.

The colours of the visible spectrum are usually described as red, orange, yellow, green, blue, indigo and violet. However, there is no sharp boundary between the colours. They merge into each other.

White light can also be separated into the colours of the visible spectrum by passing a narrow beam through a rainbow, the separation of colours is caused by droplets of water. The separation of white light into the spectrum of colours is called **dispersion**.

FIGURE 10.36 A prism is used to disperse white light.

on Resources

Video eLesson Refraction in a prism (eles-2680)

visible spectrum different colours that combine to make up white light; they are separated in rainbows

dispersion separation of the colours that make up white light

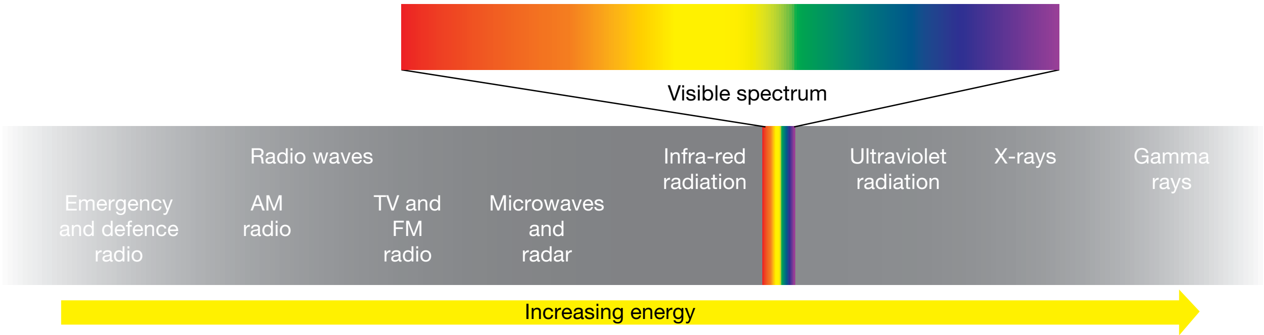
electromagnetic radiation the radiant energy such as radio waves, infrared, visible light, x-rays and gamma rays released by magnetic or electric fields

electromagnetic spectrum complete range of wavelengths of energy radiated as electric and magnetic fields

10.6.6 The electromagnetic spectrum

Visible light is just one part of a 'family' of forms of energy known as **electromagnetic radiation** emitted by the Sun and other stars. Together, this family makes up the **electromagnetic spectrum** and you are probably already familiar with most, if not all the members, including microwaves, ultraviolet radiation and x-rays (see figure 10.37). All types of electromagnetic radiation can be produced artificially here on Earth.

FIGURE 10.37 Visible light represents only a very small part of the electromagnetic spectrum.



All electromagnetic radiation travels through air at 300 million metres per second. Unlike sound waves, electromagnetic radiation can travel through a vacuum as particles are not required for this transfer of energy.

Radio waves

Radio waves include the low-energy waves that are used to communicate over long distances through radio, television. mobile phones and wi-fi. Radar uses radio waves to detect objects from a very long distance. The microwaves used in microwave ovens for cooking are also radio waves.

Infra-red radiation

Infra-red radiation, invisible to the human eye, is emitted by all objects and is sensed as heat. It has less energy than visible light but more energy than radio waves. The amount of infra-red radiation emitted by an object increases as its temperature increases. When you push a button on a remote control to operate a television, PlayStation® or other electronic device, a beam of infra-red radiation is sent towards the device. A detector in the device converts the infra-red energy into electrical energy, which operates the controls.

FIGURE 10.38 A gentle push of a button sends infra-red radiation to an electronic device at 300 million metres per second.

Ultraviolet radiation

Like infra-red radiation, **ultraviolet radiation** is invisible to the human eye. It is needed by humans to help the body produce vitamin D; however, too much exposure to ultraviolet radiation causes sunburn. Ultraviolet radiation has more energy than visible light.

FIGURE 10.39 X-rays showing a fracture in the left ulna (forearm)

X-rays

X-rays have enough energy to pass through human flesh. They can be used to kill cancer cells, find weaknesses in metals and analyse the structures of complex chemicals. X-rays are produced when fast-moving electrons give up their energy quickly. In x-ray machines, this happens when the electrons strike a target made of tungsten.

Some parts of the human body absorb more of the energy of x-rays than others. For example, bones absorb more x-ray energy than the softer tissue around them. This makes x-rays useful for obtaining images of bones and teeth. To obtain an image, x-rays are passed through the part of the body being examined. The x-rays that pass through are detected by photographic film on the other side of the body. Because bones, teeth and hard tissue such as tumours absorb more energy than soft tissue, they leave shadows on the photographic film, providing a clear image.

Computed tomography scanners (CT or CAT scanners) are x-ray machines that are rotated around the patient being examined.

radio waves low-energy electromagnetic radiation

infra-red radiation low-energy electromagnetic waves with a much lower frequency and longer wavelength than visible light

ultraviolet radiation invisible radiation similar to light but with a slightly higher frequency and more energy

x-rays high-energy electromagnetic waves that can be transmitted through solids and provide information about the structure

Gamma rays

Gamma rays are emitted by radioactive substances and larger stars. Gamma rays have even more energy than x-rays and can cause serious damage to living cells. They can also be used to kill cancer cells and find weaknesses in metals. Gamma rays are produced when energy is lost from the nucleus of an atom. This can happen during the radioactive decay of nuclei or as a result of nuclear reactions.

Gamma cameras are used in positron emission tomography scans (PET scans) to obtain images of some organs. To obtain a PET scan, a radioactive substance that produces gamma rays is injected into the body (or, in some cases, inhaled). As it passes through the organ being examined, it produces gamma rays, which are detected by the camera.

FIGURE 10.40 Cameras that detect gamma rays are used in PET scans. This patient is undergoing a PET scan of her brain.

gamma rays high-energy electromagnetic radiation produced during nuclear reaction

on Resources

eWorkbook Light energy (ewbk-5154)

assess on Additional automatically marked question sets

10.6 Exercise

learn on

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 6, 9, 10	Questions 3, 5, 7, 11, 12, 14	Questions 4, 8, 13, 15

Remember and understand

1. What is light and how fast does it travel through space?
2. MC Which of the following objects are luminous?
   A. The Sun
   B. The Moon
   C. The stars
   D. A burning candle
3. a. What does ‘incandescent’ mean?
   b. List two examples of light sources that are incandescent.
   c. List two examples of light sources that are not incandescent.
4. Why do you see the beam of light from a torch if it is foggy?
5. Describe what can happen to light energy travelling through the air when it meets a new substance.
6. List the commonly known colours of the visible spectrum.
7. List the forms of electromagnetic radiation that have more energy than visible light.
8. State two properties that all forms of electromagnetic radiation have in common.
9. Apart from visible light, what other forms of energy come to the Earth from the Sun?

Apply and analyse

10. How do you know that white light consists of different colours?
11. Explain how it is that you can see a page of a book even though it does not emit light of its own.
12. How long does it take light to travel from the Sun to the distant dwarf planet Pluto when it is 6000 million kilometres from the Sun?
13. When light energy meets the surface of your sunglasses, what is the evidence that some of it has been:
    a. transmitted
    b. reflected
    c. absorbed?

Evaluate and create

14. SIS Find out how the energy that reaches the Earth is produced by the Sun. Present your findings in a poster.
15. SIS Investigate and explain in detail how a rainbow is formed.

Fully worked solutions and sample responses are available in your digital formats.

10.7 Light forms images

LEARNING INTENTION

At the end of this subtopic you will be able to describe how images are formed by reflection, refraction and lateral inversion using mirrors and lenses.

10.7.1 Rays

Light is especially important to us because of its ability to form images. The reflection of light allows you to see images in mirrors. When you take a photo, the image is created when light is bent by a lens. In fact, everything that you see is an image, created at the back of your eye when light energy entering your eye bends. To understand how images are formed, we need to have a closer look at how light energy behaves.

Light travels in straight lines as it travels through empty space or through a uniform substance like air or water. The lines that are used to show the path of light are called rays. A beam is a stream of light rays.

FIGURE 10.41 Flat mirrors show undistorted images of people and objects.

10.7.2 Reflections

When you look in a mirror you see an image of yourself. If the mirror is a plane or flat mirror, the image will be very much like the real you. If the mirror is curved, the image might be quite strange, like the one in figure 10.42.

The images in mirrors are formed when light is reflected from a very smooth, shiny metal surface behind a sheet of glass. Images can also be formed when light is reflected from other smooth surfaces, such as a lake.

FIGURE 10.42 Mirrors that are not flat create strange, distorted images.

on Resources

Video eLesson Children's reflections are distorted by this playground mirror (eles-2681)

elog-0645

INVESTIGATION 10.5

Reflection and refraction

Aim

To investigate the reflection of light and its transmission through a prism and lens

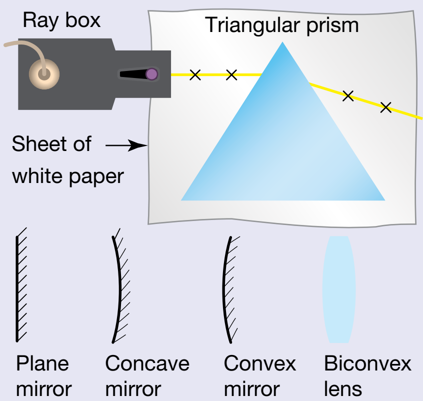
Materials

- ray box kit
- power supply
- several sheets of white paper
- ruler
- fine pencil

Method

1. Connect the ray box to the power supply. Place a sheet of white paper in front of the ray box. Move the lens backwards and forwards until a beam of light with parallel edges is projected.
2. Use one of the black plastic slides to produce a single thin beam of light that is clearly visible on the white paper.
3. Trace the path of this single beam of light as it meets the lens, prism or one of the mirrors shown in the diagram. The path can be traced by using pairs of very small crosses along the centre of the beam before and after meeting each 'obstacle'. Trace and label the shape of each 'obstacle' before you trace the light paths.
4. Change the slide in the ray box so that you can project several parallel beams towards each of the 'obstacles'.
5. Use a ruler to draw a small diagram showing the path followed by the parallel beams when they meet each of the 'obstacles'.
6. Change the black plastic slide to produce a single thin beam of light from the ray box.
7. Place the triangular prism in front of the beam and move it around until you can see a band of colours on the white paper.

Tracing the path of a beam of light



Results

Your ray tracing diagrams should appear in the results section.

1. Which colour is bent most by the triangular prism?
2. Which colour is bent least by the triangular prism?
3. Describe your observations of the path followed by the three parallel beams when they meet each of the mirrors and the lens.

Discussion

1. What happens to a beam of light when it meets a perspex surface:
   a. 'head on'
   b. at an angle?
2. What happens to a beam of light when it meets a plane mirror surface:
   a. 'head on'
   b. at an angle?
3. Explain why droplets of water can cause white light from the Sun to separate into the colours of the visible spectrum.

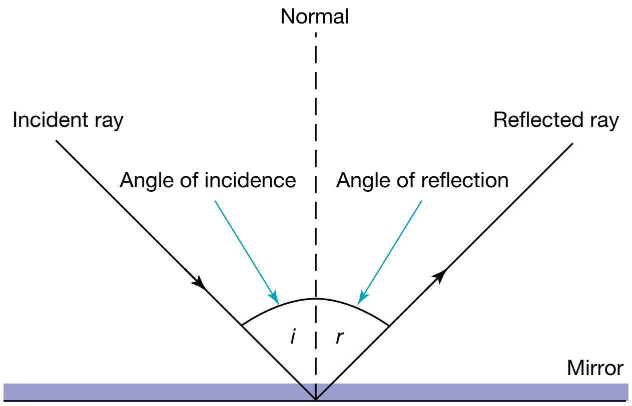
Conclusion

Write a conclusion for this investigation.

Reflections from flat mirrors

Whenever light is reflected from a smooth, flat surface, it bounces away from the surface at the same angle from which it came. This observation is known as the Law of Reflection (figure 10.43). This law can be used to find out where your image is when you look into a mirror. The best way to describe the way the light is reflected from a mirror is to draw a dotted line at right angles to the mirror. This line is called the **normal**.

FIGURE 10.43 The Law of Reflection



The Law of Reflection

When a ray of light is reflected from a smooth surface, it is reflected at the same angle from which it came; the angle of incidence, *i*, is equal to the angle of reflection, *r*.

Figure 10.45 shows how the Law of Reflection can be used to find the image of the tip of your nose.

Almost all of the light coming from the tip of your nose and striking the mirror is reflected. (A very small amount of light is absorbed by the mirror.) All of the reflected light appears to be coming from the same point behind the mirror; and that is exactly where the image is. The image of the tip of your nose is the same distance behind the mirror as the real tip of your nose is in front of the mirror.

FIGURE 10.44 Light rays from the tip of the nose reflect off the mirror and enter the eye.

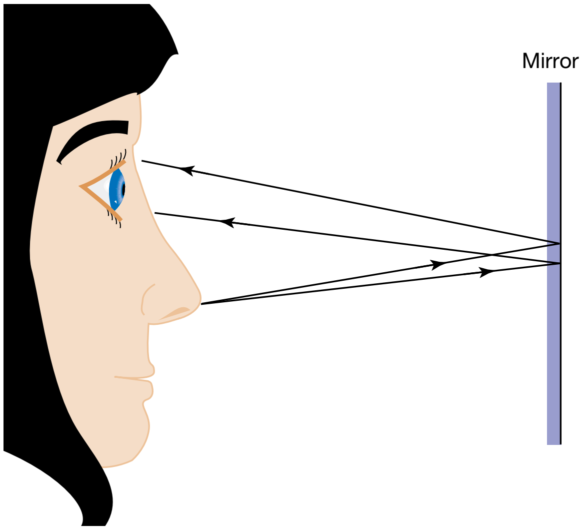
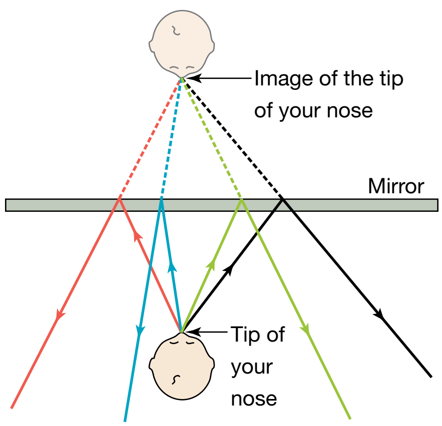


FIGURE 10.45 The reflected light appears to be coming from just one place. That's where the image is.



Reflection from curved mirrors

Flat mirrors are commonly found in the home. Curved mirrors have many applications too, including make-up mirrors, security mirrors in shops and safety mirrors at dangerous street intersections. Curved mirrors may be **concave** (curved inwards) or **convex** (curved outwards). Light reflecting from concave and convex mirrors also follows the Law of Reflection, such that the parallel rays of light are reflected to a **focal point** as shown in figure 10.46. Concave mirrors can sometimes make an image appear upside down!

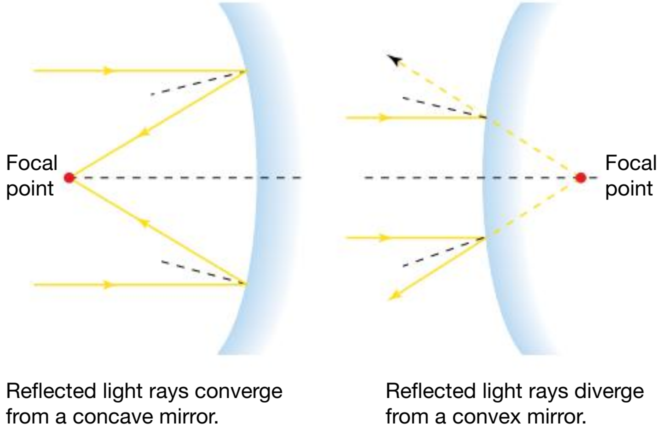
normal (the) line drawn perpendicular to a surface at the point where a light ray meets the surface

concave curved inwards

convex curved outwards

focal point a point at which parallel rays of light meet after reflection by a curved mirror of refraction through a lens

FIGURE 10.46 Concave and convex mirrors also follow the Law of Reflection.



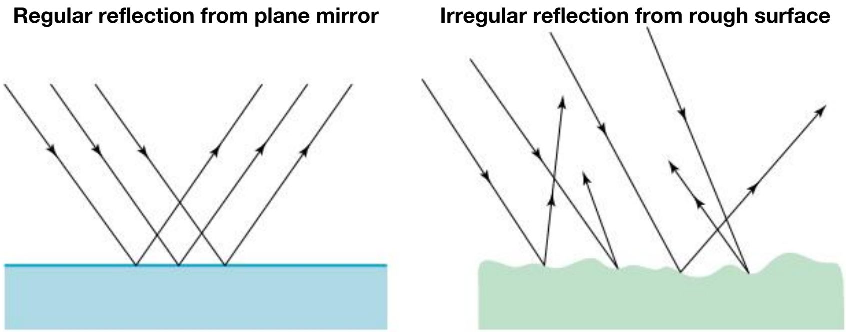
Why can't you see your image in a wall?

When you look very closely at surfaces like walls, you can see that they are not as smooth as the surface of a mirror (figure 10.47). The laws of reflection are still obeyed, but light is reflected from those surfaces in all directions. It doesn't all appear to be coming from a single point. There is no image.

lateral inversion sideways reversal of images in a mirror

refraction change in the speed of light as it passes from one substance into another

FIGURE 10.47 Rough surfaces reflect light in many directions because the light hits the surface at lots of different angles.



10.7.3 Lateral inversion

The sideways reversal of images that you see when you look at yourself in a mirror is called **lateral inversion**. The sign on the ambulance in figure 10.48 is printed so that drivers in front of it can easily read the word 'AMBULANCE' in their rear-view mirrors.

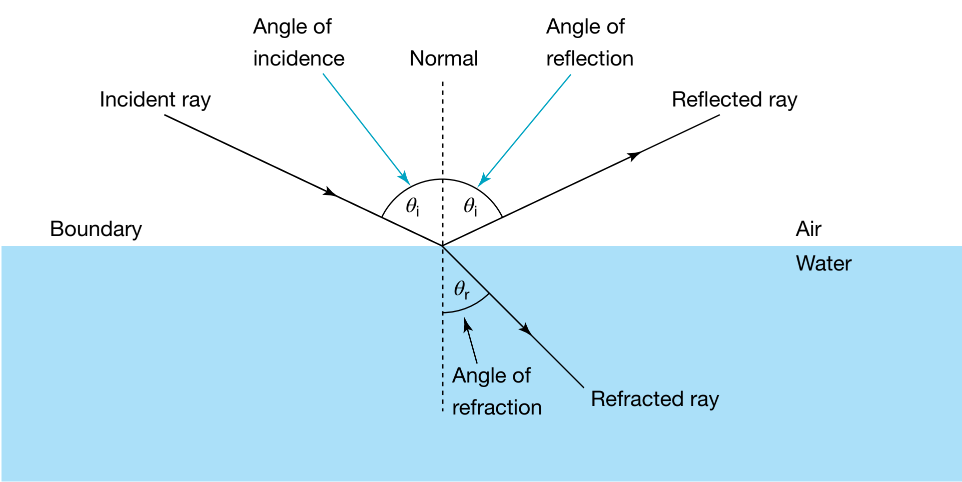
FIGURE 10.48 Why is the word 'AMBULANCE' printed in reverse?

