GRAEME LOFTS | MERRIN J. EVERGREEN

JACARANDA SCIENCE QUEST 9

AUSTRALIAN CURRICULUM | FOURTH EDITION

AUSTRALIAN CURRICULUM v9.0

learnon
www.jacplus.com.au

jacaranda
A Wiley Brand

JACARANDA
SCIENCE QUEST 9

AUSTRALIAN CURRICULUM | FOURTH EDITION

JACARANDA
SCIENCE QUEST 9

AUSTRALIAN CURRICULUM | FOURTH EDITION

GRAEME LOFTS

MERRIN J. EVERGREEN

CONTRIBUTING AUTHORS

Nick Fitzgerald | Von Hayes | Lynette Lew | Adele Norton | Courtney Simpson | Ritu Tyagi

REVIEWED BY

Courtney Rubie, Wiradjuri woman

AUSTRALIAN CURRICULUM
v9.0

jacaranda
A Wiley Brand

Fourth edition published 2023 by
John Wiley & Sons Australia, Ltd
Level 4, 600 Bourke Street, Melbourne, Vic 3000

First edition published 2011
Second edition published 2015
Third edition published 2018

Typeset in 10.5/13 pt TimesLT Std

ISBN: 978-1-394-15134-9

Front cover images: © IKON IMAGES / ROY SCOTT / SCIENCE PHOTO LIBRARY

Illustrated by various artists, diacriTech and Wiley Composition Services

Typeset in India by diacriTech

NATIONAL LIBRARY OF AUSTRALIA

A catalogue record for this book is available from the National Library of Australia

The Publishers of this series acknowledge and pay their respects to Aboriginal Peoples and Torres Strait Islander Peoples as the traditional custodians of the land on which this resource was produced.

This suite of resources may include references to (including names, images, footage or voices of) people of Aboriginal and/or Torres Strait Islander heritage who are deceased. These images and references have been included to help Australian students from all cultural backgrounds develop a better understanding of Aboriginal and Torres Strait Islander Peoples' history, culture and lived experience.

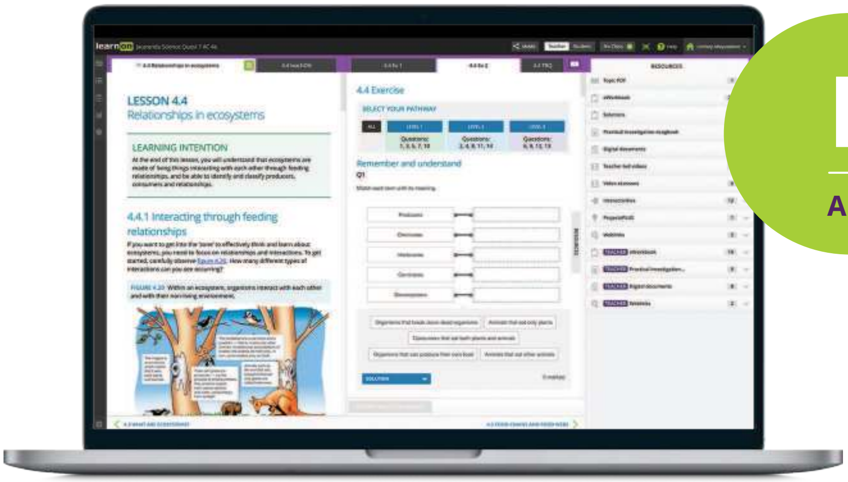
It is strongly recommended that teachers examine resources on topics related to Aboriginal and/or Torres Strait Islander Cultures and Peoples to assess their suitability for their own specific class and school context. It is also recommended that teachers know and follow the guidelines laid down by the relevant educational authorities and local Elders or community advisors regarding content about all First Nations Peoples.

All activities in this resource have been written with the safety of both teacher and student in mind. Some, however, involve physical activity or the use of equipment or tools. **All due care should be taken when performing such activities**. To the maximum extent permitted by law, the author and publisher disclaim all responsibility and liability for any injury or loss that may be sustained when completing activities described in this resource.

The Publisher acknowledges ongoing discussions related to gender-based population data. At the time of publishing, there was insufficient data available to allow for the meaningful analysis of trends and patterns to broaden our discussion of demographics beyond male and female gender identification.

Contents

About this resource


LESSON 4.4
Relationships in ecosystems

LEARNING INTENTION

4.4.1 Interacting through feeding relationships

4.4 Exercise

SELECT YOUR PATHWAY

Remember and understand

Q1

NEW FOR

AUSTRALIAN CURRICULUM V9.0

JACARANDA
SCIENCE QUEST 9
AUSTRALIAN CURRICULUM
FOURTH EDITION

Developed by teachers for students

Tried, tested and trusted. Every lesson in the new *Jacaranda Science Quest* series has been carefully designed to support teachers and help students succeed by sparking their curiosity about the world around them.

Because both what and how students learn matter

Learning is personal

Whether students need a challenge or a helping hand, you'll find what you need to create engaging lessons.

Whether in class or at home, students can access carefully scaffolded and sequenced lessons to support in-depth Science Inquiry Skills development and step students through scientific inquiry with engaging interactive content and practical investigations. Automatically marked, differentiated question sets are all supported by detailed solutions — so students can get unstuck and progress!

Learning is effortful

Learning happens when students push themselves. With learnON, Australia's most powerful online learning platform, students can challenge themselves, build confidence and ultimately achieve success.

Learning is rewarding

Through real-time results data, students can track and monitor their own progress and easily identify areas of strength and weakness.

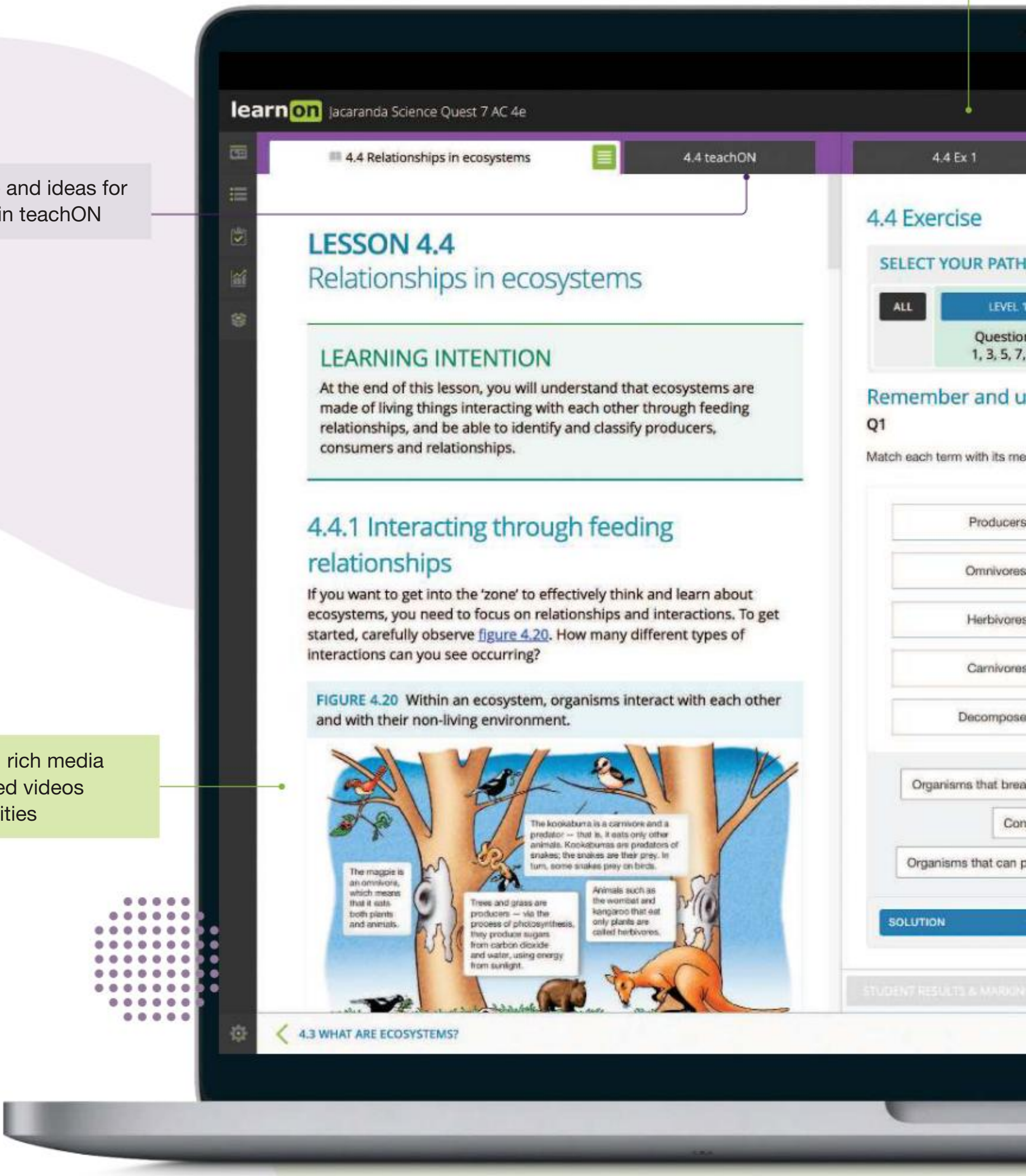
And for teachers, Learning Analytics provide valuable insights to support student growth and drive informed intervention strategies.

Learn online with Australia's most

Everything you need for each of your lessons in one simple view

- Trusted, curriculum-aligned content
- Engaging, rich multimedia
- All the teaching-support resources you need
- Deep insights into progress
- Immediate feedback for students
- Create custom assignments in just a few clicks.

Practical teaching advice and ideas for each lesson provided in teachON



LESSON 4.4
Relationships in ecosystems

LEARNING INTENTION

At the end of this lesson, you will understand that ecosystems are made of living things interacting with each other through feeding relationships, and be able to identify and classify producers, consumers and relationships.

4.4.1 Interacting through feeding relationships

If you want to get into the 'zone' to effectively think and learn about ecosystems, you need to focus on relationships and interactions. To get started, carefully observe figure 4.20. How many different types of interactions can you see occurring?

FIGURE 4.20 Within an ecosystem, organisms interact with each other and with their non-living environment.

The magpie is an omnivore, which means that it eats both plants and animals.

The kookaburra is a carnivore and a predator — that is, it eats only other animals. Kookaburras are predators of snakes; the snakes are their prey. In turn, some snakes prey on birds.

Trees and grass are producers — via the process of photosynthesis, they produce sugars from carbon dioxide and water, using energy from sunlight.

Animals such as the wombat and kangaroo that eat only plants are called herbivores.

4.3 WHAT ARE ECOSYSTEMS?

4.4 Exercise

SELECT YOUR PATH

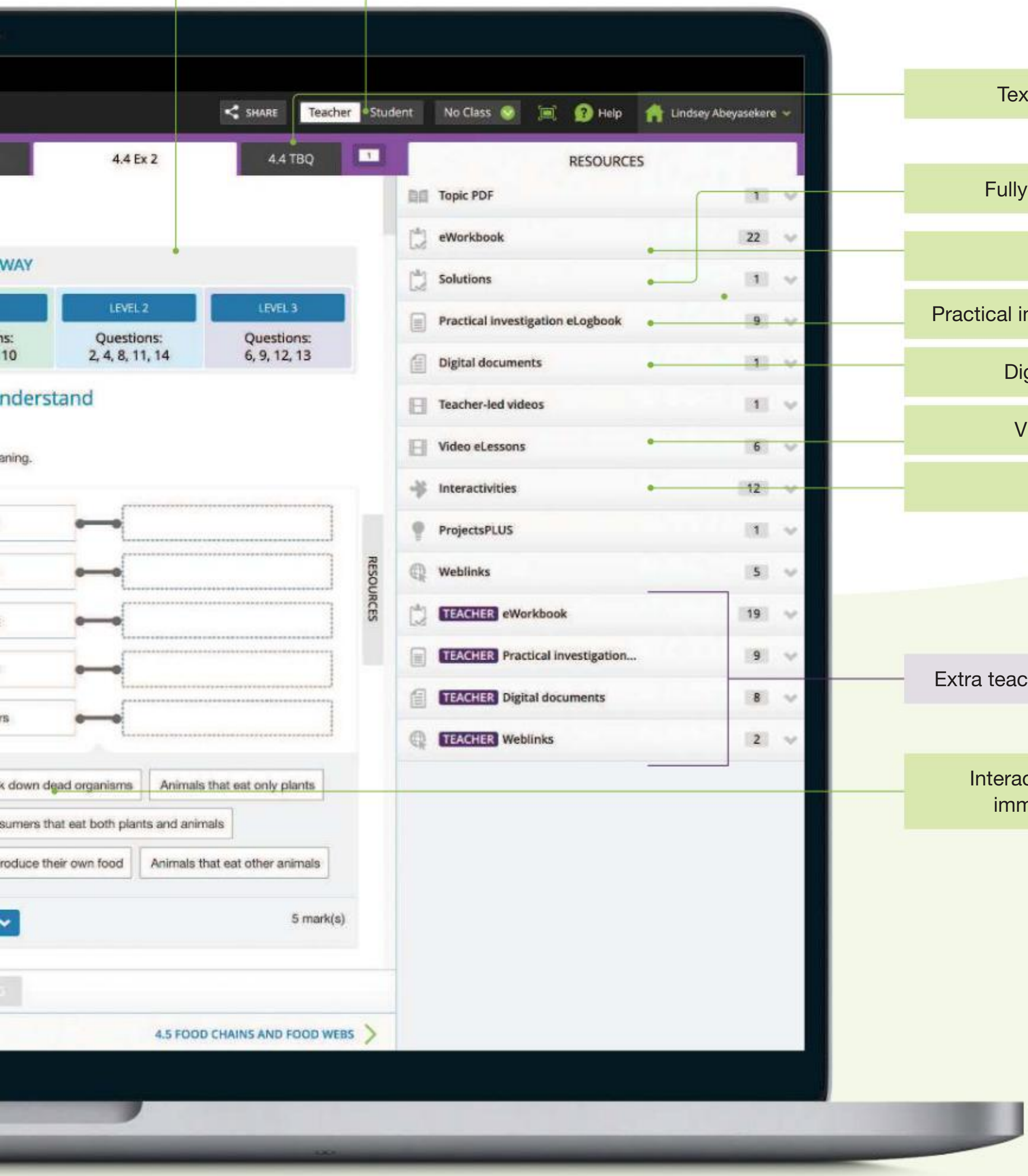
Remember and u

Q1

Match each term with its me

Reading content and rich media including embedded videos and interactivities

powerful learning tool, learnON



New! Quick Quiz questions
for skill acquisition

Differentiated question sets

Teacher and student views

Textbook questions

Fully worked solutions

eWorkbook

Practical investigation eLogbooks

Digital documents

Video eLessons

Interactivities

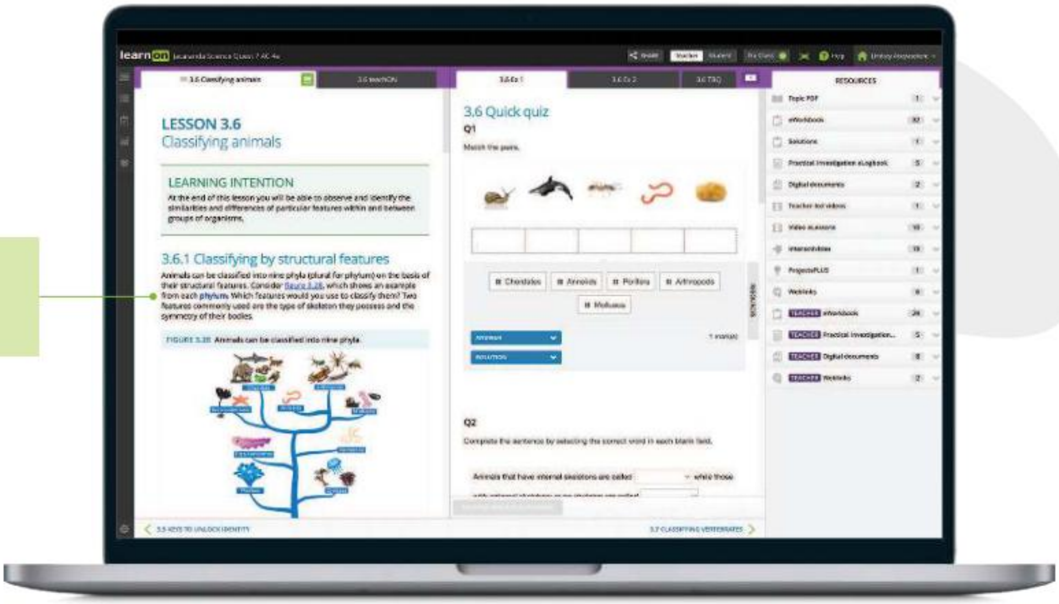
Extra teaching support resources

Interactive questions with immediate feedback

Get the most from your online resources

Online, these new editions are the complete package

Trusted Jacaranda theory, plus tools to support teaching and make learning more engaging, personalised and visible.



LESSON 3.6
Classifying animals

LEARNING INTENTION
At the end of this lesson you will be able to observe and identify the similarities and differences of particular features within and between groups of organisms.

3.6.1 Classifying by structural features
Animals can be classified into nine phyla (plural for phylum) on the basis of their structural features. Consider figure 3.28, which shows an example from each phylum. Which features would you use to classify them? Two features commonly used are the type of skeleton they possess and the symmetry of their bodies.

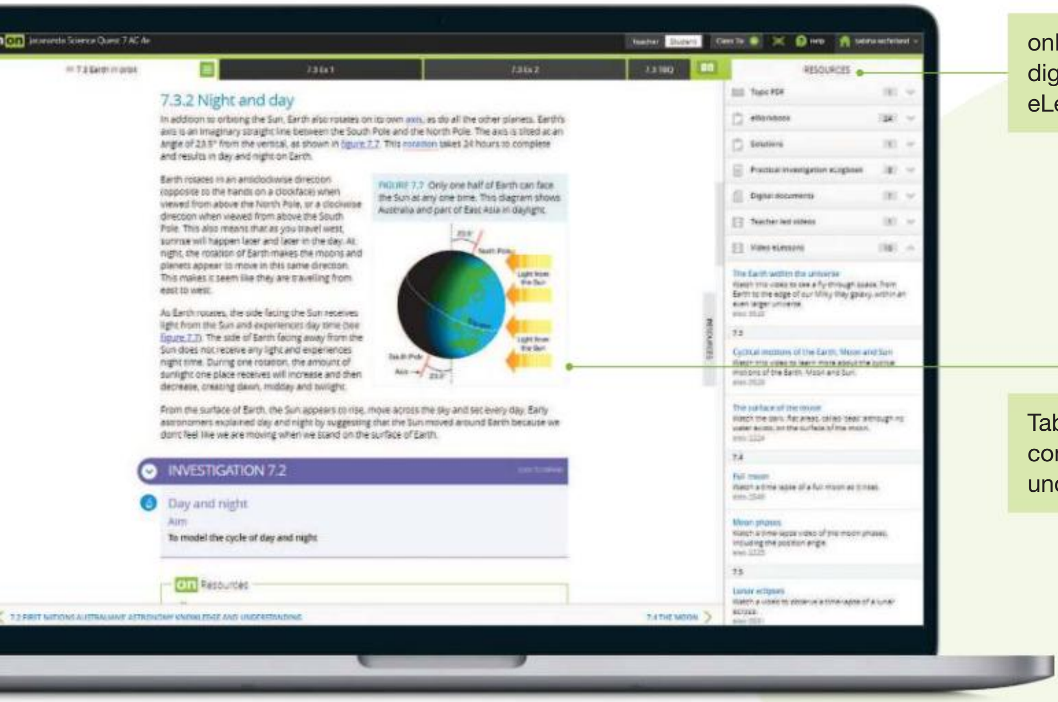
FIGURE 3.28 Animals can be classified into nine phyla

3.6 Quick quiz
Q1
Match the pairs.

Q2
Complete the sentence by selecting the correct word in each blank field.

Interactive glossary terms help develop and support scientific literacy.

onResources link to targeted digital resources including video eLessons and weblinks.

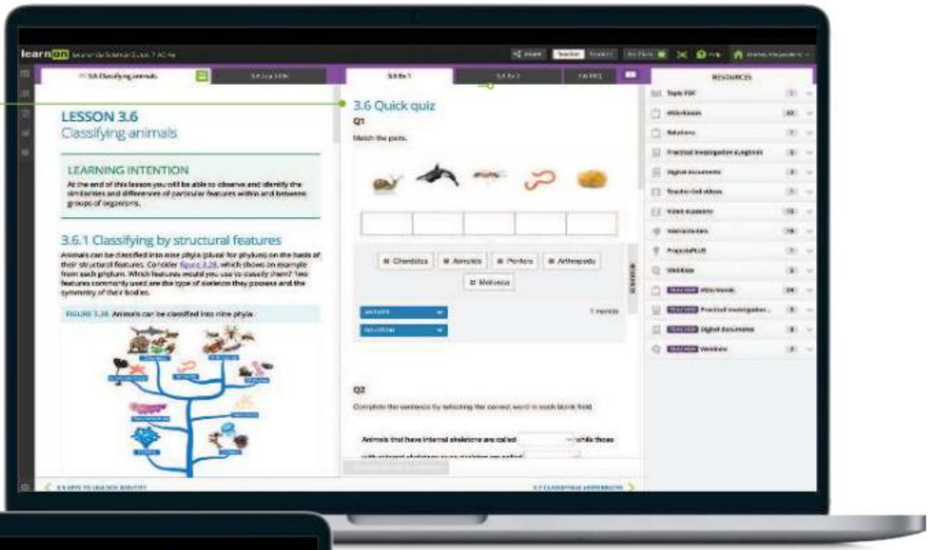


7.3.2 Night and day

INVESTIGATION 7.2
Day and night

Tables and images break down content, allowing students to understand complex concepts.

Brand new! Quick Quiz questions for skill acquisition in every lesson.



LESSON 3.6
Classifying animals

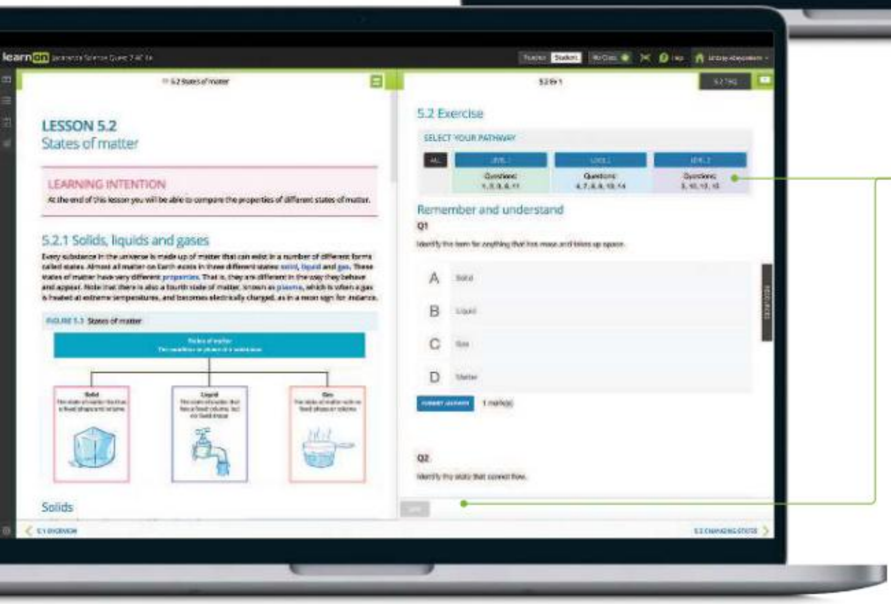
LEARNING INTENTION

3.6.1 Classifying by structural features

3.6 Quick quiz

Q1

Q2



LESSON 5.2
States of matter

LEARNING INTENTION

At the end of this lesson you will be able to compare the properties of different states of matter.

5.2.1 Solids, liquids and gases

5.2 Exercise

SELECT YOUR PATHWAY

Remember and understand

Q1

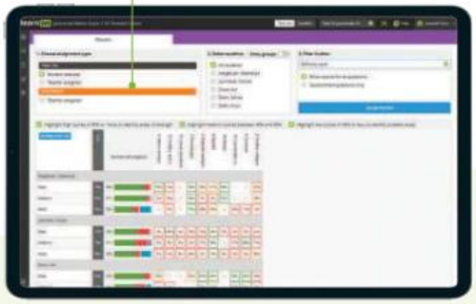
A Solid
B Liquid
C Gas
D Matter

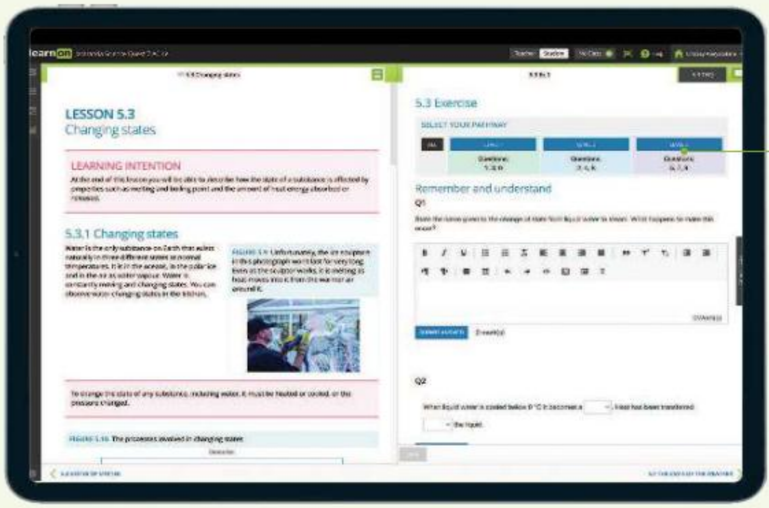
Q2

Solids

Three differentiated question sets, with immediate feedback in every lesson, enable students to challenge themselves at their own level.

Instant reports give students visibility into progress and performance.





LESSON 5.3
Changing states

LEARNING INTENTION

5.3.1 Changing states

5.3 Exercise

SELECT YOUR PATHWAY

Remember and understand

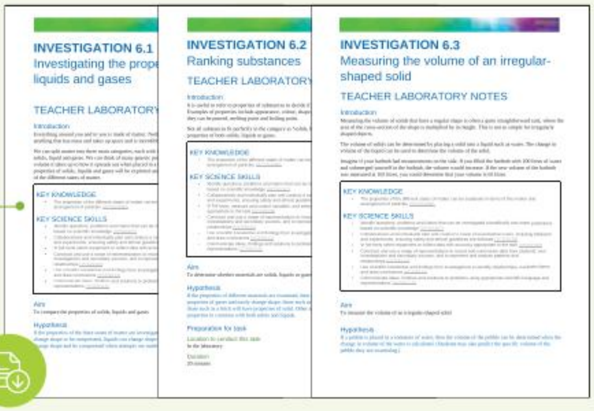
Q1

Q2

Every question has immediate, corrective feedback to help students overcome misconceptions as they occur and get unstuck as they study independently — in class and at home.

Practical Investigation eLogbook

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.



INVESTIGATION 6.1
Investigating the prope
liquids and gases

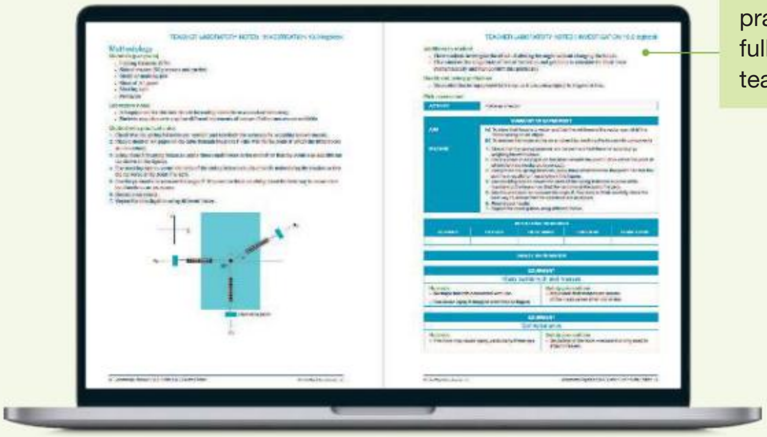
TEACHER LABORATORY

INVESTIGATION 6.2
Ranking substances

TEACHER LABORATORY

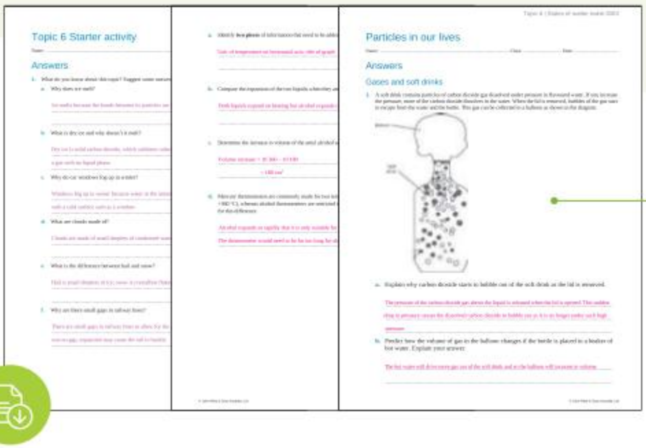
INVESTIGATION 6.3
Measuring the volume of an irregular-shaped solid

TEACHER LABORATORY NOTES



Enhanced practical investigation support includes practical investigation videos and an eLogbook with fully customisable practical investigations — including teacher advice and risk assessments.

eWorkbook



Topic 6 Starter activity

Answers

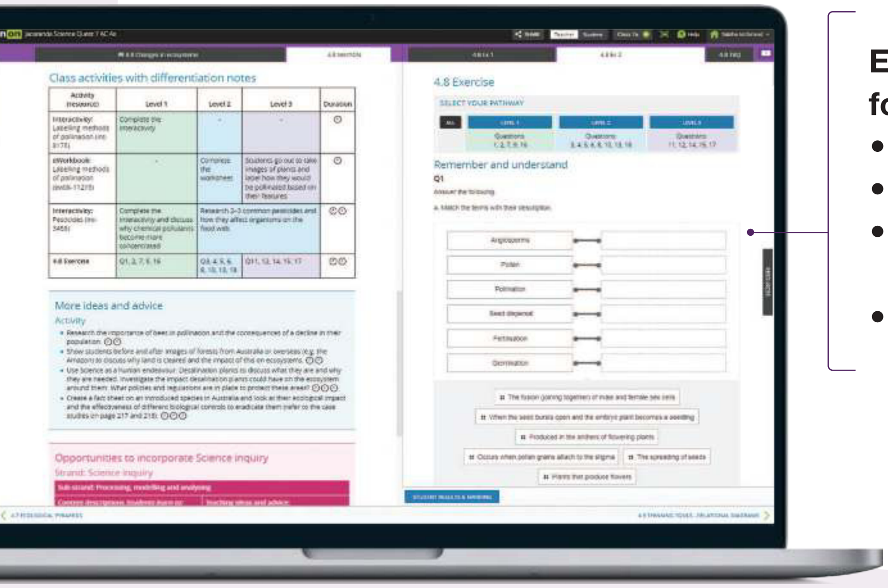
Particles in our lives

Answers

Gases and soft drinks

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.

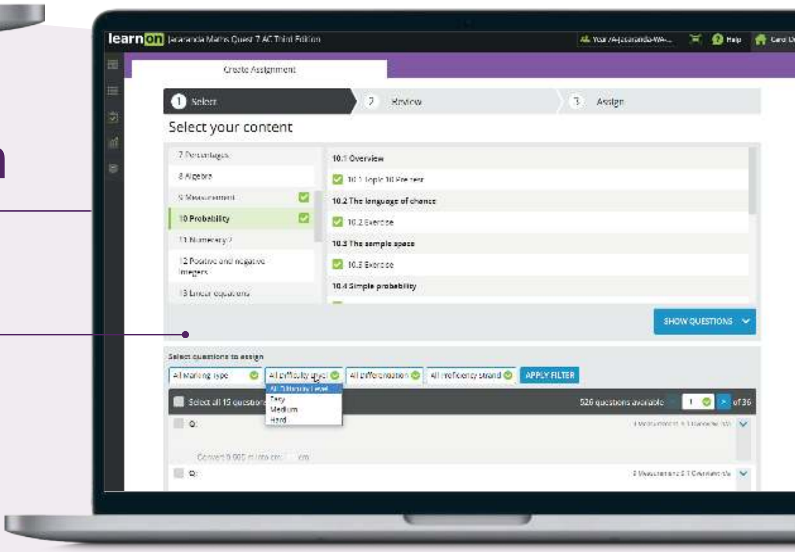
A wealth of teacher resources



Enhanced teaching-support resources for every lesson, including:

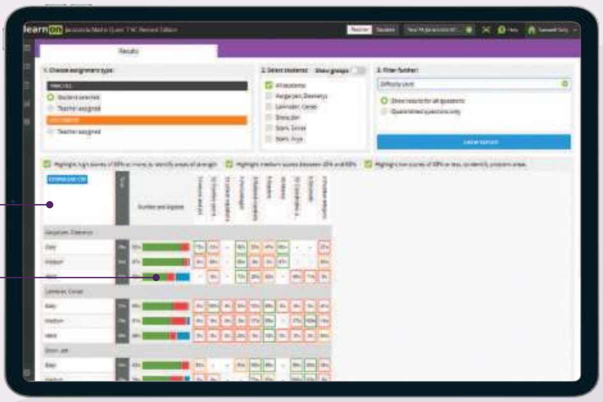
- work programs and curriculum grids
- practical teaching advice
- three levels of differentiated teaching programs
- quarantined topic tests (with solutions)

Customise and assign



An inbuilt testmaker enables you to create custom assignments and tests from the complete bank of thousands of questions for immediate, spaced and mixed practice.