10.7.4 Refraction

When light is transmitted from one substance into another substance, it can slow down or speed up. This change in speed as light travels from one substance into another is called **refraction** (figure 10.49). Refraction causes light to bend, unless it crosses at right angles to the boundary between the substances.

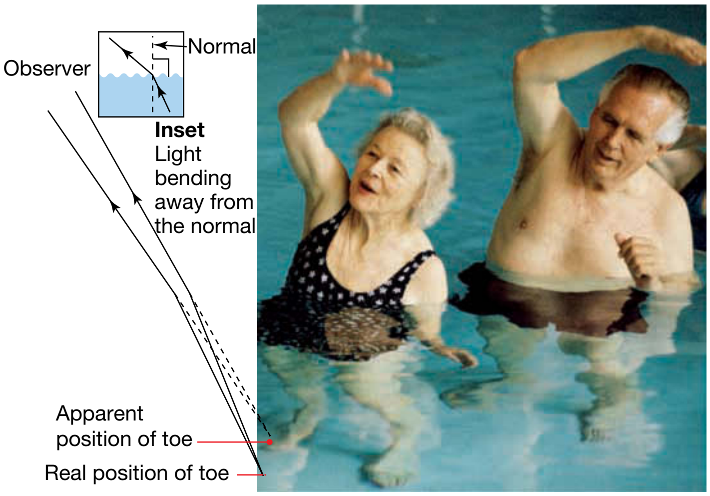
The best way to describe which way the light bends is to draw a normal line to the boundary between the two substances. When light speeds up, as it does when it passes from water into air, it bends away from the normal. When light slows down, as it does when it passes from air into water, it bends towards the normal. The angle between the normal and the incident ray is the **angle of incidence** and the angle between the normal and the refracted ray is the **angle of refraction**.

FIGURE 10.49 Angle of refraction



What happened to my legs?

FIGURE 10.50 The refraction of light as it travels from water to air makes legs look shorter when standing in water.



Looks can be deceiving! The people in figure 10.50 do not have unusually short legs. Everything you see is an **image**. An image of the scene you are looking at forms at the back of your eye. When light travels in straight lines, the image you see provides an accurate picture of what you are looking at. However, when light bends on its way to your eye, the image you see can be quite different.

The light coming from the swimmers' legs in the photograph bends away from the normal as it emerges from the water into the air. The light arrives at the eyes of an observer as if it were coming from a different direction. The diagram shows what happens to two rays of light coming from the swimmer's right toe. The rays travelling to the observer's eye can be traced back to locate where the observer sees the toe; to the observer, the rays appear to be coming from a point higher than the real position of the toe. It can be seen by looking at the diagram that the amount of bending depends on the angle at which the light crosses the boundary.

angle of incidence angle between an incident ray of light and the normal

angle of refraction angle between a refracted ray of light and the normal

image visual representation of an object; what we see

A spectrum of colour!

Refraction of light is responsible for the dispersion of white light as it passes through a prism. Each colour of light is refracted at a slightly different angle due to its **wavelength** and **frequency**, creating a visible rainbow.

wavelength distance between two neighbouring crests or troughs of a wave

frequency number of vibrations in one second, or the number of wavelengths passing in one second

on Resources

Interactivity Bend it (int-0673)

elog-0646

INVESTIGATION 10.6

Looking at images

Aim

To observe and compare the reflection of light from plane mirrors and curved mirrors

Materials

- plane mirror
- shiny tablespoon or soup spoon

Method

1. Look at your image in the back of a spoon. This surface is convex. Convex means curved outward. Move the spoon as close to your eyes as you can and then further away.
2. Record your observations in a table like the one in the results section. Is the image small or large? Right-side up or upside down? Is there anything strange about the image?
3. Look at your image in the front of the spoon. This surface is concave. Concave means curved inward. Move the spoon closer to you and then further away.
4. Record your observations in the table.
5. Look at the image of your face in a plane mirror. Wink your right eye and take notice of which eye appears to wink in the image.
6. Write the word IMAGE on a piece of paper and place it in front of the mirror so that it faces the mirror. Write down the word as you see it in the image.
7. Write down how you think an image of the word REFLECTION would look in the mirror, then use a mirror to check your answer.

Results

TABLE Observations of images using convex and concave sides of a spoon

	Observations of image		
	First observation	When you move closer	When you move further away
Convex side			
Concave side			

Include your diagrams of the word IMAGE and REFLECTION in the results section.

Discussion

1. When you wink your right eye in front of a mirror, which eye in the plane mirror image appears to wink?
2. Which letters in the image of the word IMAGE look different? Which look the same?
3. Was your hypothesis about the image of the word REFLECTION correct?
4. List some places where you have seen curved mirrors. State whether the mirrors were convex or concave and explain why they are used.

Conclusion

Write a conclusion describing how an image of an object appears when viewed in a plane, convex and concave mirror.

elog-0647

INVESTIGATION 10.7

Floating coins

Aim

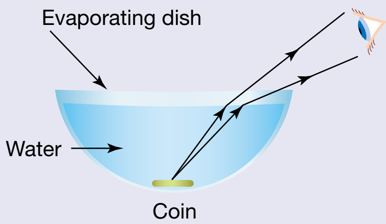
To observe the refraction of light

Materials

- 2 beakers
- evaporating dish
- coin

Method

Place a coin in the centre of an evaporating dish and move back just far enough so you can no longer see the coin. Remain in this position while your partner slowly adds water to the dish.



Results

Make a copy of the diagram. Use dotted lines to trace back the rays shown entering the observer's eye to see where they seem to be coming from. This enables you to locate the centre of the image of the coin.

Discussion

1. Is the image of the coin above or below the actual coin?
2. What appears to happen to the coin while water is added to the evaporating dish?

Conclusion

What can you conclude about the refraction of light from air through water?

on Resources

assess on Additional automatically marked question sets

10.7 Exercise

learn**on**

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 4, 5, 12	Questions 3, 7, 8, 10	Questions 6, 9, 11, 13

Remember and understand

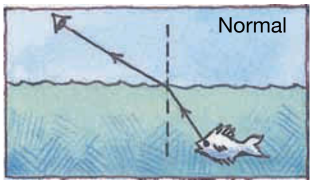
1. You cannot usually see light as it travels through the air. What makes it possible to see a beam of light?
2. What does a mirror do to light in order to form an image?
3. How is your image in a plane mirror different from the real you?
4. What is refraction?
5. Which way does light bend when it slows down while passing from air into water: towards or away from the normal?
6. How would the word 'TOYOTA' on the front of a van look in the rear-view mirror of the driver in front of it?

Apply and analyse

7. In which type of mirror can your image be upside down?
8. Which type of mirror is used to help you see around corners? Why?
9. Why do dentists use concave mirrors to examine your teeth?
10. Explain how white light is separated into different colours by a triangular prism.

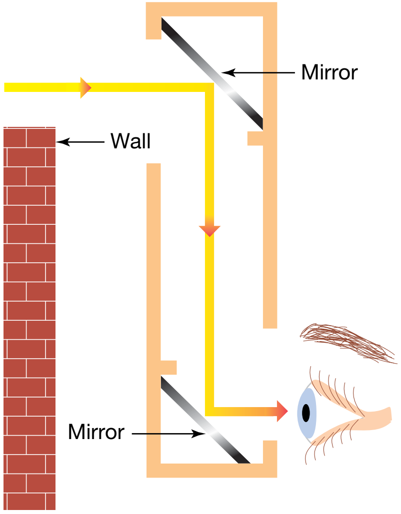
Evaluate and create

11. The illustration shows a ray of light emerging from still water after it has been reflected from a fish. Trace the rays of light entering the girl's eyes back to locate the image of the fish she sees.
    a. Should the spear be aimed in front of or behind the image of the fish? Use the diagram to explain why.
    b. Imagine that you are the fish:
       i. Will the image of the girl's head be higher or lower than her real head?
       ii. Draw a sketch of how the girl might appear to you.



12. When you look down on a coin at the bottom of a glass of water it looks closer to you than it really is.
    a. Draw a diagram to show why it looks closer.
    b. In what other way is the image of the coin different from the real coin?
13. **SIS** Design and build a simple periscope like the one shown in the diagram. You will need stiff card, scissors, two small mirrors, sticky tape or glue, a pencil and a ruler. Explain, with the aid of a diagram, how it works.

A periscope uses mirrors to enable you to see around corners or over objects.



Fully worked solutions and sample responses are available in your digital formats.

10.8 Seeing light

LEARNING INTENTION

At the end of this subtopic you will be able to describe how eyes produce images and apply this knowledge to explain corrective technologies.

10.8.1 The human eye

Everything that you see is an image, created when the energy of light waves entering your eyes is transmitted to a 'screen' at the back of each eye. This screen, called the **retina**, is lined with millions of cells that are sensitive to light. These cells respond to light by sending electrical signals to your brain through the **optic nerve**.

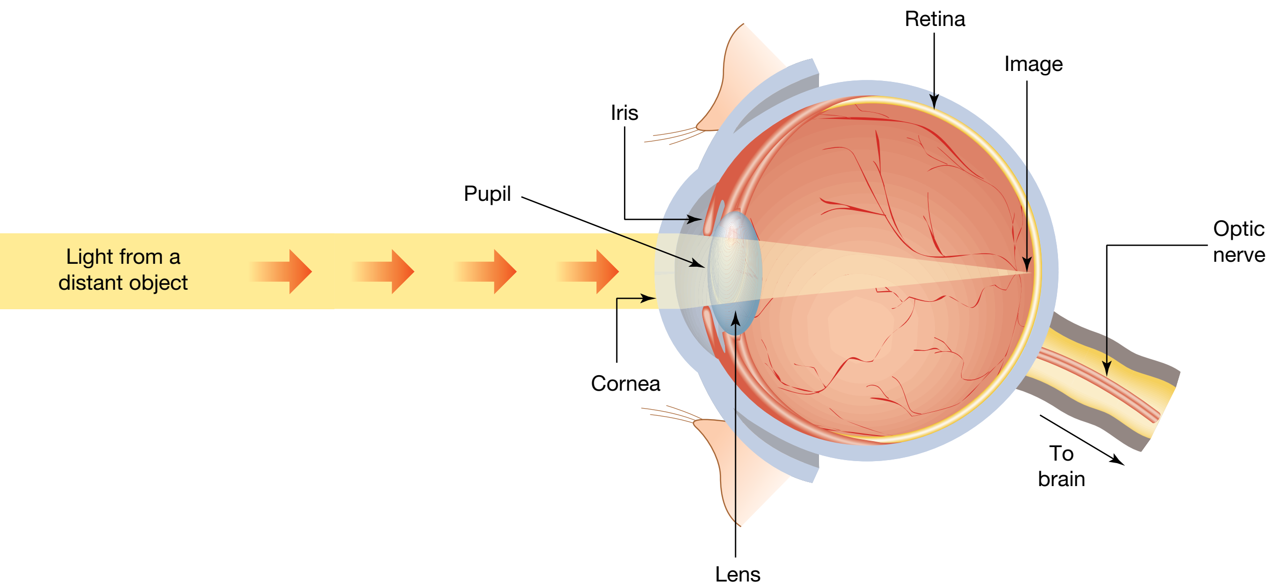
Some of the light reflected from your surroundings, along with light emitted from luminous objects such as the Sun, enters your eye. It is refracted as it passes through the outer surface of your eye. This transparent outer surface, called the **cornea**, is curved so that the light converges towards the **lens**. Most of the bending of light done by the eye occurs at the cornea.

FIGURE 10.51 The human eye

ewbk-5156

int-8226

FIGURE 10.52 Side view of a human eye



retina curved surface at the back of the eye that is lined with sight receptors

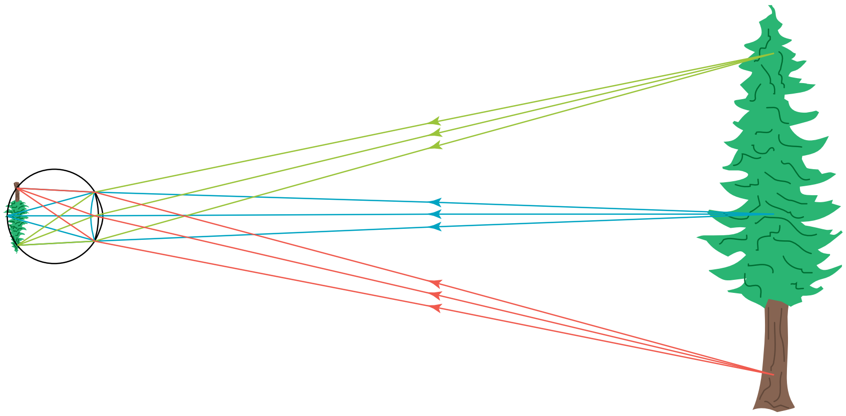
optic nerve large nerve that sends signals to the brain from the sight receptors in the retina

cornea clear, curved outer surface of the eye

lens part of the eye that focuses light onto the retina, ensuring the image is sharp

On its way to the lens, the light travels through a hole in the coloured **iris** called the **pupil**. The iris is a ring of muscle that controls the amount of light entering the lens. In a dark room the iris contracts to allow as much of the available light as possible through the pupil. In bright sunlight the iris relaxes, making the pupil small to prevent too much light from entering. The clear, jelly-like lens bends the light further, ensuring that the image formed on the retina is sharp. The image formed on the retina is inverted (figure 10.53). However, the brain is able to process the signals coming from the retina so that you see things the right way up.

FIGURE 10.53 The image formed on the retina is upside down.



iris coloured part of the eye that opens and closes the pupil to control the amount of light that enters the eye

pupil hole through which light enters the eye

converging lens lens that bends rays so that they move towards each other. Converging lenses are thicker in the middle than at the edges.

biconvex convex on both sides

focal length distance between a lens or curved mirror and its focal point

diverging lens lens that bends rays so that they spread out Diverging lenses are thinner in the middle than at the edges

biconcave concave on both sides

virtual focal point a single point from which light rays seem to be coming after passing through a concave lens

10.8.2 Getting things in focus

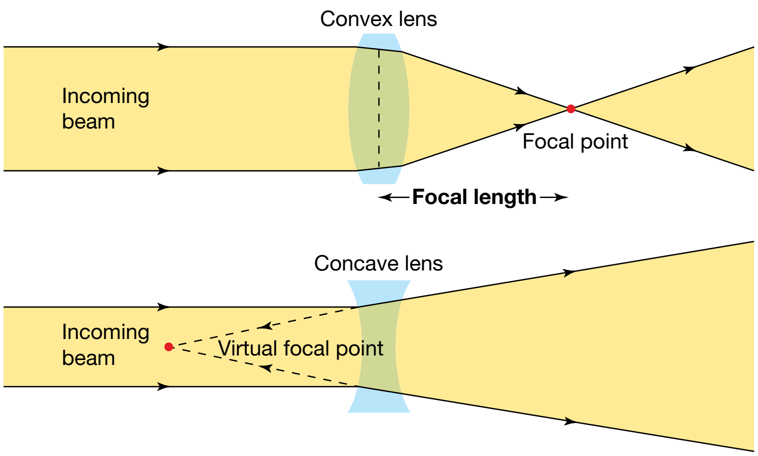
Although most of the bending of light energy done by the eye occurs at the cornea, it is the lens that ensures the image is sharp.

Two types of lenses

The lens in each of your eyes is a **converging lens**. Its shape is **biconvex** — that means it is curved outwards on both sides. A beam of parallel rays of light travelling through a biconvex lens 'closes in' (converges) towards a point called the focal point, or focus. The distance between the centre of the lens and the focal point is called the **focal length**.

Another type of lens is a **diverging lens**, which spreads light outwards because of its biconcave shape. A **biconcave** lens does not have a real focal point. When the parallel light rays emerge from a biconcave lens, they do not converge to a focal point. However, if you trace the rays back to where they are coming from, you find that they do appear to be coming from a single point. That point is called the **virtual focal point**, or virtual focus.

FIGURE 10.54 Convex lenses focus light rays whereas concave lenses make light rays spread out.



elog-0648

INVESTIGATION 10.8

Focusing on light

Aim

To investigate the transmission of light through different lenses

Materials

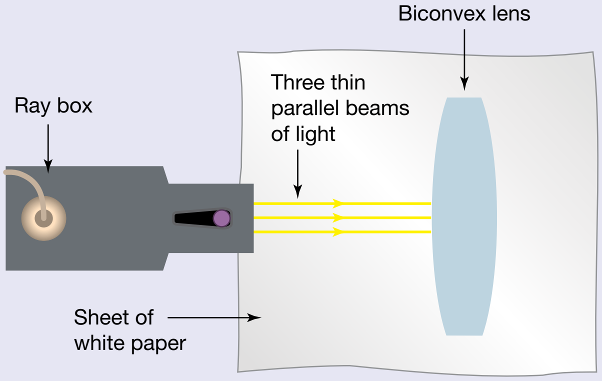
- ray box kit
- sheet of white paper
- 12 V DC power supply
- ruler and fine pencil

Method

1. Connect the ray box to the power supply and place it on a page of your notebook.

Part A: Biconvex lenses

2. Place the thinner of the two biconvex lenses in the kit on the page and trace out its shape. Project three thin parallel beams of white light towards the lens.
3. Trace the paths of the light rays as they enter and emerge from the lens. Remove the lens from the paper so that you can draw the paths of the light rays through the lens.
4. Replace the thin biconvex lens with a thicker one and repeat the previous steps.



Part B: Biconcave lenses

5. Place the thinner of the two biconcave lenses on your notebook page and trace its shape.
6. Trace the path of each of the three thin light beams as they enter and emerge from the lens. Remove the lens from the page so that you can draw the paths of the light beams through the lens.

Results

1. Your ray diagrams should appear in this section.
2. Measure and record the focal length (distance from the focal point to the centre of the lens) for each lens.

Discussion

1. Which of the biconvex lenses bends light more: the thin one or the thicker one?
2. Explain why the middle light ray does not bend.
3. How many times does each of the other rays bend before arriving at the focal point?
4. Do the diverging rays come to a focus?
5. Do the diverging rays appear to be coming from the same direction? Use dotted lines on your diagram to check.
6. Predict where the diverging rays will appear to come from if you use a thicker biconcave lens. Check your prediction with the thicker biconcave lens in the ray box kit.

Conclusion

Summarise your findings by writing a conclusion for this investigation.

Accommodation

The exact shape of the clear jelly-like lens in your eye is controlled by muscles called the **ciliary muscles**. When you look at a distant object, the ciliary muscles are relaxed and the lens is thin, producing a sharp image on the retina. When you look at a nearby object, the light needs to be bent more to produce a sharp image. The ciliary muscles contract and the jelly-like lens is squashed up to become thicker. This process is called **accommodation**.

ciliary muscles muscles that control the shape of the lens in the eye

accommodation changing the lens shape to focus a sharp image on the retina

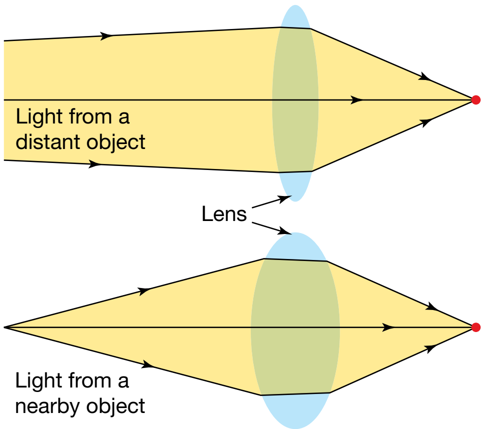
WHAT DOES IT MEAN?

The word accommodation comes from the Latin term *accommodatio*, meaning 'adjustment'.

EXTENSION: Dragonfly eyes

Each human eye contains just one convex lens. Insects have compound eyes. Each eye contains many lenses. Some types of dragonfly have more than 10 000 lenses in each eye. Each eye can focus light coming from only one direction.

FIGURE 10.55 The light coming from a nearby object needs to be bent more than the light coming from a distant object. The lens in your eye becomes thicker when you look at nearby objects.



10.8.3 Presbyopia

As you get older, the tissues that make up the lens become less flexible. The lens does not change its shape as easily. Images of very close objects (like the words you are reading now) become blurred. The lens does not bulge as much as it should and the light from nearby objects converges to a point behind the retina instead of on the retina. You may have to hold what you are reading further away in order to obtain a clear image.

This change in accommodation with age is known as **presbyopia** and is a natural process. Some people are not inconvenienced at all while others need to wear reading glasses so that they can read more easily and comfortably. Table 10.3 shows how the smallest distance at which a clear image can be obtained changes with age. The distances shown are averages and there is a lot of variation from person to person.

TABLE 10.3 The shortest distance at which a clear image can be obtained changes with age.

Age (years)	Distance (cm)
10	7.5
20	9
30	12
40	18
50	50
60	125

presbyopia blurring of images of very close objects caused by loss of flexibility of the lens in the eyes

elog-0649

INVESTIGATION 10.9

Getting a clear image

Aim

To investigate accommodation

Materials

- ruler

Method

1. Look closely at the **X** printed here from the smallest distance at which you can see it clearly and sharply with comfort. Quickly look away and focus on a distant object for a second or two and then focus on the 'X' again from the smaller distance.
2. Try to feel the action of the muscles that allow you to see a sharp image of the 'X'.
3. Use the following procedure to estimate the smallest distance at which you can obtain a clear image of a nearby object. (If you are wearing glasses, remove them during this part of the experiment.)
4. Hold this book vertically at arm's length from your eyes and focus on it. Move the book to a position about 3 or 4 centimetres from your eyes and then gradually move the book further away until you can see the print clearly and sharply.

5. Have a partner use the ruler to estimate the distance between the page and your eyes. The ruler should be placed carefully beside your head for this measurement.

Results

1. Record the distance measured.
2. Collate the results for the whole class and determine the average smallest distance at which a clear image could be obtained.

Discussion

1. How does your result compare with the average distance for your class?
2. Write down the highest single result and lowest single result for your class. Comment on the range of results.

Conclusion

Write a conclusion for this investigation.

10.8.4 Improving the image

The eye is truly an amazing optical system. It is able to focus on distant objects many kilometres away as well as very close objects only centimetres away. However, the ability to obtain sharp images varies from person to person — as well as with age.

The most common conditions that reduce the ability to obtain sharp images are **short-sightedness** and **long-sightedness**.

short-sightedness unable to obtain sharp images of distant objects

long-sightedness unable to obtain sharp images of nearby objects

Short-sightedness (myopia)

A person who is short-sighted is unable to obtain sharp images of distant objects. That happens when the cornea and lens bend the light too much. As a result, the light from a distant object focuses in front of the retina causing the image formed on the retina to be blurry.

Short-sightedness can be corrected by wearing glasses with convexo-concave lenses (see figure 10.56). These lenses diverge the light just a little before it enters the eye. As a result, the light from the object focuses on the retina instead of in front of it.

FIGURE 10.56 A convexo–concave lens has one slightly convex side and one slightly concave side. The concave side is more curved than the convex side, so it acts like a concave (diverging) lens.

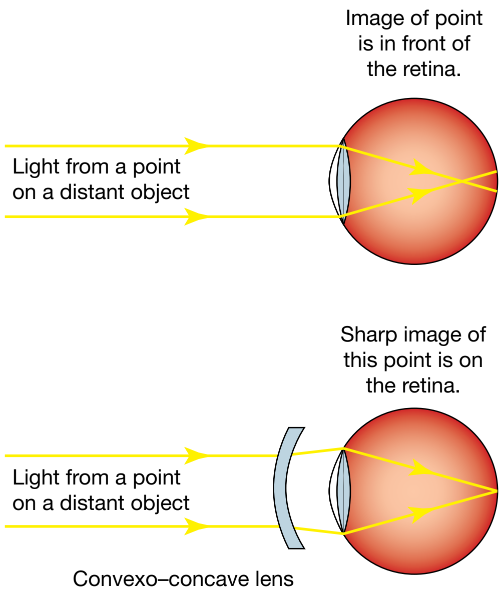
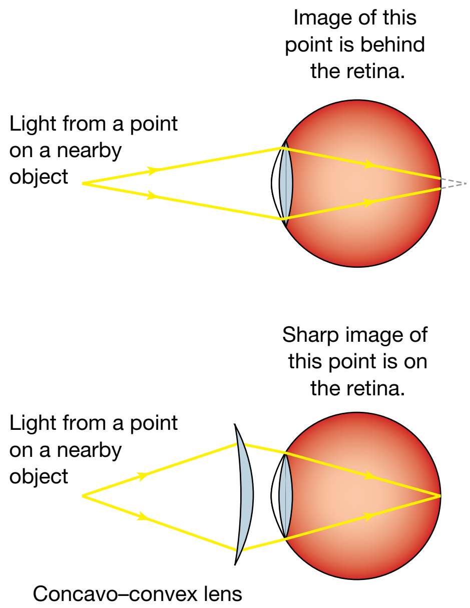


FIGURE 10.57 A concavo–convex lens has one slightly concave side and one slightly convex side. The convex side is more curved than the concave side, so it acts like a convex (converging) lens.



Long-sightedness (hyperopia)

A person who is long-sighted is unable to obtain sharp images of nearby objects. That happens when the cornea and lens don't bend the light enough. As a result, the light from a nearby object reaches the retina before it comes to a focus causing the image formed on the retina to be blurry.

Long-sightedness can be corrected by wearing glasses with concavo-convex lenses (see figure 10.57). These lenses converge the light just a little before it enters the eye. As a result, the light from the object focuses on the retina instead of behind it.

Multifocal lenses

As people get older, they are more likely to have difficulties in forming clear images of distant as well as nearby objects. In days gone by the solution to this problem was to have two pairs of glasses — one with a converging lens for reading and the other with a diverging lens for distance vision.

Multifocal lenses remove the need for two separate pairs of glasses. They can be bifocal with two parts or trifocal with three parts that merge into each other. Bifocal lenses are shaped so that the bottom part of the lens converges light to assist reading. The top part is shaped to diverge light to assist distance vision. A clear boundary between the two parts of the lens is visible. Trifocal lenses gradually change in shape from bottom to top to assist with close-up vision, arm's length vision and distance vision. There are no visible boundaries between the different parts of the lenses.

multifocal lenses lenses that are composed of different sectors of lens with differing focal length, which allow people with both short-sightedness and long-sightedness to see clearly

FIGURE 10.58 Bifocal lenses have two types of lenses that merge so that distant and nearby images are clear.

DISCUSSION

Should the eyesight of older drivers be tested when they renew their driving licence? What factors are involved in making this decision?

on Resources

Video eLesson Galileo and the telescope (eles-1765)

Interactivity Lenses (int-1017)

assesson Additional automatically marked question sets

10.8 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 4, 6, 7, 8	Questions 3, 5, 11, 13, 15	Questions 9, 10, 12, 14, 16

Remember and understand

1. Which part of the human eye does most of the bending of light occur?
2. Describe the function that the iris and pupil work together to perform.
3. Name and sketch the shape of a lens that:
   a. converges a beam of light to a single point
   b. makes the rays in a beam of light diverge.
4. What is the focal length of a converging lens a measure of?
5. What is accommodation?
6. What is the name given to the shape of the lens in the human eye?
7. Why is it common to see older people holding a newspaper at arm's length while they are reading it?
8. What are bifocal lenses and why are they used?

Apply and analyse

9. Explain why the focal point of a diverging lens is called a virtual focal point.
10. Does light slow down or speed up when it passes from the air into the cornea? How do you know this?
11. Which condition of the eye is most likely to be responsible for each of these problems?
    a. A student who can read the whiteboard from the back of the room but has to strain to read the print in a textbook and gets headaches while reading from a computer screen at home
    b. A science teacher who has never had eye problems before begins to find it easier to read books and newspapers when they are held further away
    c. A person who has no problem reading a newspaper but can't read the numbers on the scoreboard at an AFL football match
12. Sketch the shape of the lens in the eye when you are viewing:
    a. a nearby object
    b. a distant object.
    c. How does the lens change its shape?

Evaluate and create

13. SIS Use the data in the table 10.3 to draw a line graph to show how the ability to focus on nearby objects changes with age.
    a. Use your graph to predict the smallest distance at which a clear image can be obtained by an average person of your age.
    b. At what age does the decrease in focusing ability appear to be most rapid?
14. SIS Use two or more lenses and lens holders to make a model microscope or telescope on a laboratory workbench. Investigate the effect of changing the distance between the lenses on the magnification and write a report on your findings.
15. SIS Research and report on astigmatism of the eye and how it is corrected.
16. SIS Use the internet to research and report on the development of the bionic eye by Australian scientists. Include in your report information about:
    - macular degeneration
    - which patients it is designed to benefit
    - how it works
    - a comparison with the bionic ear.

Fully worked solutions and sample responses are available in your digital formats.

10.9 Sound energy

LEARNING INTENTION

At the end of this subtopic you will be able to use a wave model to describe properties of sound, measure the speed of sound, and explain how musical instruments produce sound.

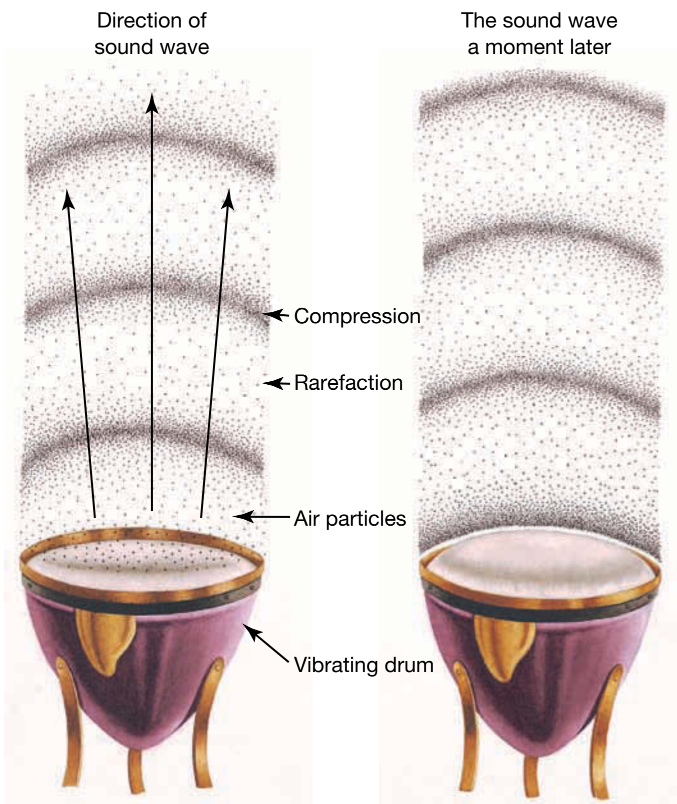
10.9.1 Sounds are caused by vibrations

Humans and other animals rely heavily on sound energy to communicate with each other. You can use your voice, whistle or tap something to make a sound. How else can you make a sound?

All sounds are caused by **vibrations**. When you speak or sing, the vocal cords in your throat vibrate. You can feel the vibrations if you put your hand over the front of your throat. When you strike a drum, the up and down movements of the drum skin cause the air around the drum to vibrate (see figure 10.60). When the drum skin moves down, the air particles near it are pulled back, spreading them out. A fraction of a second later the drum skin moves back up, squeezing the air particles together.

FIGURE 10.59 When you sing, your vocal chords vibrate, sending sound waves through the air.

FIGURE 10.60 Sound waves consist of a series of vibrating air particles.



vibrations repeated fast, back-and-forth movements

The energy of the air particles is transferred to nearby air particles, causing them to vibrate as well. This creates a moving series of **compressions** (air particles closer together than usual) and **rarefactions** (air particles further apart than usual) that move away from the source of the sound. These moving compressions and rarefactions are what we know as **sound waves**. If enough energy is transferred to the vibrating air, the sound waves reach your eardrum and you hear sound. It is important to note that although the air particles move to and fro when they vibrate about their usual position, they do not actually travel anywhere. Because the air particles move to and fro in the same direction as the sound is travelling, sound waves are a type of **longitudinal wave**. Light is not a longitudinal wave because its components vibrate perpendicular to the direction in which the wave is propagating, which classifies it as a **transverse wave**. The waves that you see on the ocean are also transverse waves because until they break on the shore the water particles are actually moving up and down. A 'Mexican wave' that you might see at some sporting events is also an example of a transverse wave.

compression a region where air particles are closer together than usual

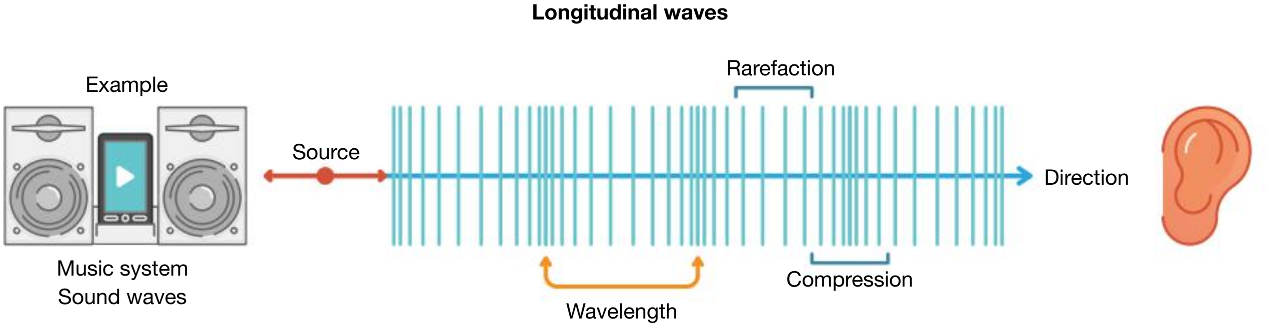
rarefactions in sound waves, the layers of air particles that are spread apart (between compressions)

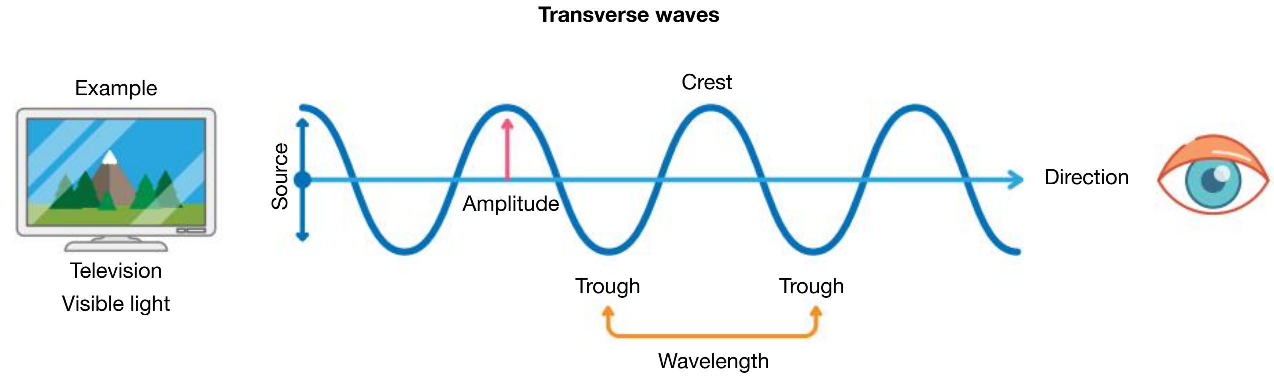
sound waves vibrations of particles in the air

longitudinal wave a wave that vibrates in the direction of propagation

transverse wave a wave that vibrates perpendicular to the direction of propagation

FIGURE 10.61 Longitudinal waves and transverse waves





WHAT DOES IT MEAN?

The word vibration comes from the Latin word *vibrare*, meaning 'to shake'.

elog-0650

INVESTIGATION 10.10

Modelling sound waves

Aim

To model sound waves on a slinky

Materials

- slinky spring

Method

1. Position one person at each end of the slinky.
2. Pull the slinky spring from both ends to stretch it a couple of metres along the floor.
3. Create vibrations at one end of the slinky by moving the coils in and out.
4. Watch the series of compressions and rarefactions travel to the opposite end and reflect back.

Results

Describe your observations when the wave moved along the slinky.

Discussion

1. Describe how your model is similar to real sound waves.
2. Describe how your model is different from real sound waves.
3. How could you use the slinky to model a transverse wave?