Reports and results



Data analytics and instant reports provide data-driven insights into progress and performance within each lesson and across the entire course.

Show students (and their parents or carers) their own assessment data in fine detail. You can filter their results to identify areas of strength and weakness.

Acknowledgements

The authors and publisher would like to thank the following copyright holders, organisations and individuals for their assistance and for permission to reproduce copyright material in this book.

© Australian Curriculum, Assessment and Reporting Authority (ACARA) 2010 to present, unless otherwise indicated. This material was downloaded from the Australian Curriculum website (www.australiancurriculum.edu.au) (Website) (accessed 27 May 2022) and was not modified. The material is licensed under CC BY 4.0 (https://creativecommons.org/licenses/by/4.0). Version updates are tracked in the 'Curriculum version history' section on the 'About the Australian Curriculum' page (http://australiancurriculum.edu.au/about-the-australian-curriculum/) of the Australian Curriculum website.

ACARA does not endorse any product that uses the Australian Curriculum or make any representations as to the quality of such products. Any product that uses material published on this website should not be taken to be affiliated with ACARA or have the sponsorship or approval of ACARA. It is up to each person to make their own assessment of the product, taking into account matters including, but not limited to, the version number and the degree to which the materials align with the content descriptions and achievement standards (where relevant). Where there is a claim of alignment, it is important to check that the materials align with the content descriptions and achievement standards (endorsed by all education Ministers), not the elaborations (examples provided by ACARA).

Images

• © a. Dudarev Mikhail/Shutterstock; b. Alberto Loyo/Shutterstock: **401** • © Ivan Kurmyshov/Adobe Stock: **446** • © Judith/Adobe Stock Photos: **139** • © a. Alexyz3d/Shutterstock; b. Vadim Petrakov/Shutterstock: **401** • © pattamod - stock.adobe.com: **444** • © Luis Line/Shutterstock: **382** • © Oksana Bessonova/Adobe Stock: **444** • © +NatureStock - stock.adobe.com: **246** • © James Insogna/Adobe Stock: **509** • © a. Mr.Somchai Sukkasem/Shutterstock; b. Roschetzky Photography/Shutterstock; c. Glenn R. Specht-grs photo/Shutterstock: **422** • © Andrew Zarivny/Shutterstock: **577** • © Magdalena Paluchowska/Shutterstock: **250** • © Nandalal - stock.adobe.com: **502** • © Anastasiia/Adobe Stock: **446** • © No formal credit line required: **230** • © Christopher Boswell/Adobe Stock: **537** • a. © Kicky_princessShutterstock; b. © attaphongShutterstock: **505** • © FABRICE COFFRINI/Getty Images: **112** • © Brain light/Alamy Stock Photo: **176** • © NIAID-RML/Alamy Stock Photo: **204** • © Rafael Ben-Ari/Alamy Stock Photo: **3** • © sciencephotos/Alamy Stock Photo: **488** • © Terry Oakley/Alamy Stock Photo: **490** • © US NATIONAL ARCHIVES/SCIENCE PHOTO LIBRARY: **9** • © Wayne Lynch/Alamy Stock Photo: **477** • © STEVE GSCHMEISSNER/Getty Images: **74** • © By National Institutes of Health - http://www.alzheimers.org/rmedia/IMAGES/HIGH/PET20YEAROLD_HIGH.JPG: Public Domain, https://commons.wikimedia.org/w/index.php?curid=5242545, **324** • © By https://www.scientificanimations.com - https://www.scientificanimations.com/wiki-images/: CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=86436446, **203** • © Source: Creative Commons: **8** • © Emily Fobert: **247** • © Getty Images: **582** • © AnitaVDB/Getty Images: **536** • © Bloomberg/Getty Images: **574** • © BSIP/UIG/Getty Images: **498** • © HANK MORGAN/SCIENCE PHOTO LIBRARY: **484** • © Science Photo Library - STEVE GSCHMEISSNER./Getty Images: **67** • © Science Picture Co/Alamy Stock Photo: **203** • © STEVE GSCHMEISSNER/Science Photo Library/Alamy Stock Photo: **260** • © Tsidvintsev/Getty Images: **525** • © VectorMine/Shutterstock: **111** • © Pictorial Press Ltd/Alamy Stock Photo: **6** • © PUBLIC HEALTH ENGLAND/SCIENCE PHOTO LIBRARY: **321** • © Science Picture Co/Alamy Stock Photo: **189** • © sciencephotos/Alamy Stock Photo/Alamy: **509** • © Sport In Pictures/Alamy Stock Photo: **15** • © STEVE GSCHMEISSNER/SCIENCE PHOTO LIBRARY: **181** • © Alex Mit/Shutterstock: **273** • © Andy Baker/Newspix: **197** • © David Crosling/Newspix: **275** • © News Ltd/Newspix: **197** • © The John Curtin School of Medical Research: ANU, **209** • © DR PETRA WALE: **284** • © DR Petra Wale: **284** • © Andrew J. Martinez/Science Photo Library: **231** • © Wiley art: **76** • © DANTE FENOLIO/Science Photo Library: **125** • © SCIENCE PHOTO LIBRARY: **168** • © Vincent Moncorge/Science Photo Library (SPL): **542** • STEVE

GSCHMEISSNER/SCIENCE PHOTO: **70** • © 3Dstock/Shutterstock: **125** • © 895Studio/Shutterstock: **264** • © a. Monkey Business Images/Shutterstock; b. bezikus/Shutterstock: **279** • © a. OneSideProFoto/Shutterstock; b. Iryna Inshyna/Shutterstock: **276** • © a. TanyaJoy/Shutterstock; b. bezikus/Shutterstock;: **279** • © a. Zdravinjo/Shutterstock; b. Suzanne Tucker/Shutterstock: **262** • © Africa Studio/Shutterstock: **364** • © Alexandr Makarov/Shutterstock: **511** • © Alexey Boldin/Shutterstock: **586** • © AnastasiyaKomkova/Shutterstock: **374** • © Andrew E Gardner/Shutterstock.com: **235** • © Antonov Maxim/Shutterstock: **277** • © bezikus/Shutterstock: **280** • © bluehand/Shutterstock: **250** • © Brandon Alms/Shutterstock: **251** • © Cassandra Cury/Shutterstock: **240** • © Catalin Petolea/Shutterstock: **368** • © ChameleonsEye/Shutterstock: **94** • © Chepko Danil Vitalevich/Shutterstock: **369** • © chinahbzyg/Shutterstock: **248** • © Chris Parypa Photography/Shutterstock: **467** • © Constantine Androsoff/Shutterstock: **424** • © Corona Borealis Studio/Shutterstock: **186, 405** • © Cre8 design/Shutterstock: **198** • © David Grabham/Carol Grabham: **483** • © Denis Zhitnik/Shutterstock: **402** • © Designua/Shutterstock: **177, 463** • © diluck/Shutterstock: **266** • © Dmitry Kovalchuk/Shutterstock: **11** • © Dmitry Lobanov/Shutterstock: **147** • © Elena Korn/Shutterstock: **5** • © Emre Terim/Shutterstock: **229** • © engel.ac/Shutterstock: **423** • © Everett Collection/Shutterstock: **328** • © Ewa Studio/Shutterstock: **26** • © goodluz/Shutterstock: **2** • © Henrik Larsson/Shutterstock: **172, 225** • © Irina Markova/Shutterstock: **247** • © Ivan_Shenets/Shutterstock: **75** • © Jacaranda Science Quest 8 for the Victorian Curriculum 2e learnON & print 9780730387183: **248** • © Jason Patrick Ross/Shutterstock: **395** • © Jason Salmon/Shutterstock: **344** • © Jeff Lueders /Shutterstock: **449, 470** • © Jose Luis Calvo/Shutterstock: **277** • © Kateryna Kon/Shutterstock: **275** • © KP Arts/Shutterstock: **207** • © Lebendkulturen.de/Shutterstock; Designua/Shutterstock: **227** • © Lizard /Shutterstock: **536** • © metamorworks/Shutterstock: **426** • © mffoto/Shutterstock: **8** • © Microgen/Shutterstock: **124** • © Miha Creative/Shutterstock: **393** • © mishabender/Shutterstock: **4** • © Mita Stock Images/Shutterstock: **270** • © Monkey Business Images/Shutterstock: **279** • © Monkey Business Images/Shutterstock: **283** • © Nasky/Shutterstock: **351** • © Natursports/Shutterstock: **475** • © NikomMaelao Production/Shutterstock: **179** • © octoflash/Shutterstock: **237** • © Olha1981/Shutterstock: **424** • © OSweetNature/Shutterstock: **493** • © Peter Waters/Shutterstock: **251** • © photong/Shutterstock: **368** • © r.classen/Shutterstock: **545** • © Rattiya Thongdumhyu/Shutterstock; Iakov Filimonov/Shutterstock: **229** • © Rich Carey/Shutterstock: **374** • © Richard Whitcombe/Shutterstock: **248** • © Rusla Ruseyn/Shutterstock: **237** • © Saulius DamuleviciusShutterstock: **145** • © Science Photo Library/Shutterstock: **285** • © Smokebuster/Shutterstock: **416** • © solarseven/Shutterstock: **224** • © Steve Cymro /Shutterstock: **462** • © Syda Productions/Shutterstock: **381** • © tammykayphoto/Shutterstock: **390** • © Tefi/Shutterstock: **280** • © THEJAB/Shutterstock: **487** • © Toa55/Shutterstock: **35** • © Tomislav Pinter /Shutterstock: **483** • © tsuneomp/Shutterstock: **417** • © vchal/Shutterstock: **261** • © VectorMine/Shutterstock: **425** • © Vera Larina/Shutterstock: **177** • © Vladimir Staykov/Shutterstock: **265** • © vrx/Shutterstock: **469** • © WFPA/Alamy Stock Photo: **111** • © whitehoune /Shutterstock: **442** • © Zoltan Major/Shutterstock: **389** • © © Sashkin/Shutterstock: **256** • shutterstock/doublep4556: vii• © Lana Veshta/Shutterstock: **596** • © CATH WADFORTH: DEPT. OF ZOOLOGY/UNIVERSITY OF HULL/SCIENCE PHOTO LIBRARY, **181** • © Logger Pro software screenshot: **44** • © Vernier Software & Technology: **43** • Alamy: **477** • © Pictorial Press/Alamy Stock Photo: **331** • Getty Images: **195** • © 0meer /Shutterstock: **491** • © 3Dsculptor/Shutterstock: **382** • © a. DAntes Design/Shutterstock; b. Andre Nantel/Shutterstock: **282** • © a. Designua/Shutterstock: **262** • © a. Designua/Shutterstock; b. Macrovector/Shutterstock: **245** • © a. Lauris A/Shutterstock; b. ArTono/Shutterstock; c. Jon Rehg/Shutterstock: **400** • © a. New Africa/Adobe Stock Photos; b.PiyawatNandeenoparit/Adobe Stock Photos; c.marcinmaslowski/Adobe Stock Photos; d.Gary Perkin/Adobe Stock Photos: **426** • © a. No formal credit line required; b. Kateryna Kon/Shutterstock: **258** • © a. Ody_Stocker/Shutterstock; b. BioFoto/Shutterstock: **257** • © a. Photo Researchers/Alamy Stock Photo; b. nechaevkon/Shutterstock; c. Albert Yuralaits/Alamy Stock Photo; d. Riccardo Mayer/Shutterstock: **172** • © a.danylyukk/Adobe Stock Photos; b.Tomasz Bidermann: **404** • © a.khunkorn/Adobe Stock Photos; b.LifetimeStock/Shutterstock: **404** • © a.SoulMyst/Adobe Stock Photos; b.Oksana/Adobe Stock Photos: **400** • © Aapsky/Adobe Stock: **447** • © Aaron Amat/Shutterstock: **65** • © AC NewsPhoto/Alamy Stock Photo: **205** • © AkeSak/Shutterstock: **64** • © Amanda Murfitt/John Wiley & Sons: **564** • © Andrea Danti/Shutterstock: **141** • © Anna Om/Shutterstock: **486** • © Anton Prohorov /Shutterstock: **519** • © Antonioguillem/Adobe Stock: **480** • © areeya_ann/Shutterstock: **105** • © bancha_photo /Shutterstock: **491** • © Belish/Shutterstock: **578** • © Bettmann/Bettmann/Getty Images: **197** • © BOLDG/Shutterstock: **543** • © Brian A Jackson/Shutterstock: **18** • © Can Balcioglu/iStockphoto: **449** • © Catmando/Shutterstock: **252** • © CDC/iStock/Getty Images: **196** •

© chaipanya/Shutterstock: **180** • © Chepko Danil Vitalevich/Shutterstock: **390** • © chromatos/Shutterstock: **325** • © CLAUS LUNAU/Science Photo Library (SPL): **469** • © Computer generated molecular model showing the crystal structure of human interferon beta: **347** • © Cosmin Manci/Shutterstock: **202** • © Courtesy of Thennicke: **578** • © D. Parer & E. Parer-Cook/ Minden Pictures/Alamy Stock Photo: **252** • © Daniele COSSU/Shutterstock: **417** • © danylyukk1/Shutterstock: **399** • © David H. Lewis/E+/Getty Images: **371** • © Dean Turner/E+/Getty Images: **28** • © Dennis Diatel/Shutterstock: **329** • © Department of the Environment and Energy: **568** • © Designua/Shutterstock: **98, 228, 396** • © Dimoza/Shutterstock: **386** • © DisobeyArt/Shutterstock: **394** • © Distribution of deaths and injuries caused by the Hiroshima bombing in 1945: **333** • © Don Bayley/Getty Images: **529** • © Dudarev Mikhail: **431** • © Edward Gooch/Hulton Archive/Getty Images: **196** • © Emre Terim/Shutterstock: **228** • © Eraxion/Getty Images: **499** • © Erik Cox Photography/Shutterstock: **238** • © ESB Professional/Shutterstock: **65** • © EYE OF SCIENCE/Science Photo Library: **223** • © Ezume Images/Shutterstock: **303** • © Featureflash Photo Agency/Shutterstock: **110** • © Figure 29.14 c from Principles of Anatomy & Physiology by Tortora & Grabowski: **10th** edition, © 2003, John Wiley & Sons, Inc. This material is reproduced with permission of John Wiley & Sons, Inc., **268** • © Figure 29.14e from Principles of Anatomy & Physiology by Tortora & Grabowski: **10th** edition © 2003, John Wiley & Sons, Inc. This material is reproduced with permission of John Wiley & Sons, Inc., **268** • © focal point/Shutterstock: **345** • © Fox Photos/Getty Images: **520** • © freevideophotoagency /Shutterstock: **448** • © fztommy /Shutterstock: **549** • © G W Willis: Md/Photodisc/Getty Images, **177** • © GE Appliances: **566** • © Greenhorn1/Wikimedia Commons; Chlorine gas in a bottle; Spilled salt and saltshaker on blue background: **349** • © Greg Brave/Adobe Stock: **576** • © gritsalak karalak/Shutterstock: **468** • © Gudellaphoto/Adobe Stock: **514** • © Ian Munro/Newspix: **139** • © Id512/Adobe Stock: **447** • © Image Addict: **557** • © Imagine Earth Photography/Shutterstock: **413** • © Inna Bigun/Shutterstock: **415** • © Innnot /Shutterstock: **410** • © italianestro /Shutterstock; Shutterstock: **516** • © iurii/Shutterstock: **443** • © James A. Sullivan: **210** • © James Steidl/Shutterstock: **501** • © Jane Dempster/Newspix: **474** • © Jason Benz Bennee/Shutterstock; Marion Kaplan/Alamy Stock Photo: **376** • © javarman/Shutterstock: **201** • © Jezper/Shutterstock: **179** • © Jsseng/Shutterstock: **231** • © juan lopez ruiz/Alamy Stock Photo: **167** • © Justin Horrocks/E+/Getty Images: **220** • © Kalfa/Shutterstock: **180** • © kanvag /Shutterstock: **548** • © Kateryna Kon/Shutterstock: **191** • © LANL/SCIENCE SOURCE/Science Photo Library (SPL): **441** • © Learnosity Ltd.: **367** • © Lidiia/Shutterstock: **594** • © litchima/Shutterstock: **21** • © Lurin/Shutterstock/Shutterstock: **251** • © Magic mine/Shutterstock: **123** • © magnetix/Shutterstock: **304** • © Maksym Gorpenyuk/Shutterstock: **370** • © Marcin Balcerzak/Shutterstock: **323** • © Marochkina Anastasiia/Shutterstock: **259** • © Mary Terriberry/Shutterstock: **383** • © Microsoft Corporation: **36, 37, 39, 40, 47** –49• © Mint Images - Frans Lanting/Getty Images; Ye.Maltsev/Shutterstock: **227** • © Mix and Match Studio/Adobe Stock; SHOTPRIME STUDIO/Adobe Stock; chathuporn/Adobe Stock: **521** • © Monkey Business Images/Shutterstock: **451** • © Morrhigan/Getty Images: **232** • © Nasky/Shutterstock.com: **370** • © National Library of Australia: nla.obj-148825818, **451** • © Neale Taylor: **6** • © Nerthuz/Shutterstock: **135** • © NicoElNino/Adobe Stock Photos: **394** • © No formal credit line required: **230, 236, 240, 249, 257, 259, 263** –268, **281, 282** • © No formal credit line required;: **238, 239** • © No formal credit line required; Stephen Aveling-Rowe/Shutterstock: **239** • © Oleksandr Riabokin /Shutterstock: **435** • © Olha Rohulya/Alamy Stock Photo: **9** • © paffy/Adobe Stock: **476** • © Paolo Cremonesi/Adobe Stock Photos: **362** • © Pascale Warnant: **16** • © Patrick Riviere/Getty Images: **75** • © Pavel1964/Shutterstock: **29** • © Pepermpron/Shutterstock: **75** • © Pepsi can;Coca-Cola can\backslash { }n ; Sprite can; Coca-Cola zeo sugar can\backslash { }n ; Pepsi MAX can: **150** • © Peshkova/Shutterstock: **541** • © Petra Wale: **284** • © Philippe Voisin/Alamy Stock Photo: **188** • © PhotoHouse/Shutterstock: **70** • © photong/Shutterstock: **22** • © PR Image Factory/Shutterstock: **472** • © Prasit Rodphan/Alamy Stock Photo: **205** • © PUBLIC HEALTH ENGLAND/SCIENCE PHOTO LIBRARY: **326** • © Rachel Skinner: **275** • © RAGUET H./BSIP/Alamy Stock Photo: **324** • © Reid Dalland/Adobe Stock: **478** • © Rich Carey/Shutterstock: **414** • © Rock Art Australia: **321** • © Roman Zaiets/Shutterstock: **106** • © royaltystockphoto.com/Shutterstock: **12** • © rumruay/Shutterstock: **283** • © Sally Harding/Newspix: **210** • © Sawatd340/Shutterstock: **228** • © Scharfsinn/Shutterstock: **429** • © sciencepics/Shutterstock: **322** • © Sebastian Loram/Alamy Stock Photo: **487** • © SHONE/Gamma-Rapho/Getty Images: **329** • © Shutterstock/swa182/Wiley Media Manager: **485** • © smx12/Shutterstock: **347** • © solar22/Shutterstock: **107** • © Soleil Nordic/Shutterstock: **189** • © Source: Best Research-Cell Efficiencies: National Renewable Energy

Laboratory. Public Domain., **578** • © Source: David Leafe: Explosive truth about Chernobyl: As the heart-stopping climax to the hit TV drama about the 1986 nuclear disaster reveals, a series of blunders triggered the impossible, **2019** . The Daily Mail., **329** • © Source: Howard University General Chemistry An Atoms First Approach: **2022** . LibreTexts., **322** • © Source: https://www.phys.unsw.edu.au/jw/didjeridu.html.: **478** • © Source: National Immunisation Program Schedule: Australian Government Department of Health and Aged Care., **198** • © Source: Public Domain: **421** • © Source: Retrieved from: http://maptd.com/new-fukushima-contamination-map/.: **330** • © Source: Robert A. Rohde et al.: Combustion reaction of methane, **2013** . Wikimedia Commons. Public Domain., **347** • © Source: Wiley Art: **126, 127, 129** –131, **133, 136, 140, 144, 146, 151, 154, 175, 178, 179, 182, 183, 187, 188, 190, 213, 214** • © Source: Wiley Art.; Kuki Ladron de Guevara /Shutterstock: **494** • © Source: Wiley Art; Mauritus Image; Anticiclo/Shutterstock; Jose Arcos Aguilar/Shutterstock: **379** • © Source: © Copyright Commonwealth of Australia 2012: Bureau of Meteorology, **416** • © SpeedKingz/Shutterstock: **63** • © Stocktrek Images/Alamy Stock Photo: **189** • © Stuart Taylor/Shutterstock: **527** • © surasak jailak /Shutterstock: **423** • © Susan Flashman/Shutterstock: **252** • © SVETLANA VERBINSKAYA/Shutterstock: **245** • © Tartila/Adobe Stock Photos: **76** • © TebNad /Shutterstock: **523** • © Teguh Mujiono/Shutterstock: **138** • © thad/E+/Getty Images: **372** • © The John Curtin School of Medical Research: ANU, **209** • © TIM VERNON: LTH NHS TRUST/SCIENCE PHOTO LIBRARY, **1** • © Titikul_B/Shutterstock: **92** • © Tomacco/Shutterstock: **386** • © ttsz/iStock/Getty Images: **465** • © Valentyn640/Adobe Stock: **447** • © vector Icon of the structure of the DNA molecule. Spiral Deoxyribonucleic acid (DNA) with formula and description of components: cytosine: guanine, adenine, thymine, nitrogenous base of DNA., **347** • © VectorMine/Shutterstock: **87, 106, 352** • © Vernier Software & Technology: **44, 45** • © Volodymyr Burdiak /Shutterstock: **472** • © wang song/Shutterstock: **577** • © wawritto/Shutterstock: **16** • © WEHI (Walter and Eliza Hall Institute of Medical Research): **209** • © Werner Langer/John Wiley & Sons: **488** • © Wiley art: **169** • © World History Archive/Alamy Stock Photo: **208** • © yurok/Shutterstock: **343** • © Scanrail/Adobe stock: **524** • © Daniel Prudek/Adobe Stock: **445** • © German Skydiver/Adobe Stock: **445** • © Melinda Nagy/Adobe Stock: **445** • © New Africa/Adobe Stock: **445** • © No formal credit line required: **269** • © Prostock-studio/Adobe Stock: **445** • © ProstoSvet/Adobe Stock: **445** • © Sergey Novikov/Adobe Stock: **445** • © Westend61/Adobe Stock: **445**

Every effort has been made to trace the ownership of copyright material. Information that will enable the publisher to rectify any error or omission in subsequent reprints will be welcome. In such cases, please contact the Permissions Section of John Wiley & Sons Australia, Ltd.

1 Investigating science

LESSON SEQUENCE

SCIENCE INQUIRY AND INVESTIGATIONS

Science inquiry is a central component of the Science curriculum. Investigations, supported by a **Practical investigation eLogbook** and **teacher-led videos**, are included in this topic to provide opportunities to build Science inquiry skills through undertaking investigations and communicating findings.

LESSON
1.1 Overview

Hey students! Bring these pages to life online

Watch videos

Engage with interactivities

Answer questions and check results

Find all this and MORE in jacPLUS

First Nations Australian readers are advised that this lesson and relevant resources may contain images of and references to people who have died.

1.1.1 Introduction

You can find out a lot about science from books and the internet, but the best way to learn about it is to conduct your own scientific investigations. Whether you are a professional scientist, or a student at school or home, every investigation starts with a question — and a plan.

In this topic, and throughout your science studies this year, you will develop your skills as a scientist. While science inquiry starts with a question, to understand the natural world you need to make predictions (hypotheses) that you can test with experiments or observations. These tests need to be planned and carried out using the scientific method. This ensures your results are reliable and robust. If the results of your investigation do not support your hypothesis, it does not mean your investigation is a failure, it just means you need to change your hypothesis. Scientific knowledge is based on refining hypotheses and experimental methods, identifying relationships, evaluating claims, drawing conclusions and then communicating this knowledge appropriately.

FIGURE 1.1 The best way to understand science is to conduct your own investigations.

on Resources

Video eLesson Australia's top scientists (eles-1079)

Watch this video eLesson to hear what inspires Australian scientists. The scientists in this video have been recognised as leaders in their fields of research and are elected fellows of the Australian Academy of Science.

Weblink The Australian Academy of Science

1.1.2 Think about science

1. How do all scientific investigations begin?
2. Which great medical discovery was helped along by a single teardrop?
3. Why is planning so important to a scientific investigation?
4. What is a controlled variable?
5. How can a spreadsheet save you time in a scientific investigation?
6. How does a data logger improve the gathering of data?
7. Which scientific discovery do you think has changed the world the most?

1.1.3 Science inquiry

Scientific inquiry starts with a question

Questions, questions, questions! That's what scientific research is all about — questions such as:

- How old is the universe?
- Why did dinosaurs become extinct?
- What is the smallest particle inside an atom?
- How can the common cold be cured?

Every science investigation, whether it is conducted in a government research laboratory, a hospital, a museum or a space shuttle, begins with at least one question.

FIGURE 1.2 What is the best shape for a boomerang?

Although you are unlikely to even attempt to try to answer the preceding questions in your school science laboratory, there are many scientific questions that you can answer. Here are some examples:

- Does an audience affect the performance of an athlete?
- What is the best shape for a boomerang?
- Which type of soil do earthworms prefer?
- How do heating and cooling affect the way that rubber stretches?

What can I investigate?

1. In groups, brainstorm a list of questions that could be answered by doing an investigation in a school science laboratory. Record all the questions that are suggested even if they seem silly or difficult. The examples above might help you to think of some other ideas.
2. From your list, remove any questions that the group feels are not likely to be answered because of a lack of the right equipment. Keep a record of the questions that are removed for this reason to submit to your teacher. You may find that equipment you thought was unavailable can be obtained, or that the question can be answered with different equipment.
3. From your list, remove any questions that the group feels would be unsafe to try to answer, or that would be cruel to animals.
4. Submit the remaining questions to your teacher for discussion by the whole class.

on Resources

eWorkbooks	Topic 1 eWorkbook (ewbk-12189) Student learning matrix (ewbk-12191) Starter activity (ewbk-12192)
Solutions	Topic 1 Solutions (sol-1135)
Practical investigation eLogbook	Topic 1 Practical investigation eLogbook (elog-2237)

LESSON
1.2 Scientists through the ages

LEARNING INTENTION

At the end of this lesson you will be able to explain how scientific understanding is open to scrutiny and is refined over time, often relying on developments in technology and technological advances.

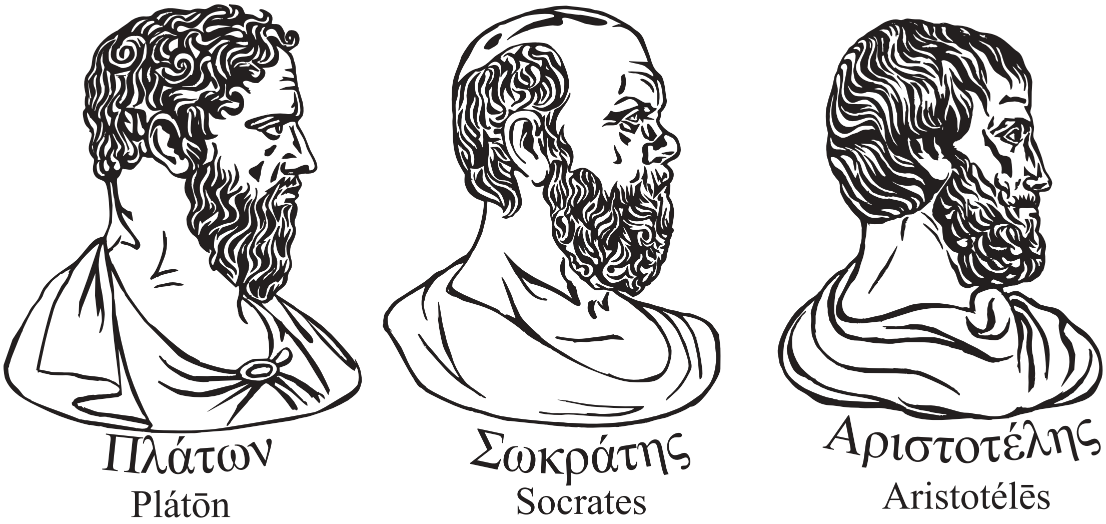
1.2.1 Early scientists

When you think of scientists, what image do you have in your mind? Albert Einstein? Marie Curie? Unfortunately, scientists are sometimes poorly portrayed as stereotypes in the media. The fact is, scientists are normal people who live similar lives to the rest of us.

Before putting on ‘the shoes of a scientist’ to conduct your own investigation, it’s worth asking the question ‘What, or who, is a scientist?’ The answer to that question has been changing constantly for more than 2000 years.

The ancient Greek ‘scientists’ were very different from the scientists of today. They were called philosophers. The ancient Greek philosophers were curious and made accurate observations but they didn’t perform experiments to test their ideas. They were thinkers, who tried to explain the structure of matter, the Sun and the night sky. They walked the streets, discussing their ideas about nature, politics and religion with each other and their followers.

FIGURE 1.3 The Ancient Greek philosophers were some of the first people to question the nature of the world.



Although the ideas of the ancient Greek philosophers were limited by a lack of technology, they provided a stepping stone for the more recent growth in scientific knowledge.

One of the early Greek philosophers was Democritus who, in about 500 BC, suggested that all matter was made of tiny particles.

Aristotle, born in Greece 14 years after the death of Democritus, reasoned that all matter was composed of four elements — earth, air, fire and water. About 2000 years later, Scottish scientist Joseph Black (1728–1798) discovered a fifth ‘element’. He had discovered a new gas that he called ‘fixed air’. We now call the gas carbon dioxide and know that it is not an element.

DISCUSSION

Find out about the Hippocratic Oath and discuss why it is important to medical practitioners.

There are many other examples, including Hippocrates, born in the same year as Democritus, who taught his medical students to use observation rather than theory to diagnose illness. Hippocrates is regarded by many as the father of modern medicine.

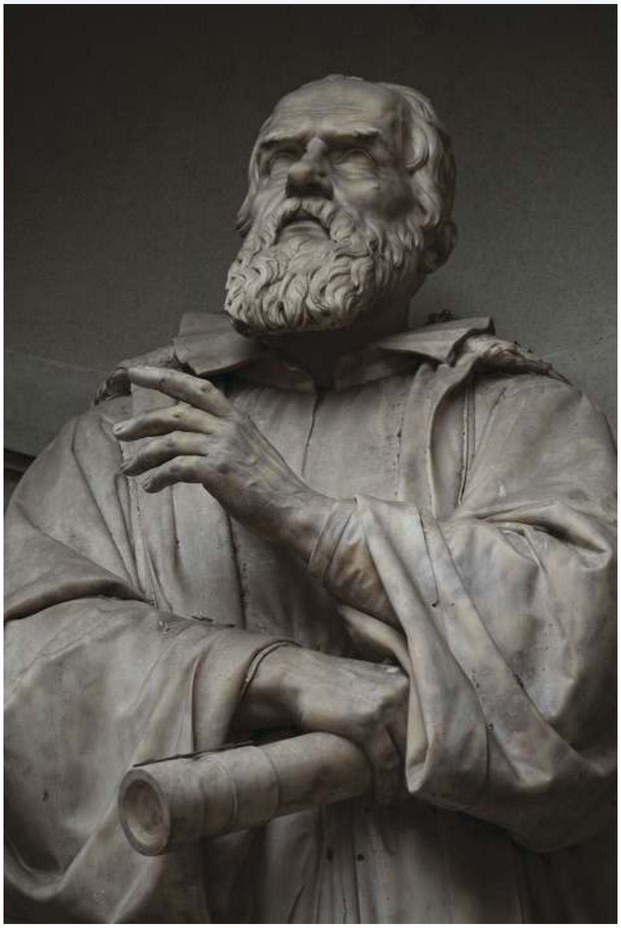
Almost without exception, present-day scientific discoveries depend on work done previously by other scientists.

1.2.2 The scientific revolution

The way in which scientists worked changed greatly during the lifetime of Galileo Galilei (1564–1642), who is probably best known for being the first person to use a telescope to study the Moon, planets and stars. Galileo also performed many experiments to investigate the motion of objects on the Earth's surface.

Galileo wrote about the need for controlled experiments and the importance of accurate observations and mathematical analysis. In fact, Galileo is described by many scientists and historians as the founder of the scientific method.