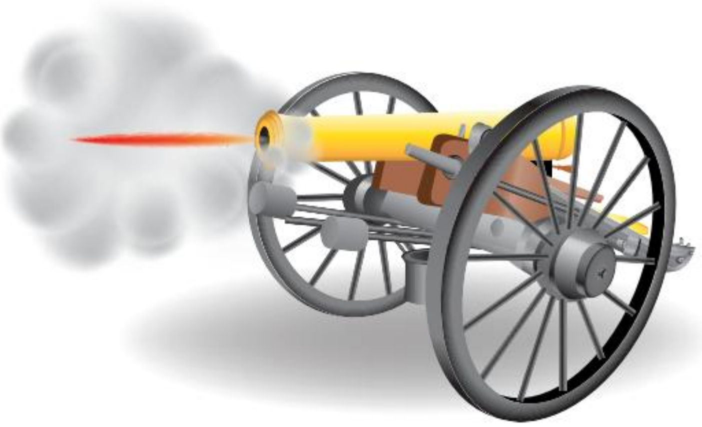
Conclusion

What can you conclude about modelling sound waves?

10.9.2 Measuring the speed of sound

The first known attempt to measure the speed of sound was made by French philosopher and scientist Pierre Gassendi in 1635. He measured the time taken between seeing the flash made by a cannon and hearing the sound it made from a long distance. He assumed (correctly) that the time taken for light from the flash to reach his eyes was very close to zero. In fact, we now know that light takes only 0.000 002 seconds to cover a distance of 500 metres. Gassendi measured the speed of sound to be 478 m/s, which is quite a bit more than the correct value of about 340 m/s at a temperature of 20 °C. But remember there were no accurate timing devices in 1635.

FIGURE 10.62 The flash of light from a cannon will reach you before the sound of the shot will.



CASE STUDY: The speed of sound

During a thunderstorm, the flash of lightning and the crash of thunder occur only a tiny fraction of a second apart. So why do you always hear thunder one or more seconds after you see the lightning? The answer lies in one of the differences between sound and light. Sound energy travels through the air at a speed of about 340 metres per second. Light energy travels through air at a speed of 300 000 kilometres per second. The delay between seeing lightning and hearing thunder is about 3 seconds for each kilometre that you are away from the lightning.

The number of compressions (or rarefactions) that reach your ear per second is known as the frequency of the sound. The musical note middle C, for example, creates 256 compressions every second. Frequency is measured in **hertz** (Hz), a unit named after Heinrich Hertz, the German physicist who, in 1887, was the first person to detect radio waves. One hertz is equal to one vibration every second. So, the frequency of the note middle C is 256 Hz.

The frequency of a sound determines its **pitch**. The pitch that you hear depends on the frequency of the vibrating air. The faster a sound-producing object vibrates, the higher its frequency and the higher the pitch of the sound you hear. A short string vibrates faster than a long one and so has a higher frequency and pitch.

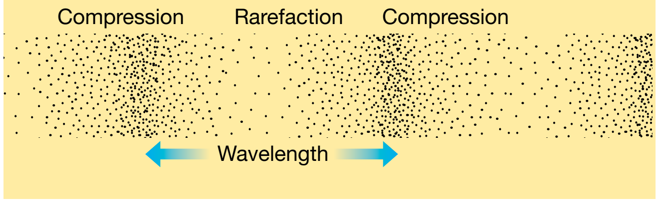
hertz unit of frequency; its abbreviation is Hz

pitch the highness or lowness of a sound

When you blow across the top of a straw, the air inside it vibrates. If the straw is shortened, the air inside vibrates faster, producing a higher frequency and a high pitch. A longer straw would produce slower vibrations, a lower frequency and a lower pitch.

The distance between two neighbouring compressions (or rarefactions) is known as the wavelength (figure 10.63). The wavelength of the musical note middle C is about 1.3 metres. The wavelength of the sounds produced during normal speech varies between about 5 centimetres and about 2.5 metres. When the frequency of a sound increases, the compressions become closer together, decreasing the wavelength of the sound. If you know the frequency and wavelength of a sound wave, you can calculate its speed using the following formula.

FIGURE 10.63 The wavelength of a sound is the distance between the centres of two neighbouring compressions or rarefactions.



Wave equation

Wave speed = wavelength × frequency

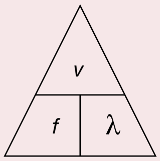
$$v = f \times \lambda$$

where:

v is the speed of wave (m/s)

f is the frequency of wave (Hz)

λ is the wavelength of the wave (m)



The particles of air that vibrate when a sound is made don't move from the source of the sound to your ear. They just move backwards and forwards. Each vibrating particle makes the next one vibrate — that's how the sound energy travels through the air. The distance that each vibrating particle moves from its usual resting place is known as the sound's **amplitude**. Higher amplitudes make louder sounds.

amplitude maximum distance that a particle moves away from its undisturbed position

elog-0651

INVESTIGATION 10.11

Measuring the speed of sound

This investigation should be conducted on a school sporting oval or a safe open space on a calm day.

Aim

To measure the speed of sound in air

Materials

- stopwatches (mobile phone stop watches are ideal)
- trundle wheel or long measuring tape
- starting pistol that emits smoke, two large blocks of wood or a pair of hand cymbals

CAUTION

Only a teacher wearing earplugs should fire a starting pistol.

Method

1. Position as many students with stopwatches as possible at a distance of at least 150 metres from the location of the starting pistol or wooden blocks. A longer distance up to 300 metres could be used if possible.
2. The sound is made by firing the starting pistol, banging the wooden blocks together or crashing the cymbals. Practise measuring the time taken between seeing the smoke, the wooden blocks being banged together or the hand cymbals crashed together. Repeat the practice several times to allow those with stopwatches to react as quickly as possible.
3. Prepare for a final recording of the time taken between seeing the sound being made and hearing the sound.
4. Conduct the timing and record the times measured by those with stopwatches.

Results

1. Calculate the average time for the sound to travel the distance.
2. Use the formula $\text{speed} = \frac{\text{distance}}{\text{average time}}$ to calculate the average speed of sound measured by the class.

Discussion

1. How does your measurement compare with the known speed of sound of about 340 m/s?
2. What is the biggest cause of error in your measurement of the time taken for the sound to reach the observers?
3. Suggest how you could make your results more accurate.
4. What assumption about the speed of light has been made in your calculation of the speed of sound?

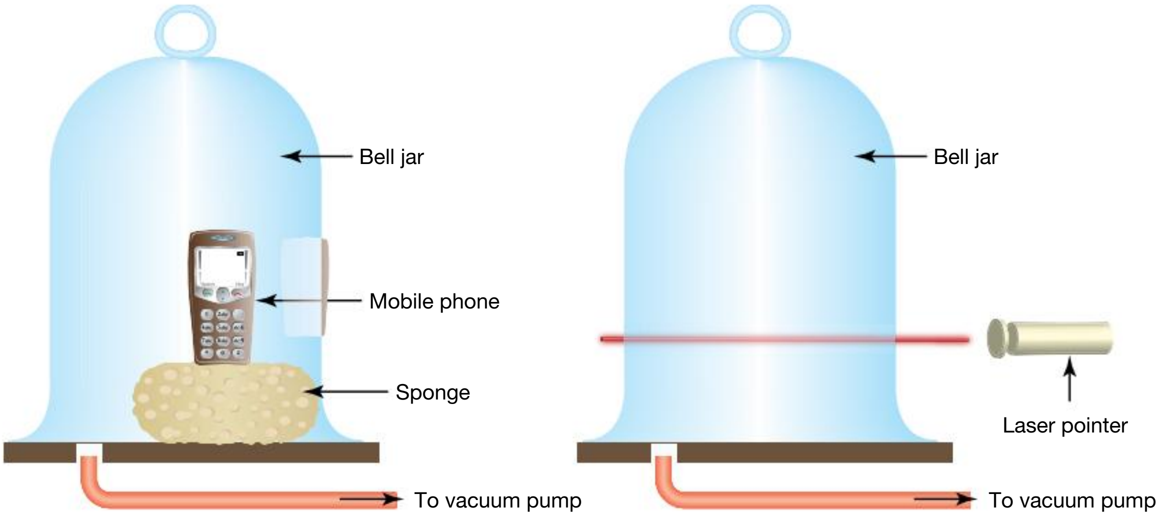
Conclusion

Write a conclusion for this investigation.

The need for air

When a mobile phone rings in a bell jar, the sound can be heard clearly. But if the air inside is sucked out by a vacuum pump, the sound can't be heard. Sound energy cannot travel through empty space — it can travel only by making particles vibrate. In empty space there are no particles to vibrate. Light energy, unlike sound, can travel through empty space. It doesn't need particles. So you can still see the ringing phone in the bell jar, even if you can't hear it.

FIGURE 10.64 Sound energy cannot travel through empty space. Sound waves require a medium to travel through; light does not.



10.9.3 Making it louder

If you pluck a stretched guitar string while it is not attached to a guitar, it vibrates but makes very little sound. If you strike a stretched drum skin while it is not attached to the drum, it makes very little noise. Even your own vocal cords make very little noise while they are vibrating. In each of these cases, a vibration is needed to create the sound but an enclosed region of air is needed to make the sound louder.

The air inside the body of an acoustic guitar is set vibrating by the strings. The air inside a drum vibrates when the drum skin is struck. The vibrating air inside your throat and mouth makes the sound created by your vocal cords loud enough to be heard.

elog-0652

INVESTIGATION 10.12

Vibrations and pitch

Aim

To investigate the relationship between the size of a vibrating object and the pitch of the sound it produces

Materials

- ruler
- 2 straws
- scissors
- spatula
- small beaker
- large beaker

Method

1. Hold a ruler over the edge of a table so that one end is firmly held down. Flick the overhanging end of the ruler.
2. Move the ruler so that more of it is over the edge of the table and flick it again.
3. Cut one straw into two so that one part is twice as long as the other part. Place the top of the uncut straw lightly against your bottom lip and blow gently across the opening. Listen to the sound made.
4. Blow across the two shorter (cut) pieces of straw in the same way and listen to the sounds.
5. Tap the side of a small beaker gently with a spatula and listen to the sound. Do the same with a larger beaker.

Results

1. How does the sound change as the vibrating part of the ruler is made longer?
2. How does the sound change as the straws get shorter?
3. How does the sound of the large beaker compare with the sound of the smaller one?

Discussion

How would you change each of the following to make a higher pitched sound?

a. The length of a vibrating strip of wood
b. The length of a tube of air
c. The size of a cymbal

Conclusion

What can you conclude about the relationship between the size of a vibrating object and the pitch of the sound it produces?

elog-0653

INVESTIGATION 10.13

Making it louder

Aim

To explore methods of increasing the loudness of sound

Materials

- guitar
- guitar string
- tuning fork

Method

1. Pluck a stretched guitar string. Listen to the sound it makes.
2. Pluck a similar string attached to a guitar.
3. Strike a tuning fork on the sole of your shoe and listen to the sound it makes. While it is still vibrating, place the base of the fork on a solid table surface.

Results

1. How does the sound of a plucked string change when it is attached to a guitar?
2. How does the sound change when the tuning fork is placed on the table?

Discussion

Explain why the sound changes in each case.

Conclusion

What can you conclude about the ways to increase loudness?

10.9.4 Music

How do musical instruments produce sound? The energy comes from the person playing the instrument — but what does the instrument do to convert that energy into sound?

With an acoustic guitar, the vibrations are made by plucking the strings. The air around the sound hole vibrates, causing the air inside the body of the guitar to vibrate. In an electric guitar, a microphone or pick-up detects the vibrating air and an amplifier is used to make the sound louder. The pitch of the sound made by a guitar is increased by shortening the strings using your fingers, tightening the strings or using lighter strings.

FIGURE 10.65 On a stringed instrument, vibrations are made by plucking strings.

A saxophone's vibrations are first made when air is blown across a thin wooden reed. The air inside the saxophone then vibrates, making a loud sound. The pitch can be changed by using keys to open or close holes. When all the holes are closed, the saxophone contains a long column of air, producing a low-pitched sound. As holes are opened, the length of the air column becomes shorter, and the pitch increases.

The didgeridoo is a wind instrument that has no holes to change the length of the column of vibrating air. The player blows into the instrument using loosely vibrating lips to control how quickly the air inside vibrates.

on Resources

Video eLessons A street musician playing a didgeridoo, which is a wind instrument (eles-2682)
A saxophone player (eles-2683)

ACTIVITY: Making music

Have someone demonstrate how different types of musical instruments work.

1. For each instrument, write down:
   a. what the player does to make the instrument work
   b. what vibrates to make musical sounds.
2. What do all of the musical instruments have in common when it comes to the way they make sound?
3. What differences are there in how they make sound?

10.9.5 When sound meets a substance

Like light, sound energy can be transmitted, reflected or absorbed when it meets a new substance.

- All materials transmit some sound, some better than others. That's why you can sometimes hear conversations from the other side of a wall.
- Sound is reflected from hard substances like the tiles in your bathroom. Each note that you sing in the shower lasts longer because it is reflected over and over again from hard surfaces. This effect is called **reverberation**.
- Soft materials, such as curtains and carpet, absorb much more sound than walls of plaster or tiles.

reverberation longer-lasting sound caused by repeated reflection from hard surfaces

Concert halls are designed to control the transmission, reflection and absorption of sound. For example, the timber in the panelling on the ceiling and walls of the concert hall in the Melbourne Recital Centre was selected because it minimises reflection and reverberation. In the Melbourne Concert Hall, Hamer Hall, heavy curtains behind the audience can be closed to increase the amount of sound absorbed.

FIGURE 10.66 The Elisabeth Murdoch Hall at the Melbourne Recital Centre

on Resources

assess on Additional automatically marked question sets

10.9 Exercise

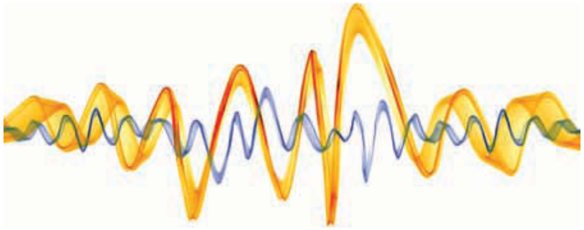
learn on

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 3, 4, 6, 8, 9	Questions 2, 5, 10, 11, 13, 14	Questions 7, 12, 15, 16

Remember and understand



1. What is the cause of all sounds?
2. When compared with air particles in a silent room, how are the particles in compressions and rarefactions different?
3. a. Name the unit of frequency and describe what it measures.
   b. Which quality of sound that you hear does the frequency determine?
4. a. What distance is the wavelength of a sound wave the measure of?
   b. What happens to the wavelength of a sound wave when its frequency increases?
5. What characteristic of vibrating air does amplitude describe?
6. Explain why sound can't travel through empty space.

Apply and analyse

7. If you blow across the top of a straw, a sound is made. How could you increase the pitch of the sound?
8. Which vibrates more quickly: a long string or a short string made of the same material?
9. How do we know, without taking any measurements, that light travels through air faster than sound?
10. Describe what can happen to sound energy travelling through the air when it meets a new substance.
11. Is sound energy a form of kinetic energy? Explain your answer.
12. How would you expect a carpeted classroom to sound compared with one with a hard vinyl floor? Give reasons for the differences.
13. Complete the gaps in the following table.

TABLE Making sound with the musical instruments

Musical instrument	What vibrates first?	What makes the sound louder?
Guitar	Plucked string	Air inside guitar
Trumpet	Player's lips	
Drum		Air inside drum
Saxophone		Air inside saxophone
	String hit by hammers	Air inside instrument

Evaluate and create

14. SIS The speed of sound in air at different temperatures is shown in the table.

TABLE The speed of sound at different temperatures

Temperature (°C)	Speed of sound (m/s^{-1})
–10	325.4
–5	328.5
0	331.5
5	334.5
10	337.5
15	340.5
20	343.4
25	346.3
30	349.2

a. Plot a graph of the speed of sound versus the air temperature.
b. Describe the relationship between the speed of sound and the air temperature.
c. Use your graph to determine the speed of sound in air when the temperature is 17 °C.

15. SIS Make a string telephone. You will need about five metres of string and two open and empty cans. Punch a small hole in the bottom of each can. Thread the string through each hole and tie a knot to keep the string in place. Hold the cans far enough apart so that the string is tight. Talk into the can at one end while your partner listens at the other end.
a. How does the sound travel from one can to the other?
b. Does the sound change if you make the string tighter or looser?
c. Would a string telephone work without the cans? Why are the cans used?

16. SIS Research and then provide a brief description of the following careers that involve using and understanding sound energy.
a. Audiologist
b. Acoustic engineer
c. Audio engineer

Fully worked solutions and sample responses are available in your digital formats.

10.10 Thinking tools — Matrixes and Venn diagrams

10.10.1 Tell me

What is a matrix?

A matrix is a very useful thinking tool for comparing topics and identifying ways in which these topics are similar and different. A matrix shows similarities and differences between topics. They are sometimes called a table, grid or decision chart.

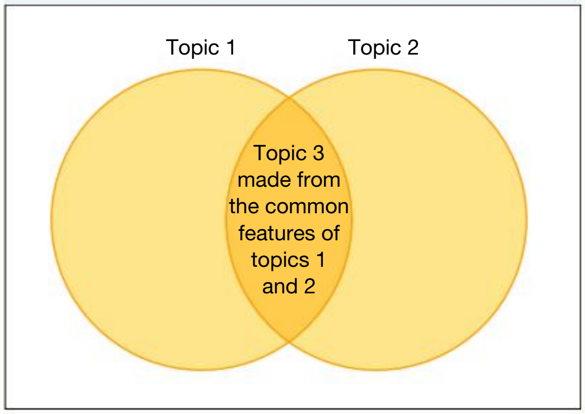
FIGURE 10.67 A matrix

Topic	Feature A	Feature B	Feature C	Feature D	Feature E
1	✓		✓	✓	✓
2		✓			✓
3		✓		✓	✓
4			✓	✓	✓

Why use a matrix over a Venn diagram?

Similar to a matrix, a Venn diagram identifies common points between two separate topics. However, they use different graphic formats to show the common features. A matrix uses a grid or table, whereas a Venn diagram uses overlapping circles.

FIGURE 10.68 A Venn diagram



10.10.2 Show me

To create a matrix

1. Write the topics in the left-hand column of the matrix.
2. Write the characteristics to be compared along the top row of the matrix.
3. If a characteristic applies to a topic, put a tick in the appropriate cell of the matrix.
4. The matrix now shows how the various topics are related.

The example below shows a matrix indicating the forms of energy that electrical energy is transformed into by each of the electrical devices.

TABLE Conversion of electrical energy by different electrical devices

Device	Electrical energy is converted into …				
	Light energy	Sound energy	Thermal energy	Kinetic energy	Potential energy
Hair dryer		✓	✓	✓	✓
Television	✓	✓	✓	✓	✓
Desk lamp	✓		✓	✓	✓
Vacuum cleaner		✓	✓	✓	✓
Home computer	✓	✓	✓	✓	✓
Incandescent light bulb	✓		✓	✓	✓
Air-conditioner		✓	✓	✓	✓
Elevator going up		✓	✓	✓	✓

Note: All substances and objects possess potential energy, but you can't tell unless something happens to transform the potential energy into a different energy type.

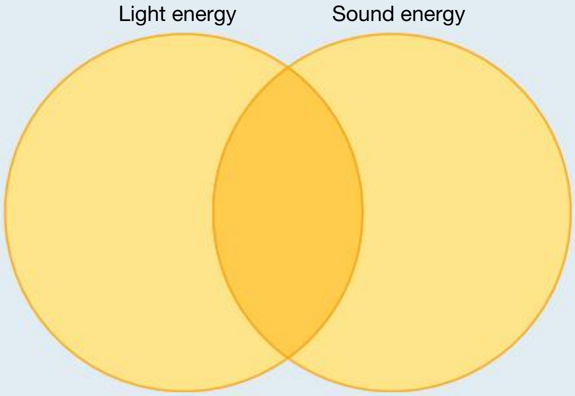
10.10.3 Let me do it

10.10 ACTIVITIES

1. **a.** Complete this matrix. Use ticks to show which statements refer to light and which refer to sound. Some of the statements refer to both light and sound.

Statement	Light energy	Sound energy
Travels through air at 300 000 kilometres per second		
Travels faster than a speeding bicycle		
Can be reflected		
Can be absorbed		
Is always caused by vibrating objects or substances		
Is observed in an electrical storm		
Can travel through empty space		
Can be produced from another form of energy		
Is used by physiotherapists to treat some muscle problems		

   b. The information in the matrix provided can be represented in a Venn diagram. Convert the information in the matrix into a large Venn diagram based on the example provided.



Fully worked solutions and sample responses are available in your digital formats.

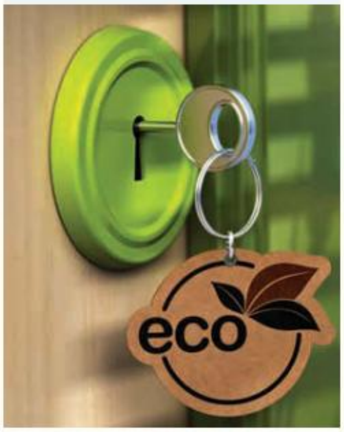
10.11 Project — Going green

Scenario

As the supply of fossil fuels dwindles, cities become more crowded and human-caused global warming becomes an unavoidable reality, an increasing number of people are opting for a more self-sufficient lifestyle. To meet this need, an increasing number of architecture and building firms specialise in the design and construction of energy-efficient houses that are able to exist off the electricity grid indefinitely because they use electricity generation systems that meet all of the household's needs using renewable energy sources.

You and your team at Sustainable Housing Solutions have been approached by a potential client who wants to build a series of sustainable eco-tourist cottages in remote locations across the country. To see whether your company should be awarded the lucrative contract to oversee the work on the whole chain of cottages, the client has asked you to make a presentation detailing how you would make one of these cottages as energy efficient and self-sustaining as possible. You can place this trial cottage anywhere in the country for your presentation purposes, provided that it is at least 100 km away from any town with a population greater than 10 000 people. Other criteria must also be met as follows:

FIGURE 10.69 Sustainable eco-tourist cottages



- All of the cottages will have the same layout and will be constructed of mud bricks and have tiled roofs (you will be given a copy of the plan). While you can change the orientation and location of the cottage, you cannot change the design or the construction materials.
- Each cottage must have the following appliances: refrigerator, washing machine, stove, microwave, TV set, DVD player and stereo system. Smaller appliances such as toasters, shavers, hair dryers and computers may occasionally be used by guests as well.
- The cottages must be cool in summer and warm in winter; the client is not opposed to the idea of a reverse-cycle air-conditioner or fans.
- There must be sufficient lighting to be able to read in every room.
- The cottages will not be attached to the national electricity grid — all of the electricity needs of each cottage must be met using a renewable energy source in its area. (Water will be provided from rainwater tanks and septic tanks will take care of the sewage.)

Your task

Your team will prepare and deliver a report for the client that provides the following information.

- The best location to place the trial cottage (keeping in mind that it can be placed somewhere close to a source of renewable energy)
- Suggestions as to how the cottage can be made as energy efficient as possible
- A detailed estimate of how much electricity will need to be generated to power the cottage and run appliances
- A justified recommendation as to which renewable energy system should be used to generate that amount of electricity and how it would be supplied to the trial cottage
- An estimate of how much the energy system will cost, using costs for similar systems available on the internet as a guideline

on Resources

ProjectsPLUS Going green (proj-0093)

10.12 Review

Access your topic review eWorkbooks

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-5170	ewbk-5172	ewbk-5174

on Resources

10.12.1 Summary

Different forms of energy

- Energy cannot be created or destroyed. This statement is known as the Law of Conservation of Energy.
- There are many different types of energy, all of which fall under one of two categories: potential or kinetic.
- Potential energy is energy that is stored in objects. Types of potential energy include gravitational, elastic, chemical, nuclear, electrical and magnetic.
- Kinetic energy is energy that involves movement. Types of kinetic energy include translational, thermal, radiant, sound and electrical.

Transforming energy

- Energy can be transformed from one type to another type.
- Potential energy can be transformed into kinetic energy in many ways. An example is gravitational potential energy transforming into kinetic energy when an object is dropped.
- Most energy transformations convert energy from one form into multiple other forms. Some of the forms that it is converted into are not very 'useful' and are sometimes classified as wasted energy.
- The efficiency of an energy transformation is the percentage of the initial energy that is converted into the desired form. $\text{Efficiency} = \frac{\text{useful energy output}}{\text{energy input}} \times 100\%$

Transferring energy

- Energy can be transferred from an object to another object, or from one form into another form by forces or by heating.
- For example, when an object falls the gravitational force converts gravitational potential energy into kinetic energy. When the object hits the ground the upwards force on it converts the kinetic energy into sound and heat energy, along with elastic potential energy, causing it to bounce.
- The transfer of thermal energy is known as heat.
- There are three ways in which heat can be transferred.
  - Conduction is the transfer of heat due to the direct collisions of particles in a solid.
  - Convection is the transfer of heat in liquids and gases that occurs due to circulation of hotter particles throughout the liquid or gas.
  - Radiation is the transfer of heat by electromagnetic radiation. It is the only form of heat transfer that does not require the collision of warmer particles with other, cooler particles.

A costly escape

- Heat can escape buildings in many ways. Loss from conduction occurs in walls, floors and ceilings, and convection can move warmed or cooled air out through gaps under doors and around windows.
- To counter these unwanted heat transfers, many forms of insulation have been invented including insulation batts, foam inside walls, cavity bricks and double glazing.

Light

- Objects that radiate visible light are said to be luminous.
- Incandescent light sources radiate light because of their temperature. Sources that radiate light but are not hot are not incandescent.

- Objects that are not luminous can still be seen because they reflect light from other sources.
- When light meets a substance three things can happen.
  - It can be transmitted (travel through the substance).
  - It can be absorbed (transferred into the substance).
  - It can be reflected off the substance.
- Visible light is only a small segment of the larger electromagnetic spectrum.
- Other forms of electromagnetic radiation are radio waves, infra-red, ultraviolet, x-rays and gamma rays.

Light forms images

- Light travels in straight lines known as rays.
- When light reflects off a smooth surface the angle of incidence is equal to the angle of reflection.
- Reflections off curved mirrors distort images.
- Focal points are points at which parallel rays converge after reflection off a curved surface.
- Most surfaces are not smooth when you look at them on a very close scale. Rays of light bounce off these surfaces in all directions due to the roughness, reflecting light in all directions.
- When light passes from one substance to another it changes speed, causing it to refract (bend).

Seeing light

- The human eye is designed to obtain images by focusing light on the retina, which then converts the light into an image that is sent to the brain via the optic nerve.
- Light is focused as it passes through the cornea and the lens.
- As you get older the muscles in the eye that control the thickness of the lens become less effective making light focus either in front of or behind the retina. Glasses with slightly convex or concave lenses can counter this, ensuring the light focuses on the retina.

Sound energy

- Sound is the vibration of particles through substances.
- Sound waves are longitudinal waves caused by pressure variations in the air (or substance) through which it travels.
- The frequency of a sound wave is the number of wavelengths it travels per second and is known as the pitch of the sound.
- Instruments create and amplify vibrations at particular frequencies, causing sound waves to travel through the air.
- Sound can be transmitted, absorbed or reflected.

10.12.2 Key terms

absorbed taken in
accommodation changing the lens shape to focus a sharp image on the retina
amplitude maximum distance that a particle moves away from its undisturbed position
angle of incidence angle between an incident ray of light and the normal
angle of refraction angle between a refracted ray of light and the normal
biconcave concave on both sides
biconvex convex on both sides
bioluminescent describes living things that release light energy
ciliary muscles muscles that control the shape of the lens in the eye
compression a region where air particles are closer together than usual
concave curved inwards
conduction transfer of heat through collisions between particles
convection transfer of heat through the flow of particles
converging lens lens that bends rays so that they move towards each other. Converging lenses are thicker in the middle than at the edges.
convex curved outwards

cornea clear, curved outer surface of the eye
deciduous trees and shrubs that lose their leaves and become dormant during winter
dispersion separation of the colours that make up white light
diverging lens lens that bends rays so that they spread out Diverging lenses are thinner in the middle than at the edges
efficiency the fraction of energy supplied to a device as useful energy
electromagnetic radiation the radiant energy such as radio waves, infrared, visible light, x-rays and gamma rays released by magnetic or electric fields
electromagnetic spectrum complete range of wavelengths of energy radiated as electric and magnetic fields
electromagnetic waves waves of electromagnetic radiation, light being just one example
element pure substance made up of only one type of atom
fission the process whereby a large nucleus splits into smaller fragments releasing large amounts of energy
focal length distance between a lens or curved mirror and its focal point
focal point a point at which parallel rays of light meet after reflection by a curved mirror of refraction through a lens
frequency number of vibrations in one second, or the number of wavelengths passing in one second
fusion the process whereby two small nuclei combine to form a larger nuclei releasing large amounts of energy
gamma rays high-energy electromagnetic radiation produced during nuclear reaction
hertz unit of frequency; its abbreviation is Hz
image visual representation of an object; what we see
incandescent describes objects that emit light when they are hot
infra-red radiation low-energy electromagnetic waves with a much lower frequency and longer wavelength than visible light
insulator a material that is a poor conductor of heat
iris coloured part of the eye that opens and closes the pupil to control the amount of light that enters the eye
isotope atoms of the same element that differ in the number of neutrons in the nucleus
kinetic energy energy due to the motion of an object
lateral inversion sideways reversal of images in a mirror
Law of Conservation of Energy a law that states that energy cannot be created or destroyed
lens part of the eye that focuses light onto the retina, ensuring the image is sharp
longitudinal wave a wave that vibrates in the direction of propagation
long-sightedness unable to obtain sharp images of nearby objects
luminous releasing its own light
multifocal lenses lenses that are composed of different sectors of lens with differing focal length, which allow people with both short-sightedness and long-sightedness to see clearly
non-luminous describes objects that do not emit their own light, but can be seen by reflected light
normal (the) line drawn perpendicular to a surface at the point where a light ray meets the surface
nuclear decay the spontaneous decay of unstable nuclei to a new nucleus
optic nerve large nerve that sends signals to the brain from the sight receptors in the retina
pitch the highness or lowness of a sound
potential energy energy that has the potential to do work and so the energy is ‘stored’, such as gravitational energy, elastic energy and chemical energy
presbyopia blurring of images of very close objects caused by loss of flexibility of the lens in the eyes
pupil hole through which light enters the eye
radiation emission of energy as electromagnetic waves
radiant heat heat transferred by electromagnetic radiation
radio waves low-energy electromagnetic radiation
rarefactions in sound waves, the layers of air particles that are spread apart (between compressions)
reflected bounced off
refraction change in the speed of light as it passes from one substance into another
retina curved surface at the back of the eye that is lined with sight receptors
reverberation longer-lasting sound caused by repeated reflection from hard surfaces
scattered describes light sent in many directions by small particles within a substance
short-sightedness unable to obtain sharp images of distant objects
sound waves vibrations of particles in the air
transmitted passed through something, such as light or sound passing through air

transmutation the process whereby a nucleus is bombarded with high energy neutrons in an attempt to convert it to another element
transverse wave a wave that vibrates perpendicular to the direction of propagation
ultraviolet radiation invisible radiation similar to light but with a slightly higher frequency and more energy
vibrations repeated fast, back-and-forth movements
virtual focal point a single point from which light rays seem to be coming after passing through a concave lens
visible spectrum different colours that combine to make up white light; they are separated in rainbows
wavelength distance between two neighbouring crests or troughs of a wave
x-rays high-energy electromagnetic waves that can be transmitted through solids and provide information about the structure

Resources

Digital document	Key terms glossary (doc-34974)
eWorkbooks	Study checklist (ewbk-5163) Literacy builder (ewbk-5164) Crossword (ewbk-5166) Word search (ewbk-5168)
Practical investigation eLogbook	Topic 10 Practical investigation eLogbook (elog-0639)

10.12 Exercise

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

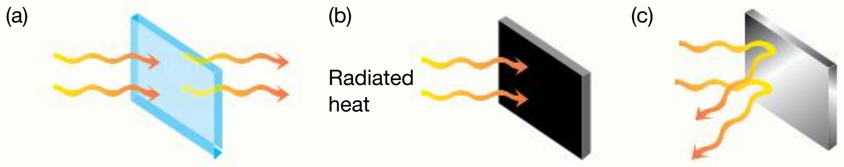
Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 3, 5, 8, 10, 13, 14, 24	Questions 4, 7, 9, 12, 15, 17, 19, 21, 22, 25	Questions 6, 11, 16, 18, 20, 23

Remember and understand

1. Replace each of the following descriptions with a single word.
   a. Energy associated with all moving objects
   b. Energy associated with the position of an object
   c. The form of energy that causes an object to have a high temperature
   d. The form of energy stored in a battery that is not connected to anything
   e. The source of most of the Earth's light
2. Explain why the amount of energy in the universe never changes.
3. Describe an example of an object that has:
   a. elastic potential energy
   b. gravitational potential energy.
4. Heat moves from regions of high temperature to regions of low temperature by conduction, convection or radiation. Identify the method of heat transfer in each of the following situations.
   a. From a frying pan to an egg being fried
   b. From the sun to the planets of the solar system
   c. Through water in a saucepan on a hotplate or gas burner
   d. Through a metal spoon being used to stir hot soup
   e. From a very hot and bright light globe near the ceiling to your body directly beneath

5. Each of the surfaces in the figure below shows radiated heat falling on a solid object. Which figure shows heat being:

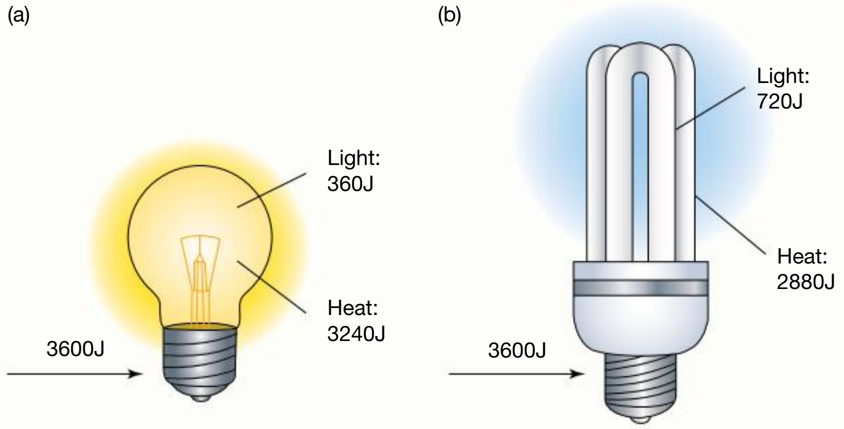


a. absorbed
b. reflected
c. transmitted?

6. You can't normally see the beam of light coming from a car headlight. However, you can see the beams if there is fog or smoke in the air. How does the fog or smoke make a difference?
7. Describe one example of evidence that white light is made up of many different colours.
8. To which form of electromagnetic radiation do microwaves belong?
9. Which form of electromagnetic radiation has:
   a. the least energy
   b. the most energy?
10. Which part of the electromagnetic spectrum is used:
    a. in remote control devices
    b. to help the human body produce vitamin D?
11. How does amplitude of a sound wave affect the sound that you hear?
12. Explain the difference in meaning of each of the following pairs of words.
    a. Ray and beam
    b. Scattering and reflection
    c. Refraction and dispersion
13. Describe the role of each of the following parts of the eye.
    a. Cornea
    b. Iris
    c. Lens
    d. Retina
    e. Ciliary muscles

Apply and analyse

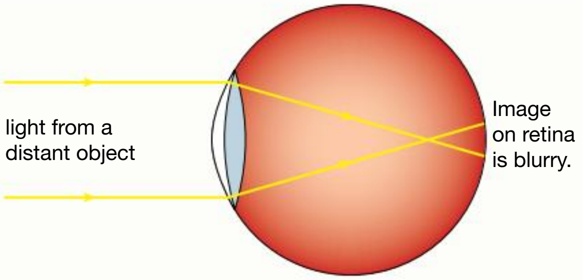
14. Calculate the efficiency of the light bulbs shown in figures a. and b.



15. When a kettle of water is boiled on a gas cooktop, not all of the energy stored in the gas is used to heat the water. Where does the rest of the energy go?
16. Explain why it is not possible for an energy converter like a battery or car to have an efficiency of 100 per cent.
17. Explain how fibreglass batts are able to reduce the loss of heat through the ceiling by both conduction and convection.

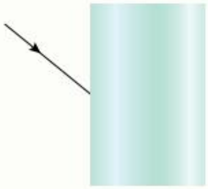
18. Explain how your body keeps its core temperature at 37 °C even when the air temperature is greater than this.
19. Explain how you are able to see an object such as a tree even though it doesn't produce its own light energy.
20. When a sound is made, what happens to the particles in the regions of the air nearby that are called:
    a. compressions
    b. rarefactions?
21. When an object vibrates faster what happens to the sound's:
    a. frequency
    b. pitch
    c. amplitude?
22. When you sing in the shower the sound of your voice reverberates.
    a. What happens to sound energy to cause reverberation?
    b. Why don't you observe reverberation when you sing in a room with carpet and soft curtains?
    c. In some outdoor places, if you speak loudly you can hear an echo. For example, you might say 'hello' and a second or two later you hear the word 'hello' again. Explain how an echo is different from a reverberation.
23. The figure shows how light rays from a distant object arrive at the retina of a person with blurry distance vision.
    a. What is the name of the condition illustrated in the figure?
    b. What does the correcting lens need to do to the incoming light to correct the problem?