FIGURE 1.4 Galileo Galilei



Galileo's legacy

Some of the great scientists of the seventeenth century who followed Galileo and used the scientific methods he wrote about were:

- Johannes Kepler (1571–1630), who developed a number of laws about the motion of planets around the Sun
- William Harvey (1578–1657), who used scientific methods to discover how blood circulates through the human body
- Robert Boyle (1627–1691), who applied the scientific method in chemistry to investigate the structure of matter more than 200 years before the current model of the atom was developed
- Robert Hooke (1635–1703), who used the newly invented microscope to observe and investigate the cells that make up living organisms.

These scientists were followed by Sir Isaac Newton (1642–1727), who was born in the same year that Galileo died. Newton was able to use mathematics to describe and explain the role of gravity in the motion of the Earth and other planets around the Sun. He also explained much of the behaviour of light.

The work of the scientific pioneers of this era has influenced the thinking of those who followed and continues to influence scientists in the twenty-first century.

CASE STUDY: Modelling DNA

Scientific developments are almost always built upon the work of others. Two of the most famous scientists in the field of biochemistry were James Watson and Francis Crick.

Watson and Crick established the structure of deoxyribonucleic acid, or DNA, the substance that makes up genes. Like many scientists, they relied on models to help them understand. Their original model is shown in figure 1.5. They won the Nobel Prize in 1962 for their work.

The model of DNA developed by Watson and Crick was based on the results of other scientists including:

- the work of Erwin Chargaff, who determined the basis of parts of DNA in 1951
- the x-ray diffraction photographs (taken using x-rays rather than light) developed in 1949 by Rosalind Franklin and Maurice Wilkins.

Watson and Crick's breakthrough with DNA was possible thanks to the earlier discoveries of other scientists. Scientists today continue to build on the work of Watson and Crick. Their breakthrough has allowed other scientists to understand inherited diseases, and enabled the new field of genetic engineering to emerge.

These include:

- genetic identity testing for forensic analysis
- identifying genetic diseases including Down syndrome and Huntington disease
- identifying genetic susceptibility to disease, including risks of hereditary breast and ovarian cancer
- genetic sequencing of bacteria and viruses to trace their origin and spread.

Other branches of science work in a similar way. There are many examples of scientists furthering the work done by their colleagues, such as the recent achievements of genetic researchers.

FIGURE 1.5 Original model of DNA made by Watson and Crick

FIGURE 1.6 Rosalind Franklin provided an important stepping stone in the discovery of DNA.

1.2.3 Working in teams

Until the twentieth century, most scientists worked alone, with little or no financial support. Communication between individual scientists was difficult. Many of them wrote to each other and read the work of their fellow scientists. However, the telephone was not invented until 1876 and, of course, there was no email, no computers and no overseas travel except by ship.

Since the early twentieth century, most scientists have worked in teams. Their work is almost always supported and funded by organisations, industry or governments. Communication and teamwork between scientists all over the world are easier to achieve because of phones, video conferencing, the internet, email and jet aircraft.

1.2 Activities

1.2 Quick quiz on

1.2 Exercise

Select your pathway

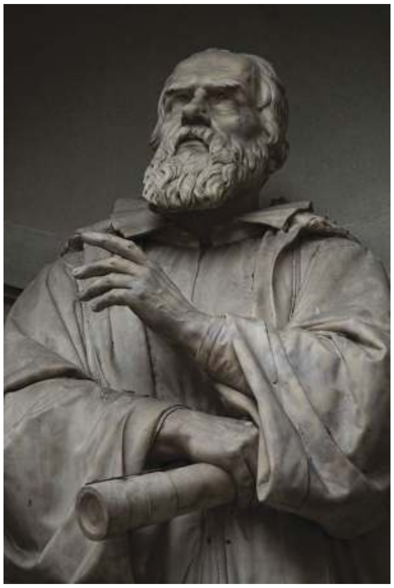
🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 2, 4	3, 5, 7	6, 8

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand



1. **MC** Ancient Greek philosophers began the development of what is now called ‘the scientific method’.
   It was based on observations and
   A. hypotheses. **B.** thinking.
   C. looking. **D.** sleeping.
2. **MC** According to Aristotle, all matter was composed of four elements. What were those four elements?
   A. Air **B.** Babylon **C.** Earth **D.** Space
   E. Ether **F.** Dirt **G.** Fire **H.** Water
3. Why was Galileo described by many as the founder of the scientific method?

Apply and analyse

4. List four of the qualities that you would expect a present-day scientist to have.
5. Why was the period of the seventeenth century labelled ‘the scientific revolution’?
6. Name some major technologies that were not available to the early Greeks and that have helped modern scientists to test their hypotheses.
7. Which technologies did seventeenth-century scientists have available to them that the early Greek scientists did not have?

Evaluate and create

8. Imagine that Galileo Galilei could return to a university in Italy today and observe the way in which scientists at the university worked. Write a one-page account of the observations that he might enter into his diary at the end of the day.

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

LESSON
1.3 Accidents and observations

LEARNING INTENTION

At the end of this lesson you will be able to explain how advances in scientific understanding often rely on developments in technology and technological advances.

1.3.1 A matter of luck?

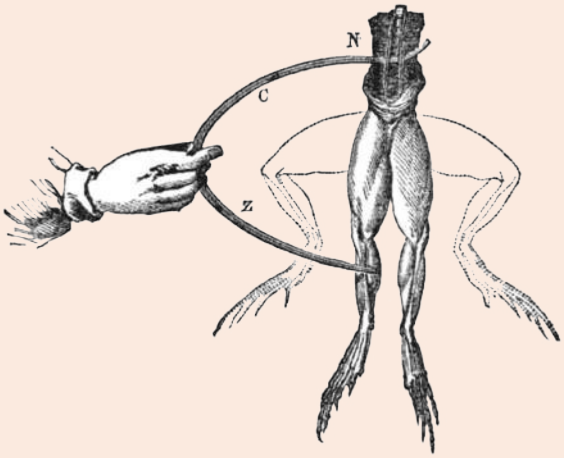
Some of the greatest scientific discoveries have been made by accident. The development of batteries, penicillin and x-rays began with ‘accidents’ in laboratories. However, was it all just a matter of luck?

CASE STUDY: The world's first electric cell

The very first electric cell was created by accident over 200 years ago. Luigi Galvani, an Italian physician, was dissecting the leg of a recently killed frog. The leg was held by a brass hook (figure 1.7). When he cut the leg with an iron knife, the leg twitched. Galvani investigated further by hanging the frog's legs on an iron railing with brass hooks. Whenever the frog's legs came into contact with the iron railing, they twitched. Galvani incorrectly proposed a theory of 'animal electricity' as the reason behind the muscle spasms.

Reports of Galvani's observations reached his friend Alessandro Volta, another Italian scientist. Volta suggested that the twitch was caused by a sudden movement of electric charge between the two different metals. The frog's flesh, he suggested, conducted the charge. Galvani had, without realising it, produced the world's first electric cell. The **galvanometer**, an instrument used to measure small electric currents, was named after Luigi Galvani.

FIGURE 1.7 Galvani's experiment on a frog's legs helped to understand electric charge.



galvanometer an instrument used to measure small electric currents; named after Luigi Galvani

CASE STUDY: X-rays

X-ray images allow doctors, dentists and veterinarians to 'see' through living flesh. The pictures, called radiographs, are taken with x-rays. These are obtained by passing x-rays through objects onto a photographic plate. Unlike light, x-rays pass through the human body. Some parts of the body absorb more of the x-rays than others, leaving a shadow on the plate. Bones leave the sharpest shadows, making it possible to detect fractures and abnormalities.

X-rays have many other uses. They are used in metal detectors at airports and to detect weaknesses and cracks in metal objects. X-rays can be used by archaeologists to examine ancient objects (including Egyptian mummies) found under the ground or in ruins without touching and damaging them.

FIGURE 1.8 X-ray pictures can reveal broken bones and disease in internal organs.

X-rays were discovered by accident in 1895 while German physicist Wilhelm Röntgen (pronounced 'Rentjen') was experimenting with a glass tube that glowed as electrons moved through it at high voltage. He had, by chance, left a photographic plate on a nearby bench. Röntgen noticed that whenever electrons were passing through the tube, the photographic plate glowed. This was puzzling because the glass tube was wrapped in heavy black paper and, since the room was in total darkness, there was no light to expose the photographic plates.

Röntgen investigated his puzzling observations further. He found that these mysterious rays that seemed to be coming from the tube could pass through human flesh as well as black paper. He obtained a clear image of the bones in his wife's hand as she rested it on the photographic film.

Röntgen's accidental discovery changed the face of medical practice in many ways.

CASE STUDY: Penicillin, the drug that changed the world

Penicillin is one of the most commonly used drugs in the treatment of diseases caused by bacteria. The discovery and production of penicillin followed a series of accidental observations. The first observation of penicillin was made in 1928 by Scottish bacteriologist Sir Alexander Fleming.

Fleming's interest in bacterial diseases intensified during World War I, when he was treating wounded soldiers. He noticed that the antiseptics used to treat wounds killed white blood cells more quickly than the harmful bacteria they were designed to kill. The white blood cells form part of the body's natural resistance to bacteria.

penicillin a powerful antibiotic substance found in moulds of the genus *Penicillium* that kills many disease-causing bacteria

lysozyme a chemical (enzyme) in human teardrops able to kill some types of bacteria as part of your body's natural defence

After the war, Fleming began searching for substances that would kill bacteria without harming the body's natural defences.

One day during his search, a teardrop fell into a dish containing a layer of bacteria. When he checked the dish the following day, he noticed a clear layer where the teardrop had fallen. Fleming then found that a chemical in human teardrops, which he named **lysozyme**, was able to kill some types of bacteria without harming the body's natural defences. Unfortunately, lysozyme was not effective against most disease-causing bacteria.

FIGURE 1.9 Fleming noticed the Penicillium notatum mould stopped the growth of bacteria.

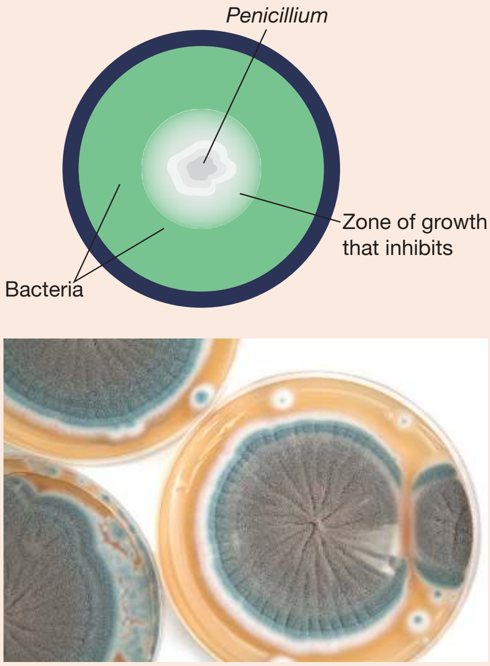


FIGURE 1.10 Mass production of penicillin has helped save millions of lives since World War II.

Fleming's greatest discovery occurred in 1928 when he was trying to find a cure for influenza. A tiny piece of mould had fallen into a Petri dish, in which he was growing bacteria, before the lid was put on. Fleming noticed that there was no further growth of bacteria around the mould (figure 1.9). He later admitted that if it had not been for his earlier experience with the teardrop, he may have thrown the dish away because it had been spoiled.

The mould, *Penicillium notatum*, contained a substance calledpenicillin, which kills many disease-causing bacteria without harming the body's natural defences. A new problem arose — how to separate and purify the substance. It was an Australian scientist, Howard Florey (1898–1968), who succeeded in separating and purifying the penicillin antibiotic. Together with Boris Chain, a Jewish refugee from Germany, Florey found a way of producing enough penicillin to treat a number of diseases. Their success came just in time for use in treating the many wounded in World War II. Fleming, Florey and Chain shared the Nobel Prize in Medicine in 1945 and their work has saved millions of lives.

1.3 Activities

learnon

1.3 Quick quiz on	1.3 Exercise

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 2, 3	4, 6	5, 7

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. MC Which modern-day device was accidentally created by Luigi Galvani?
   A. The world's first electric cell B. Galvanised metal C. The iPad
   D. The telephone E. The electric stove
2. MC What form of radiation was discovered by Wilhelm Röntgen?
   A. Alpha particles B. Beta particles C. Gamma particles D. X-rays
3. MC Which drug was later produced as a result of Alexander Fleming's accidental observation?
   A. Aspirin B. Penicillin C. Antibodies D. Isobrufin

Apply and analyse

Your answers to questions 4 and 5 could be presented in a table.

4. Consider the discoveries made by Galvani, Röntgen and Fleming. In each case, describe the skills and scientific knowledge used in making and developing their discovery.
5. Make a list of the personal qualities that enabled Galvani, Röntgen and Fleming to take advantage of their chance observations.

Evaluate and create

6. Were the discoveries of the electric cell, x-rays and penicillin really just accidents? Explain your answer.
7. Do you think that the electric cell, x-rays and penicillin would have been discovered if it had not been for the chance observations of Galvani, Röntgen and Fleming? Explain your answer.

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

LESSON
1.4 A question of ethics

LEARNING INTENTION

At the end of this lesson you will be able to explain how ethics guides how science is carried out and the potential conflicts between science and beliefs.

SCIENCE AS A HUMAN ENDEAVOUR: Science and ethics

Ethics is the system of moral principles on the basis of which people, communities and nations make decisions about what is right or wrong. Scientific inquiry takes place in communities that have political, social and religious views and is undertaken by people who have personal views about all sorts of issues. It is a human endeavour and, therefore, cannot be separated from ethics and questions about right and wrong.

ethics the system of moral principles on the basis of which people, communities and nations make decisions about what is right or wrong

Ethical values vary between countries, religions, communities and individuals — even among members of the same family. For example, capital punishment, the execution of a person for committing a crime, is considered by some to be right and by others to be wrong.

Science interacts with ethics in several ways, including:
- affecting the way in which science is conducted
- affecting the types of scientific research carried out
- in the conflict or match between scientific ideas and religious beliefs
- providing scientific community practices that act as a model for ethical behaviour.

Animal testing

Animals are used in scientific research in many ways, including: to test the effects of potential drugs; to test cosmetics for allergies; to understand the functioning of parts of the body; and to test new surgical techniques. In some research and testing, the animals die. Animals used include monkeys, bees, mice, worms and dogs, among others.

There are ethical issues about whether animals should ever be used in scientific research, or if some types of animals shouldn't be used, or if some types of research shouldn't be carried out at all.

FIGURE 1.11 The European Union has banned the sale of cosmetics tested on animals.

DISCUSSION

Should animals be used for testing in the development of cosmetics? What about in drug development?

Medical research

Medical research is carried out partly by public institutions such as universities and specialist research departments, and partly by private companies. Traditionally, the main purpose of research in public institutions has been to increase understanding and to provide solutions to existing problems; while private companies aim to provide new products or services that can be sold for profit. However, increasingly many research institutions are developing their discoveries into commercial ventures. Whether the research is conducted by private or public research institutions, the ethics of any new drug production should be examined to balance profitability and the benefit to the community.

Life expectancy varies greatly around the world, as do patterns of disease. Cancer, heart disease and diabetes kill many Australians and billions of dollars are spent on researching their causes and treatment. Diarrhoeal diseases and malaria are readily treated in Australia, but kill millions of people each year in Africa, Asia and South America — sometimes because of lack of information and sometimes because of lack of low-cost products. This raises ethical and social questions, such as:
- Is it right that effective drugs are unavailable to millions because of their cost?
- What is the fundamental purpose of developing pharmaceuticals?
- Should the type of treatment be determined by the profit it generates?

The ethics of new drug testing should also be examined. When pharmaceutical companies design new drugs, they need to test these thoroughly before being able to sell them. Some people argue that the testing regime is too lengthy and that new drugs that have the potential to treat deadly diseases should be supplied to the people dying from these diseases even if the drug has not been fully tested. Other people believe that a drug should undergo lengthy testing to ensure no harm is done, even if inadvertently.

DISCUSSION

In the case of a global pandemic, do you think the process of human trials for potential cures or vaccines should be less rigorous? What if it means new drugs could be developed more quickly?

Agriculture

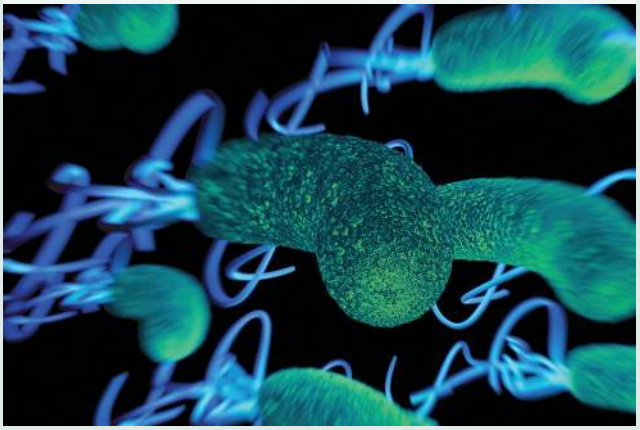
Traditional plant breeding methods — manually putting pollen from one plant into the flower of another to produce a 'cross'— were once the only means of modifying plant types; a slow and laborious process. Now, using techniques for moving genes from one plant to another, it is possible to design plants that have certain characteristics. This technique of **genetic modification (GM)** is controversial. GM crops are greatly restricted in Australia. GM techniques have been used to produce crops that:

- are resistant to herbicide so that weed control is more effective (canola)
- produce their own pesticides to reduce insect attack (cotton)
- contain added nutrients (rice).

Discussion about the ethics of GM crops often focuses on the role of companies in developing GM crops for the profit they are expected to bring. Ethical issues are also raised about whether GM techniques should be used by public research laboratories and international agencies to improve food supply in regions where many people are undernourished.

EXTENSION: Unusual research methods uncover the cause of stomach ulcers

FIGURE 1.12 *Helicobacter pylori* bacteria in the human stomach cause stomach ulcers. They move their hair-like structures to travel around the stomach lining.



When Barry Marshall and Robin Warren came to the conclusion that stomach ulcers were probably caused by a bacteria, they were faced with some tricky ethical and safety considerations. A stomach ulcer occurs when the lining of the walls of the stomach becomes damaged and the acid inside the stomach eats away at the stomach wall. It is a very painful condition. Previously it was thought that ulcers were caused by lifestyle factors, including stress, so it was difficult to treat ulcers. People were usually told to avoid stress, for example by changing job or cutting their work hours, and to cut out particular foods, sometimes with no improvement to their health.

Barry Marshall and Robin Warren suspected that ulcers were actually caused by bacteria called *helicobacter pylori*. They had found these bacteria in the stomachs of people suffering from stomach ulcers but not in the stomachs of healthy individuals. They had also studied the bacterium. The only way to know for sure would be to deliberately infect someone with the bacteria and find out whether they developed a painful ulcer. There were risks involved; for instance, the bacteria could cause other health problems. It could even kill the patient. There were also ethical issues associated with deliberately trying to make a healthy person sick. In the end, Barry Marshall carefully weighed up the risks involved and decided to test his hypothesis on himself. He swallowed a solution of the bacteria and soon became ill and developed the early symptoms associated with the development of stomach ulcers. He then treated himself with antibiotics. Now when a patient is diagnosed with a stomach ulcer, treatment is simple — a course of antibiotics usually fixes the problem.

genetic modification (GM) the technique of modifying the genetic structure of organisms making it possible to design organisms that have certain characteristics

1.4 Activities

learnon

1.2 Quick quiz on | 1.2 Exercise

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 2, 4	3, 6	5, 7, 8

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. **MC** Identify an illness that affects people worldwide and kills millions in poor countries but almost no-one in Australia.
   A. Malaria **B.** Polio **C.** Cancer **D.** Ebola
2. Explain why scientific inquiry should not take place without considering whether it is right or wrong.
3. Explain how genetically modified (GM) crops are different from other crops.

Apply and analyse

4. **MC** Identify two ethical issues associated with the experiment carried out by Barry Marshall.
   A. Helicobacter pylori could cause other health problems (apart from ulcers) in humans.
   B. The outcome was unknown.
   C. Is it justified to make a healthy person sick in order to test a theory?
   D. Should people be subject to experiments?
   E. The outcome was specific to Barry Marshall and the results could not be applied to anyone else.
5. What does a bioethicist do? What training does a bioethicist require?

Evaluate and create

6. Justify your opinion of the following issue. All medical research, including research into new drugs, should be done by non-profit organisations rather than by companies aiming to make a profit.
7. Justify your opinion of the following issue. Food made from genetically modified crops should have a special label to show that it contains genetically modified (GM) ingredients.
8. Outline some of the arguments for and against using genetically modified crops. Discuss your arguments with other students in your class or use a Plus, Minus, Interesting (PMI) chart to summarise your arguments.

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

LESSON
1.5 Planning your own investigation

LEARNING INTENTION

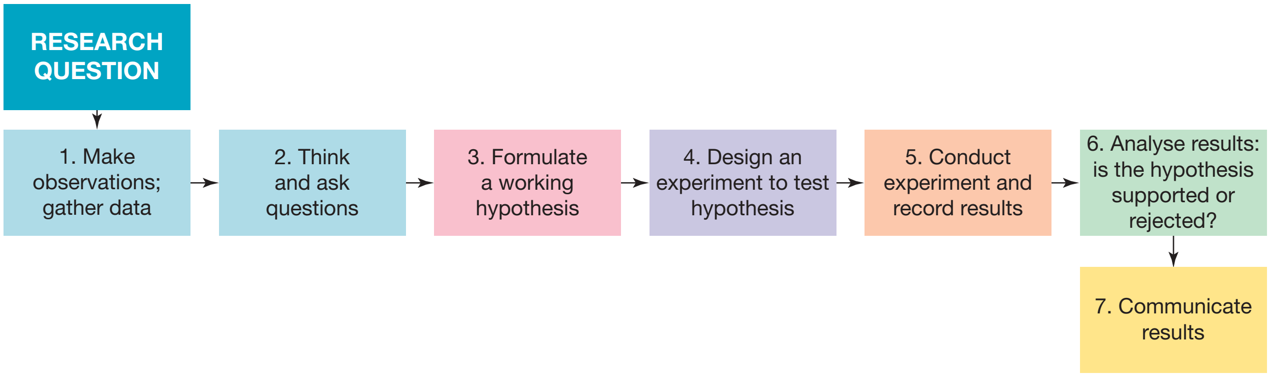
At the end of this lesson you will understand the scientific method and be able to design your own investigation with attention to variables, reports and scientific processes.

1.5.1 The scientific method

As a science student you are required to undertake scientific investigations. These investigations will not only help you understand scientific concepts, they can also be a lot of fun! Scientists around the world all follow what is known as the **scientific method** (figure 1.13). This allows scientists to examine each other's work and build on the scientific knowledge gained. An important aspect of science is being able to reproduce someone else's experiment. The more evidence a scientist has about a theory, the more accepted the theory will be.

scientific method a systematic and logical process of investigation to test hypotheses and answer questions based on data or experimental observations

FIGURE 1.13 The scientific method



The skills you will develop in conducting scientific investigations include the following:

- questioning and predicting
- planning and conducting
- processing, modelling and analysing
- evaluating
- communicating scientifically.

Whenever you take a trip away from home, you need to plan ahead and have some idea of where you are going. You need to know how you are going to get there, what you need to pack and have some idea of what you are going to do when you get there.

It's the same with an experimental investigation. Planning ahead increases your chances of success.

Finding a topic

The first step in the scientific method is to develop a research question. You can think of this as finding a topic. Your investigation is much more likely to be of high quality if you choose a topic that you will enjoy working on. These steps might help you choose a good topic:

1. Think about your interests and hobbies. They might give you some ideas about investigation topics.
2. Make a list of your ideas.
3. Brainstorm ideas with a partner or in a small group. You might find that exchanging ideas with others is very helpful.
4. Find out what other students have investigated in the past. Although you will not want to cover exactly the same topics, investigations performed by others might help you to think of other ideas.
5. Do a quick search in the library or at home for books or newspaper articles about topics that interest you. Search the internet. You might also find articles of interest in magazines or journals. You could use a table like table 1.1 to organise your ideas.

TABLE 1.1 Summary of topic research

Topic area	Name of book, magazine, website etc.	Chapter or article	Topic ideas

FIGURE 1.14 Brainstorm and research ideas based on your hobbies and interests, and discuss your ideas with others.

Making observations and asking questions

Many ideas for scientific investigations start with a simple observation. Some well-known investigations and inventions from the past started that way. Even though the discoveries by Galvani, Röntgen and Fleming described in the case studies of lesson 1.3 were made by accident, they would not have been made without observation skills. There are also other important 'ingredients' in these discoveries — curiosity and the ability to ask questions and form ideas that can be tested by experiment and further observation.

Danish scientist Hans Ørsted discovered the connection between electric current and magnetism when, in 1819, he noticed that a compass needle pointed in the wrong direction every time it was placed near a wire carrying an electric current. He went on to design experiments to find out exactly how different electric currents affected compass needles. The results of his experiments started a flood of inventions, including electric generators and motors.

An investigation by a 15-year-old student began with an observation that her friends seemed to perform better in athletic events when there was an audience cheering them on. You have probably seen this yourself. Her investigation 'Does an audience affect the performance of an athlete?' involved three different sporting activities and compared the performance of a large group of students under three different conditions:

- no audience
- a quiet audience
- a cheering audience.

The sporting activities were:

- goal shooting in basketball
- sit-ups
- shot-put.

FIGURE 1.15 Could an audience really affect this team's performance? To answer this question scientifically, an investigation is needed.

What do you think she found out? Perhaps you could try a similar investigation.

Defining the question

Once you have decided on your topic, you need to determine exactly what you want to investigate. It is better to start with a simple, very specific question than a complicated or broad question. For example, the topic 'earthworms' is very broad. There are many simple questions that could be asked about earthworms.

For example:
- Which type of soil do earthworms prefer?
- How much do earthworms eat?
- Do earthworms prefer meat or vegetables?
- How fast does a population of earthworms grow?

Your question needs to be realistic. In defining the question, you need to consider whether:
- you can obtain the background information that you need
- the equipment that you need is available
- the investigation can be completed in the time you have available
- the question is safe to investigate.

FIGURE 1.16 There are many problems relating to earthworms that could be investigated.

1.5.2 Keeping records

A **logbook** is an essential part of a long scientific investigation. It provides you with a complete record of your investigation, from the time you begin to search for a topic through to conclusion. Your logbook will make the task of writing your report very much easier.

A logbook is just like a diary. Make an entry whenever you spend time on your investigation. Each entry should be clearly dated. It's likely that the first entry will be a mind map or list of possible topics. Other entries might include:
- notes on background research conducted in the library; include all the details you will need for the **bibliography** of your report (see section 1.5.8)
- a record of the people whom you asked for advice (including your teacher), and their suggestions
- diagrams of equipment, and other evidence that you have planned your experiments carefully
- all of your 'raw' results, in table form where appropriate
- an outline of any problems encountered and how you solved them
- first drafts of your reports, including your thoughts about your conclusions.

logbook a complete record of an investigation from the time a search for a topic is started through to conclusion

bibliography list of references and sources at the end of a scientific report

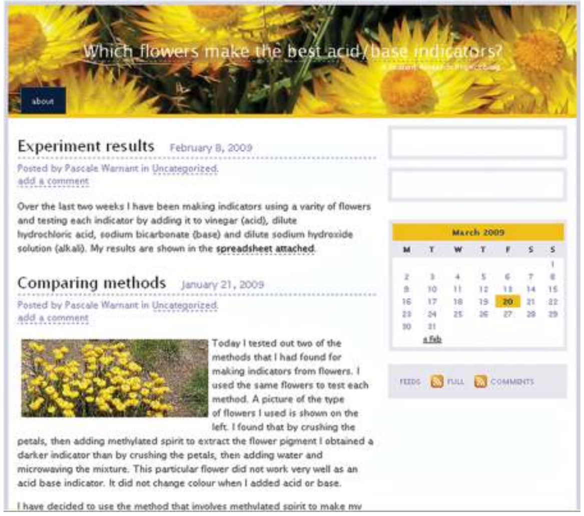
blog a personal website or web page where an individual can upload documents, diagrams, photos and short videos, add links to other sites and invite other people to post comments

An online logbook

An exercise book can be used as a logbook, but there are several advantages in maintaining your logbook online in the form of a **blog** or in a program such as OneNote. If you choose to use a blog to record your investigation, there are many sites that will allow you to set up a free blog (figure 1.17). Your teacher might be able to provide some suggestions. Once you set up a blog, every entry you make will be dated automatically. You can upload documents, diagrams, photos and short videos. You can also add links to other sites and invite friends, family and teachers to post comments about your progress.

There are some precautions that you should take if you decide to use a blog as a logbook.
- Limit your posts to those related to your science investigation. Don't use your logbook blog for social networking.
- Do not include your address or phone number.

FIGURE 1.17 A blog used as a logbook for a student research investigation



Experiment results February 8, 2009

Posted by Pascale Warnant in Uncategorized.
add a comment

Over the last two weeks I have been making indicators using a varity of flowers and testing each indicator by adding it to vinegar (acid), dilute hydrochloric acid, sodium bicarbonate (base) and dilute sodium hydroxide solution (alkali). My results are shown in the spreadsheet attached.

Comparing methods January 21, 2009

Posted by Pascale Warnant in Uncategorized.
add a comment

Today I tested out two of the methods that I had found for making indicators from flowers. I used the same flowers to test each method. A picture of the type of flowers I used is shown on the left. I found that by crushing the petals, then adding methylated spirit to extract the flower pigment I obtained a darker indicator than by crushing the petals, then adding water and microwaving the mixture. This particular flower did not work very well as an acid base indicator. It did not change colour when I added acid or base.

I have decided to use the method that involves methylated spirit to make my

March 2009

M	T	W	T	F	S	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

« Feb

- If your blog is on the internet (rather than a school intranet):
  - do not post any photos of yourself in school uniform or any other clothing that will identify where you go to school
  - do not include your full name, address, phone number or the name of your school in the blog. Use only your first name or a nickname
  - use privacy settings or use a password to ensure that only trusted school friends, family and your teacher have access to the blog.

1.5.3 Designing the experiments

In order to complete a successful investigation, you need to make sure that your experiments are well designed. Once you've decided exactly what you are going to investigate, you need to be aware of:

- which variables need to be controlled and which variables can be changed
- whether a control is necessary
- what observations and measurements you will make and what equipment you will need to make them
- the importance of repeating experiments (replication) to make your results more reliable
- how you will record and analyse your data.

A poorly designed investigation is likely to produce a conclusion that is not **valid**.

Understanding variables

A **variable** is an observation or measurement that can change during an experiment. You should change only one variable at a time in an experiment.

It is important you understand and identify the different types of variables in your experiment.

- **Independent variable**: the variable that you deliberately change during an experiment.
- **Dependent variable**: the variable that is being affected by the independent variable — that is, the variable you are measuring.

For example, if you were performing an experiment to find out which brand of fertiliser was best for growing a particular plant, the independent variable would be the brand of fertiliser. The dependent variable would be the heights of the plants after a chosen number of days.

When you are testing the effect of an independent variable on a dependent variable, all other variables should be kept constant. Such variables are called **controlled variables**. For example, in the fertiliser experiment, the type of plant, amount of water provided to each plant, soil type, amount of light, temperature and pot size are all controlled variables. The process of controlling variables is also known as **fair testing**.

Writing a hypothesis

A hypothesis is a statement that predicts what you think will happen in your experiment. It links the independent and dependent variables in a sentence, which can be both tested and proven wrong.

A hypothesis is a tentative, **testable** and **falsifiable** statement for an observed phenomenon that acts as a prediction for the investigation.

A hypothesis is usually written in an 'IF ... THEN ...' format (for example, 'IF the concentration of the acid is increased THEN the reaction with magnesium will be faster).

valid describes an experiment that truly investigates what it sets out to investigate (via an appropriate method, controlling variables etc.)

variable any factor that can be changed, kept constant (controlled) or measured during an experiment

independent variable the variable that you deliberately change during an experiment

dependent variable the variable that is being affected by the independent variable — that is, the variable you are measuring

controlled variables the conditions that must be kept constant throughout an experiment

fair testing testing where only one variable is changed and keeps all other variables constant when attempting to answer a scientific question

testable able to be supported or proven false through the use of observations and investigation

falsifiable can be proven false

The need for a control

Some experiments require a **control**. A control is needed in the fertiliser experiment to ensure that the result is due to the fertilisers and not something else. The control in this experiment would be a pot of plants to which no fertiliser was added. All other variables would be the same as for the other three pots.

FIGURE 1.18 A control is used to compare the difference in growth to a plant with no fertiliser.

Valid experiments

A valid experiment measures what it actually sets out to measure. If your **aim** was to find out whether watering plants with sea water affects their growth rate, comparing the number of radish seeds that germinate after one week when watered with tap water or sea water would not be a valid method because it does not actually measure growth rate. It tests the effect of sea water on seed germination.