The eye of a person with blurry distance vision

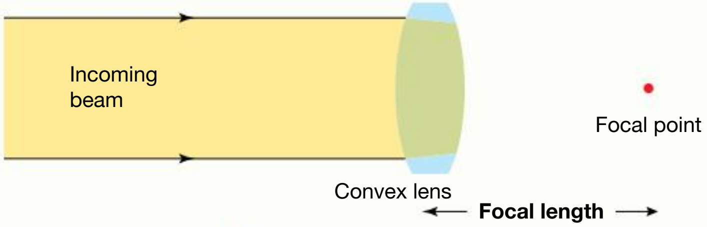


24. Complete the diagrams to show the path of light after it meets the objects shown.

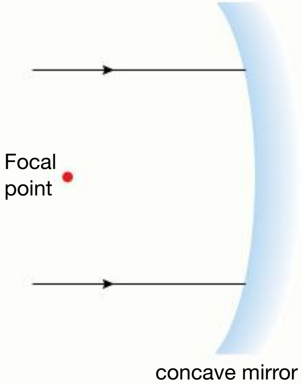
a.



b.



c.



Evaluate and create

25. Draw a flowchart to illustrate the energy transformations that take place:
   a. after you switch on a torch
   b. when a firecracker is lit
   c. when a ball rolls down a hill and then up another hill.

Fully worked solutions and sample responses are available in your digital formats.

on Resources

eWorkbook Reflection (ewbk-3038)

teachon

Test maker
Create customised assessments from our extensive range of questions, including teacher-quarantined questions.
Access the assignments section in learnON to being creating and assigning assessments to students.

RESOURCE SUMMARY

on Resources

Below is a full list of **rich resources** available online for this topic. These resources are designed to bring ideas to life, to promote deep and lasting learning and to support the different learning needs of each individual.

10.1 Overview

eWorkbooks
- Topic 10 eWorkbook (ewbk-5158)
- Student learning matrix (ewbk-5160)
- Starter activity (ewbk-5161)

Practical investigation eLogbook
- Topic 10 Practical investigation eLogbook (elog-0639)

Video eLesson
- Energy transformations (eles-2677)

10.2 Different forms of energy

Video eLesson
- Energy in disguise (eles-0063)

10.3 Transforming energy

eWorkbooks
- Skateboard flick cards (ewbk-5148)
- Types of energy (ewbk-5150)

Video eLesson
- The Australian–International Model Solar Challenge (eles-0068)

Interactivity
- Coaster (int-0226)

10.4 Transferring energy

Practical investigation eLogbook
- Investigation 10.1: Moving particles (elog-0641)

Video eLesson
- Convection currents (eles-2056)

Interactivities
- Convection currents (int-5346)
- A hot-water system (int-3399)
- Transmission, absorption and reflection (int-3400)

10.5 A costly escape

eWorkbook
- A costly escape (ewbk-5152)

Practical investigation eLogbook
- Investigation 10.2: Investigating insulators (elog-0642)

Interactivity
- A thermos flask (int-3401)

10.6 Light

eWorkbook
- Light energy (ewbk-5154)

Practical investigation eLogbooks
- Investigation 10.3: Observing a radiometer (elog-0643)
- Investigation 10.4: Seeing the light (elog-0644)

Video eLessons
- Bioluminescent click beetle (*Pyrophorus* sp.) (eles-2678)
- Crookes radiometer (eles-2679)
- Refraction in a prism (eles-2680)

10.7 Light forms images

Practical investigation eLogbooks
- Investigation 10.5: Reflection and refraction (elog-0645)
- Investigation 10.6: Looking at images (elog-0646)
- Investigation 10.7: Floating coins (elog-0647)

Video eLesson
- Children's reflections are distorted by this playground mirror (eles-2681)

Interactivity
- Bend it (int-0673)

10.8 Seeing light

eWorkbook
- Labelling the human eye (ewbk-5156)

Practical investigation eLogbooks
- Investigation 10.8: Focusing on light (elog-0648)
- Investigation 10.9: Getting a clear image (elog-0649)

Video eLesson
- Galileo and the telescope (eles-1765)

Interactivities
- Lenses (int-1017)
- Labelling the human eye (int-8226)

10.9 Sound energy

Practical investigation eLogbooks
- Investigation 10.10: Modelling sound waves (elog-0650)
- Investigation 10.11: Measuring the speed of sound (elog-0651)
- Investigation 10.12: Vibrations and pitch (elog-0652)
- Investigation 10.13: Making it louder (elog-0653)

Video eLessons
- A street musician playing a didgeridoo, which is a wind instrument (eles-2682)
- A saxophone player (eles-2683)

10.11 Project — Going green

ProjectsPLUS
- Going green (proj-0093)

10.12 Review

eWorkbooks
- Topic review Level 1 (ewbk-5170)
- Topic review Level 2 (ewbk-5172)
- Topic review Level 3 (ewbk-5174)
- Study checklist (ewbk-5163)
- Literacy builder (ewbk-5164)
- Crossword (ewbk-5166)
- Word search (ewbk-5168)
- Reflection (ewbk-3038)

Practical investigation eLogbook
- Topic 10 Practical investigation eLogbook (elog-0639)

Digital document
- Key terms glossary (doc-34974)

To access these online resources, log on to **www.jacplus.com.au**.

GLOSSARY

abrasive a property of a material or substance that easily scratches another
absorbed taken in
absorption the taking in of a substance, for example from the intestine to the surrounding capillaries
accommodation changing the lens shape to focus a sharp image on the retina
accuracy how close an experimental measurement is to a known value
adult stem cells undeveloped cells found in blood and bone marrow
alchemist olden-day 'chemist' who mixed chemicals and tried to change ordinary metals into gold. Alchemists also tried to predict the future.
alimentary canal passage from the mouth to the anus. Digestion of food occurs as it moves through the canal.
alloy a mixture of a metal with a non-metal or another metal
alveoli tiny air sacs in the lungs at the ends of the narrowest tubes. Oxygen moves from alveoli into the surrounding blood vessels, in exchange for carbon dioxide. Singular = alveolus.
ammonia a nitrogenous waste product of protein break down
amniocentesis the removal and testing of fluid from the amniotic sac surrounding the fetus
amplitude maximum distance that a particle moves away from its undisturbed position
amygdala emotional centre of the brain that processes primal feelings, such as fear and rage
amylases an enzyme in saliva that breaks starch down into sugar
angiosperms plants that have flowers and produce seeds enclosed within a carpel
angle of incidence angle between an incident ray of light and the normal
angle of refraction angle between a refracted ray of light and the normal
Animalia the kingdom of organisms that have cells with a membrane-bound nucleus, but no cell wall, large vacuole or chloroplasts (e.g. animals)
anther the male part of a flower that makes pollen
antibiotics a substance derived from a micro-organism and used to kill bacteria in the body
antiseptics a mild disinfectant used on body tissue to kill microbes
anus the final part of the digestive system, through which faeces are passed as waste
aorta a large artery through which oxygenated blood is pumped at high pressure from the left ventricle of the heart to the body
arteries hollow tubes (vessels) with thick walls carrying blood pumped from the heart to other body parts
arterioles vessels that transport oxygenated blood from the arteries to the capillaries
arthritis a condition in which inflammation of the joints causes them to swell and become painful
asexual reproduction a type of reproduction that does not require the fusion of sex cells (gametes)
assisted reproductive technologies (ART) medical procedures used primarily to address infertility
asthma narrowing of the air pipes that join the mouth and nose to the lungs
atom a very small particle that makes up all things. Atoms have the same properties as the objects they make up.
atomic number number of protons in the nucleus of an atom. The atomic number determines which element an atom is.
atoms very small particles that make up all things. Atoms have the same properties as the objects they make up.
bactericidal an antiseptic that kills bacteria
bacteriostatic an antiseptic that stops bacteria from growing or dividing but doesn't kill them
ball and socket joints joints where the rounded end of one bone fits into the hollow end of another
basalt a dark, igneous rock with small crystals formed by fast cooling of hot lava. It sometimes has holes that once contained volcanic gases.
batholiths intrusive rock mass that measures more than 100 kilometres across
beaker container for mixing or heating substances
benign a tumour that does not spread to other parts of the body
biconcave concave on both sides
biconvex convex on both sides

bicuspid a type of valve with two cusps (points). The valve between the heart's left atrium and left ventricle is a bicuspid valve.
bile a substance produced by the liver that helps digest fats and oils
binary fission reproduction by the division of an organism (usually a single cell) into two new organisms
binocular microscope a microscope with two eyepieces through which the specimen is seen using both eyes
biodegradable describes a substance that breaks down or decomposes easily in the environment
bioluminescent describes living things that release light energy
bladder sac that stores urine
blastocyst an embryo with a fluid-filled cavity that is beginning to differentiate, five or six days after fertilisation
blood cells living cells in the blood
blood pressure measures how strongly the blood is pumped through the body's main arteries
blood vessels the veins, arteries and capillaries through which the blood flows around the body
body system groups of organs, within our bodies that carry out specific functions
boiling point the temperature at which a liquid changes to a gas
bolus round, chewed-up ball of food made in the mouth that makes swallowing easier
bonded joined by a force that holds particles of matter, such as atoms, together
bone marrow a substance inside bones in which blood cells are made
bones the pieces of hard tissue that make up the skeleton of a vertebrate
Bowman's capsule a cup-like structure at one end of a nephron within the kidney, surrounding the glomerulus. It serves as a filter to remove wastes and excess water.
breathing movement of muscles in the chest causing air to enter the lungs and the altered air in the lungs to leave. The air entering the lungs contains more oxygen and less carbon dioxide than the air leaving the lungs.
breech a birth in which the baby is born feet or bottom first
brittle breaks easily into many pieces
bronchi the narrow tubes through which air passes from the trachea to the smaller bronchioles and alveoli in the respiratory system. Singular = bronchus.
bronchioles small branching tubes in the lungs leading from the two larger bronchi to the alveoli
budding the formation of a new organism from an outgrowth (bud) of the parent
burn any damage to the skin; combustion of a substance with oxygen in a flame
burning combining a substance with oxygen in a flame
burping release of swallowed gas through the mouth
caesarean an operation to remove a baby by cutting the mother's abdomen
calcium an element occurring in limestone, chalk, also present in vertebrates and other animals as a component of bone, shell etc. It is necessary for nerve conduction, heartbeat, muscle contraction and many other physiological functions.
calibrate to check or adjust a measuring instrument to ensure accurate measurements
cancer a disease resulting in the uncontrolled growth of body cells, forming tumours
capillaries numerous tiny blood vessels, that are only a single cell thick to allow exchange of materials to and from body cells. Every cell of the body is supplied with blood through capillaries.
carbon dioxide a colourless gas in which molecules (CO_2) are made up of one carbon and two oxygen atoms; essential for photosynthesis and a waste product cellular respiration. The burning of fossil fuels also releases carbon dioxide.
carcinogens chemicals that cause cancer
cardiac muscle special kind of muscle in the heart that never tires. It is involved in pumping blood through the heart.
carnivore animal that eats other animals
cartilage a waxy, whitish, flexible substance that lines or connects bone joints or, in some animals such as sharks, replaces bone as the supporting skeletal tissue. The ears and tips of noses of people are shaped by cartilage.
catalyst chemical that helps to start or speed up a chemical reaction

cell the smallest unit of life. Cells are the building blocks of living things. There are many different sizes and shapes of cells.
cell membrane the structure that encloses the contents of a cell and allows the movement of some materials in and out
cell sap the mixture inside a plant's vacuoles
cell theory theory that states that all living things are made up of cells and that all cells come from pre-existing cells
cellular respiration a series of chemical reactions in which the chemical energy in molecules such as glucose is transferred into ATP molecules, which is a form of energy that the cells can use
cellulose a natural substance that keeps the cell wall of plants rigid
chemical change change that results in a new substance being formed. During a chemical change, some chemical bonds break and others form.
chemical digestion the chemical reactions changing food into simpler substances that are absorbed into the bloodstream for use in other parts of the body
chemical formula shows the ratio of the atoms of each element present in a molecule or compound
chemical properties properties that describe how a substance combines with other substances to form new chemicals or how a substance breaks up into two or more different substances
chemical reaction a chemical change between two or more substances in which one or more new chemical substances are produced
chemical symbol the standard way that scientists write the names of the elements, using either a capital letter or a capital followed by a lowercase letter. For example, carbon is C and copper is Cu.
chlorophyll the green-coloured chemical in plants that absorbs light energy so that it can be used in the process of photosynthesis
chloroplasts oval-shaped organelles that are involved in the process of photosynthesis that results in the conversion of light energy into chemical energy
chorionic villus sampling a procedure in which cells from the developing placenta are removed for testing at 10–12 weeks of pregnancy, allowing certain abnormalities to be detected
chromosomes the tiny, thread-like structures inside the nucleus of a cell. Chromosomes contain the DNA that carries genetic information.
ciliary muscles muscles that control the shape of the lens in the eye
circulatory system the heart, blood and blood vessels which are responsible for circulating oxygen and nutrients to your body cells and carbon dioxide and other wastes away from them
clone an identical copy
cloning the process used to produce genetically identical organisms
coal a sedimentary rock formed from dead plants and animals that were buried before rotting completely followed by compaction and some heating
colon the part of the large intestine where food mass passes from the small intestine, and where water and other remaining essential nutrients are absorbed into the body
combustion the process of combining with oxygen, most commonly burning with a flame
compound substance made up of two or more different types of atoms that have been joined (bonded) together
compounds two or more atoms or ions of different elements joined (bonded) together
compression a region where air particles are closer together than usual
concave curved inwards
conception the successful embedding of a fertilised egg in the uterus wall
condensation the change of state by which a gas changes into a liquid
conduction transfer of heat through collisions between particles
conglomerate sedimentary rock containing large particles of various sizes cemented together
contraception the prevention of fertilisation of an egg or prevention of a fertilised egg becoming embedded in the uterus wall
contraceptives devices or substances that prevent fertilisation of an egg or prevent a fertilised egg becoming embedded in the uterus wall
contract shorten or become smaller in size

convection transfer of heat through the flow of particles
converging lens lens that bends rays so that they move towards each other. Converging lenses are thicker in the middle than at the edges.
convex curved outwards
cornea clear, curved outer surface of the eye
corrosion a chemical reaction between air, water or chemicals in the air or water with a metal, which causes the metal to wear away
corrosive describes a chemical that wears away the surface of substances, especially metals
cotyledons special leaves of the embryo plant inside a seed that provide food for the developing seedling
CRISPR Cas9 a tool used for gene editing
cross-pollination the transfer of pollen from stamens of one flower to the stigma of a flower of another plant of the same species
cryopreservation when cryoprotectant chemicals and cooling are used to safely freeze biological material such as human embryos
crystal geometrically-shaped substance made up of atoms and molecules arranged in one of seven different shapes. The elements that make up a crystal and the conditions present during the crystal's growth determine the arrangement of atoms and molecules and the shape of the crystals.
cullet used glass
cytokinesis the division of the cytoplasm at the end of the cell division process so that one cell divides to form two
cytoplasm the jelly-like material inside a cell. It contains many organelles such as the nucleus and vacuoles
cytosol the fluid found inside cells
data information collected which can be used for studying or analysing
deciduous trees and shrubs that lose their leaves and become dormant during winter
decomposition breaking up of a substance into smaller parts
deltas a landform created by the deposition of sediment at the end of a river as it enters a body of water
denatured describes the condition of proteins after they have been overheated
deoxygenated blood blood from which some oxygen has been removed
deoxyribonucleic acid (DNA) the chemical substance found in all living things that encodes the genetic information of an organism
dependent variable a variable that is expected to change when the independent variable is changed. The dependent variable is observed or measured during the experiment.
deposition the settling of transported sediments
dermis the medical name for the deeper part of the skin
diaphragm flexible, dome-shaped, muscular layer separating the chest and the abdomen. It is involved in breathing.
diarrhoea excessive discharge of watery faeces
diastolic pressure the lower blood pressure reading during relaxation of the heart muscles
differentiation when cells become different to each other and start to become specialised
diffusion movement of one substance through another due to a movement of particles, for example from a region of higher concentration to lower concentration
digestion breakdown of food into a form that can be used by an animal. It includes both mechanical digestion and chemical digestion.
digestive system a complex series of organs and glands that processes food to supply the body with the nutrients it needs to function effectively
diploid containing two sets of chromosomes
disinfectants a chemical used to kill bacteria on surfaces and non-living objects
disperse the scattering of the seeds from plants
dispersion separation of the colours that make up white light
diverging lens lens that bends rays so that they spread out Diverging lenses are thinner in the middle than at the edges
diverse a variety of different features within a population or different organisms in an ecosystem

ductile capable of being drawn into wires or threads; a property of most metals
durability the quality of lasting, not easily being worn out
ectothermic describes an animal whose body temperature is determined by its environment
efficiency the fraction of energy supplied to a device as useful energy
egg the female reproductive cell in animals and plants; an ovum
elastic describes a material that is able to return to its original size after being stretched
elasticity the property that allows a material to return to it original size after being stretched
electrocardiogram (ECG) graph made using the tiny electrical impulses generated in the heart muscle, giving information about the health of the heart
electromagnetic radiation the radiant energy such as radio waves, infrared, visible light, x-rays and gamma rays released by magnetic or electric fields
electromagnetic spectrum complete range of wavelengths of energy radiated as electric and magnetic fields
electromagnetic waves waves of electromagnetic radiation, light being just one example
electron microscopes instrument for viewing very small objects. An electron microscope is much more powerful than a light microscope and can magnify things up to a million times.
electrons very light, negatively charged particles inside an atom. Electrons move around the central nucleus of an atom.
element pure substance made up of only one type of atom
embryo a group of cells formed from the zygote and is developing into different body organs
embryonic stem cells stem cells derived from the inner cell mass of a blastocyst. These cells are pluripotent and can give rise to most cell types
emphysema condition in which the air sacs in the lungs break open and join together, reducing the amount of oxygen taken in and carbon dioxide removed
emulsify combine two liquids that do not normally mix easily
endocrine system the body system of glands that produce and secrete hormones into the bloodstream to regulate processes in various organs
endoskeleton skeleton that lies inside the body
endosperm the food supply for the embryo plant in a seed
endothermic describes an animal that requires heat input to maintain its body temperature
environmental impact statement (EIS) study of the possible effects of a planned project on the environment
enzymes special chemicals that speed up reactions but are themselves not used up in the reaction
epidermis the outermost layer of the skin
epiglottis leaf-like flap of cartilage behind the tongue that closes the air passage during swallowing
erosion the wearing away and removal of soil and rock by natural elements, such as wind, waves, rivers and ice, and by human activity
erythrocytes red blood cells
ethical issues issues that consider the moral implications, fairness and equity involved in an issue
eukaryote any cells or organisms with a membrane-bound nucleus (e.g. plants, animals, fungi and protists)
evaporates changes state from a liquid to a gas. Evaporation occurs only from the surface of a liquid.
evaporation changes state from a liquid to a gas. Evaporation occurs only from the surface of a liquid.
excretion removal of wastes from the body
excretory system the body system that removes waste substances from the body
exoskeleton skeleton or shell that lies outside the body
expand increase in size due to particles moving apart
external fertilisation reproduction occurs when the eggs are released by the female into water and fertilised by sperm released nearby
extinction the state or process of being or becoming extinct
extrusive igneous rock that forms when lava cools above the Earth's surface
fair test a method for determining an answer to a problem without favouring any particular outcome — another name for a controlled experiment
fertilisation fusion of the male gamete (sperm) and the female gamete (ovum)
fetus the unborn young of an animal that has developed a distinct head, arms and legs