Repeatable and reliable experiments

Replication is the repeating of an experiment to make sure you have collected **reliable data**. In the case of the fertiliser experiment, a more reliable result could be obtained by setting up two, three or four pots for each brand of fertiliser or having a number of seedlings in each pot. The results are checked for consistency and an average result for each brand or the control could then be calculated.

A reliable experiment provides consistent results when repeated, even if it is repeated on different days and under slightly different conditions; for example, in a different room or with a different researcher collecting the data. Replication increases the reliability of an experiment. This can involve simply doing the same experiment a few times, or having different groups repeat the same experiment and pooling the data gathered by each group when writing the report.

control an experimental set-up in which the independent variable is not applied that is used to ensure that the result is due to the variable and nothing else

aim a statement outlining the purpose of an investigation

reliable data data that is able to be replicated in different circumstances but the same conditions

Surveys

A survey is a list of questions that you ask to a large group of people. Some surveys are read out, sometimes over the phone. Some require participants to fill in a form, and increasingly surveys are done online. Surveys are used to collect census data, for market research, to find out what product characteristics consumers find most appealing, to determine voting intentions and also for scientific purposes. A great deal of data about health and lifestyle has been gathered through the use of surveys, sometimes in combination with other tests. To investigate whether there is a link between diet and blood pressure, researchers might collect data about the participant's diet through the use of a survey.

FIGURE 1.19 Surveys are often conducted using multiple-choice questions.

These are some features of well-designed surveys:

- A large sample size is used — many participants take part in the survey.
- Questions are unambiguous — participants can understand the questions.
- A control group is used or, where appropriate, different degrees of exposure to the factor under investigation. An investigation on the effect of loud music on hearing could include a survey where participants were asked about the number of concerts and dance parties they attended over the last 12 months and the participants' hearing could be tested. The data would be of little value if all the participants had a similar level of exposure to loud music. The participants need to be people who are exposed to loud music frequently, some occasionally and some rarely.
- Data can be analysed mathematically. Multiple-choice questions often lend themselves better to this type of analysis.

1.5.4 Using information and communications technology

Computer hardware and software are important tools used by scientists during their investigations.

For example:

- spreadsheets can be used to organise and analyse data
- data loggers can be used to collect large numbers of measurements of variables that are difficult to collect in other ways
- databases can be used to arrange data or information so that it is easier to locate.

These tools are described in lessons 1.12, 1.13 and 1.14.

1.5.5 Getting approval

You should now be ready to write a plan for your investigation. You should not commence any experiments until your plan has been approved by your science teacher. Your plan should include the information below.

1. **Title**
   The likely title — you may decide to change it before your work is completed. The title should be in the form of a question; for example, how does watering grass seeds with a detergent solution affect their growth?
2. **The problem**
   A statement of the question that you intend to answer. Include a hypothesis. A hypothesis is an educated guess about the outcome of your experiments. It is usually based on observations and always able to be tested by further observations or measurements.
3. **Outline of your experiments**
   Outline how you intend to go about answering the question. This should briefly outline the experiments that you intend to conduct.
4. **Equipment**
   List here any equipment that you think will be needed for your experiments.
5. **Resources**
   List here the sources of information that you have already used and those that you intend to use. This list should include library resources, organisations and people.

FIGURE 1.20 Write out a plan for your investigation.

1.5.6 Gathering data

Once your plan has been approved by your teacher, you may begin your experiments.

Details of how you conducted your experiments should be recorded in your logbook. All observations and measurements should be recorded. Use tables where possible to record your data.

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

Photographs or videos should be taken if appropriate.

You might need to change your experiments if you get results you don't expect. Any major changes should be checked with your teacher.

FIGURE 1.21 All observations and measurements should be recorded.

Precision and accuracy

As you plan and carry out your investigation you need to ensure that the data you collect is **precise** and **accurate**. Choosing the most appropriate instruments to make your measurements is important.

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

accurate refers to how close an experimental measurement is to a known value

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

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 1.22. If there is a large variation in the results, the precision is low. If the results are all very similar, and only vary by a very small amount, then the precision is high.

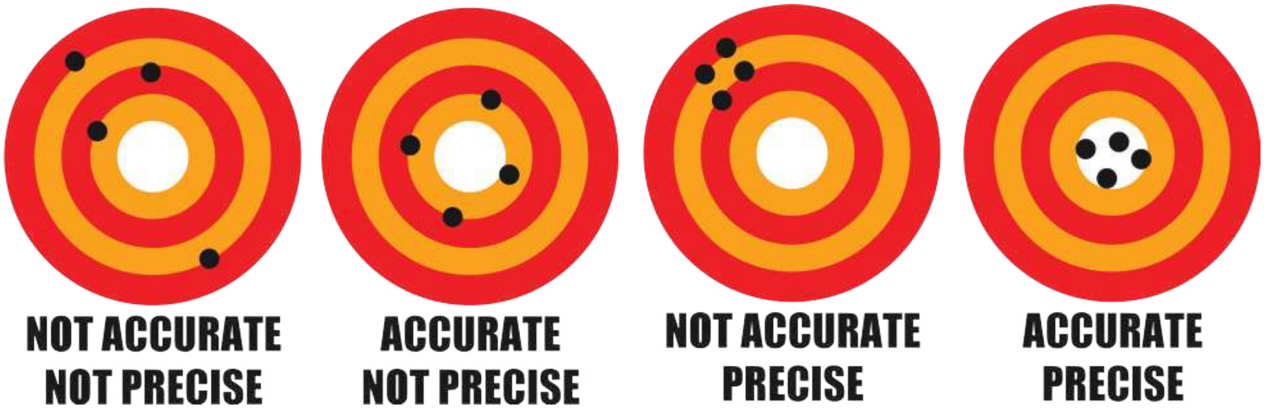
The degree of precision of the measurements taken in an experiment depends on the instruments that have been used. If you want to measure the length of your classroom, you could use a trundle wheel with marks every 10 cm, or you could use a tape measure marked in millimetres. The tape measure would provide the most precise measurement. Similarly, to measure 100 mL of 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.

Accurate results

Accuracy is different to precision. Accuracy refers to how close an experimental measurement is to a known value. Sometimes results that are not precise can still be accurate, if the average of them is close to the actual value. 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 two 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, it may 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.

If an archer is precise, their arrows hit close to one another. If an archer is accurate, their arrows hit close to the target. This is illustrated in figure 1.22.

FIGURE 1.22 Comparing precision and accuracy



Choosing equipment for precision

Choosing the correct piece of equipment is critical to ensure that your results are precise. Your bathroom scales and the electronic scales in a science laboratory both measure mass, but the laboratory scales are more precise. Your school might have different sets of scales that measure to one or two decimal places. Scales that measure to two decimal places are more precise. High-precision scales are needed for some of the senior chemistry experiments.

For measuring instruments with a scale, such as thermometers, rulers and measuring cylinders, the graduations (lines) on the scale give an indication of the precision of the instrument. Generally, an instrument with smaller gradations is more precise,

FIGURE 1.23 Precision laboratory scales

Measuring volumes of liquids

When liquids are placed in a vessel, the surface of the liquid is often curved. This curved surface of a column of liquid is called a meniscus. When measuring the volume of a liquid, make sure you read the volume from the bottom of the meniscus, not the top.

SAMPLE PROBLEM 1: Measuring readings of a meniscus

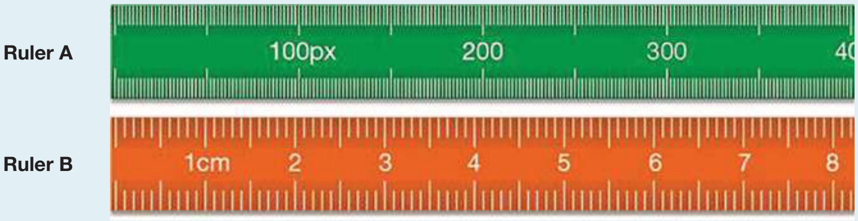
What is the measurement of this liquid in a measuring cylinder?

THINK	WRITE
1. The liquid level should be read from the bottom of the meniscus, not where it touches the glass. Imagine a line drawn across from the bottom of the meniscus to the glass.	
2. Look for the scale marking below the liquid level and above the liquid level. These are 55 mL and 60 mL. To calculate the volume between the two scale markings, subtract the smaller reading from the larger reading.	60 – 55 = 5 mL

3. There are five divisions between these two scale markings. To determine the size of each small scale marking, divide the volume calculated in step **2** by 5.	5 ÷ 5 = 1 Each scale division is 1 mL.
4. To read the measurement of the liquid level, count up from the lower scale marking, 55, to the liquid level; this is two scale divisions.	55 + 2 = 57 mL

SAMPLE PROBLEM 2: Precision

Which of the rulers in the diagram below is the more precise?



THINK	WRITE
Look at the number of divisions on each ruler between each marked measurement. On ruler A, between 100 and 200, there are 50 divisions. On ruler B, between 2 cm and 4 cm, there are 20 divisions.	As ruler A has more graduations over the same space as ruler B, ruler A is more precise.

Ensuring equipment is accurate

Measurements can be very precise, but incorrect. Every so often current affair programs bring attention to service stations that overcharge consumers for petrol by having faulty petrol pumps that give inaccurate readings of the amount of petrol delivered by the pump. For each litre of petrol pumped, the machine might give a reading of 1.1 L and the customer is charged accordingly. The machine is quite precise, but not accurate.

CASE STUDY: Calibrating a pH meter

Some measuring instruments require calibration to ensure that they provide accurate measurements. The calibration might be part of the manufacturing process, or it may need to be carried out by the user regularly. A pH meter is a device that needs to be calibrated regularly (figure 1.24). pH is a measure of the acidity of a substance. You can measure pH with a universal indicator. For a more precise reading a pH meter can be used. It is a device that is placed in the solution and it gives a reading of the pH to one or two decimal places. Over time it can lose its calibration and give inaccurate readings. A reading of 6.25 might be displayed when the solution actually has a pH of 5.38. To calibrate the pH meter, you place it in solutions of known pH and adjust the device until it reads the correct values for these solutions. You can then use the meter to measure the pH of a solution with an unknown concentration.

FIGURE 1.24 A pH meter needs to be calibrated regularly to ensure it gives accurate readings.

1.5.7 Graphing variables

Many different types of data can be collected in scientific experiments. Data is often presented in tables or as graphs.

Tables

Tables can be used to record data to help separate and organise your information. All tables should:

- have a heading
- display the data clearly
  - the independent variable in the first column
  - the dependent variable(s) in later columns
- include units in the column headings and not with every data point
- be designed to be easy to read.

Always include a title for your table.

Include the measurement units in the headings.

The column heading shows clearly what has been measured.

TABLE 1.2 The effect of different brands of fertiliser on the growth of seedlings

Fertiliser	Day 2 Height (cm)	Day 4 Height (cm)	Day 6 Height (cm)	Day 8 Height (cm)	Day 10 Height (cm)
Brand X	2	3	5	6	9
Brand Y	3	5	7	9	11
Brand Z	1	2	3	5	7
Control	0	0.6	1.8	2.5	4

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.

Graphs

Graphs can help you see patterns and trends in your data. Once your data has been recorded in a table, you need to work out what is the best graph to choose. You can do this by recognising what type of data you have.

- **Qualitative data** is expressed in words. It is also known as categorical data – you can think of this data as falling into categories. It is descriptive and not numerical and can be easily observed but not measured. In our experiment with the fertiliser, the brands of fertiliser is qualitative data. There are two types of qualitative data:
  - *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. In our experiment with the fertiliser, the height of the seedlings is quantitative data. There are two types of quantitative data:
  - *continuous data* can take any numerical value, such as the change in temperature of a cup of coffee over time
  - *discrete data* can only take on set values that can be counted, such as the number of protons in an atom or the change in temperature of a cup of coffee in different types of cups after 10 minutes.

qualitative data (or categorical data) data expressed in words

quantitative data (or numerical data) data that can be precisely measured and have values that are expressed in numbers

The most common types of graphs are listed below.

- *Scatterplots*: require both sets of data to be numerical (or quantitative). Each dot represents one observation. A scatterplot can easily show trends between data sets, and correlations can be seen.
- *Line graphs*: a scatterplot with the dots joined. The dots are usually joined using a straight line, but sometimes the line is curved. They are used for continuous data.
- *Bar/Column graphs*: when one piece of data is qualitative and the other is quantitative. The bars are separated from each other. The horizontal axis has no scale because it simply shows categories. The vertical axis has a scale showing the units of measurements.
- *Histograms*: a special kind of bar graph that show continuous categories, and are often used when examining frequency. The bars are not separated.
- *Pie charts and divided bar charts*: used to show frequencies or portions of a whole. This includes percentages or fractions.

You would normally graph the independent variable (the one you changed) on the *x*-axis, and the dependent variable (the one you measured) on the *y*-axis. When the dependent variable changes with time, you can graph time on the *x*-axis and the dependent variable on the *y*-axis. For example, in the fertiliser experiment, two types of graphs could be used, a line graph or a column graph (bar chart).

FIGURE 1.25 a. Line graph of the growth of plants over 10 days in different brands of fertiliser. **b.** Column graph of the height of plants at the end of 10 days in different brands of fertiliser.

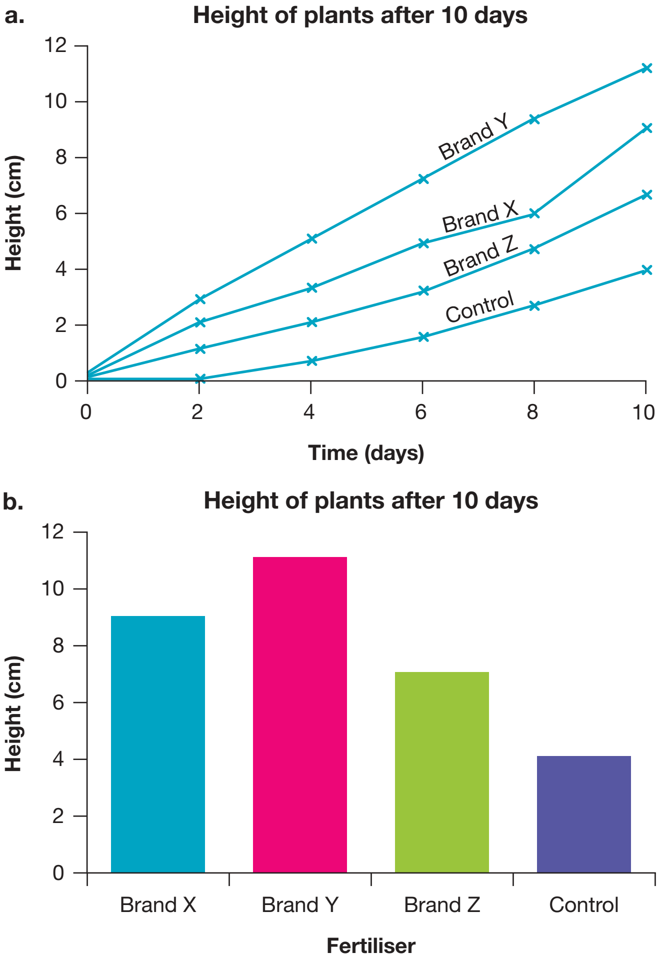


FIGURE 1.26 Features of a line graph

3. Setting up and labelling the axes

Graphs represent a relationship between two variables.

Usually the independent variable is plotted on the horizontal *x*-axis and the dependent variable on the vertical *y*-axis.

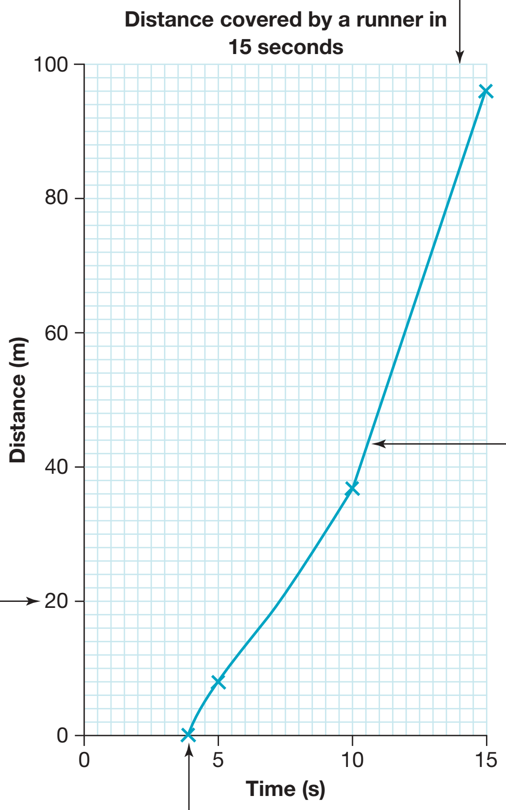
After deciding on the variable for each axis, you must clearly label each axis with the variable and its units. The units are written in brackets after the name of the variable.

2. Title

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

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.



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.

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. Only include a point for (0, 0) if you have the data for this point.

TABLE 1.6 Data table

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

SAMPLE PROBLEM 3: Choosing types of graphs

Identify the type of graph that would be most appropriate to display the following data:

a. Data from Melbourne Zoo showing how the mass of a baby elephant has increased over time

b. The mass of each elephant at Melbourne Zoo

c. The proportion of visitors using various modes of transport to travel to Melbourne Zoo.

THINK	WRITE
a. The mass of one elephant is a number that changes over time, so it is quantitative data. Mass can take any numerical value, so it is continuous data.	Mass is continuous data, so a line graph would be the best choice.
b. We compare the mass of different elephants by showing the name of each elephant and its mass at a set point in time. The name of each elephant is qualitative, and the mass of each elephant is quantitative (continuous).	As we have both qualitative and quantitative data, a bar or column graph would be the best choice.
c. The proportion of visitors using various modes of transport shows fractions or percentages of a whole.	As the data is showing the proportion of people using different modes of transport, the best choice would be a pie chart or a divided bar chart.

1.5.8 Writing your report

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 and presented in a folder. It should begin with a table of contents, and the pages should be numbered. Your report should include the following headings (unless they are inappropriate for your investigation).

Scientific report structure

Abstract

The abstract provides the reader with a brief summary of your whole investigation. 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. Include the hypothesis.

Materials and methods

Describe in detail how you did your experiments. Begin with a list or description of equipment that you used. You could also include photographs of your equipment, if appropriate. The method description must be detailed enough to allow somebody else to repeat your experiments. It should also convince the reader that your investigation is 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 (often referred to as data) are presented here. Data should, wherever possible, be presented in table form 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. Make sure you use the most appropriate type of graph for your data. Some examples of graphs are shown in section 1.5.7.

Discussion

Discuss your results here. Begin with a statement of what your results indicate about the answer to your question. Explain how your results might be useful. Any weaknesses in your design or difficulties in measuring could be outlined here. Explain how you could have improved your experiments. What further experiments are suggested by your results?

Conclusion

This is a brief statement of what you found out. 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. You should not be disappointed if it is not supported. In fact, some scientists deliberately set out to reject hypotheses!

Bibliography

Make a list of books, other printed or audio-visual material and websites 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.

The way a resource is listed depends on whether it is a book, magazine (or journal) or website. For each resource, list the following information in the order shown:

- author(s), if known (book, magazine or website)
- title of book or article, or name of website
- volume number or issue (magazine)
- URL (website) and the date you accessed the web page
- publisher (book or magazine), if not in title
- place of publication, if given (book)
- year of publication (book, magazine or website)
- chapter or pages used (book).

Some examples of different sources are listed below:

- Taylor, N., Stubbs A., Stokes, R. (2020) *Jacaranda Chemistry 2 VCE Units 3 & 4*. 2nd edition. Milton: John Wiley & Sons.
- Gregg, J. (2014) ‘How Smart are Dolphins?’ *Focus Science and Technology*, Issue 264, February 2014, BBC, pages 52–57.
- Australian Marine Wildlife Research & Rescue Organisation, accessed 26 June 2020, <http: www.amwrro.org.au,2014>.

Acknowledgements

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

1.5.9 Everyone has talent

In most states and territories, there are competitions or events that provide opportunities for you to present reports of your own scientific research. Each year, tens of thousands of dollars in prizes are awarded to hundreds of entrants. Information about these competitions and events can be obtained from your science teacher.

on Resources

eWorkbooks Setting up a logbook (ewbk-12194)
Variables and controls (ewbk-12196)
Investigating (ewbk-12198)
Organising and evaluating results (ewbk-12200)
Drawing conclusions (ewbk-12202)
Summarising (ewbk-12204)
Evaluating media reports (ewbk-12206)

1.5 Activities

learnon

1.5 Quick quiz on | **1.5 Exercise**

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 2, 3, 8	4, 7, 9, 10, 12	5, 6, 11, 13

Remember and understand

1. MC What is the advantage of repeating an experiment several times?
   A. It is a form of double-checking the original results.
   B. It makes the results more reliable.
   C. It is a requirement of the scientific method.
   D. It gives you more time to write the report.
2. Describe the difference between an independent and a dependent variable.
3. MC In which section of your report do you describe possible improvements to your experiments?
   A. Methods
   B. Results
   C. Discussion
   D. Conclusion
4. Distinguish between precision and accuracy.
5. Outline what calibrating an instrument involves.
6. Describe the use of a control in an experiment with reference to independent and dependent variables.

Apply and analyse

7. Why is it better to write the abstract of a scientific report last, even though it appears at the beginning?
8. Josie wanted to find out whether the water in her drink bottle would stay cold for longer if she wrapped the bottle in foil or a towel. From the options given, identify the independent and dependent variable and one variable that would need to be controlled.

   Colour of towel, Size of wrapping and bottle, How long the bottle stays cool, Wrapping material

9. Charlotte would like to find out whether ice blocks made from green-coloured water melt at the same temperature as uncoloured ice blocks. From the options given, identify the independent and dependent variable and one variable that would need to be controlled.

   Melting temperature, Mass of ice blocks, Colour of ice blocks

10. Jayden is testing the hypothesis that tall people are faster long-distance runners than short people. From the options given, identify the independent and dependent variable and one variable that would need to be controlled.

    Weight of person, Distance they run, Time taken to run long distance, Height of person

11. Shinji is testing the idea that plants grow faster if you play them music for at least 2 hours a day. From the options given, identify the independent and dependent variable and one variable that would need to be controlled.
    Colour of pots used to grow plants in, Type of music, Growth rate of plants, Music playing or not

Evaluate and create

12. Construct a flow chart to show the steps that you need to take before beginning your experiments.
13. The television show *MythBusters* involves a team led by Adam and Jamie carrying out investigations to test various myths.
    a. Define the term myth. (Use a dictionary if necessary.)
    b. Use the internet to find a list of the myths Adam and Jamie have investigated and pick at least three that you could test using equipment available at home or at school.
    c. If your school has any episodes of *MythBusters* available, watch an episode. Make a list of the myths tested in the episode and discuss the validity of the experiments carried out by Adam, Jamie and their team.

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

LESSON

1.6 SkillBuilder — Controlled, dependent and independent variables

LEARNING INTENTION

At the end of this lesson you will be able to identify independent, dependent and controlled 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.

Go online to access:

- **Tell me:** an overview of the skill and its application in science
- **Show me:** a video and a step-by-step process to explain the skill
- **Let me do it:** an interactivity, question set and SkillBuilder activity for you to practice and consolidate your understanding of the skill

on Resources

eWorkbook	SkillBuilder — Controlled, dependent and independent variables (ewbk-12208)
Video eLesson	Controlled, dependent and independent variables (eles-4156)
Interactivity	Controlled, dependent and independent variables (int-8090)

LESSON
1.7 SkillBuilder — Writing an aim and forming a hypothesis

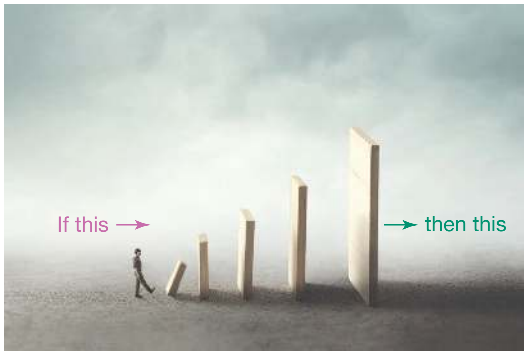
LEARNING INTENTION

At the end of this lesson you will be able to write aims and hypotheses.

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 that 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.

Go online to access:

- **Tell me:** an overview of the skill and its application in science
- **Show me:** a video and a step-by-step process to explain the skill
- **Let me do it:** an interactivity, question set and SkillBuilder activity for you to practice and consolidate your understanding of the skill

on Resources

eWorkbook	SkillBuilder — Writing an aim and forming a hypothesis (ewbk-12210)
Video eLesson	Writing an aim and forming a hypothesis (eles-4155)
Interactivity	Writing an aim and forming a hypothesis (int-8089)

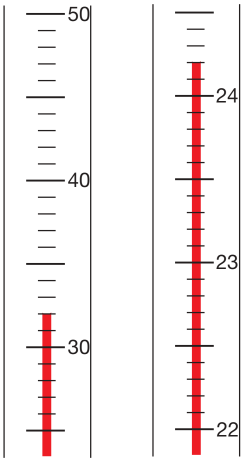
LESSON
1.8 SkillBuilder — Measuring and reading scales

LEARNING INTENTION

At the end of this lesson you will be able to read and record measurements accurately.

online only

How do you read a scale?



In science, a scale or set of numbered markings generally accompanies each measuring device. For example, your ruler measures length, and its scale has markings enabling you to measure with an accuracy of 0.1 cm. When reading a scale, it is important to determine what each of the markings on the scale represents.

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. Measurements should always be made with your eye in line with the reading you are taking. When scales are read from a different angle, the reading is not accurate. This type of reading error is called parallax error.

Go online to access:

- **Tell me:** an overview of the skill and its application in science
- **Show me:** a video and a step-by-step process to explain the skill
- **Let me do it:** an interactivity, question set and SkillBuilder activity for you to practice and consolidate your understanding of the skill

on Resources

eWorkbook	Skillbuilder — Measuring and reading scales (ewbk-12212)
Video eLesson	Measuring and reading scales (eles-4153)
Interactivity	Measuring and reading scales (int-0201)

LESSON
1.9 SkillBuilder — Drawing a line graph

LEARNING INTENTION

At the end of this lesson you will be able to construct line graphs.

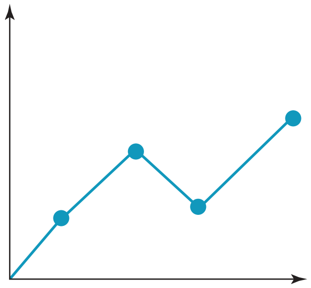
online only

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.

Go online to access:

- **Tell me:** an overview of the skill and its application in science
- **Show me:** a video and a step-by-step process to explain the skill
- **Let me do it:** an interactivity, question set and SkillBuilder activity for you to practice and consolidate your understanding of the skill



Line graph continuous, ungrouped data

on Resources

eWorkbook	SkillBuilder — Drawing a line graph (ewbk-12214)
Video eLesson	Drawing a line graph (eles-1635)
Interactivity	Drawing a line graph (int-3131)

LESSON
1.10 SkillBuilder — Creating a simple column or bar graph

LEARNING INTENTION

At the end of this lesson you will be able to construct simple column or bar graphs.

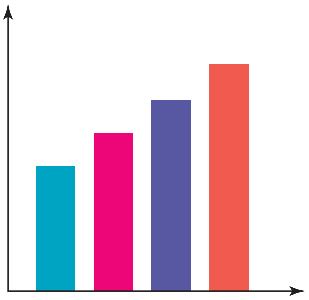
online only

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.

Go online to access:

- **Tell me:** an overview of the skill and its application in science
- **Show me:** a video and a step-by-step process to explain the skill
- **Let me do it:** an interactivity, question set and SkillBuilder activity for you to practice and consolidate your understanding of the skill



Column graph, ungrouped data

on Resources

eWorkbook	SkillBuilder — Creating a simple column or bar graph (ewbk-12216)
Video eLesson	Creating a simple column or bar graph (eles-1639)
Interactivity	Creating a simple column graph (int-3135)

LESSON
1.11 Case study

LEARNING INTENTION

At the end of this lesson you will be able to describe how an investigation is planned and presented as a scientific report.

1.11.1 Investigating muddy water

Sean, a Year 9 student, conducted an experimental investigation to compare the turbidity (cloudiness) of water in the following three locations:

- a creek near his school
- a creek near his home
- a river near his home.

His search for information in the library revealed that the cloudiness was caused by particles of soil (and sometimes pollution) suspended in the water. Sean chose his topic because he was interested in the environment. He felt that clean water was the right of all living things. His research and background knowledge led him to form the hypothesis that ‘the clearest water will be in the river’.

Sean took water samples from each of the three locations on 4 days. He found a method of measuring turbidity from a library book. It involved adding a chemical called potash alum to a sample of water in a jar. The potash alum makes the particles of suspended soil clump together and fall to the bottom of the jar. A layer of mud is formed. The height of the mud at the bottom is then measured.

SEAN’S INVESTIGATION

Aim

To compare the turbidity of three local creeks and rivers

Materials

- 4 large jars or bottles with lids for collecting water samples (capacity of about 1 L each)
- 4 identical jam jars with lids, labelled 1, 2, 3 and 4
- metal teaspoon (not plastic, in case it breaks)
- potash alum (potassium aluminium sulfate)
- 4 water samples from different locations
- ruler with 1-millimetre graduations
- 100 mL measuring cylinder
- permanent marker

Method

1. Water samples (about 1 litre each) were collected from a specific part of the creeks and river on the same day.
2. Each of three clean jars was filled to the same level with the water samples — a labelled jar for each location. A fourth labelled jar was filled to the same level with distilled water.
3. One level teaspoon of potash alum was added to each jar. Lids were put on the jars and the jars were shaken.
4. The jars were left for 30 minutes to allow the particles to settle.
5. The height of the layer of mud on the bottom of each jar was measured and recorded.
6. The jars were emptied and washed and the experiment was repeated three more times.
7. Water samples were collected from the same locations on three other days over a ten-day period and the entire experiment was repeated three more times.

A summary of Sean’s method, including a list of materials and equipment required, is provided. You will notice that Sean used a fourth sample. It was needed as a control and contained distilled water. This was to ensure that there was nothing in the pure water to cause a layer at the bottom of the jar when the potash alum was added. His results are in table 1.3.

TABLE 1.3 Results table measuring the levels of mud in water samples from three areas

Water sample	Height of mud (mm)															
	Day 1				Day 2				Day 3				Day 4			
	Test			Average	Test			Average	Test			Average	Test			Average
	1	2	3		1	2	3		1	2	3		1	2	3	
1. Home creek	3.5	4.0	5.0	4.2	5.0	4.5	5.0	4.8	4.5	5.0	4.5	4.3	5.0	4.5	4.0	4.5
2. School creek	2.5	2.0	2.0	2.2	3.0	2.5	2.5	2.7	2.0	2.5	2.5	2.3	2.0	2.0	2.5	2.2
3. Barnes River	1.0	0.5	0	0.5	2.0	1.0	1.5	1.5	0.5	1.0	0.5	0.7	0.5	0.5	0.5	0.5
4. Distilled water	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

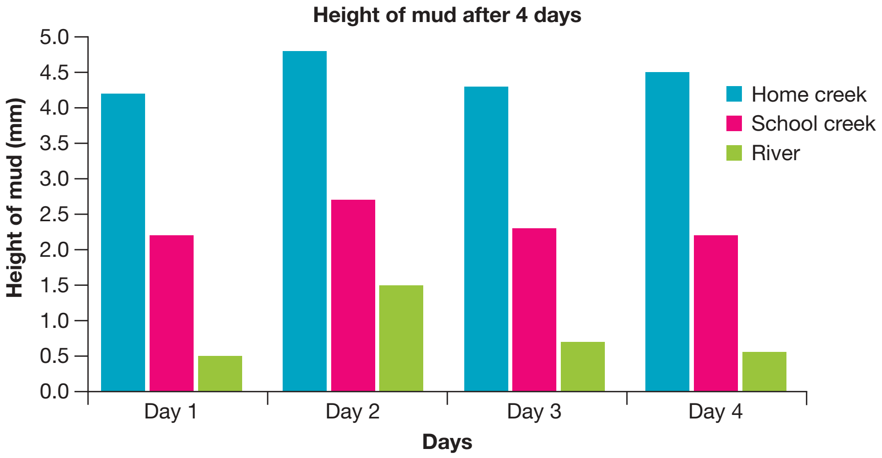
1.11.2 Analysing the data

Sometimes it is necessary to refine the raw data (the data initially collected), presenting them in a different way. Sean was planning to use his average measurements to make a column graph. He decided to simplify his table so that it was easier to construct the column graph. The simplified table (table 1.4) and column graph (figure 1.27) make it easier for others to read the results, and easier for Sean to see patterns and draw conclusions.

TABLE 1.4 Average heights of mud in water from three different areas

Sample number and source	Height of mud (mm)			
	Day 1	Day 2	Day 3	Day 4
1. Home creek	4.2	4.8	4.3	4.5
2. School creek	2.2	2.7	2.3	2.2
3. River	0.5	1.5	0.7	0.5

FIGURE 1.27 Sean's graph makes it easier to see patterns and draw conclusions.



1.11.3 Being critical

Sean was pleased with his results and was able to draw conclusions. In the discussion section of his report, he suggested that further studies be done. The turbidity was affected by weather conditions and the sampling needed to be done over a longer period, and in different weather conditions. Sean had recorded weather details on each day that he sampled water and was able to explain the very high mud level in the river on day 2. It is almost always possible to suggest improvements to your experiments.

1.11.4 Drawing conclusions

Sean's hypothesis, that the clearest water would be in the river, was supported. His conclusion was written in point form.

1. The home creek has the muddiest water, with sample values ranging from heights of 4.2 to 4.8 mm of mud per 200 mL of water. The school creek has moderate amounts of mud compared to the other two samples. Sample values ranged from 2.2 to 2.7 mm of mud per 200 mL of water. The river water is the clearest, with sample values of 0.5 to 1.5 mm of mud per 200 mL of water.
2. Weather conditions can alter the amount of mud in water bodies by either adding run-off from drains or stirring up the water. This was particularly noticeable in the samples taken from the river site on day 2, which followed a period of rain.

Sean's teacher was pleased, and suggested that Sean carry out further research and rewrite his material. They also suggested that he should think about entering his project into a competition.

The last word comes from Sean. After successfully completing his student research project, he said: 'It all depends on the experimental design — get that right and the rest is likely to run smoothly.'

FIGURE 1.28 Chemical waste running into a river. How might you test for such materials in a water sample from this site?

1.11 Activities

learnon

1.11 Quick quiz on

1.11 Exercise

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 2	3, 5	4, 6

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS ▶

Remember and understand

1. For Sean's experiment, identify:
   a. the independent variable
   b. the dependent variable
   c. the variables he controlled.

Apply and analyse

2. Explain why a sample of distilled water was included in Sean's experiment.
3. Explain why Sean repeated the experiment three times each day on four separate days.
4. Suggest how Sean could improve the reliability and accuracy of his experiment.
5. Why did Sean use a column graph rather than another type of graph to present his results?

Evaluate and create

6. In your opinion, is Sean's conclusion valid? Give reasons for your answer.

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

LESSON
1.12 Using spreadsheets

LEARNING INTENTION

At the end of this lesson you will be able to use a spreadsheet to record, graph and analyse data.

1.12.1 The advantages of spreadsheets

A spreadsheet is a computer program that can be used to organise data into columns and rows. Once the data are entered, mathematical calculations, such as adding, multiplying and averaging, can be carried out easily using the spreadsheet functions.

Spreadsheets have many advantages over handwritten or word-processed results. For example, with spreadsheets you can:

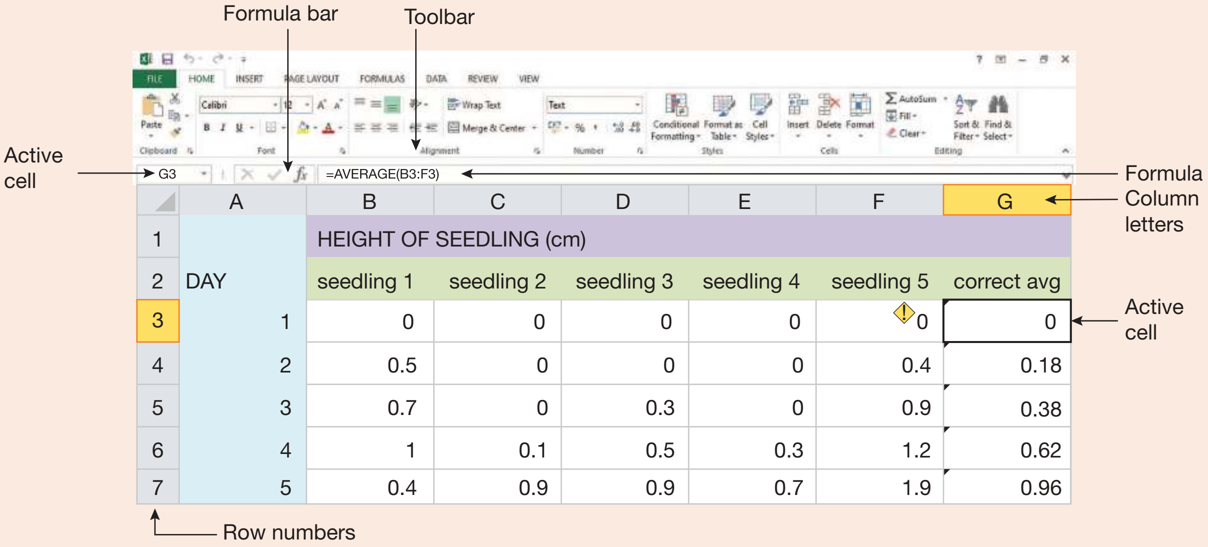
- make calculations quickly and accurately
- change data or fix mistakes without redoing the whole spreadsheet
- use the spreadsheet's charting function to present your results in graphic form.

1.12.2 Elements of a spreadsheet

Although there are a number of spreadsheet programs available, they all have the same basic features and layout, as shown in example 1 below. The data shown are from a student research project about the different factors on the growth of bean plants.

ELEMENTS OF A SPREADSHEET: Example 1

- At the top of the spreadsheet are the toolbar and formula bar.
- A *row* is identified by a number; for example, 'row 1' or 'row 2'.
- A *column* is identified by a letter; for example, 'column A' or 'column B'.
- A *cell* is identified by its column and row address. For example, 'cell G3' refers to the cell formed by the intersection of column G with row 3. In this example, cell G3 is the active cell (shown by its heavy border). The active cell address and its contents (once data are entered) are shown to the left of the formula bar.
- A *range* is a block of cells. For example, 'range C3:F4' includes all the cells in columns C through to F and rows 3 through to 4.



G3 =AVERAGE(B3:F3)

	A	B	C	D	E	F	G
1		HEIGHT OF SEEDLING (cm)					
2	DAY	seedling 1	seedling 2	seedling 3	seedling 4	seedling 5	correct avg
3	1	0	0	0	0	0	0
4	2	0.5	0	0	0	0.4	0.18
5	3	0.7	0	0.3	0	0.9	0.38
6	4	1	0.1	0.5	0.3	1.2	0.62
7	5	0.4	0.9	0.9	0.7	1.9	0.96

1.12.3 Entering data into cells

You can enter different types of data into a cell:

- a number or value
- a label, that is, text (for titles and headings)
- a formula (an instruction to make a calculation).

Decide in which cell you want to insert the data (the active cell). Type the data in the cell and press ‘Enter’. To edit or change the data, simply highlight the cell and type in the new data — it will replace the old data when you press ‘Enter’. Example 2 that follows shows a spreadsheet in which data have been entered.

1.12.4 Creating formulae

To create a formula, you need to start with a special character or symbol to indicate that you are keying in a formula rather than a label or value. This is usually one of the symbols =, @ or +, depending on the spreadsheet program. For example, a formula to add the contents of cell B1 to cell C1 would take one of the following forms: =B1+C1 or @B1+C1 or +B1+C1.

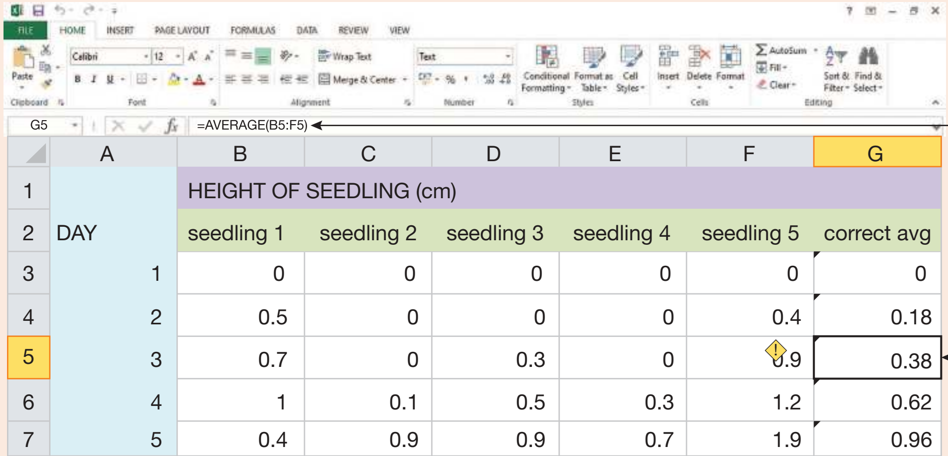
Once you have entered the formula in a cell, the result of the calculation, rather than the formula, will be shown. The formula can be seen in the status bar when the cell is active (see example 2 that follows). If you subsequently needed to change the values in B1 or C1, the spreadsheet will automatically use the formula to recalculate and show the new result.

The symbols used for mathematical operations in spreadsheets are:

+ for addition
– for subtraction
* for multiplication
/ for division.

CREATING FORMULAE: Example 2

The spreadsheet in example 1 has been further developed. Formulae have now been entered to average the heights of the seedlings.



G5 =AVERAGE(B5:F5)

	A	B	C	D	E	F	G
1		HEIGHT OF SEEDLING (cm)					
2	DAY	seedling 1	seedling 2	seedling 3	seedling 4	seedling 5	correct avg
3	1	0	0	0	0	0	0
4	2	0.5	0	0	0	0.4	0.18
5	3	0.7	0	0.3	0	0.9	0.38
6	4	1	0.1	0.5	0.3	1.2	0.62
7	5	0.4	0.9	0.9	0.7	1.9	0.96

Archive cell contents

This is the active cell. The formula in the bar above is the formula for this cell.

1.12.5 Using functions

Some common types of calculations are built into the spreadsheet, so that you don't always need to type out the full formulae. These are called **functions**. All functions have two parts: the name and a value (called the argument) that the function will operate on. The value is normally placed in parentheses, (), and can be written as a set of numbers or as a range (a block of cells). For example, a function to calculate the average of the amounts entered in cells B1, B2, B3 and B4 would be written: =AVERAGE(B1:B4).

This is also known as the mean of the values, which is calculated by adding up the values and dividing by how many there are.

The mode is the value that appears most in the chosen cells.

The median is the middle value when the cells are arranged in order of value.

Some of the common functions found in spreadsheets are shown in the table 1.5.

functions common type of calculation built into spreadsheets

TABLE 1.5 Common spreadsheet functions

Name	Application	Example	Result
AVERAGE	calculates the average of the argument values	=AVERAGE(1,2,3,4)	2.5
COUNT	counts the number of values in the argument	=COUNT(A3:A6)	4
MAX	returns the largest value in the argument	=MAX(1,9,5)	9
MIN	returns the smallest value in the argument	=MIN(1,9,5)	1
MODE	returns the most common value in the argument	=MODE(1,1,5,5,1)	1
MEDIAN	returns the median value of the argument values	=MEDIAN(1, 2, 3, 5, 6)	3
ROUND	rounds the argument to the number of decimal places specified	=ROUND(12.25,1)	12.3
SUM	calculates the sum of the values in the argument	=SUM(1,9,5)	15

1.12.6 Copying cells

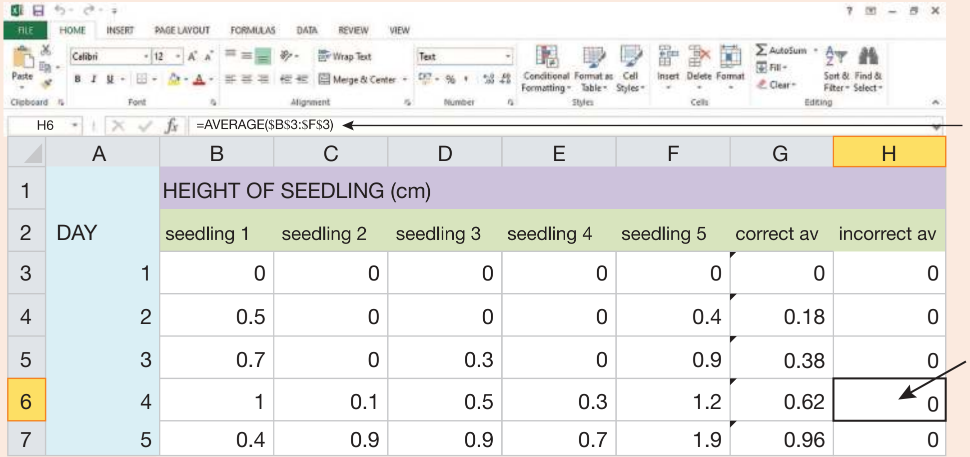
Spreadsheets have a command that allows you to copy a formula or value from one cell to another cell (or into a range of cells). This is usually found in the *Edit* menu (*Fill Down* or *Fill Right*). The way a formula is copied depends on whether the cell references use:

- **relative referencing**, which you use when you want the cell address in the formula to change according to the relative location of the cell that you have copied it to. Example 2 in section 1.7.4 uses relative referencing. The formula AVERAGE(B5:F5) in the active cell G5 was copied downwards, so that there was no need to type the formulae in the rest of the column. The formula in the next cell (G6) is therefore AVERAGE(B6:F6) and so on.
- **absolute referencing**, which you use when you want a cell address in the formula to be constant, no matter where it is copied to. Absolute referencing is denoted by the symbol $ placed in the cell address. For example, $B$3 (see example 3 below).

relative referencing used in a spreadsheet when the cell address in the formula is changed

absolute referencing used in a spreadsheet when a cell address in the formula remains constant, no matter where it is copied to

COPYING CELLS: Example 3



=AVERAGE($B$3:$F$3)

	A	B	C	D	E	F	G	H
1		HEIGHT OF SEEDLING (cm)						
2	DAY	seedling 1	seedling 2	seedling 3	seedling 4	seedling 5	correct av	incorrect av
3	1	0	0	0	0	0	0	0
4	2	0.5	0	0	0	0.4	0.18	0
5	3	0.7	0	0.3	0	0.9	0.38	0
6	4	1	0.1	0.5	0.3	1.2	0.62	0
7	5	0.4	0.9	0.9	0.7	1.9	0.96	0

The formula has a $ sign in front of the cell coordinates, so that the coordinates do not adjust automatically as the row number changes.

The formula above is the formula for this cell in row 5.

1.12.7 Formatting cells

Investigate your spreadsheet program (most come with a tutorial) to learn how to use other useful features, such as:

- adding and deleting rows or columns (useful if you have forgotten to include some calculations in your planning or decide you don't need some items)
- changing column widths (to show the full cell contents when the data are longer than the default column width) and changing row heights so that you can use larger font sizes for titles and headings
- inserting horizontal or vertical lines to improve the presentation of your spreadsheet
- changing cell formats to control how the data are to be displayed, such as using different fonts and character styles (underlining, bold, italic).

You can also format numeric values in a variety of ways. For example, the *Fixed* or *Number* format will display values to the number of specified decimal places. The *Percent* format will display values as a percentage, to the number of specified decimal places.

Once you have keyed in your data and included any necessary calculations, print out your spreadsheet and save it to a disk so that you can store the document and use it later.

1.12.8 Spreadsheet graphics

The three main types of graphs — pie, bar and line graphs — can usually be produced by a spreadsheet. It means that you can easily display your results graphically, but you still need to decide which is the most appropriate type of graph for your data.

The first step in producing a spreadsheet graph is to select the block of the cells that contains the data to be graphed. Use the spreadsheet's charting function, which usually brings up a window where you can indicate the type of graph, and add title and label details. When you are satisfied with the result, you can display and print out your graph.

on Resources

eWorkbooks Spreadsheeting and graphing (ewbk-12218)
Calculating using a spreadsheet (ewbk-12220)

1.12 Activities

learn**on**

1.12 Quick quiz on

1.12 Exercise

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1	2, 3	4

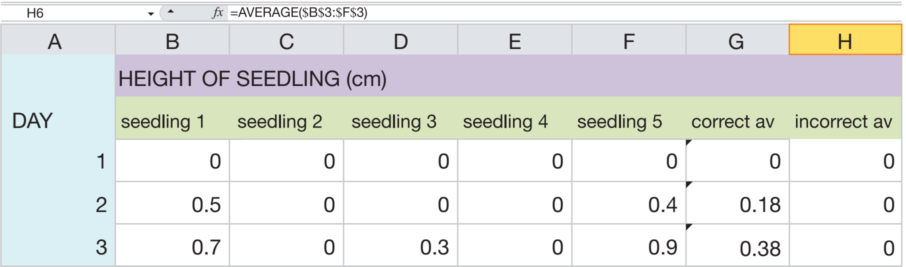
These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. Look at the section of a spreadsheet presented below and answer the following questions:



H6 =AVERAGE($B$3:$F$3)

A	B	C	D	E	F	G	H
	HEIGHT OF SEEDLING (cm)						
DAY	seedling 1	seedling 2	seedling 3	seedling 4	seedling 5	correct av	incorrect av
1	0	0	0	0	0	0	0
2	0.5	0	0	0	0.4	0.18	0
3	0.7	0	0.3	0	0.9	0.38	0

a. What does cell G3 contain?
b. Does cell E2 contain a value or a label?
c. If the formula in cell G4 is AVERAGE(B4:F4), what would the formula be in cells G5 and G6?

Apply and analyse

2. The following table shows the results of an experiment that tested the amount of time taken for eucalyptus oils and other substances (0.1 mL of each) to evaporate at a constant temperature. The experiment was done twice.

TABLE Time taken to evaporate different substances

	Time (s)	
Substance	**Trial 1**	**Trial 2**
Methylated spirits	4.17	1.85
Turpentine	63.48	43.02
Water	54.42	57.05
Oil from *E. rossi*	195.92	191.23
Oil from *E. nortonii*	103.99	105.39

a. Enter the data into a spreadsheet.
b. Use the spreadsheet function to calculate the average time that each substance took to evaporate.

3. The following table shows the distance travelled by Jesse at 3-second intervals during a 100-metre sprint. The data were recorded during the sprint by attaching a paper tape to Jesse's waist. As he ran, the tape was pulled through a timer that printed a dot every 3 seconds.

TABLE Distance and speed travelled in 3-second intervals

Time (s)	Distance travelled in time interval (m)	Average speed for time interval (m/s)
0	0	
3	35	
6	25	
9	15	
12	15	
15	10	

   a. Enter the data into a spreadsheet. Calculate the average speed travelled in each 3-second interval by applying a formula to the first cell in the column, and then copying it down. Remember that average speed can be calculated by dividing the distance travelled by the time taken:

$$\text{Speed} = \frac{\text{distance}}{\text{time}}$$

   b. What was Jesse's average speed over the total time?

Evaluate and create

4. The following data was collected by two car servicing centres in Canberra, at the request of a student. The table shows the level of carbon monoxide and carbon dioxide emissions (as a percentage of total emissions) from cars of various ages.

TABLE Carbon monoxide and carbon dioxide emissions of cars by year of manufacture

Year car manufactured	Carbon monoxide (%)	Carbon dioxide (%)
1977	3.17	11.8
1983	2.48	13.6
1985	3.7	11.4
1987	1.6	13.1
1989	1.08	10.2
1996	0.19	15.2

   a. Enter the data into a spreadsheet and create a graph to display these results.
   b. Create formulae to work out the average carbon monoxide and carbon dioxide emissions for:
      i. cars manufactured up to 1985
      ii. cars manufactured from 1987 onwards.
   c. Car manufacturers were required to install catalytic converters in cars made after 1986. Catalytic converters cut down carbon monoxide emissions by converting some of the carbon monoxide to carbon dioxide. What can you conclude from this data about the success of catalytic converters?

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

LESSON
1.13 SkillBuilder — Using a spreadsheet

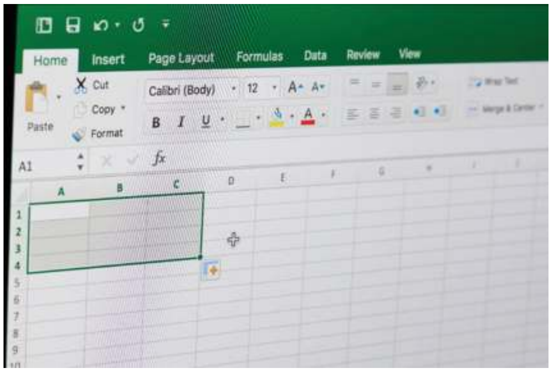
LEARNING INTENTION

At the end of this lesson you will be able to create, label and utilise formulas in a spreadsheet, and insert and label graphs to analyse data.

online only

How do you use a spreadsheet to record, analyse and graph your results?

Spreadsheets, through programs such as Excel, provide very powerful ways to identify trends and patterns in your data. They allow for data to be recorded in cells to format tables, and allow for the quick analysis of data and creation of different types of graphs.



Go online to access:

- **Tell me:** an overview of the skill and its application in science
- **Show me**: a video and a step-by-step process to explain the skill
- **Let me do it:** an interactivity, question set and SkillBuilder activity for you to practice and consolidate your understanding of the skill

Resources

Video eLesson	Using a spreadsheet (eles-4230)
Interactivity	Using a spreadsheet (int-8160)
eWorkbook	SkillBuilder — Using a spreadsheet (ewbk-12222)

LESSON
1.14 Using data loggers and databases

LEARNING INTENTION

At the end of this lesson you will be able to use a data logger, analyse the data generated and how to create a simple database.

1.14.1 The data logger

A data logger is a device that stores a large number of pieces of information (data) sent to it by sensors attached to it. The data logger can transfer this data to another device, such as a graphing calculator or, more commonly, a computer, which can use data logger software or a spreadsheet program to manipulate the data (see section 1.12.1). Usually the computer or calculator graphs the collected data, and we can use these graphs to see patterns and trends easily.

When can a data logger be used?

Data loggers are particularly useful whenever an experiment requires several successive measurements. Sometimes, these measurements will take place over several hours or days — such as when measuring the way air pressure varies with the weather. Sometimes, many measurements must be taken over a short time interval — such as when measuring changes in air pressure as sound waves pass by. Data loggers are very flexible and can help scientists gather and analyse data for these types of experiments, as well as many others. As an example of how a data logger might help you in your scientific investigations, let's consider the following common exothermic and endothermic experiments.

CASE STUDY: Using a data logger to investigate exothermic and endothermic processes

In an experiment, we investigate temperature changes in chemical processes. In part 1, we observe the reaction of magnesium metal with dilute hydrochloric acid and, in part 2, citric acid and baking soda. In addition to the laboratory equipment required for this experiment, including safety glasses, we will need a data logger with a temperature sensor attached to it. The data logger will need to be attached to a computer on which the data logger software has been installed.

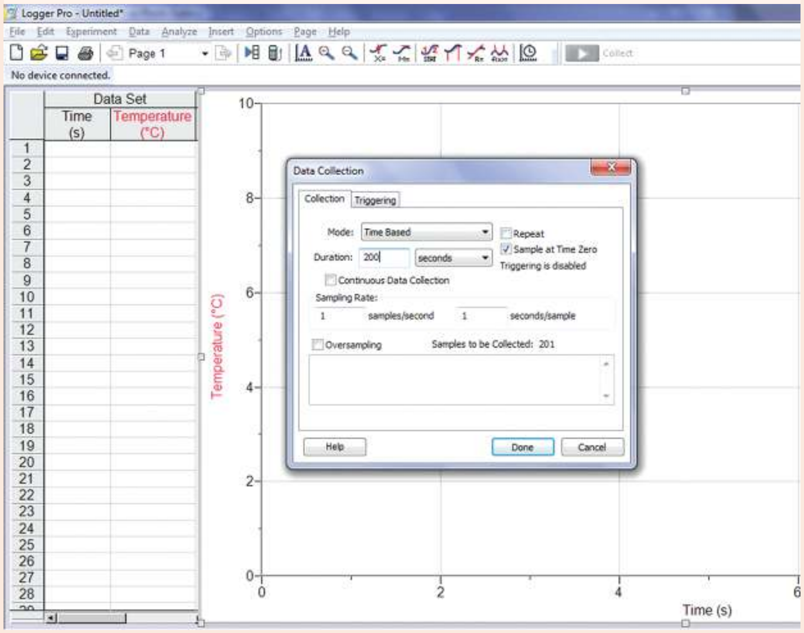
Part 1: Magnesium in hydrochloric acid

Active metals react with dilute acids to give off hydrogen gas and leave behind a salt that usually stays dissolved in the water in which the acid was dissolved. To investigate whether heat is given off or taken in during the reaction, we will need the equipment shown in figure 1.29. We could use a test tube or a beaker (as shown in the photo). If we use a beaker, we will have to use more acid; in this case, we will use 100 mL of 0.5 mol/L hydrochloric acid.

FIGURE 1.29 The equipment required for *Part 1: Magnesium in hydrochloric acid*

We now set up the data logger to collect data for the length of time that we need and at the rate we require. The data logger itself or its software allows us to do this. Figure 1.30 shows the data logger being set to collect temperature data for 200 seconds at the rate of once per second. Now it's a simple matter of putting the temperature sensor in the dilute acid, pressing the button on the data logger to start data collection and adding the magnesium.

FIGURE 1.30 Set the data logger to take temperature data for 200 seconds at the rate of once per second.



Data Collection

Collection | Triggering

Mode: Time Based

Duration: 200 seconds

☐ Repeat

☑ Sample at Time Zero

Triggering is disabled

☐ Continuous Data Collection

Sampling Rate:

1 samples/second 1 seconds/sample

☐ Oversampling

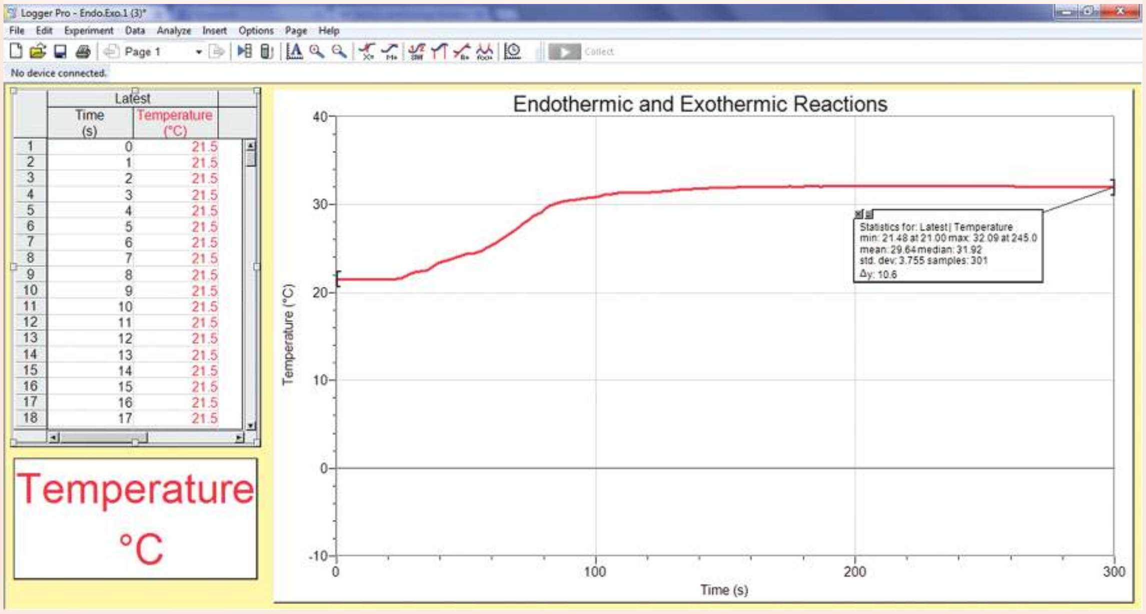
Samples to be Collected: 201

Help | Done | Cancel

FIGURE 1.31 Place the temperature sensor into the beaker of dilute acid and add the magnesium.

The reaction proceeds for 200 seconds and the sensor sends a temperature measurement every second to the data logger. When the selected time has passed (that is, after 200 seconds), the data logger sends all the data to the computer, which (via the software) displays it as a graph, as shown in figure 1.32.

FIGURE 1.32 Graphed data for part 1 of the *exothermic and endothermic processes* experiment



Latest

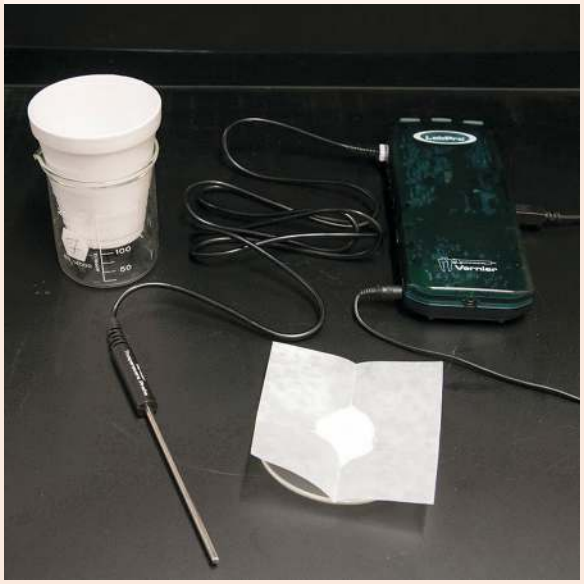
	Time (s)	Temperature (°C)
1	0	21.5
2	1	21.5
3	2	21.5
4	3	21.5
5	4	21.5
6	5	21.5
7	6	21.5
8	7	21.5
9	8	21.5
10	9	21.5
11	10	21.5
12	11	21.5
13	12	21.5
14	13	21.5
15	14	21.5
16	15	21.5
17	16	21.5
18	17	21.5

Statistics for: Latest | Temperature
min: 21.48 at 21.00 max: 32.09 at 245.0
mean: 29.64 median: 31.92
std. dev: 3.755 samples: 301
Δy: 10.6

Part 2: Citric acid and baking soda

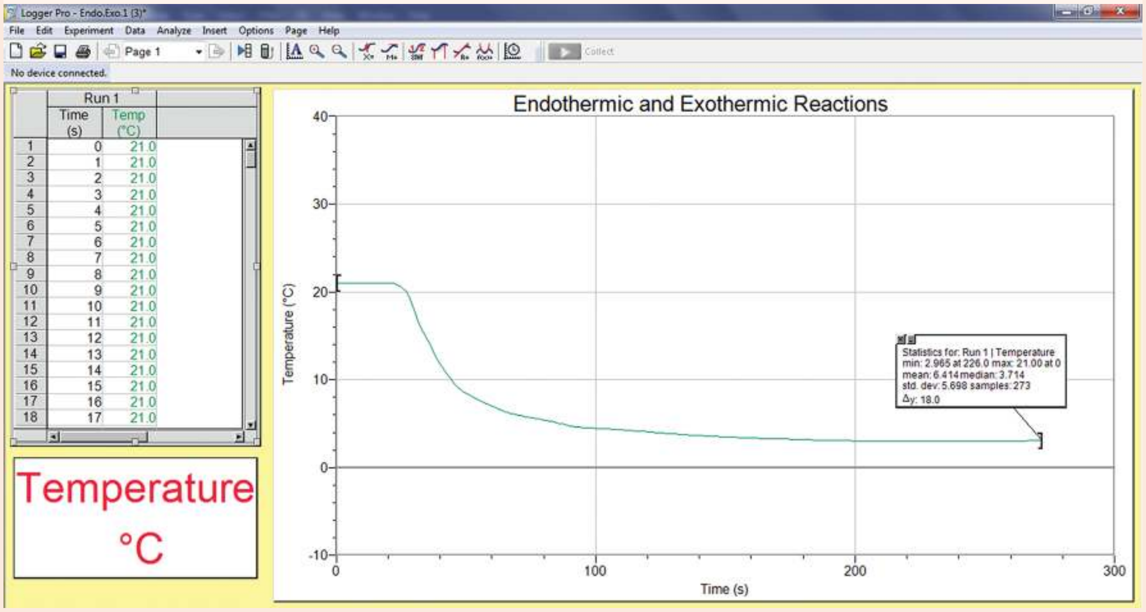
For this part of the experiment, we will need baking soda, citric acid, a beaker, a foam cup, other necessary laboratory equipment such as safety glasses, as well as a data logger and temperature sensor. We will use 30 mL of citric acid and 10 g of baking soda. These items are shown in the photograph in figure 1.33.

FIGURE 1.33 The equipment required for *Part 2: Citric acid and baking soda*



Once again, we set the run time to 200 seconds and the data collection rate to once per second. We insert the temperature sensor into the acid, press a button on the data logger to start data collection and then add the baking soda to the acid. The data logger collects the data, which the computer software automatically graphs after completion of the run, as shown in figure 1.34.

FIGURE 1.34 Graphed data for part 2 of the *exothermic and endothermic processes* experiment



No device connected.