filter funnel used with filter paper to separate solids from liquids
first-floor thinkers thinkers who gather information
fission the process whereby a large nucleus splits into smaller fragments releasing large amounts of energy
flaccid cells that are not firm due to loss of water
flammability an indicator of how easily a substance catches fire
flammable describes substances such as methylated spirits that burn easily
flatulence release of gas through the anus. This gas is produced by bacteria in the large intestine.
flint a fine-grained sedimentary rock that leaves a very sharp edge when broken
floodplain flat, open land beside a river where sediments are deposited during floods
flowers the reproductive part of angiosperms containing petals, stamens and carpels. They are often colourful to attract pollinating insects
fluid a substance that flows and has no fixed shape. Gases and liquids are fluids.
focal length distance between a lens or curved mirror and its focal point
focal point a point at which parallel rays of light meet after reflection by a curved mirror of refraction through a lens
fossil any remains, impression, or trace of an animal or plant of a former geological age; evidence of life in the past
fossil fuel substance, such as coal, oil and natural gas, that has formed from the remains of ancient organisms. Coal, oil and natural gas are often used as fuels; that is, they are burnt in order to produce heat.
fracture a break in a bone
fraternal twins twins developed from different fertilised eggs
freezing the change of state by which a liquid changes to a solid
frequency number of vibrations in one second, or the number of wavelengths passing in one second
fruit a ripened ovary of a flower, enclosing seeds
fuels substances, such as coal, oil and natural gas, that are often used as fuels; that is, they are burnt in order to produce heat
Fungi the kingdom of organisms made up of cells that possess a membrane-bound nucleus and cell wall, but no chloroplasts (e.g. mushrooms). Some fungi can help to decompose dead and decaying matter.
fusion the process whereby two small nuclei combine to form a larger nuclei releasing large amounts of energy
gabbro a dark-coloured intrusive igneous rock with a similar mineral composition to basalt but with larger crystals
gall bladder a small organ that stores and concentrates bile within the body
galvanising protecting a metal by covering it with a more reactive metal that will corrode first
gametes (reproductive cells) reproductive cells (sperm or ova) containing half the genetic information of normal cells
gamma rays high-energy electromagnetic radiation produced during nuclear reaction
gas state of matter with no fixed shape or volume
gastrointestinal tract also called the digestive tract and the alimentary canal, tubular passage that starts with the mouth and ends with the anus; it intakes and digests food (absorbing energy and nutrients) and expels waste
gene editing changing the genetics of a cell or organism
generation refers to all offspring at the same stage of development
genetic screening is the study of a person's DNA in order to identify genetic differences or susceptibility to particular diseases or abnormalities
geothermal energy using heat from the Earth as a energy source
germination the first sign of growth from the seed of a plant
gestation the time spent by offspring developing in the uterus
glaciers large bodies of ice that move down slopes and push boulders, rocks and gravel
glomerulus a cluster of capillaries in the kidney that acts as a filter to remove wastes and excess water
glucose a six-carbon sugar (monosaccharide) that acts as a primary energy supply for many organisms
gneiss a coarse-grained metamorphic rock with light and dark bands formed mainly as a result of great pressure on granite

gonads reproductive organs where gametes are produced; the testes and ovaries
granite a light-coloured intrusive igneous rock with mineral crystals large enough to see
greenstick fracture a break that is not completely through the bone, often seen in children
group in the periodic table of elements, a single vertical column of elements with a similar nature
guard cells cells on either side of a stoma that work together to control the opening and closing of the stoma
habits of mind types of thinking behaviours promoted by Bena Kallick and Arthur Costa
haemodialysis the process of passing blood through a machine to remove wastes
haemoglobin the red pigment in red blood cells that carries oxygen
haploid containing a single set of chromosomes
hardness a measure of how difficult it is to scratch the surface of a solid material, hardness can be ranked using Moh's scale
heart a muscular organ that pumps deoxygenated blood to the lungs to be oxygenated and then pumps the oxygenated blood to the body
heartbeat contraction of the heart muscle occurring about 60–100 times per minute
heartburn burning sensation caused by stomach acid rising into the oesophagus
herbivore animal that eats only plants
hermaphrodites organism that has both male and female reproductive organs
hertz unit of frequency; its abbreviation is Hz
hinge joints joints in which two bones are connected so that movement occurs in one plane only
hippocampus area of the brain stem able to transfer information between short- and long-term memory
hydrogen the element with the smallest atom. By itself, it is a colourless gas and combines with other elements to form a large number of substances, including water. It is the most common element in living things.
hypothesis a suggested, testable explanation for observations or experimental results; it acts as a prediction for the investigation
identical twins twins developed from the same fertilised egg
igneous rock formed when hot, molten rock cools and hardens (solidifies)
image visual representation of an object; what we see
immovable joints joints that allow no movement except when absorbing a hard blow
implantation the process whereby the embryo becomes embedded in the wall of the uterus
incandescent describes objects that emit light when they are hot
independent variable the variable that the scientist chooses to change to observe its effect on another variable
inert not reactive
infectious diseases diseases that can be transferred from one organism to another
infertility the inability to have children
infra-red radiation low-energy electromagnetic waves with a much lower frequency and longer wavelength than visible light
insect-pollinated flowers flowers that receive pollen carried on the body parts of insects from other flowers
insulator a material that is a poor conductor of heat
internal fertilisation reproduction occurs when the egg remains in the female and is fertilised by sperm inserted into the female
interpersonal communication communication with others
interpersonal intelligences one of the multiple intelligences that involves 'we' learning, which can be developed through team projects, social interactions, debates and games
intrapersonal intelligences one of the multiple intelligences that involves 'I' learning, which can be developed through reflecting, self-assessment and creative expression
intrusive igneous rock that forms when magma cools below the Earth's surface
investigations activities aimed at finding information
involuntary muscles muscles not under the control of the will; they contract slowly and rhythmically. These muscles are at work in the heart, intestines and lungs.
iris coloured part of the eye that opens and closes the pupil to control the amount of light that enters the eye
isotope atoms of the same element that differ in the number of neutrons in the nucleus

IVF (invitro fertilisation) the fertilisation between eggs and sperm and the culture of embryos in the laboratory for fertility treatment
joints region where two bones meet
kidneys body organs that filter the blood, removing urea and other wastes
kinesics the use of bodily movements or actions to convey a specific meaning or idea
kinetic energy energy due to the motion of an object
labour the process of delivering the baby, placenta and umbilical cord from the uterus
large intestine the penultimate part of the digestive system, where water is absorbed from the waste before it is transported out of the body
lateral inversion sideways reversal of images in a mirror
lava molten rock flowing on the surface
Law of Conservation of Energy a law that states that energy cannot be created or destroyed
left atrium upper left section of the heart where oxygenated blood from the lungs enters the heart
left ventricle lower left section of the heart, which pumps oxygenated blood to all parts of the body
lens part of the eye that focuses light onto the retina, ensuring the image is sharp
leucocytes white blood cells
life cycle the cycle of one organism's life from birth through reproductive age to death; may include distinct stages and forms
ligament band of tough tissue that connects the ends of bones or keeps an organ in place
light microscopes instrument for viewing very small objects. A light microscope can magnify things up to 1500 times.
lignin a hard substance in the walls of dead xylem cells that make up the tubes carrying water up plant stems. Lignin forms up to 30 per cent of the wood of trees.
limestone a sedimentary rock formed from the remains of sea organisms. It consists mainly of calcium carbonate (calcite).
line of best fit a smooth curve or line that passes as close as possible to all plotted points on a graph
lipases enzymes that break fats and oils down into fatty acids and glycerol
lipids type of nutrients that include fats and oils
liquid state of matter that has a fixed volume, but no fixed shape
lithify to transform sediment into rock
lithosphere the outermost layer of the Earth, includes the crust and uppermost part of the mantle
liver largest gland in the body. The liver secretes bile for digestion of fats, builds proteins from amino acids, breaks down many substances harmful to the body and has many other essential functions.
long-sightedness unable to obtain sharp images of nearby objects
long-term storage a function of the brain that enables memories to be stored, sorted and retrieved
longitudinal wave a wave that vibrates in the direction of propagation
'lub dub' the sound made by the heart valves as they close
luminous releasing its own light
lungs the organ for breathing air. Gas exchange occurs in the lungs.
lustre appearance of a mineral caused by the way it reflects light. A mineral can appear glassy, waxy, metallic, dull, pearly, silky
magma a very hot mixture of molten rock and gases, just below the Earth's surface, that has come from the mantle
magnification the number of times the image of an object has been enlarged using a lens or lens system. For example, a magnification of two means the object has been enlarged to twice its actual size.
malignant a type of tumour that damages cells and can spread to other parts of the body
malleable able to be beaten, bent or flattened into shape
marble a metamorphic rock formed as a result of great heat or pressure on limestone
mass the quantity of matter in an object (usually measured in grams or kilograms)
mass extinction an event where a large amount of life in the fossil record no longer continue
matter everything that takes up space and has mass is matter
measuring cylinder used to measure volumes of liquids accurately

mechanical digestion digestion that uses physical factors such as chewing with the teeth
melting the change of state by which a solid changes to a liquid
melting point the temperature at which a solid substance turns into a liquid (melts) or a liquid turns into a solid (freezes)
menstrual cycle beginning of one period to the beginning of the next period
menstruation the monthly bleeding, also called 'periods'. It occurs as the lining of the uterus is released.
metabolism the chemical reactions occurring within an organism that enable the organism to use energy and grow and repair cells
metalloids elements that have the appearance of metals but not all the other properties of metals
metals elements that conduct heat and electricity; shiny solids that can be made into thin wires and sheets that bend easily. Mercury is the only liquid metal.
metamorphic rocks formed from the change (alteration) of pre-existing rocks in response to increasing temperature and/or pressure conditions
metamorphism the process that changes rocks by extreme pressure or heat (or both)
meteorologist a scientist who uses observations of the atmosphere to predict or explain the weather
micrometre one millionth of a metre
microscope an instrument for viewing small objects
mineral a naturally occurring, inorganic and solid substance with a defined chemical formula and an ordered arrangement of atoms
minerals substances that make up rocks. Each mineral has its own chemical make-up.
mining the process of removing natural resources from the Earth
mitochondria small rod-shaped organelles that are involved in the process of cellular respiration, which results in the conversion of energy into a form that the cells can use. Singular = mitochondrion
mitochondrial DNA (mtDNA) genetic material from the mitochondria, which is only passed to offspring from the mother
mitosis the cell division process that results in new cells, which are genetically identical to each other and to the original cell
mixtures a combination of substances in which each keeps its own properties
mnemonic a strategy to help you to remember things
molecule two or more atoms joined (bonded) together
monocular microscope a microscope with a single eyepiece through which the specimen is seen using only one eye
moraine a long hill made out of sediments deposited by a glacier
mould cavity in a rock that shows the shape of the hard parts of an organism
mouth the opening of the alimentary canal through which food is taken into the body
mudstone a fine-grained, sedimentary rock without layering
multicellular made up of many cells
multicellular organisms living things comprised of specialised cells that perform specific functions
multifocal lenses lenses that are composed of different sectors of lens with differing focal length, which allow people with both short-sightedness and long-sightedness to see clearly
multiple fission a reproduction method where a single-celled organism divides into more than two cells
multipotent stem cells that can give rise to only certain cell types, e.g. various types of blood or skin cells
muscles tissue consisting of cells that can shorten
musculoskeletal system consists of the skeletal system (bones and joints) and the skeletal muscle system (voluntary or striated muscle). Working together, these two systems protect the internal organs, maintain posture, produce blood cells, store minerals and enable the body to move.
nanometre one billionth of a metre
nanotechnology a science and technology that focuses on manipulating the structure of matter at an atomic and molecular level
native elements elements found uncombined in the Earth's crust
natural fibres fibres that form naturally; that is, they have not been made by humans. Natural fibres include wool and silk from animals and cotton from plants.

nectaries parts of a flower, at the base of the petals, that secrete nectar
nephrons the filtration and excretory units of the kidney
nervous system neurons, nerves and the brain, which are responsible for detecting and responding to both internal and external stimuli to keep us alive
neutrons tiny, but heavy, particle found in the nucleus of an atom. Neutrons have no electrical charge.
nitrogenous wastes waste products from protein break down, including ammonia, urea and uric acid
noble gas elements in the last column of the periodic table. They are extremely inert gases.
non-infectious diseases diseases that cannot be transferred from one organism to another
non-invasive prenatal testing (NIPS) the testing of maternal (mother's) blood for signs of chromosomal abnormality in the fetus
non-luminous describes objects that do not emit their own light, but can be seen by reflected light
non-metals elements that do not conduct electricity or heat. They melt and turn into gases easily and are brittle and often coloured.
normal (the) line drawn perpendicular to a surface at the point where a light ray meets the surface
nuclear decay the spontaneous decay of unstable nuclei to a new nucleus
nucleus (in biology) roundish structure inside a cell that acts as the control centre for the cell; (in chemistry) the central part of an atom, made up of protons and neutrons. Plural = nuclei.
nutrients substances that provide energy and chemicals that living things need to stay alive, grow and reproduce
nylon synthetic fibre. The monomers are joined by the elimination of water molecules at the joins.
observations information obtained by the use of our senses or measuring instruments
obsidian a black, glassy rock that breaks into pieces with smooth shell-like surfaces
oesophagus part of the digestive system composed of a tube connecting the mouth with the stomach
offspring the young born of a living organism
omnivore animal that eats plants and other animals
open-cut mining mining that scours out soil and rocks on the surface of the land
optic nerve large nerve that sends signals to the brain from the sight receptors in the retina
ore mineral a mineral from which a valuable metal can be removed for profit
organelles any specialised structure in a cell that performs a specific function
organisms living things
organs structures, composed of tissue, that perform specific functions
oscillation one complete swing of a pendulum
osmosis the movement of water across a semipermeable membrane from where it is in a high concentration to where it is in a low concentration
ossification hardening of bones
osteoporosis loss of bone mass that causes bones to become lighter, more fragile and easily broken
ova female gametes or sex cells. Singular = ovum.
ovaries female gonads, produce the female gametes (egg cells; ova)
overburden waste rock removed from below the topsoil. This rock is replaced when the area is restored.
ovulation the release of an ovum from a mature follicle in the ovary into the fallopian tube
ovule the receptacle within an ovary that contains egg cells
oxidation chemical reaction involving the loss of electrons by a substance
oxygen atom that forms molecules (O_2) of tasteless and colourless gas; it is essential for cellular respiration for most organisms and is a product of photosynthesis
oxygenated blood the bright red blood that has been supplied with oxygen in the lungs
pacemaker electronic device inserted in the chest to keep the heart beating regularly at the correct rate. It works by stimulating the heart with tiny electrical impulses.
palaeontologist a scientist who studies fossils
pancreas a large gland in the body that produces and secretes the hormone insulin and an important digestive fluid containing enzymes
paralinguistics how something is said that may modify meaning
parthenogenesis the development of new individuals from unfertilised eggs

particle model a description of the moving particles that make up all matter and how they behave. The model explains the properties of solids, liquids and gases.

pendulum an object swinging on the end of a string, chain or rod

percussion flaking a process in which tool stones, such as flint or obsidian, were struck with harder stones, such as quartzite, to shear large flakes off until it was a desired shape

period the time taken for one oscillation of a pendulum

periodic table a table listing all known elements. The elements are grouped according to their properties and in order of the number of protons in their nucleus.

peristalsis the process of pushing food along the oesophagus or small intestine by the action of muscles

permineralization the most common method of fossilisation, in which minerals fill the cellular spaces and crystallise. The shape of the original plant or animal is preserved in great detail.

petals the coloured parts of a flower that attract insects

pheromones chemicals that are important in communication between members of the opposite sex

phloem a type of tissue that transports sugars made in the leaves to other parts of a plant

phosphorus a substance that plays an important role in almost every chemical reaction in the body. Together with calcium, it is required by the body to maintain healthy bones and teeth.

photosynthesis a series of chemical reactions that occur within chloroplasts in which the light energy is converted into chemical energy. The process also requires carbon dioxide and water, and produces oxygen, water and sugars — which the plant can use as 'food'.

physical changes changes in which no new chemical substances are formed. A physical change may be a change in shape, size or state. Many physical changes are easy to reverse.

physical property property that you can either observe using your five senses – seeing, hearing, touching, smelling and tasting — or measure directly

pitch the highness or lowness of a sound

pivot joint joint that allows a twisting movement

placenta an organ formed in the mother's womb through which the baby receives food and oxygen from the mother's blood and the baby's wastes are removed

Plantae the kingdom of organisms that have cells with a membrane-bound nucleus, cell wall, large vacuole and chloroplasts (e.g. plants)

plasma the yellowish liquid part of blood that contains water, minerals, food and wastes from cells

plastic synthetic substance capable of being moulded

platelets small bodies involved in blood clotting. They are responsible for healing by clumping together around a wound.

plumule a small bud at the tip of the embryo plant in a seed

pluripotent stem cells that can give rise to most cell types; e.g. blood cells, skin cells and liver cells

pollen the fine powder containing the pollen grains (the male sex cells of a plant)

pollen grains the male gametes of a flower

pollen tube a long tube growing from a pollen grain through the style to the ovule

pollination the transfer of pollen from the stamen (the male part) of a flower to the stigma (the female part) of a flower

polyester synthetic fibre. The monomers are joined together by the elimination of water molecules at the joins.

polymer substance made by joining smaller identical units. All plastics are polymers.

pores small openings in the skin. Perspiration reaches the surface of the skin through pores

potential energy energy that has the potential to do work and so the energy is 'stored', such as gravitational energy, elastic energy and chemical energy

precipitate solid product of a chemical reaction that does not dissolve in water

precipitation falling water in solid or liquid form. The type of precipitation depends mostly on the temperature in the clouds and the air around them.