	Run 1	
	Time (s)	Temp (°C)
1	0	21.0
2	1	21.0
3	2	21.0
4	3	21.0
5	4	21.0
6	5	21.0
7	6	21.0
8	7	21.0
9	8	21.0
10	9	21.0
11	10	21.0
12	11	21.0
13	12	21.0
14	13	21.0
15	14	21.0
16	15	21.0
17	16	21.0
18	17	21.0

Temperature
°C

Endothermic and Exothermic Reactions

Statistics for: Run 1 | Temperature
min: 2.965 at 226.0 max: 21.00 at 0
mean: 6.414 median: 3.714
std. dev: 5.698 samples: 273
Δy: 18.0

This investigation is summarised in the following investigation box.

elog-2249

tlvd-10797

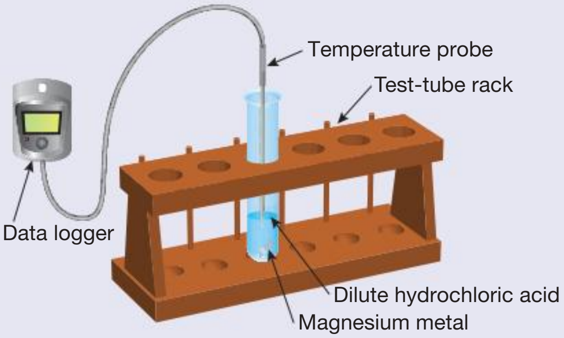
INVESTIGATION 1.1

Exothermic and endothermic processes

Part 1 is for Teacher Demonstration only

Materials

- safety glasses
- bench mat
- 4 large test tubes and test-tube rack
- 10 mL measuring cylinder
- balance
- data logger
- temperature probe
- stirring rod
- magnesium ribbon
- sandpaper
- 0.5 mol/L hydrochloric acid
- 30 mL citric acid solution (10 g dissolved in 100 mL water)
- 10 g baking soda (dissolved in 100 mL water)



Method

Part 1: Magnesium in hydrochloric acid

1. Pour 10 mL of 0.5 mol/L hydrochloric acid into a test tube in a test-tube rack. Place a thermometer or probe in the test tube and allow it to come to a constant temperature. Record the temperature of the solution.
2. Clean a 10 cm piece of magnesium ribbon using the sandpaper until it is shiny on both sides. Coil the magnesium ribbon and place it into the test tube of hydrochloric acid.
3. Observe the temperature of the solution as the magnesium reacts with the hydrochloric acid. Record the final temperature of this solution.

Part 2: Citric acid and baking soda

4. Pour 10 mL of citric acid solution into a test tube in a test-tube rack. Place a thermometer in the water in the test tube and allow it to come to a constant temperature. Record the temperature of the water.
5. Use a balance to weigh 3 g of baking soda; add it to the water in the test tube and stir gently.
6. Observe the temperature of the solution as the baking soda dissolves in the water. Record the final temperature of this solution.

1.14.2 Using databases

Databases are simply information or data arranged in one or more tables. We use databases every day; for example, when we look up information in the index of a book.

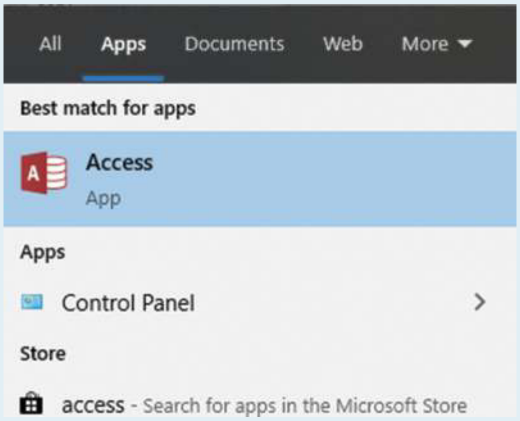
An electronic database is one of the most powerful computer applications and is an important tool for a business, an organisation or a scientist. A database's design is crucial to its usefulness, so a database must be designed with ease of searching uppermost in mind. The most common is Microsoft Access. In the activity that follows you will create a database using some of the features of Microsoft Access.

ACTIVITY: Creating a database of Nobel Prize winners

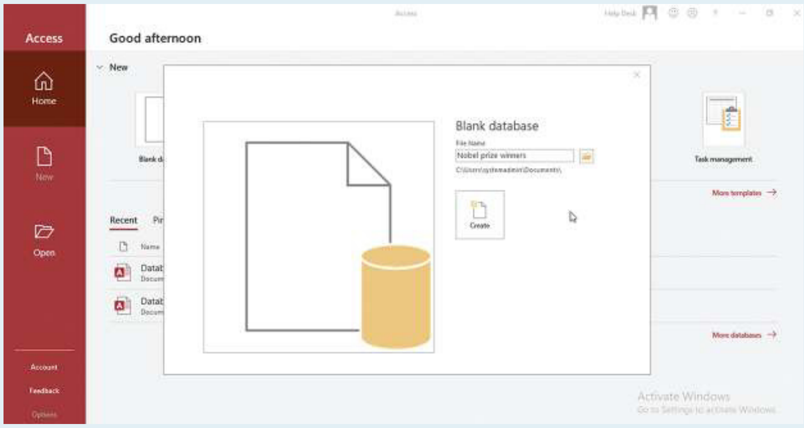
Before creating your database, you will need to find some information to put in it. This is best done as a class activity with each student in the class researching one or two Nobel Prize winners.

- Each student in the class should research one or two different Nobel Prize winners. Choose people who have won a Nobel Prize for work in the categories of Chemistry, Physics or Medicine.

- For each prize winner, collect the data listed below. Ideally the data should be written on cards that can be passed around the class, or they could be displayed in large writing on large sheets of paper around the room.
    - First name
    - Last name
    - Country of birth
    - Year of birth
    - Category of award (such as Chemistry, Physics or Medicine)
    - Organisation (where the person worked)
    - Nobel Prize awarded for (one sentence or phrase that outlines the work for which the scientist received the award)
    - Share received (if the award was shared by a group of people)
- Microsoft Access software is commonly used to create databases. The following instructions may not be the same as your edition of this software. Other editions are similar to use but the screens are not exactly the same. You can start Access by clicking on the search bar of your PC and then the Access icon is shown.

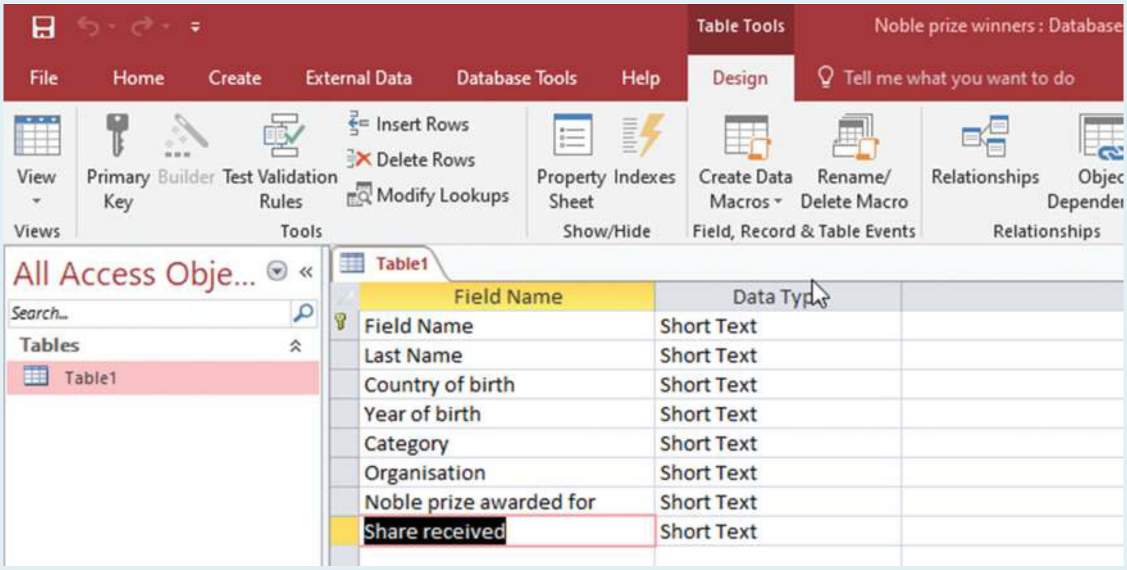


- When you open the software, a list of options will appear along the top of the screen. Choose the option *Blank database*. A dialog box will appear for you to enter a name for your database and click *Create*.



File Name: Nobel prize winners

- A *Table* window will open. Ensure you are in *Design* view by clicking on the drop-down *View* options under *File*. This will prompt you to Save the table. Give the table a suitable name (such as ‘Table 1’) and click *OK*. Now you can enter field names, which are the column headings for the database. Enter the field names as shown in the next figure. You will note that, by default, the data type may be *Autonumber*. Use the drop-down menu to choose *Short text*.

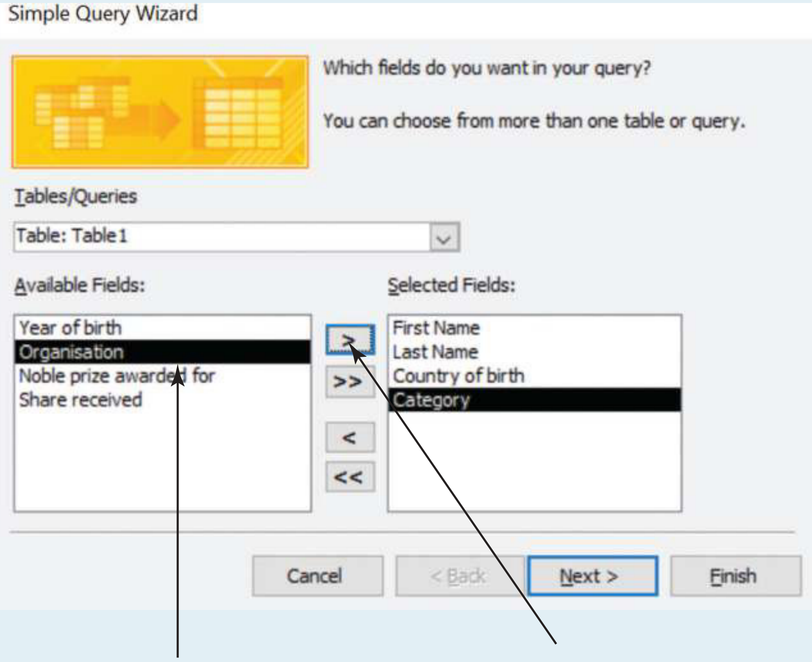


Field Name	Data Typ
Field Name	Short Text
Last Name	Short Text
Country of birth	Short Text
Year of birth	Short Text
Category	Short Text
Organisation	Short Text
Noble prize awarded for	Short Text
Share received	Short Text

- Now that you have designed the database, it is time to change to datasheet view. Click on the Datasheet view button on the left-hand corner of the screen. You will be prompted to save the table. Give the table a suitable name (such as ‘Table 1’) and click *OK*.
- Enter the data that you and your classmates found into the table. You can do this manually or import data from a spreadsheet or text file by using the *External data* tab on the ribbon. When you have done this, save your database.

The great thing about databases is that they allow you to search for data that match particular criteria. This is called running a *query*. We are going to create a query to find all the Nobel Prize winners in our database who were awarded a prize for Medicine and were born in the United States.

- Make sure you are in datasheet view. Click *Create* on the ribbon. Select *Query wizard,* then *Simple Query Wizard* and then click *OK*. The fields in your table will be displayed; click on the ones you want to appear in the query, then click on the single arrow to move them into the *Selected Fields* box. Select the following fields: first name, last name, country of birth and category. When you have done this, click *Next*. In the next dialog box, enter a name for your query, select *Modify the query design* and click on *Finish*.



Which fields do you want in your query?

You can choose from more than one table or query.

Table: Table1

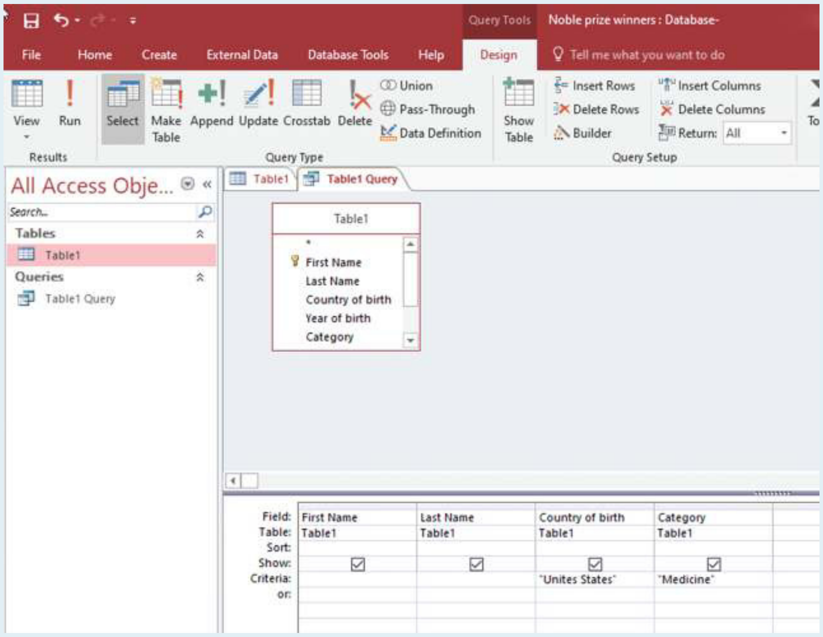
Available Fields:
- Year of birth
- Organisation
- Noble prize awarded for
- Share received

Selected Fields:
- First Name
- Last Name
- Country of birth
- Category

Click on a field to select it.

Click on the single arrow to move the field into the Selected Fields box.

- The screen below will appear. Now enter the criteria you want the query to look for in the appropriate boxes. In the Category column, type 'Medicine' (without the quotation marks) in the *Criteria* row. In the Country of birth column, type 'United States' in the *Criteria* row. Quotation marks will automatically appear when you press [Enter]. This is shown below.



Field:	First Name	Last Name	Country of birth	Category
Table:	Table1	Table1	Table1	Table1
Sort:				
Show:	☑	☑	☑	☑
Criteria:			"Unites States"	"Medicine"
or:				

- Now click on the Run button in the toolbar near the top of the screen. The query will run and a table displaying the Nobel Prize winners that match your criteria will appear.
- Create a new query to display the Nobel Prize winners who won the Nobel Prize for Physics and were born in England.

1.14 Activities

1.14 Quick quiz on | **1.14 Exercise**

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 3	2, 4	5, 6

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. Describe a data logger and what it does in a way that a Year 7 student would understand.
2. a. List the advantages of using a data logger over taking the measurements manually.
   b. Describe an experiment in which using a data logger provides an advantage over manual data collection.
3. Acids are corrosive substances; they react with most metals, such as the magnesium in part 1 of the case study and Investigation 1.1. The temperature probe is made of metal but it doesn't react with acids. What sort of metal is it and what protects it from the acid?

Apply and analyse

4. Sensors are the devices that take the measurements that the data logger collects. Think of scientific investigations that could use data collected by sensors that measure:
   a. electric current
   b. acidity of solutions
   c. concentration of carbon dioxide in the air
   d. total dissolved solids (salt content)
   e. light intensity.

Evaluate and create

5. Look back at *Part 1: Magnesium in hydrochloric acid* in the case study.
   a. Write a word equation for the reaction that occurs.
   b. Look at the graph of temperature vs time for this reaction in figure 1.31. Was the reaction exothermic or endothermic? How do you know?
   c. How long after data collection began was the magnesium ribbon added to the acid? How do you know?
   d. How did the person who conducted this investigation know when the reaction was complete?
   e. What was the initial temperature of the dilute acid used in this experiment?
   f. What change in temperature did this reaction cause in the liquid in the beaker?
6. Look at the graph of the collected data produced by the computer in figure 1.33 for *Part 2: Citric acid and baking soda* in the case study.
   a. What was the temperature of the acid at the start of the experiment?
   b. What was the lowest temperature that the solution of citric acid and baking soda reached? How long after first adding the baking soda did this occur?
   c. Is dissolving baking soda in citric acid an exothermic or endothermic process? How do you know?

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

LESSON
1.15 Thinking tools — Visual thinking tools

1.15.1 Tell me

There are so many different ways to see and share what is happening inside your brain. Here are some tools that can be used to make your thinking visible so that you can share and discuss it with others.

Like a builder, it is important for you to use the right tool to get the job done.

- **Storyboards**, **flow charts**, **timelines**, **fishbone diagrams** and **cycle maps** are useful tools to order or sequence your thoughts (figure 1.35).
- **Priority grids**, **target maps**, **continuums** or **pie charts** can be used to quantify or rank ideas (figure 1.36).
- **Matrices**, **SWOT analysis charts**, **Venn diagrams**, and **bubble maps** are useful when you want to analyse or compare your thoughts (figure 1.37).
- **Concept maps**, **PMI charts** and **mind maps** help you to visualise or reflect on an idea (figure 1.38).

There are also times when combinations of these tools can help you to use your brain and time more effectively.

1.15.2 Show me

The following diagrams show various ways to organise your thinking. The tool you choose to use depends on what topics, ideas, events or process you are examining.

These tools are explored in more detail in the following topics:

- Topic 3: Priority grids and matrices
- Topic 4: Cycle maps and relations diagrams
- Topic 5: SWOT analysis
- Topic 6: Concept maps and plus, minus, interesting charts
- Topic 7: Matrices and plus, minus, interesting charts
- Topic 8: Double bubble maps
- Topic 9: Plus, minus, interesting charts
- Topic 10: Flow charts

storyboard a visual thinking tool that summarises a sequence of scenes

flow chart a visual thinking tool that shows a sequence of events or steps in a process

timeline a visual thinking tool that shows a sequence of events by date

fishbone diagram a visual thinking tool that analyses and compares by breaking an event into smaller causes to show why something has happened

cycle map a visual thinking tool that describes a cyclical process

priority grid a visual thinking tool that quantifies and ranks based on two criteria

target map a visual thinking tool that quantifies and ranks based on relevance

continuum a visual thinking tool that shows extremes of an idea or where people stand on a particular idea or issue

pie chart a diagram using sectors of a circle to compare the sizes of parts making up a whole quantity

matrix a visual thinking tool that organises, analyses and compares using a grid

SWOT analysis chart a visual thinking tool that helps classify or organise thoughts according to strengths, weaknesses, opportunities and threats

Venn diagram a visual thinking tool that analyses and compares by showing common features and different features

bubble map a visual thinking tool that organises, analyses and compares by showing common and different features of topics

concept map a visual thinking tool that shows the connections between ideas

PMI chart visual thinking tool that classifies using positive, negative and interesting features

mind map a visual thinking tool with a central idea and associated ideas arranged around it

FIGURE 1.35 Thinking tools that help you order or sequence your thoughts

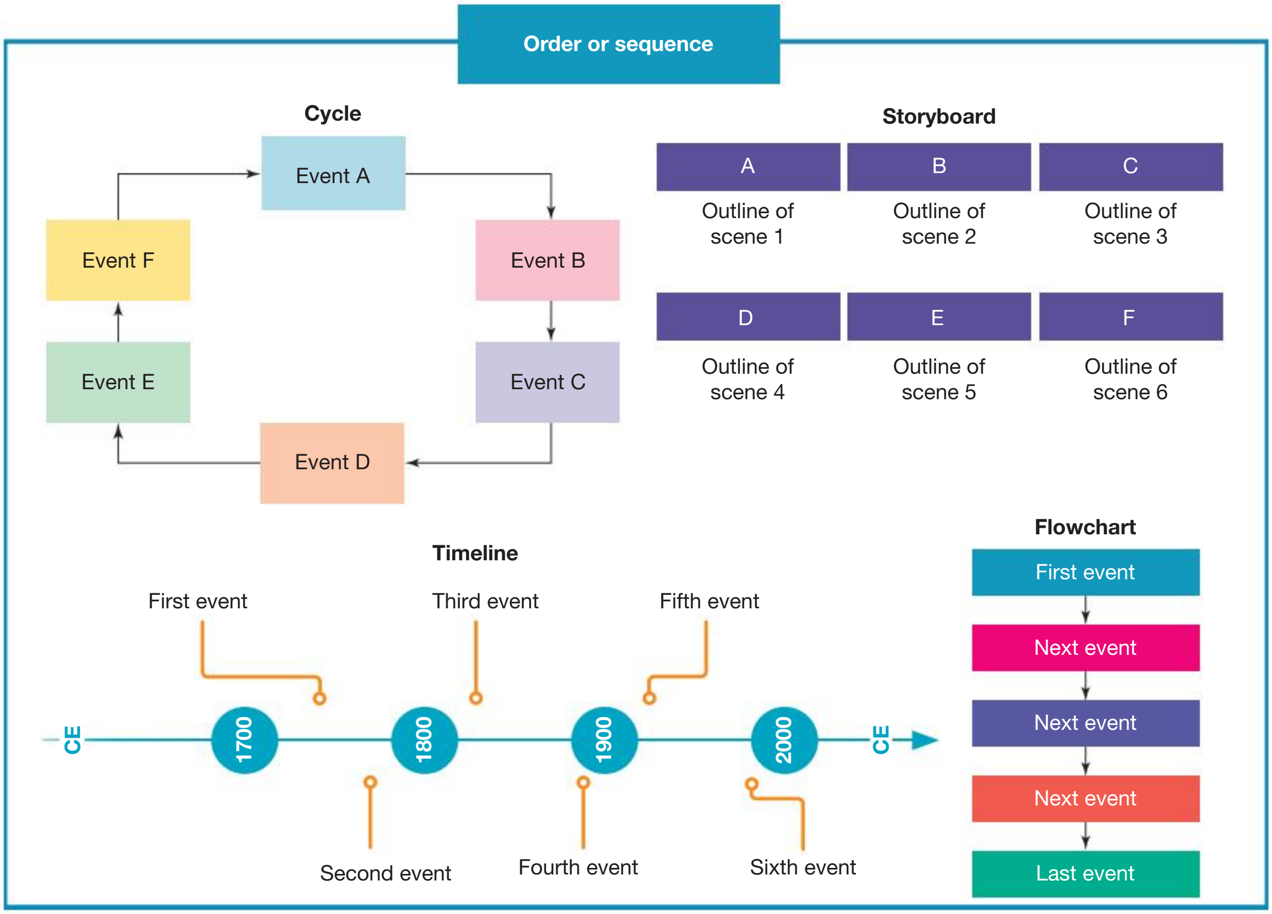


FIGURE 1.36 Thinking tools that help you quantify or rank your thoughts

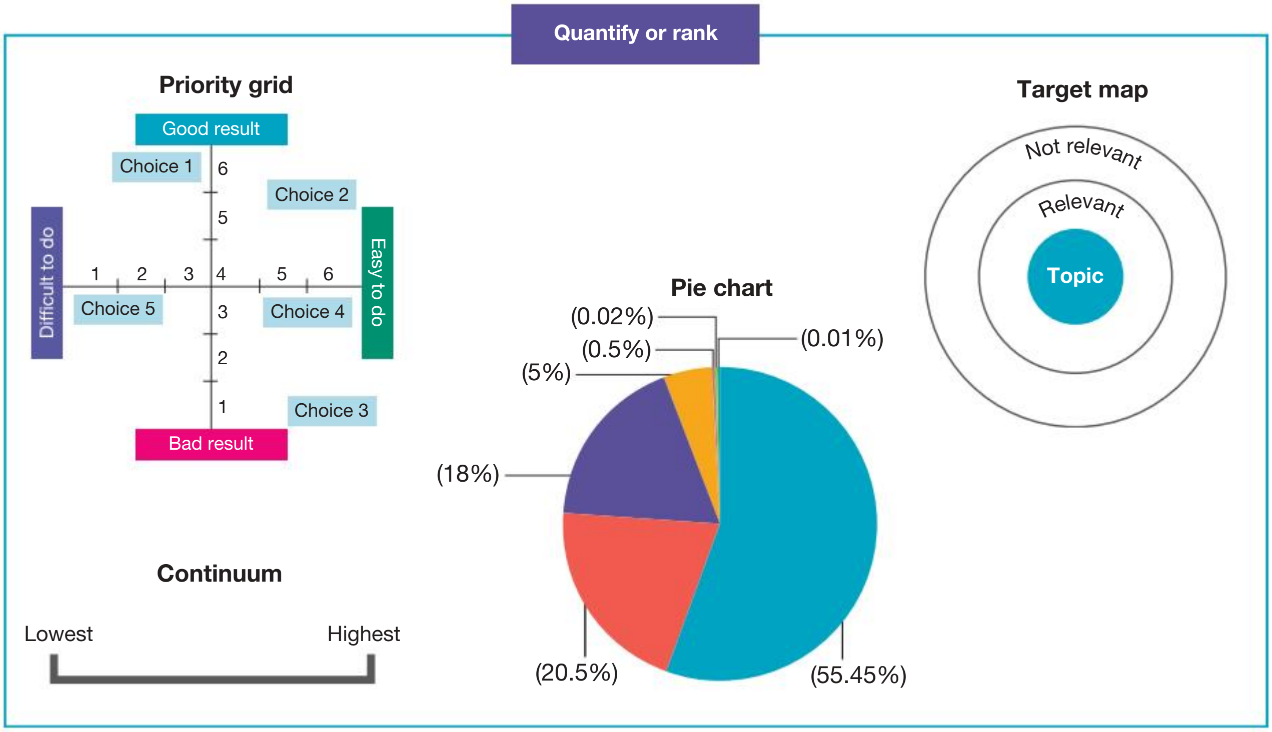
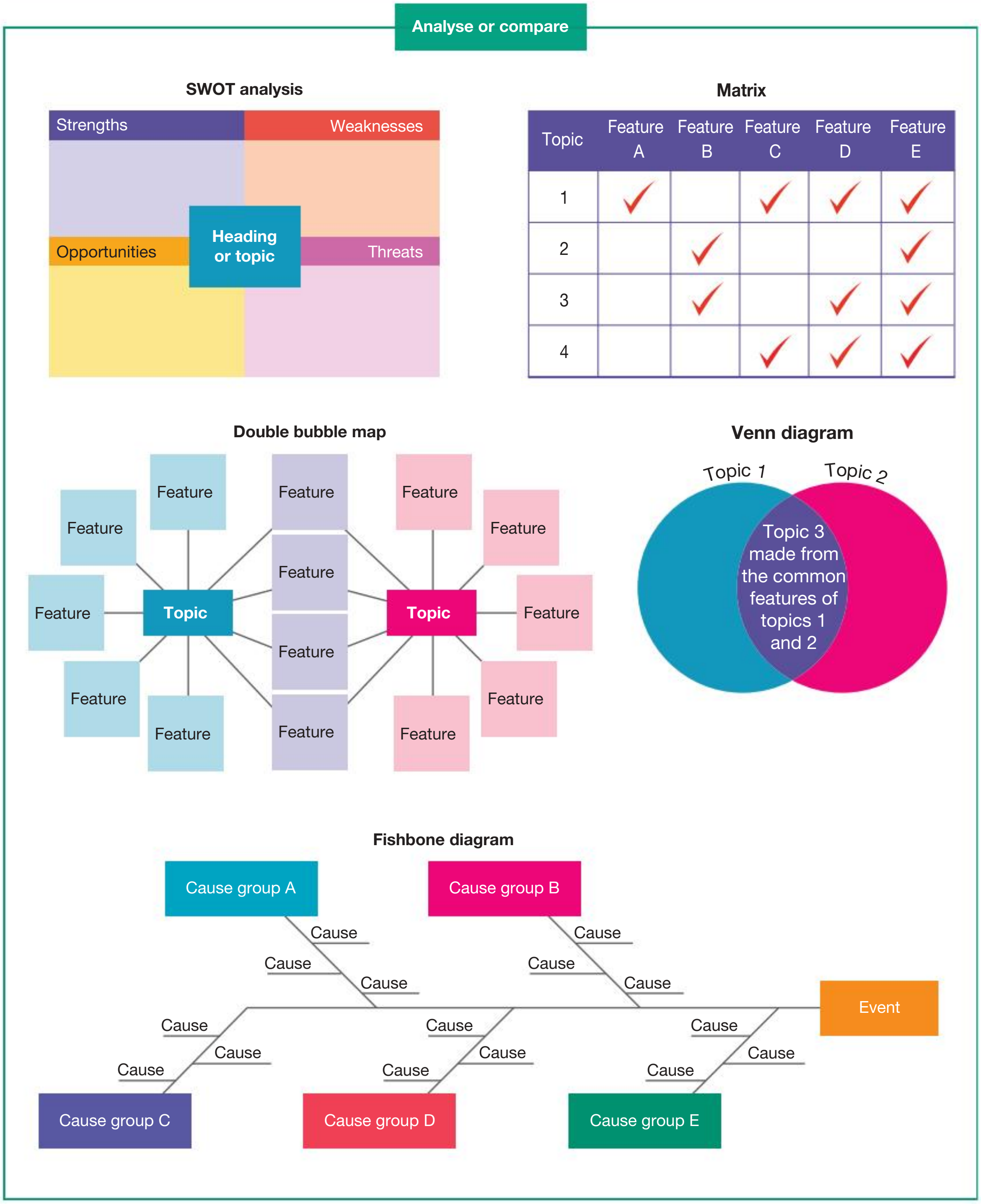
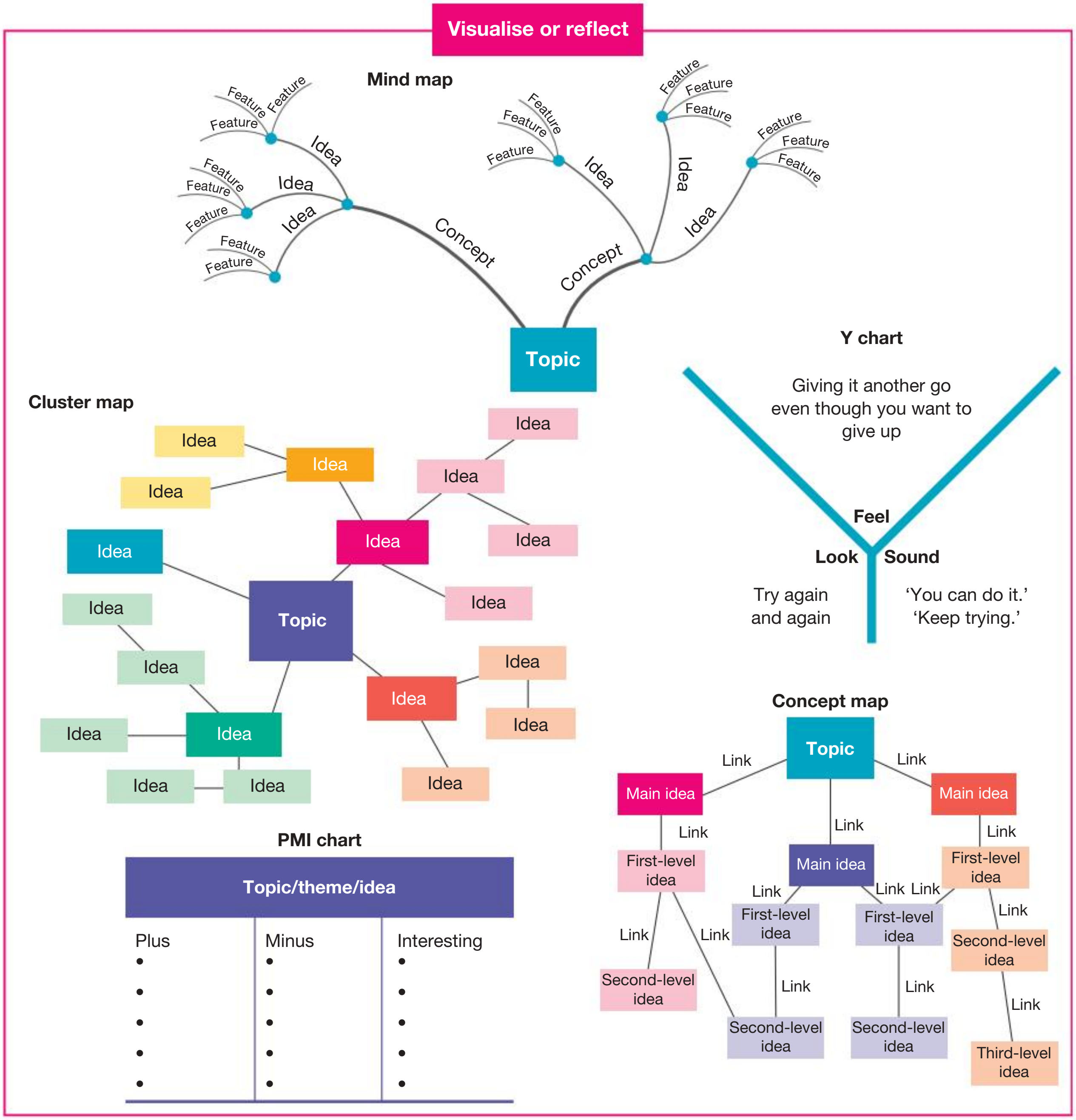


FIGURE 1.37 Thinking tools that help you analyse or compare your thoughts



Topic	Feature A	Feature B	Feature C	Feature D	Feature E
1	✓		✓	✓	✓
2		✓			✓
3		✓		✓	✓
4			✓	✓	✓

FIGURE 1.38 Thinking tools that help you visualise or reflect on your thoughts



1.15.3 Let me do it

1.15 Activity

1. State the types of visual thinking tools that are best suited to:
   a. quantifying or ranking ideas
   b. visualising or reflecting
   c. analysing or comparing
   d. ordering or sequencing.
2. Use a visual thinking tool to summarise key or interesting points from each lesson within this chapter.

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

LESSON
1.16 Review

Hey students! Now that it's time to revise this topic, go online to:

Review your results

Watch teacher-led videos

Practise questions with immediate feedback

Find all this and MORE in jacPLUS

Access your topic review eWorkbooks

on Resources

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-12224	ewbk-12226	ewbk-12228

1.16.1 Summary

Scientists through the ages

- The earliest scientists were the ancient Greek philosophers who used logic and conducted thought experiments.
- The scientific revolution started when Galileo Galilei invented the telescope and used it to propose new theories about the planets and stars. His work formed the basis of many other influential scientists' discoveries.
- Isaac Newton furthered our understanding of the universe by creating the theory of gravity, which explained the movement of the planets around the Sun.
- Modern-day scientists work more collaboratively than past scientists and can, therefore, conduct research more efficiently.

Accidents and observations

- Many of the great scientific discoveries came about by accident.
- Luigi Galvani created the first electric cell by accident while dissecting a frog.
- X-rays were discovered when German physicist Wilhelm Röntgen noticed that a photographic plate he had left sitting around glowed when high voltage electricity passed through a glass tube.
- Penicillin was discovered when a spot of mould on a dish that was growing bacteria prevented the bacteria from growing near it.

A question of ethics

- Ethics is the system of moral principles on the basis of which people, communities and nations make decisions about what is right or wrong.
- Ethics affects the way experiments are conducted, types of research and practices within the scientific community.
- Animal testing is not allowed in Australia and most places around the world.
- The ethics of any new drug production should be examined to balance profitability and the benefit to the community.
- Genetic modification involves moving genes from one plant to another, to enable the plants to have certain characteristics.

Planning your own investigation

- The scientific method provides a template that allows scientific research to be communicated worldwide.
- A hypothesis is a tentative, testable and falsifiable statement for an observed phenomenon that acts as a prediction for the investigation.

- The first step in the scientific method is to develop a valid question.
- A logbook provides a complete record of your investigations; it should be dated and contain notes, results, diagrams, evidence, problems, and evaluations and drafts of your conclusions.
- There are three types of variables:
  - Independent variables are deliberately changed in an experiment.
  - Dependent variables are the variables that are measured in an experiment.
  - Controlled variables are kept constant throughout an experiment.
- The process of controlling variables is also known as fair testing.
- Scientific experiments are valid if they measure what they set out to measure. For example, if you were investigating the growth rate of plants and you measured the number of plants that germinated over a period of time, your experiment would be invalid as it is not measuring the growth rate.
- Precision is a measure of how close together your measurements are across multiple trials.
- Accuracy is a measure of how close your results are to known values.
- There are two types of data:
  - Quantitative data is data that is numerical.
  - Qualitative data is expressed in words.
- Data is much easier to understand when it is presented graphically. Types of graphs include scatterplots, line graphs, bar/column graphs, histograms, pie charts and divided bar charts.
- On a line graph, the independent variable is shown on the x-axis, and the dependent variable on the y-axis.
- A scientific report should contain an abstract, introduction, aim, materials, method, results, discussion, conclusion, bibliography and any acknowledgements.
- Valid investigations are able to be replicated in different circumstances but with the same conditions.
- Surveys should have a large sample size, the questions should be clear, and a control group should be used if necessary.

Case study

- Sean's investigation into the turbidity (cloudiness) of water sources near his home show how an investigation can be completed, from start to finish.

Using spreadsheets

- Spreadsheets can be used to analyse or graph data automatically. This can save time and reduce errors.
- Spreadsheets contain many functions that can be used to extract information from data or perform calculations automatically. Examples include average, count, max, min, round and sum.

Using data loggers and databases

- 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.
- Databases are information or data arranged in one or more tables. Spreadsheets can be used to draw conclusions about the data in a database.

1.16.2 Key terms

absolute referencing used in a spreadsheet when a cell address in the formula remains constant, no matter where it is copied to
accurate refers to how close an experimental measurement is to a known value
aim a statement outlining the purpose of an investigation
bibliography list of references and sources at the end of a scientific report
blog a personal website or web page where an individual can upload documents, diagrams, photos and short videos, add links to other sites and invite other people to post comments
bubble map a visual thinking tool that organises, analyses and compares by showing common and different features of topics

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

concept map a visual thinking tool that shows the connections between ideas

continuum a visual thinking tool that shows extremes of an idea or where people stand on a particular idea or issue

control an experimental set-up in which the independent variable is not applied that is used to ensure that the result is due to the variable and nothing else

controlled variables the conditions that must be kept constant throughout an experiment

cycle map a visual thinking tool that describes a cyclical process

dependent variable the variable that is being affected by the independent variable — that is, the variable you are measuring

ethics the system of moral principles on the basis of which people, communities and nations make decisions about what is right or wrong

fair testing testing where only one variable is changed and keeps all other variables constant when attempting to answer a scientific question

falsifiable can be proven false

fishbone diagram a visual thinking tool that analyses and compares by breaking an event into smaller causes to show why something has happened

flow chart a visual thinking tool that shows a sequence of events or steps in a process

functions common type of calculation built into spreadsheets

galvanometer an instrument used to measure small electric currents; named after Luigi Galvani

genetic modification (GM) the technique of modifying the genetic structure of organisms making it possible to design organisms that have certain characteristics

independent variable the variable that you deliberately change during an experiment

logbook a complete record of an investigation from the time a search for a topic is started through to conclusion

lysozyme a chemical (enzyme) in human teardrops able to kill some types of bacteria as part of your body's natural defence

matrix a visual thinking tool that organises, analyses and compares using a grid

mind map a visual thinking tool with a central idea and associated ideas arranged around it

penicillin a powerful antibiotic substance found in moulds of the genus *Penicillium* that kills many disease-causing bacteria

pie chart a diagram using sectors of a circle to compare the sizes of parts making up a whole quantity

PMI chart visual thinking tool that classifies using positive, negative and interesting features

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

priority grid a visual thinking tool that quantifies and ranks based on two criteria

qualitative data (or categorical data) data expressed in words

quantitative data (or numerical data) data that can be precisely measured and have values that are expressed in numbers

relative referencing used in a spreadsheet when the cell address in the formula is changed

reliable data data that is able to be replicated in different circumstances but the same conditions

scientific method a systematic and logical process of investigation to test hypotheses and answer questions based on data or experimental observations

storyboard a visual thinking tool that summarises a sequence of scenes

SWOT analysis chart a visual thinking tool that helps classify or organise thoughts according to strengths, weaknesses, opportunities and threats

target map a visual thinking tool that quantifies and ranks based on relevance

testable able to be supported or proven false through the use of observations and investigation

timeline a visual thinking tool that shows a sequence of events by date

valid describes an experiment that truly investigates what it sets out to investigate (via an appropriate method, controlling variables etc.)

variable any factor that can be changed, kept constant (controlled) or measured during an experiment

Venn diagram a visual thinking tool that analyses and compares by showing common features and different features

Resources

eWorkbooks	Study checklist (ewbk-12230) Reflection (ewbk-12237) Literacy builder (ewbk-12231) Crossword (ewbk-12233) Word search (ewbk-12235)
Solutions	Topic 1 Solutions (sol-1135)
Practical investigation eLogbook	Topic 1 Practical investigation eLogbook (elog-2237)
Digital document	Topic 1 Key terms glossary (doc-40107)

1.16 Activities

1.16 Review questions

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 2	3, 5	4, 6

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. Match the words in the list below with their meanings.

Words	Meanings
a. Conclusion	A. Concerns that deal with what is morally right or wrong
b. Abstract	B. The variable that is deliberately changed in an experiment
c. Discussion	C. The part of a journal article where a brief overview of the article is given
d. Results	D. A list of steps to follow in an experiment
e. Hypothesis	E. The answer to the aim or the problem
f. Ethical considerations	F. A list of equipment needed for the experiment
g. Independent variable	G. The variable that is measured in an experiment
h. Dependent variable	H. States what was seen or measured during an experiment. May be presented in the form of a table or graph.
I. Method	i. A sensible guess to answer a problem
j. Apparatus	J. The part of a report where problems with the experiment and suggestions for improvements are discussed

2. List some of the factors affecting the decision about whether money is spent on finding a cure for a particular disease.

Apply and analyse

3. Should farmers be allowed to plant the type of crop they believe produces the best yield, irrespective of whether others object to the manner in which the crop was bred?
4. In the film *Super Size Me*, the film-maker Morgan Spurlock gains weight and suffers health problems after thirty days of eating from only one fast-food chain. The film suggests that this fast food is unhealthy.
   a. What factors should be taken into account when considering the effects of a fast-food diet compared with a broader eating pattern?
   b. Was this a controlled experiment?
   c. Is Spurlock's argument valid? Explain your answer.
   d. What type of arguments could the fast-food chain put forward in response to the film *Super Size Me*?

Evaluate and create

5. Gemina and Habib wanted to investigate whether the type of surface affects how high a ball bounces. Habib thought the ball would probably bounce the highest off a concrete floor. They dropped tennis balls from different heights onto a concrete floor, a wooden floor and carpet. Their results are shown in the table provided.

TABLE Height of ball bounce off different surfaces

	Average height of bounce (cm)		
Distance ball dropped (cm)	**Concrete**	**Wood**	**Carpet**
25	22	14	8
50	46	34	18
75	70	50	26
100	94	66	34
125	X	85	Z
150	128	94	48
175	129	Y	50
200	130	100	51

   a. Write a hypothesis for this experiment.
   b. Construct a line graph of Gemina and Habib's results.
   c. Use your graph to estimate the values X, Y and Z.
   d. Identify two variables that had to be kept constant in this experiment.
   e. Identify two trends in the results.
   f. Do the results support the hypothesis you wrote?
   g. Predict how high the tennis ball would bounce off each floor if it was dropped from a height of 225 cm.

6. Miranda wanted to test the following hypothesis: Hot soapy water washes out tomato sauce stains better than cold soapy water.

TABLE Observations of washing in different water temperatures

Water temperature (°C)	Observations
20	Dark stain left after washing
40	Faint stain left after washing
60	No stain left after washing
80	No stain left after washing

   a. List the equipment she will need.
   b. Identify the independent and dependent variables in this investigation.
   c. List the variables that will need to be controlled.
   d. Outline a method that could be used to test the hypothesis.
   e. Write a conclusion based on Miranda's results.

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

Online Resources

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.

1.1 Overview

eWorkbooks
- Topic 1 eWorkbook (ewbk-12189)
- Student learning matrix (ewbk-12191)
- Starter activity (ewbk-12192)

Solutions
- Topic 1 Solutions (sol-1135)

Practical investigation eLogbook
- Topic 1 Practical investigation eLogbook (elog-2237)

Video eLesson
- Australia's top scientists (eles-1079)

Weblink
- The Australian Academy of Science

1.5 Planning your own investigation

eWorkbooks
- Setting up a logbook (ewbk-12194)
- Variables and controls (ewbk-12196)
- Investigating (ewbk-12198)
- Organising and evaluating results (ewbk-12200)
- Drawing conclusions (ewbk-12202)
- Summarising (ewbk-12204)
- Evaluating media reports (ewbk-12206)

1.6 SkillBuilder — Controlled, dependent and independent variables

eWorkbook
- SkillBuilder — Controlled, dependent and independent variables (ewbk-12208)

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

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

1.7 SkillBuilder — Writing an aim and forming a hypothesis

eWorkbook
- SkillBuilder — Writing an aim and forming a hypothesis (ewbk-12210)

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

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

1.8 SkillBuilder — Measuring and reading scales

eWorkbook
- Skillbuilder — Measuring and reading scales (ewbk-12212)

Video eLesson
- Measuring and reading scales (eles-4153)

Interactivity
- Measuring and reading scales (int-0201)

1.9 SkillBuilder — Drawing a line graph

eWorkbook
- SkillBuilder — Drawing a line graph (ewbk-12214)

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

Interactivity
- Drawing a line graph (int-3131)

1.10 SkillBuilder — Creating a simple column or bar graph

eWorkbook
- SkillBuilder — Creating a simple column or bar graph (ewbk-12216)

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

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

1.12 Using spreadsheets

eWorkbooks
- Spreadsheeting and graphing (ewbk-12218)
- Calculating using a spreadsheet (ewbk-12220)

1.13 SkillBuilder — Using a spreadsheet

eWorkbook
- SkillBuilder — Using a spreadsheet (ewbk-12222)

Video eLesson
- Using a spreadsheet (eles-4230)

Interactivity
- Using a spreadsheet (int-8160)

1.14 Using data loggers and databases

Practical investigation eLogbook
- Investigation 1.1: Exothermic and endothermic processes (elog-2249)

Teacher-led video
- Investigation 1.1: Exothermic and endothermic processes (tlvd-10797)

1.16 Review

eWorkbooks
- Topic review Level 1 (ewbk-12224)
- Topic review Level 2 (ewbk-12226)
- Topic review Level 3 (ewbk-12228)
- Study checklist (ewbk-12230)
- Literacy builder (ewbk-12231)
- Crossword (ewbk-12233)
- Word search (ewbk-12235)
- Reflection (ewbk-12237)

Digital document
- Topic 1 Key terms glossary (doc-40107)

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

SkillBuilder — Controlled, dependent and independent variables

1.6.1 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.

1.6.2 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)

1.6.3 Let me do it

Complete the following activities to practise this skill.

1.6 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 — Writing an aim and forming a hypothesis

1.7.1 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.

1.7.2 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)

1.7.3 Let me do it

Complete the following activities to practise this skill.

1.7 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 — Measuring and reading scales

1.8.1 Tell me

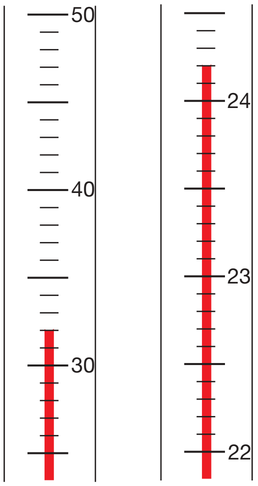
Why do we need to measure and read scales?

When conducting experiments, it is critical that measurements and data are recorded accurately. Whether measuring volume or temperature, or interpreting alternate scales, it is important that they are recorded accurately.

What is the application of measuring and reading scales in science?

In science applications, measuring and reading scales are used to observe and record many variables including volumes of liquids or gas, mass, length and temperature. It is important that scales are used correctly to reduce random errors and ensure that the data obtained is accurate, in order to obtain valid conclusions.

FIGURE 1 The temperatures measured by thermometers A and B are 32 °C and 24.2 °C, respectively.



1.8.2 Show me

How do we measure and read scales?

Materials

- thermometer with a liquid column (alcohol or mercury)
- 250 mL measuring cylinder or burette

Method

Step 1

A thermometer with a liquid column should have markings on its scale. Find the top of the measuring column and position your eye so that it is level with the top of the column. This will avoid any parallax errors in reading the temperature. Read the number on the largest scale division below the top of the column.

Step 2

Read the number on the largest scale division above the top of the column and count how many scale divisions there are between the lower and higher scale divisions. Divide the number of divisions into the temperature difference between the upper and lower scale divisions. This will give you the amount each scale division is worth. Count up from the lower scale division and read the correct temperature. If the column is in the middle of two divisions, the reading will be half a scale division above the lower reading.

Step 3

Liquids in containers such as measuring cylinders often have a curved surface at the top edge. The curve is called a meniscus. The edges of the meniscus may curve up or down. Locate the middle flat section of the meniscus and position your eye so it is level with it.

Step 4

Using the procedure in Step 2, read the volume of the middle flat section of the meniscus.

on Resources

eWorkbook SkillBuilder — Measuring and reading scales (ewbk-4153)

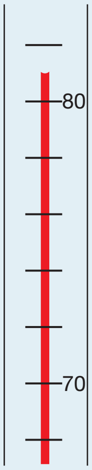
Interactivity Measuring and reading scales (int-0201)

1.8.3 Let me do it

Complete the following activities to practise this skill.

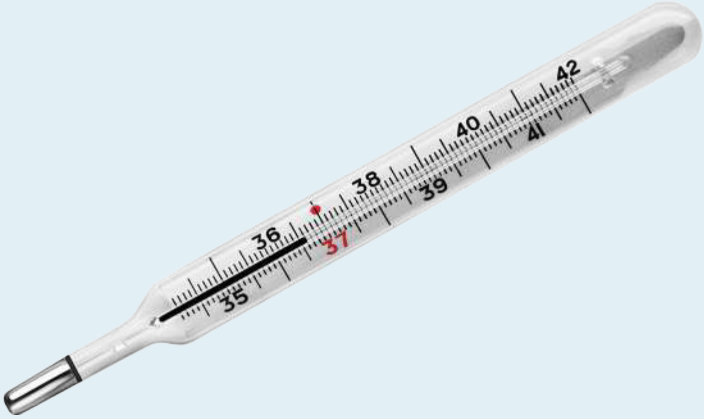
1.8 ACTIVITIES

1. MC The diagram shows a portion of a thermometer measuring a temperature in degrees Celsius. Answer the questions that follow.

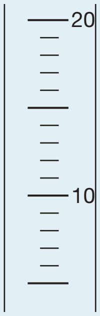


- **a. i.** Write the value of the lower scale marker.
  - **ii.** Write the value of the higher scale marker.
  - **iii.** Calculate the value of each scale division.
  - **iv.** What is the reading of the red column of the thermometer?

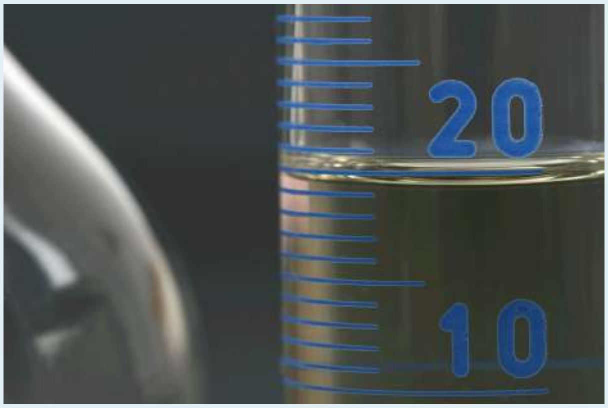
2. Human body temperature is normally 37 ˚C. If a person is said to be running a temperature, they may be suffering an illness. The thermometer below shows the temperature of a patient. Write the temperature that is shown.



3. The diagram that follows represents a section of an alcohol thermometer. Colour in the centre strip to show a temperature of 14 °C.



4. a. **MC** The photo below shows a measuring cylinder containing some water. Read the scale to determine the volume of water in the measuring cylinder. Select which of the available options is the correct reading.



A. 19.5 mL **B.** 20.5 mL **C.** 21.0 mL **D.** 22.0 mL

b. Give an explanation of how you reached your answer.

Checklist

I have:

- positioned my eye parallel with the top of the column or the meniscus of the liquid that is to be measured
- noted the lower scale reading below the column or meniscus
- noted the upper scale reading above the column or meniscus
- calculated the scale divisions between the upper and lower scale divisions and used this to count up from the lower division to take the column reading.

SkillBuilder — Drawing a line graph

1.9.1 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.

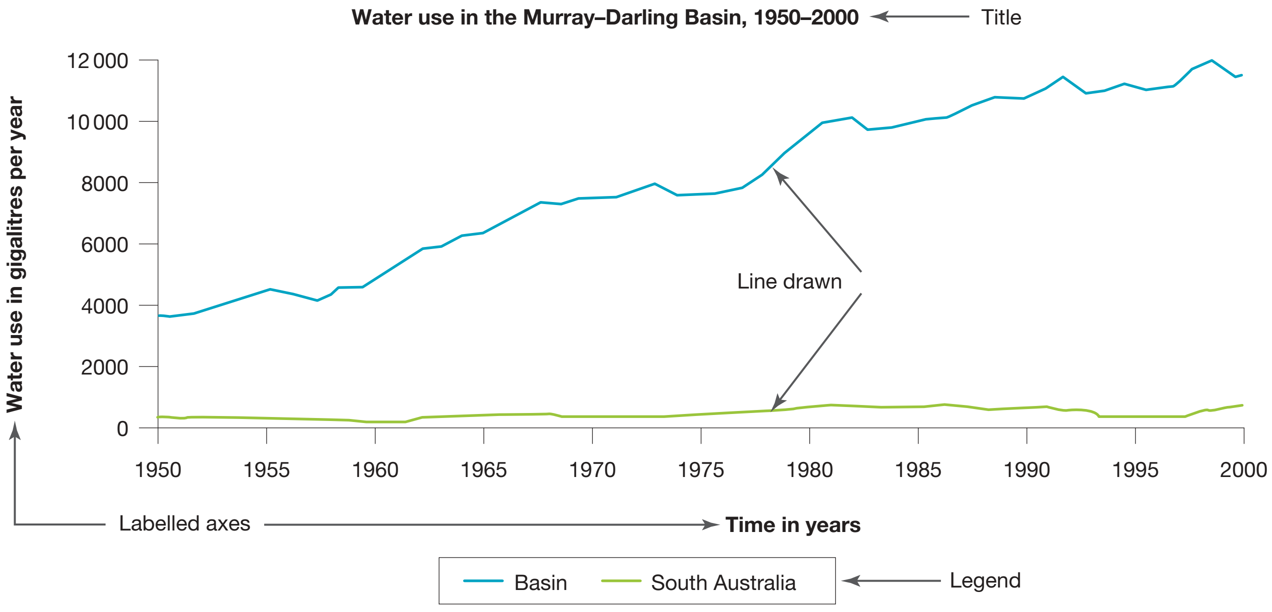
How are line graphs useful?

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



Source: © Department of Environment, Water and Natural Resources, South Australia Government ← Source

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.

1.9.2 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

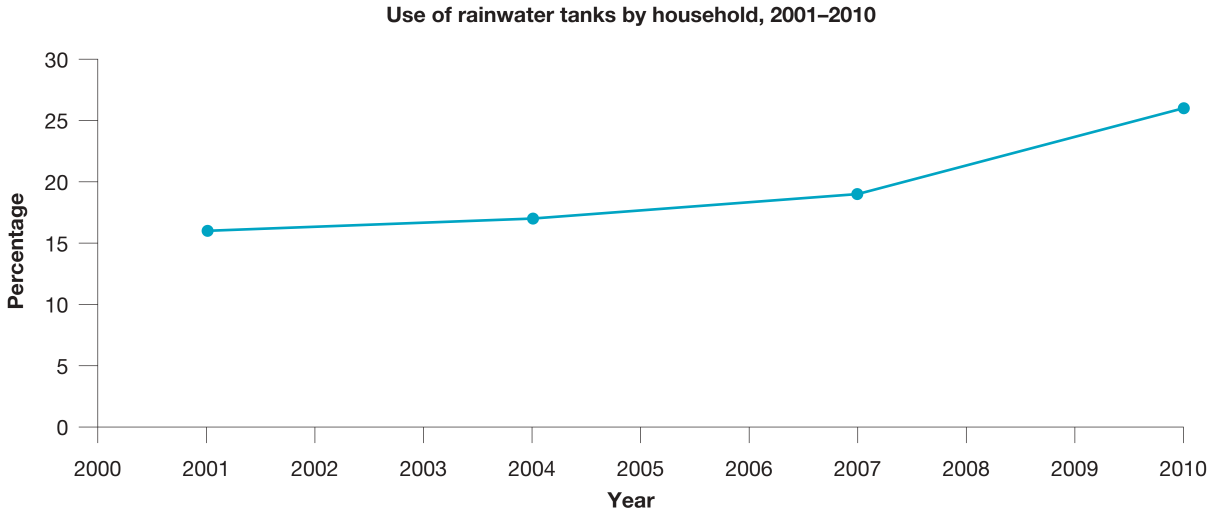
Label the X and Y axes. In this case, the X axis would be labelled ‘Year’, and the Y axis would be labelled ‘Percentage’.

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)

1.9.3 Let me do it

Complete the following activities to practise this skill.

1.9.3 1.9 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.

SkillBuilder — Creating a simple column or bar graph

1.10.1 Tell me

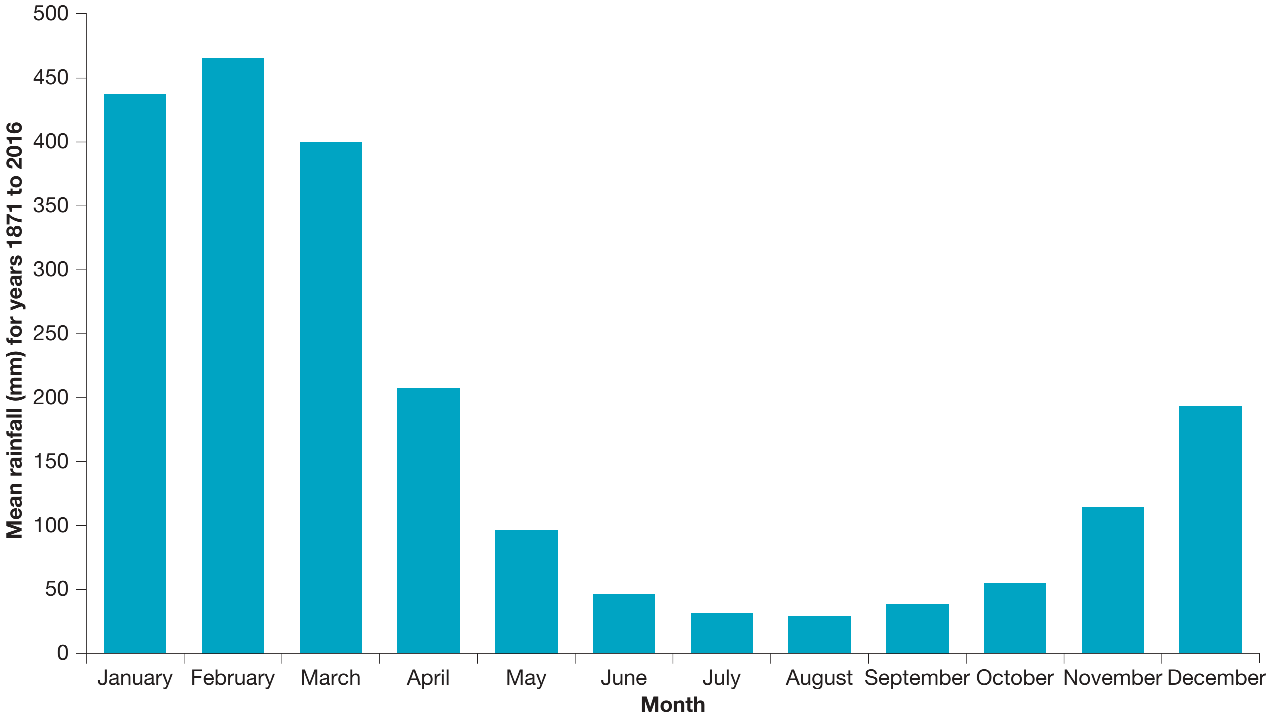
What are column or bar graphs?

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.

1.10.2 Show me

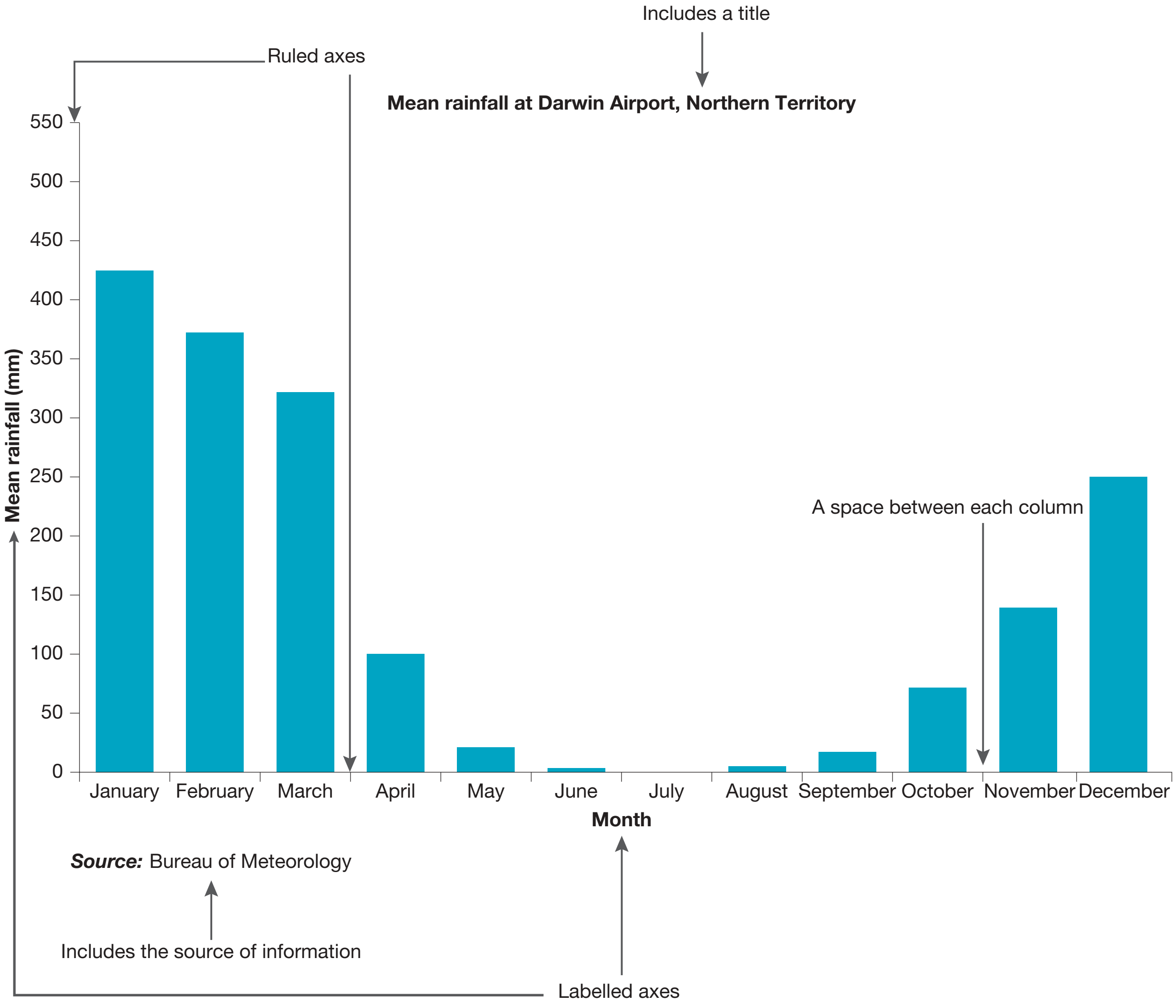
How to complete a column graph

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

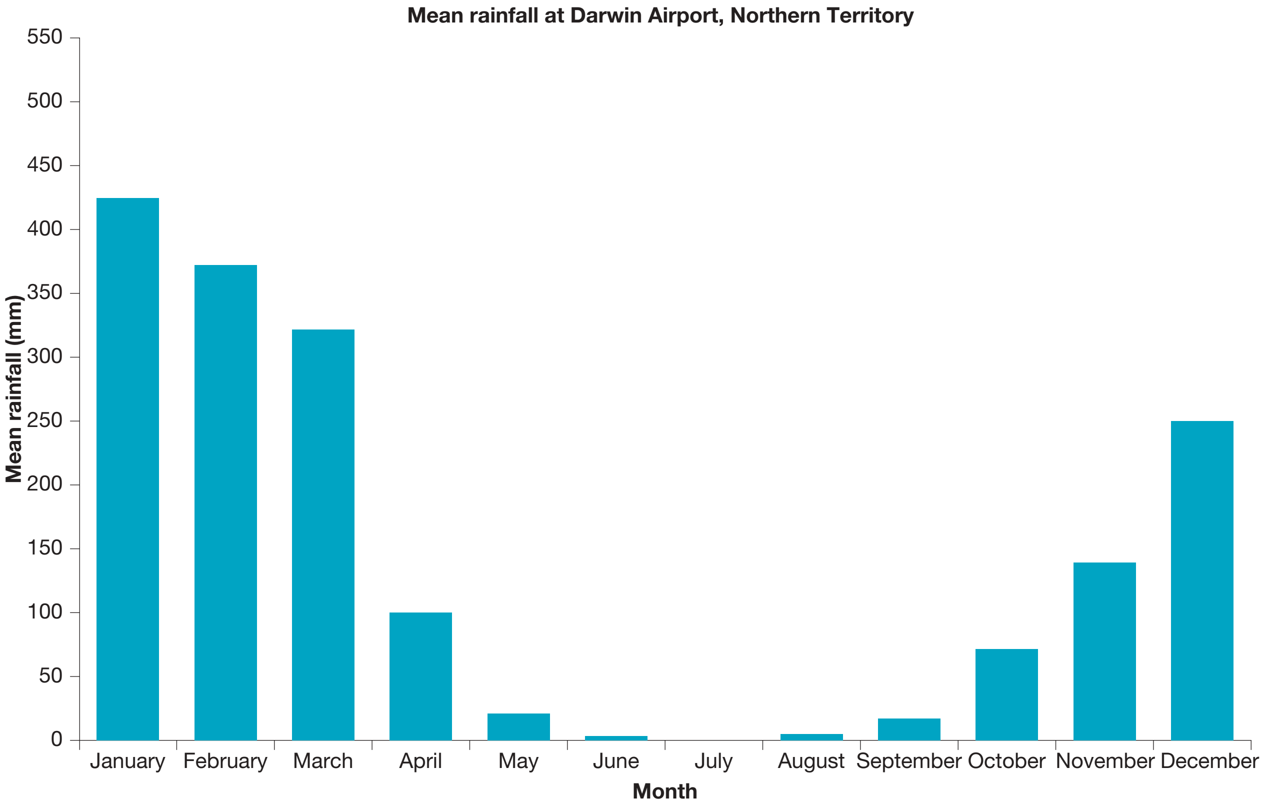
Step 2
Decide on the width and spacing of the columns and draw your horizontal axis to fit. Ensure that each column is the same width.