precision how close multiple measurements of the same investigation are to each other

prefix letters that are placed at the start of a word to convey a specific meaning

preimplantation genetic diagnosis PGD a procedure to diagnose and exclude genetic abnormalities in embryos before implantation into the mother's body

preimplantation genetic screening the screening of embryos for genetic abnormalities to improve pregnancy and live birth rates

premature a baby born less than 37 weeks after conception

presbyopia blurring of images of very close objects caused by loss of flexibility of the lens in the eyes

pressure the force exerted per unit area

product new chemical substance that results from a chemical reaction

Prokaryotae the kingdom of unicellular organisms made up of a single cell that does not possess a membrane-bound nucleus or other membrane-bound organelles (e.g. bacteria). Also called *Monera*

prokaryote any cells or organisms without a membrane-bound nucleus (e.g. bacteria)

properties characteristics or features of an object or substance

proteases enzymes that break proteins down into amino acids

protein chemical made up of amino acids needed for growth and repair of cells in living things

Protoctista the kingdom of organisms made up of cells that possess a membrane-bound nucleus but vary in other features and do not fit into other groups (e.g. protozoans). Also called *Protista*

protons tiny, but heavy, positively charged particle found in the nucleus of an atom

puberty the life stage when the sex glands become active and bodily changes occur to enable reproduction

pulmonary artery the vessel through which deoxygenated blood, carrying wastes from respiration, travels from the heart to the lungs

pulmonary vein the vessel through which oxygenated blood travels from your lungs to the heart

pulse alternating contraction and expansion of arteries due to the pumping of blood by the heart

pumice a glassy, pale igneous rock that forms when frothy rhyolite lava cools in the air. Pumice often floats on water as it is very light and full of holes that once contained gas.

pupil hole through which light enters the eye

qualitative data categorical data that examines the quality of something (e.g. colour or gender) rather than a measurement or quantity

quantitative data numerical data that examines the quantity of something (e.g. length or time)

quartzite an extremely compact and hard metamorphic rock consisting essentially of quartz

radiant heat heat transferred by electromagnetic radiation

radiation emission of energy as electromagnetic waves

radicle the beginnings of a root making up part of a plant embryo inside a seed

radio waves low-energy electromagnetic radiation

rapport a relationship of mutual trust and understanding

rarefactions in sound waves, the layers of air particles that are spread apart (between compressions)

reactants chemical substances used up in a chemical reaction. Some chemical bonds in a reactant are broken during the reaction.

reaction rate speed at which a reaction takes place

reactivity a measure of how likely a particular substance reacts to make new substances

receptors specialised structures that sense or receive stimuli

recipient the person or couple receiving embryos or gametes from another person

record the first step in forming a memory

rectum the final section of the digestive system, where waste food matter is stored as faeces before being excreted through the anus

recycled reuse an unwanted substance or object for another purpose

red blood cells living cells in the blood that transport oxygen to all other living cells in the body

reflected bounced off

refraction change in the speed of light as it passes from one substance into another

rehabilitated restored to its previous condition

relative age the age of a rock compared with the age of another rock

reproductive maturity the age at which an organism can reproduce

reproductive system body system in which human males and females possess different reproductive organs with the overall aim of reproducing the offspring of the next generation

respiration the chemical process that takes place in every cell to release energy. Glucose reacts with oxygen to produce carbon dioxide and water.
respiratory system the lungs and associated structures that are responsible for getting oxygen into your body and carbon dioxide out
reticular activation system a part of the brain that filters incoming information on the basis of importance
retina curved surface at the back of the eye that is lined with sight receptors
retrieve the ability to recall memories
reverberation longer-lasting sound caused by repeated reflection from hard surfaces
rhyolite a light-coloured extrusive igneous rock with a similar mineral composition to granite but with smaller crystals
ribosomes small structures within a cell in which proteins such as enzymes are made
right atrium upper right section of the heart where deoxygenated blood from the body enters
right ventricle lower right section of the heart, which pumps deoxygenated blood to the lungs
rock cycle a cycle of processes that rocks experience in the Earth's crust as they constantly change from one type to another
rock salt a sedimentary deposit formed when a salt lake or seabed dried up. The sediments are made of sodium chloride (halite).
rust a brown substance formed when iron reacts with oxygen and water
rusting the corrosion of iron
safety glasses plastic glasses used to protect the eyes during experiments
saliva watery substance in the mouth that contains enzymes involved in the digestion of food
salivary glands glands in the mouth that produce saliva
sandstone a sedimentary rock with medium-sized grains. The sand grains are cemented together by silica, lime or other salts.
scattered describes light sent in many directions by small particles within a substance
scavengers animals that eat dead plant and animal material
scientists people skilled in or working in the fields of science; scientists use experiments to find out about the material world around them
scoria a dark, igneous rock formed from basalt lava that cools quickly and full of holes that once contained gas
second-floor thinkers thinkers who process information
sediment material broken down by weathering and erosion that is moved by wind or water and collects in layers
sedimentary rocks formed through the deposition and compaction of layered sediment
seed a product of a fertilised ovule
seed coat the protective layer around a seed
seedling a young plant produced from the embryo in the seed after germination
self-pollination the transfer of pollen from the flower's own stamen to its stigma
semen ejaculate from the male reproductive organs made up of sperm and secretions essential for its viability
semilunar a type of valve that is half-moon shaped. The aortic valve is semilunar and is located between the heart's left ventricle and aorta.
sensor device connected to an instrument such as a data logger that measures and sends information
sensory register a system in the brain that filters incoming information on the basis of importance
sexual intercourse the act of inserting sperm into the female; also called copulation or mating
shale a fine-grained sedimentary rock formed in layers by the consolidation of clay
short-sightedness unable to obtain sharp images of distant objects
silicates group of minerals consisting primarily of SiO_4^{2-} combined with metal ions, forming a major component of the rocks in the Earth's crust
siltstone a sedimentary rock with a particle size between that of sandstone and mudstone
skeletal muscle system voluntary or striated muscle
skeletal system consists of the bones and joints
skeleton the bones or shell of an animal that support and protect it as well as allowing movement
skin external covering of a vertebrate's body
slate a fine-grained metamorphic rock formed as a result of moderate heat and pressure on shale

small intestine the part of the digestive system between the stomach and large intestine, where much of the digestion of food and absorption of nutrients takes place
solid state of matter that has a fixed shape and volume
somatic stem cells derived from bone marrow, skin and umbilical cord blood. These cells are multipotent and can give rise to only certain types of cells
sound waves vibrations of particles in the air
sperm the male reproductive cell. It consists of a head, a middle section and a tail used to swim towards the egg
spinneret device like a nozzle with small holes through which a plastic material passes, forming threads, also the organ used by spiders to create their webs
spores reproductive cells capable of developing into a new individual without fusion with another reproductive cell
sprains injury caused by tearing a ligament
state condition or phase of a substance. The three main states of matter are solid, liquid and gas.
state of matter condition or phase of a substance. The three main states of matter are solid, liquid and gas.
stem cells undeveloped cells found in blood and bone marrow that can reproduce themselves indefinitely
stereo microscope a type of binocular microscope through which the detail of larger specimens can be observed
sterile a person unable to produce reproductive cells
stigma the female part of a flower, at the top of the carpel, that catches the pollen during pollination
stomach a large muscular organ that churns and mixes food with gastric juice to start to break down protein
stomata small openings mainly on the lower surface of leaves. These pores are opened and closed by guard cells. Singular = stoma.
Stone Age a prehistoric time when weapons and tools were made of stone, bone or wood
store storage of a memory in the appropriate part of the brain
streak colour of a mineral as a fine powder, found by rubbing it onto an unglazed white ceramic tile
style the supporting part of a flower that holds the stigma
sublimation the change in state from a solid into a gas without first becoming a liquid
substrate substance acted upon by an enzyme
suffix letters that are placed at the end of a word to convey a specific meaning
surface protection coating over a metal surface to prevent corrosion
surrogacy a pregnancy that occurs when the fertilised egg is placed in the uterus of another woman who did not produce the egg
survival is the ability to continue life, species survival depends on reproductive success
sustainable describes the concept of using the Earth's resources so that the needs of the world's present population can be met, without damaging the ability of future populations to meet their needs
sweat gland a tiny, coiled tube in the skin through which water and salt are removed from the body, helping to control body temperature
synovial fluid the liquid inside the cavity surrounding a joint that helps bones to slide freely over each other
systolic pressure the higher blood pressure reading during contraction of the heart muscles
target cell a specific cell in which a hormone can cause a response
teeth hard structures within the mouth that allow chewing
temperature a measure of how hot or cold something is
tendons tough rope-like tissue connecting a muscle to a bone
tennis elbow repeated grasping and bending back of your wrist can lead to the inflammation of the tendon that connects the muscles of your forearm to the bone in your upper arm causing pain
test tube thin glass container for holding, heating or mixing small amounts of substances
testes organs that produce sperm and sex hormones
thalamus part of the brain at the top of the brain stem that passes sensory information to key areas in the brain for processing
thinking hats a thinking tool developed by Edward de Bono using different coloured hats for different types of thinking
third-floor thinkers thinkers who apply information
tissue group of cells of similar structure that perform a specific function

torn hamstring a common sporting injury caused by overstretching the hamstring muscle, which joins the pelvis to the knee joint
totipotent the most powerful stem cells that can give rise to all cell types
toxic describes chemicals that are dangerous to touch, inhale or swallow
toxicity the danger to your health caused when poisonous substances combine with chemicals in your body to produce new substances and damaging effects
trace fossils fossils that provide evidence, such as footprints, that an organism was present when the rock was formed
trachea narrow tube from the mouth to the lungs through which air moves
translocation process in which sugars and amino acids are transported within the plant by phloem tissue in plants
transmitted passed through something, such as light or sound passing through air
transmutation the process whereby a nucleus is bombarded with high energy neutrons in an attempt to convert it to another element
transpiration the loss of water from plant leaves through their stomata
transpiration stream the movement of water through a plant as a result of loss of water from the leaves
transverse wave a wave that vibrates perpendicular to the direction of propagation
tricuspid a type of valve with three cusps (points). The valve between the heart's right atrium and right ventricle is a tricuspid valve.
tumour an abnormal growth
turgid something that is firm
ultraviolet radiation invisible radiation similar to light but with a slightly higher frequency and more energy
underground mining mining that uses shafts and tunnels to remove rock from deep below the surface
unicellular made up of only one cell
urea a nitrogen-containing substance produced by the breakdown of proteins and removed from the blood by the kidneys
ureters tubes from each kidney that carry urine to the bladder
urethra tube through which urine is emptied from the bladder to the outside of the body
uric acid a nitrogenous waste product of protein break down
urination passing of urine from the bladder to the outside of the body
urine yellowish liquid, produced in the kidneys. It is mostly water and contains waste products from the blood such as urea, ammonia and uric acid.
uterus the site of embryo implantation, and supports the developing fetus from implantation to birth. About the size of a pear if not pregnant
vacuoles sacs within a cell used to store food and wastes. Plant cells usually have one large vacuole. Animal cells have several small vacuoles or none at all.
valves flap-like folds in the lining of a blood vessel or other hollow organ that allow a liquid, such as blood, to flow in one direction only
variables quantities or conditions in an experiment that can change
varicose veins expanded or knotted blood vessels close to the skin, usually in the legs. They are caused by weak valves that do not prevent blood from flowing backwards.
vascular bundles groups of xylem and phloem vessels within plant stems
vegetative propagation the reproduction of plants using parts other than sex cells
veins blood vessels that carry blood back to the heart. They have valves and thinner walls than arteries.
vena cava large vein leading into the top right chamber of the heart
venules small veins
vibrations repeated fast, back-and-forth movements
villi tiny finger-like projections from the wall of the intestine that maximise the surface area of the structure to increase the efficiency of nutrient absorption. Singular = villus.
virgin births births that do not involve the joining of eggs and sperm
virtual focal point a single point from which light rays seem to be coming after passing through a concave lens
viscosity a measure of a fluid's resistance to flow

visible spectrum different colours that combine to make up white light; they are separated in rainbows
vital capacity the largest volume of air that can be breathed in or out at one time
vitamin D a nutrient that regulates the concentration of calcium and phosphate in the bloodstream and promotes the healthy growth and remodelling of bone
volume the amount of space taken up by an object or substance
voluntary muscle muscle attached to bones; it moves the bones by contracting and is controlled by an animal's thoughts
vomiting the forceful ejection of matter from the stomach through the mouth
water vapour water in the gaseous state
wavelength distance between two neighbouring crests or troughs of a wave
weathering the physical or chemical break down of rocks on the surface
white blood cells living cells that fight bacteria and viruses as part of the human body's immune system
wilt plant stems and leaves droop due to insufficient water in their cells
wind-pollinated flowers flowers that receive pollen carried by the wind from another flower
x-rays high-energy electromagnetic waves that can be transmitted through solids and provide information about the structure
xylem vessels pipelines for the flow of water up plants. They are made up of the remains of dead xylem cells fitted end to end with the joining walls broken down. Lignin in the cell walls gives them strength.
zona pellucida surrounds the ovum and embryo for the first week of development
zygote a cell formed by the fusion of two gametes; fertilised ovum before it starts to divide into more cells

PERIODIC TABLE

Alkali metals → Group 1

Alkaline earth metals → Group 2

Key

Period 1	1 Hydrogen **H** **1.0**	2 Helium **He** **4.0**	← Atomic number ← Name ← Symbol ← Relative atomic mass

Transition metals (Group 3–Group 12)

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9
Period 1	1 Hydrogen **H** **1.0**								
Period 2	3 Lithium **Li** **6.9**	4 Beryllium **Be** **9.0**							
Period 3	11 Sodium **Na** **23.0**	12 Magnesium **Mg** **24.3**							
Period 4	19 Potassium **K** **39.1**	20 Calcium **Ca** **40.1**	21 Scandium **Sc** **45.0**	22 Titanium **Ti** **47.9**	23 Vanadium **V** **50.9**	24 Chromium **Cr** **52.0**	25 Manganese **Mn** **54.9**	26 Iron **Fe** **55.8**	27 Cobalt **Co** **58.9**
Period 5	37 Rubidium **Rb** **85.5**	38 Strontium **Sr** **87.6**	39 Yttrium **Y** **88.9**	40 Zirconium **Zr** **91.2**	41 Niobium **Nb** **92.9**	42 Molybdenum **Mo** **96.0**	43 Technetium **Tc** **(98)**	44 Ruthenium **Ru** **101.1**	45 Rhodium **Rh** **102.9**
Period 6	55 Caesium **Cs** **132.9**	56 Barium **Ba** **137.3**	57–71 Lanthanoids	72 Hafnium **Hf** **178.5**	73 Tantalum **Ta** **180.9**	74 Tungsten **W** **183.8**	75 Rhenium **Re** **186.2**	76 Osmium **Os** **190.2**	77 Iridium **Ir** **192.2**
Period 7	87 Francium **Fr** **(223)**	88 Radium **Ra** **(226)**	89–103 Actinoids	104 Rutherfordium **Rf** **(261)**	105 Dubnium **Db** **(262)**	106 Seaborgium **Sg** **(266)**	107 Bohrium **Bh** **(264)**	108 Hassium **Hs** **(267)**	109 Meitnerium **Mt** **(268)**

- Alkali metal
- Alkaline earth metal
- Transition metal
- Lathanoids
- Actinoids
- Unknown chemical properties
- Post-transition metal
- Metalloid
- Reactive non-metal
- Halide
- Noble gas

Lanthanoids

57 Lanthanum **La** **138.9**	58 Cerium **Ce** **140.1**	59 Praseodymium **Pr** **140.9**	60 Neodymium **Nd** **144.2**	61 Promethium **Pm** **(145)**	62 Samarium **Sm** **150.4**	63 Europium **Eu** **152.0**

Actinoids

89 Actinium **Ac** **(227)**	90 Thorium **Th** **232.0**	91 Protactinium **Pa** **231.0**	92 Uranium **U** **238.0**	93 Neptunium **Np** **(237)**	94 Plutonium **Pu** **(244)**	95 Americium **Am** **(243)**

Noble gases → Group 18

Halogens → Group 17

Non-metals → Group 14

Group 10	Group 11	Group 12	Group 13	Group 14	Group 15	Group 16	Group 17	Group 18
								2 Helium **He** **4.0**
			5 Boron **B** **10.8**	6 Carbon **C** **12.0**	7 Nitrogen **N** **14.0**	8 Oxygen **O** **16.0**	9 Fluorine **F** **19.0**	10 Neon **Ne** **20.2**
			13 Aluminium **Al** **27.0**	14 Silicon **Si** **28.1**	15 Phosphorus **P** **31.0**	16 Sulfur **S** **32.1**	17 Chlorine **Cl** **35.5**	18 Argon **Ar** **39.9**
28 Nickel **Ni** **58.7**	29 Copper **Cu** **63.5**	30 Zinc **Zn** **65.4**	31 Gallium **Ga** **69.7**	32 Germanium **Ge** **72.6**	33 Arsenic **As** **74.9**	34 Selenium **Se** **79.0**	35 Bromine **Br** **79.9**	36 Krypton **Kr** **83.8**
46 Palladium **Pd** **106.4**	47 Silver **Ag** **107.9**	48 Cadmium **Cd** **112.4**	49 Indium **In** **114.8**	50 Tin **Sn** **118.7**	51 Antimony **Sb** **121.8**	52 Tellurium **Te** **127.6**	53 Iodine **I** **126.9**	54 Xenon **Xe** **131.3**
78 Platinum **Pt** **195.1**	79 Gold **Au** **197.0**	80 Mercury **Hg** **200.6**	81 Thallium **Tl** **204.4**	82 Lead **Pb** **207.2**	83 Bismuth **Bi** **209.0**	84 Polonium **Po** **(210)**	85 Astatine **At** **(210)**	86 Radon **Rn** **(222)**
110 Darmstadtium **Ds** **(271)**	111 Roentgenium **Rg** **(272)**	112 Copernicium **Cn** **(285)**	113 Nihonium **Nh** **(280)**	114 Flerovium **Fl** **(289)**	115 Moscovium **Mc** **(289)**	116 Livermorium **Lv** **(292)**	117 Tennessine **Ts** **(294)**	118 Oganesson **Og** **(294)**

64 Gadolinium **Gd** **157.3**	65 Terbium **Tb** **158.9**	66 Dysprosium **Dy** **162.5**	67 Holmium **Ho** **164.9**	68 Erbium **Er** **167.3**	69 Thulium **Tm** **168.9**	70 Ytterbium **Yb** **173.1**	71 Lutetium **Lu** **175.0**

96 Curium **Cm** **(247)**	97 Berkelium **Bk** **(247)**	98 Californium **Cf** **(251)**	99 Einsteinium **Es** **(252)**	100 Fermium **Fm** **(257)**	101 Mendelevium **Md** **(258)**	102 Nobelium **No** **(259)**	103 Lawrencium **Lr** **(262)**

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