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)

1.10.3 Let me do it

Complete the following activities to practise this skill.

1.10 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.

2 Control and coordination

CONTENT DESCRIPTION

Compare the role of body systems in regulating and coordinating the body's response to a stimulus, and describe the operation of a negative feedback mechanism (AC9S9U01)

Source: F–10 Australian Curriculum 9.0 (2024–2029) extracts © Australian Curriculum, Assessment and Reporting Authority; reproduced by permission.

LESSON SEQUENCE

SCIENCE INQUIRY AND INVESTIGATIONS

Science inquiry is a central component of the Science curriculum. Investigations, supported by a **Practical investigation eLogbook** and **teacher-led videos**, are included in this topic to provide opportunities to build Science inquiry skills through undertaking investigations and communicating findings.

LESSON
2.1 Overview

Hey students! Bring these pages to life online

Watch videos

Engage with interactivities

Answer questions and check results

Find all this and MORE in jacPLUS

2.1.1 Introduction

You are a multicellular organism made up of a number of body systems that work together to keep you alive. Your body systems are made up of organs, which are made up of tissues, which are made up of particular types of cells. Your cells communicate with each other using electrical impulses in nerves and chemicals such as neurotransmitters and hormones. The coordination of this communication is essential so that the requirements of your cells are met and a stable internal environment is maintained.

Figure 2.1 shows a scanning electron micrograph of the tongue surface, showing the papillae that give the tongue its texture. The papillae also contain the tastebuds, and are part of the sensory system that sends information to the brain.

FIGURE 2.1 A scanning electron micrograph image of a human tongue

on Resources

Video eLesson Neurons in the brain (eles-2631)

Watch this short animation demonstrating the interconnectedness between the neurons in the brain.

2.1.2 Think about control and coordination

1. How fast can a body react to threatening situations?
2. Can your reactions be consciously controlled in all situations?
3. Which body systems are used for a fight-or-flight response?
4. Which hormones regulate blood glucose levels?
5. What's the link between hormones and the menstrual cycle?
6. Which senses allow our body to detect changes to our environment?

2.1.3 Science inquiry

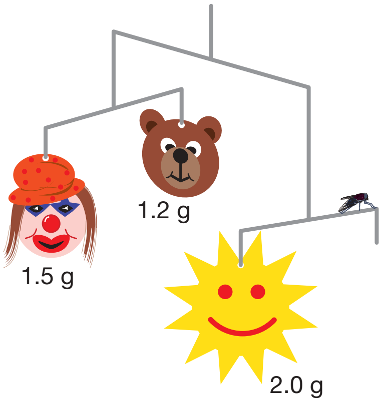
Speedy reactions?

When you first see danger, you detect it using receptors in your eyes. This message is then sent to your nervous system, which will tell your body what to do. Figure 2.2 shows potential dangers. In these situations your endocrine system may also react by producing hormones such as adrenaline to trigger your body to 'get up and go'. Hopefully this all happens fast enough to avoid anyone getting hurt! The time it takes to respond to a detected event (a stimulus) is known as the response time.

FIGURE 2.2 Dangers in everyday life are often detected using receptors in your eyes.

Answer the following questions, considering reaction time and different responses.

FIGURE 2.3 What would be the response time to solve this puzzle?



1. Read each of the following scenarios and responses and then order them from fastest to slowest response time.
   - a. *Scenario:* A mobile has lost a piece and is hanging crooked. When a fly lands on the mobile, it becomes balanced again. Given the masses in figure 2.3, what is the mass of the fly?
     Response: Solving the puzzle
   - b. *Scenario:* Ouch! You step on a sharp object.
     Response: You lift your foot quickly.
   - c. *Scenario:* You have been in three classes before lunch. You had very little breakfast and you feel that you have no energy. Your friend Janine, who knows everything, tells you that you have low blood sugar and must eat your lunch so that your blood sugar level can get back to normal. The bell rings, and you rush to the canteen to get lunch.
     Response: Getting your blood sugar back to normal
2. Consider the different ways you respond to your environment. Suggest reasons for the different types of responses and how your body processes the information to bring about the response.
3. Propose another scenario and predict what your body's response would be. Suggest why and how it would respond in this way.
4. Find out how seeing danger quickly approaching can result in a change of behaviour (such as running faster, stopping or screaming). Outline the involvement of both nerves and hormones.
5. An investigation is being conducted to determine reaction time to press a button when it glows red.
   - a. Write a suitable aim for this investigation.
   - b. Suggest a question or hypothesis for the scenario that you could investigate.
   - c. Describe one piece of qualitative data and one piece of quantitative data that may be collected.
   - d. What dependent and independent variables could there be?
   - e. Explain two factors that may lead to differences in results between different students.
   - f. Write a clear methodology for this investigation, with an explanation of how you collect results and how you will control variables.

on Resources

eWorkbooks	Topic 2 eWorkbook (ewbk-12238) Student learning matrix (ewbk-12239) Starter activity (ewbk-12240)
Solutions	Topic 2 Solutions (sol-1136)
Practical investigation eLogbook	Topic 2 Practical investigation eLogbook (elog-2239)
Weblink	Reaction time test

LESSON
2.2 Sense organs

LEARNING INTENTION

At the end of this lesson you will be able to describe the links and differences between the senses and different types of receptors in the human body.

2.2.1 Your senses

Your survival can depend on detecting changes in your environment.

Imagine not being about to see, hear, feel or sense the world outside your body. No sound, no colour, no taste or smell — just darkness and silence. Without senses, you might not even be able to sense that!

Sense organs are used to detect stimuli (such as light, sound, touch, taste and smell) in your environment. Examples of human sense organs are your eyes, ears, skin, tongue and nose. These sense organs contain special cells called **receptors**. These receptors are named according to the type of stimuli that they respond to (as shown in table 2.1).

sense organ a specialised structure that detects stimuli (such as light, sound, touch, taste and smell) in your environment

receptors chemical structures that receives and converts signals in the body

TABLE 2.1 Examples of different types of receptors

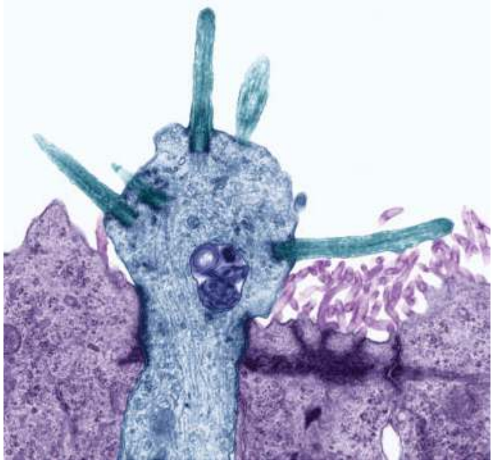
Sense	Sense organ	Stimulus	Receptor	Type of receptor
Sight	Eye	Light	Rods and cones in the retina	Photoreceptor
Hearing	Ear	Sound	Hairs in the cochlea	Mechanoreceptor
Touch	Skin	Heat, cold, pressure, movement	Separate receptors for each type of stimulus	Thermoreceptor Mechanoreceptor
Taste	Tongue	Chemical substances: sweet, salty, bitter and sour	Tastebuds	Chemoreceptors
Smell	Nose	Chemicals: odours	Olfactory nerves inside the nose	Chemoreceptors

Five receptors

1. **Thermoreceptors** enable you to detect variations in temperature and are located in your skin, body core and part of your brain, called the hypothalamus.
2. **Mechanoreceptors** are sensitive to touch, pressure, sound, motion and muscle movement and are located in your skin, skeletal muscles and inner ear.
3. **Chemoreceptors** are sensitive to particular chemicals and are located in your nose and tastebuds (see figure 2.4).
4. **Photoreceptors** are sensitive to light and are located only in your eyes.
5. **Pain receptors** enable you to respond to chemicals released by damaged cells. Detection of pain is important because it generally indicates danger, injury or disease. Although these receptors are located throughout your body, they are not found in your brain.

Each type of receptor is a different shape as they are specialised to respond to a different stimulus as listed in table 2.1.

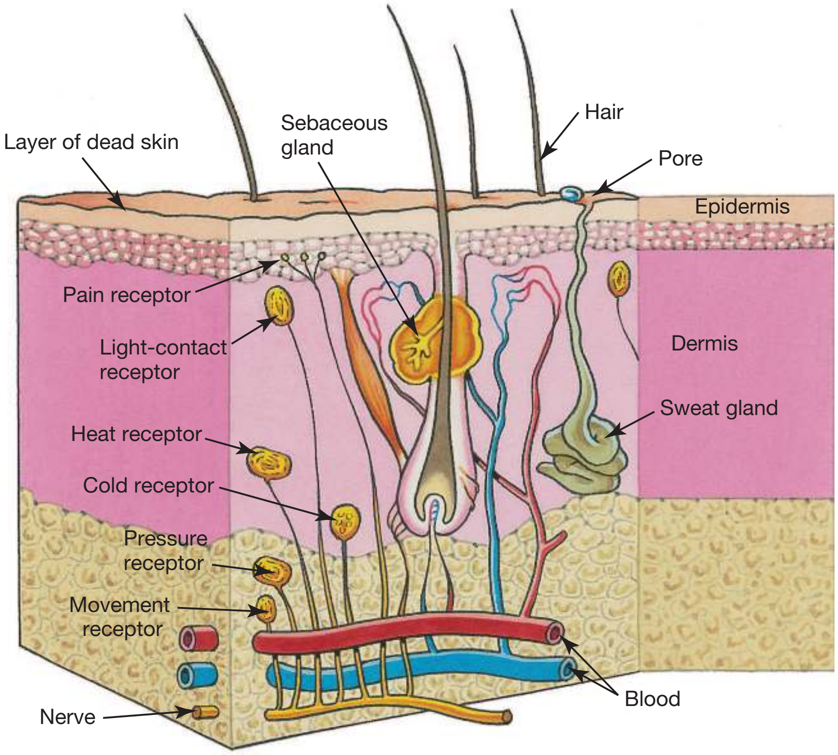
FIGURE 2.4 Transmission electron microscope (TEM) image of a chemoreceptor



2.2.2 Touch receptors

Your skin contains different types of receptors (figure 2.5). Pain receptors and mechanoreceptors enable you to detect whether objects are sharp and potentially dangerous. There are also hot thermoreceptors that detect an increase in skin temperature above the normal body temperature (37.5 °C) and cold thermoreceptors that detect a decrease below 35.8 °C. These thermoreceptors can also protect you from burning or damaging your skin. The sensitivity of these receptors can depend on how close together they are and their location in your skin.

FIGURE 2.5 Your skin contains a variety of receptors that provide you with a sense of touch.



thermoreceptors special cells located in your skin, part of your brain and body core that are sensitive to temperature

mechanoreceptors special cells within the skin, inner ear and skeletal muscles that are sensitive to touch, pressure and motion

chemoreceptors special cells within a sense organ that are sensitive to particular chemicals

photoreceptor a special cell located in your eye that is stimulated by light

pain receptors special cells located throughout the body (except the brain) that send nerve signals to the brain and spinal cord in the presence of damaged or potentially damaged cells

elog-2241

INVESTIGATION 2.1

Touch receptors in your skin

Aim

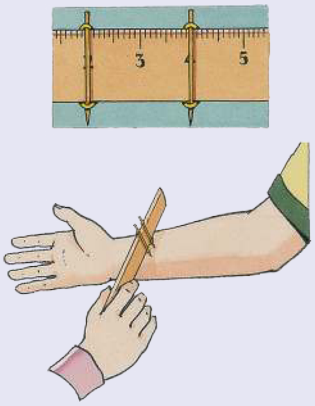
To detect where the skin is most sensitive to light contact

Materials

- 2 toothpicks
- ruler
- 2 rubber bands
- blindfold

Method

1. Use rubber bands to attach two toothpicks to a ruler so that they are 2 cm apart.
2. Predict in which areas of the body the skin will be most sensitive and least sensitive.
3. Blindfold your partner. Gently touch your partner's inside forearm with the points of the two toothpicks. Ask your partner whether two points were felt.
4. Move one toothpick towards the other in small steps until your partner is unable to feel both points. To make sure that there is no guesswork, use just one point from time to time.
5. Record the distance between the toothpicks when your partner can feel only one point when there are really two points in contact.
6. Repeat this procedure on the palm of one hand, a calf (back of lower leg), a finger and the back of the neck.
7. Swap roles with your partner and repeat the experiment.



Results

Record your observations in the table.

TABLE Observations for the distance between two points on different parts of the skin

	Distance (cm) between two points when only one point is felt	
Part of the skin	**Your partner**	**You**
Inside forearm		
Palm of hand		
Calf		
Finger		
Back of neck		

Discussion

1. Which touch receptors were being used in this experiment?
2. Construct a graph to represent your data and comment on observed patterns.
3. Which area of the skin was (a) most sensitive and (b) least sensitive?
4. Suggest why the skin is not equally sensitive all over the body.
5. Which parts of the skin are likely to have the most contact receptors?
6. Discuss how your predictions compared to your experimental results.
7. Suggest improvements to this investigation and further experiments to investigate contact receptors.

Conclusion

Summarise the findings for this investigation about touch receptors.

2.2.3 Smell receptors

Imagine the sweet scent of a rose or the stink of rubbish. Gaseous molecules from the air are breathed in through your nose. When dissolved in the mucus of your nasal cavity, the hair-like cilia of your nasal chemoreceptors are stimulated to send a message via your **olfactory nerve** to your brain to interpret it, giving you the sensation of smell (figure 2.6).

FIGURE 2.6 A flow chart of how we process smell

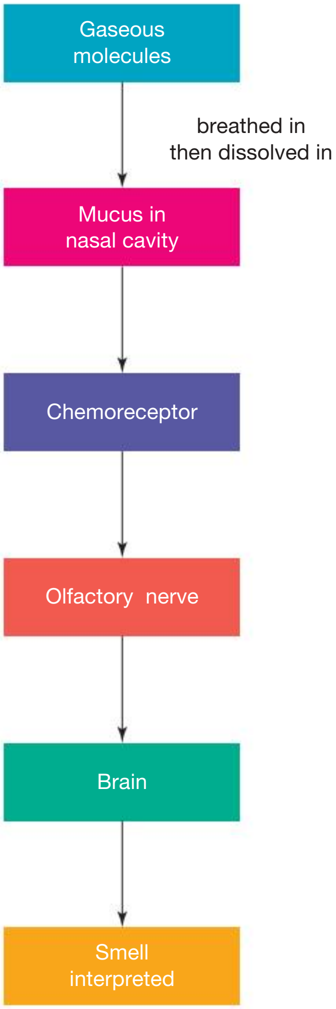
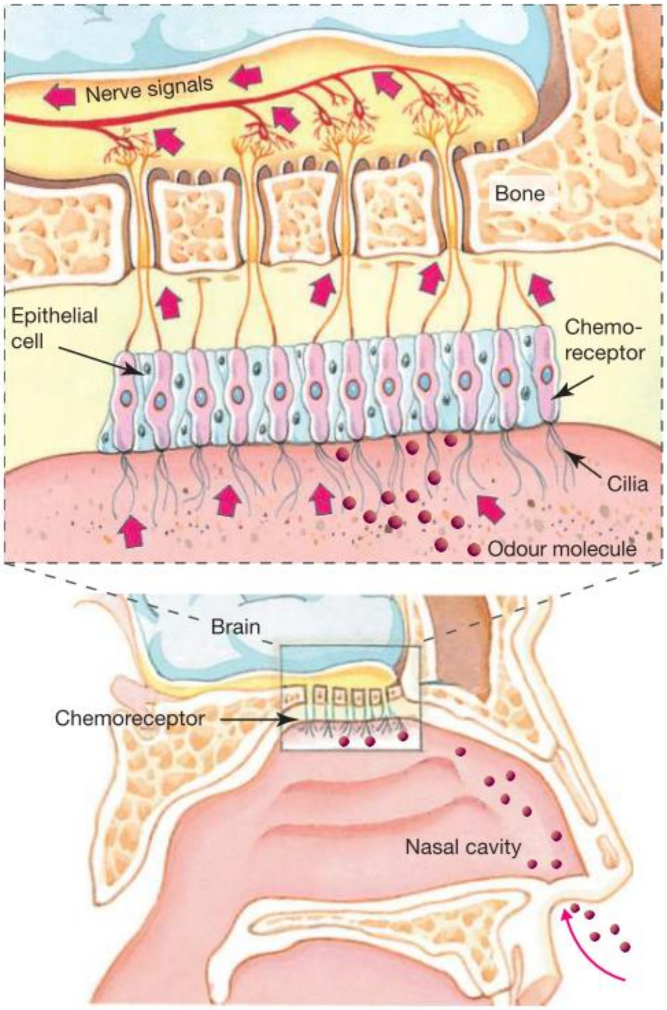


FIGURE 2.7 Chemoreceptors in your nose enable you to have a sense of smell.



2.2.4 Sight receptors

Images we see are formed when energy of light waves enters our eyes and is transmitted to the retina at the back of the eye. When you look at your eye in the mirror you will see:

- the **iris**, the coloured part of your eye, which is a ring of muscle
- the **pupil**, the dark spot in the centre of your eye. Your pupil is simply a hole in the iris.

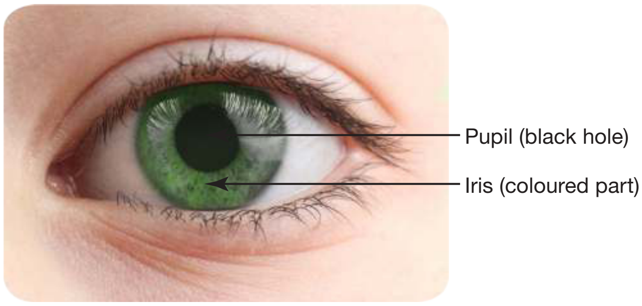
olfactory nerve nerve that sends signals to the brain from the chemoreceptors in the nose

iris coloured part of the eye that opens and closes the pupil to control the amount of light that enters the eye

pupil a hole through which light enters the eye

The iris controls the amount of light entering the eye. When the iris relaxes, the pupil appears bigger, letting more light into the eye; and when it contracts, the pupil looks smaller, letting less light into the eye. In a dark room, your pupil is large so that as much light as possible can enter your eye. If you were to move outside into bright light, your pupil would become smaller. This reflex action helps to protect your eyes from being damaged from too much light.

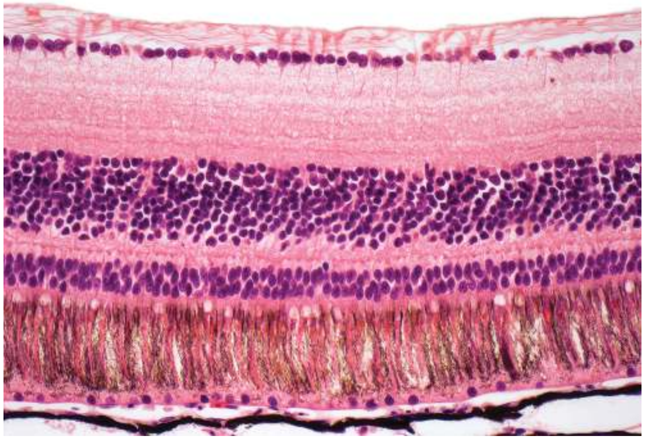
FIGURE 2.8 The iris and the pupil in the eye



Structure of the eye

The **cornea** is the clear outer 'skin' of your eye. It is curved so that the light approaching your eye is bent towards the pupil. The clear, jelly-like **lens** bends or focuses light onto a thin sheet of tissue that lines the inside of the back of your eye called the **retina**. The lens is connected to muscles, which can make it thick or thin. This allows your retina to receive a sharp image of distant or nearby objects. Your retina contains photoreceptor cells called **cones** and **rods**. The rod cells detect light intensity and the cone cells respond specifically to colour (figure 2.9).

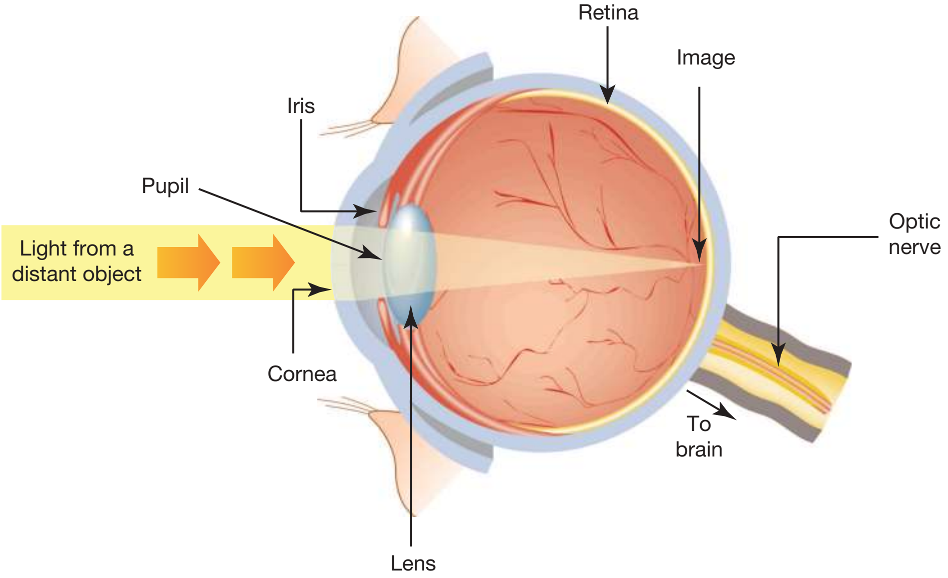
FIGURE 2.9 A view of the cones and rods in your eye



ewbk-12243

eles-2635

FIGURE 2.10 There are a number of structures within your eyes that function together so that you can detect and respond to light.



cornea the curved, clear outer covering of your eye

lens a transparent curved object that bends light towards or away from a point called the focus

retina curved surface at the back of the eye

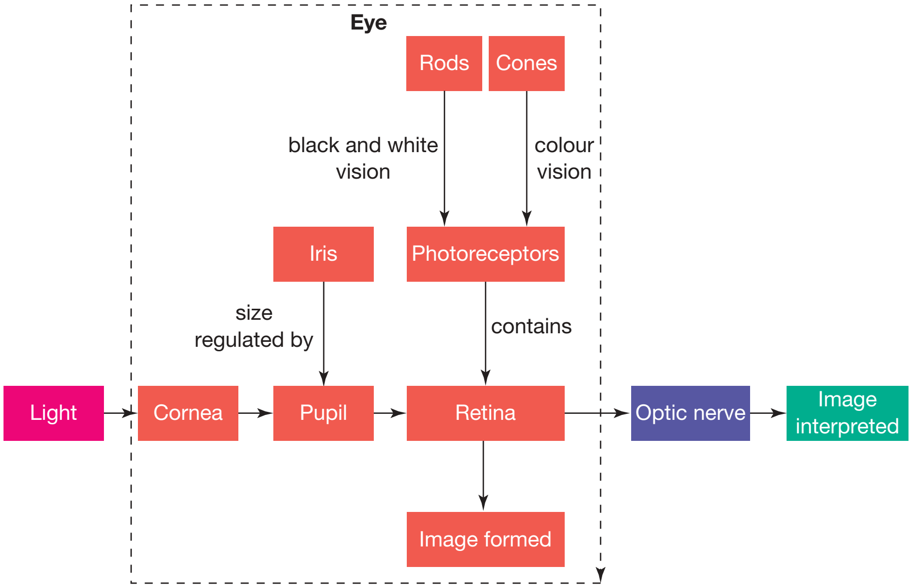
cones photoreceptors located in the retina that respond to red, green or blue light

rods photoreceptors located in the retina that respond to low levels of light and allow you to see in black and white in dim light

Although your eye receives light and produces an image of what you see, it is your brain that interprets and makes sense of the image. The photoreceptors in the retina respond to the light stimuli by sending signals to your **optic nerve**, which then forwards them to your brain for interpretation. The process is outlined in figure 2.11.

optic nerve large nerve that sends signals to the brain from the sight receptors in the retina

FIGURE 2.11 Flow chart of how cells and nerves work together to allow us to see



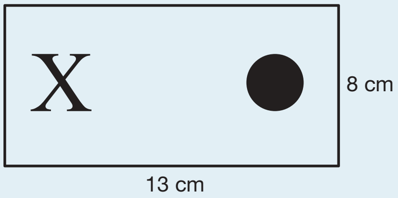
on Resources

Weblink The human eye

ACTIVITY: Blind spot

There is a certain point in your vision where there is a blind spot or, in other words, where you cannot see, as this is the spot in the retina where the optic nerve connects.

To test where your blind spot is, cut out an 8 cm × 13 cm piece of card and mark it with a cross and circle in black as shown.



Then hold the card at your eye level at an arm’s length away, with the cross on the left and the circle on the right (you should be able to see both images). Close your right eye and focus your left eye at a point in front of you. Without moving your head, slowly move your arm holding the card to the left and note down where the circle disappears and reappears. This can be measured. Then try this with your left eye closed and your arm moving to the right. Is there a difference in where the cross disappears and reappears in each eye?

elog-2242

tlvd-10798

INVESTIGATION 2.2

Dissection of a mammal's eye

Aim

To investigate the structure of an eye

CAUTION

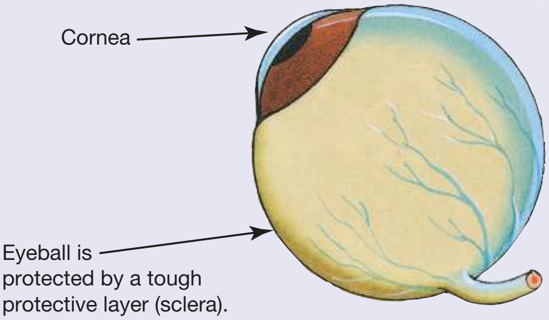
Handle dissecting instruments with care and ensure they are placed in a sterilising solution after use. Wear safety glasses and disposable gloves throughout the dissection and wash your hands thoroughly at the end.

Materials

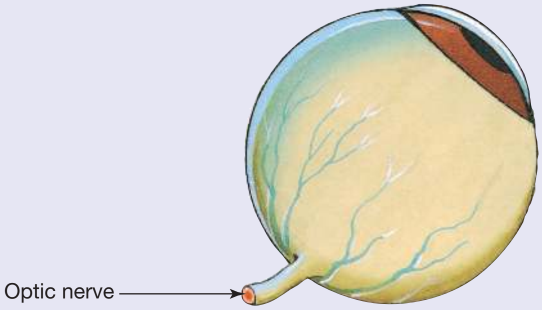
- bull's eye or similar
- dissection board
- newspaper
- paper towelling
- scalpel or razor blade
- safety glasses
- forceps
- stereo microscope
- water
- disposable gloves

Method

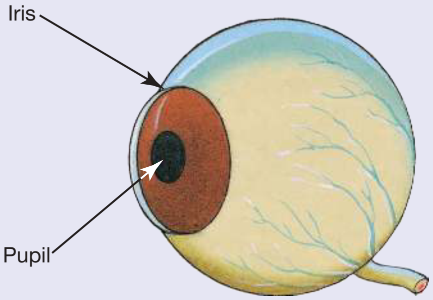
1. Put on safety glasses just in case any of the aqueous or vitreous humour squirts out at you. Aqueous and vitreous humour are jelly-like liquids that give eyes their shape.
2. Carefully place the bull's eye on a dissection board covered with newspaper and paper towelling. Place bull's eye on dissection board covered with newspaper. Locate the transparent skin of the cornea.
   Draw and label the structures of the bull's eye before and after your dissection. (Use the diagrams provided to help you to label your drawing.)



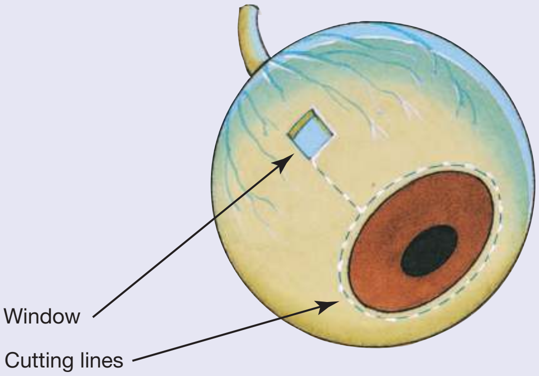
3. Locate the optic nerve. It is a hard, white, solid tube at the back of the eye. You may have to remove some fat to see it. Add descriptive comments to your labels as you make your observations throughout this activity.



4. Look at the coloured part of the eye (iris) and the black part in the centre (pupil).



5. Cut a small window in the eyeball. Be careful that the vitreous humour does not run out. Starting from this window, cut forward and around the iris. Record your observations regarding the toughness of the sclerotic coating.



6. From this window, cut towards and then all the way around the iris so that you have cut the eye into two parts.
7. Lift off the top part of the eye and examine the iris.
8. Remove the lens with forceps and see if you can read the print on the newspaper through it.
9. Use water to rinse out the jelly-like material (humour) from inside the eye and examine the retina. Record your observations.
10. Follow your teacher's instructions regarding the cleaning of equipment and disposal of the dissected eye.

Results

1. Draw labelled diagrams of the eye before and after the dissection.
2. What is the black part in the middle of the iris? What is its function?
3. What did you observe when you looked at the newspaper through the lens?
4. What did the retina look like? Could you find the optic nerve?

Discussion

1. What does the diaphragm in a microscope do?
2. Which part of the eye does the diaphragm in a monocular microscope most resemble?
3. Summarise your findings in a table.

Conclusion

Summarise the findings for this investigation about the structure of the eye.

ACTIVITY: In the dark

Investigate the effect of light intensity on the iris of a human eye.

- Cup your hands loosely over both eyes so that you cannot see anything but your hands. Keep your eyes open. Look at the insides of your hands.
- After about one minute, have your partner look carefully at your pupils.

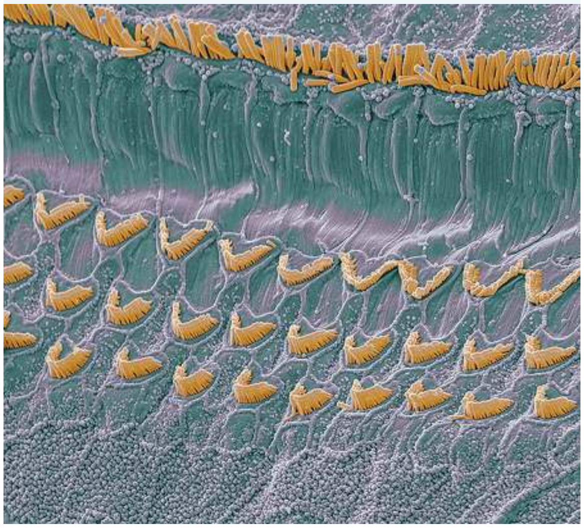
1. What happens to the iris as your hands are removed?
2. Explain your observations.

2.2.5 Hearing receptors

The ear is your sense organ that detects sound. The steps involved in the detection of sound and the process of hearing:

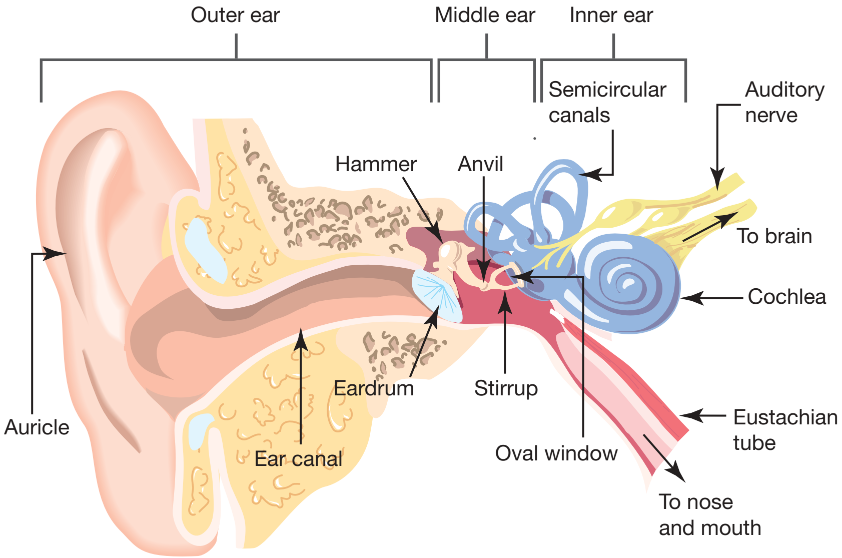
1. Sound travels by waves, which are vibrations in the air.
2. When the air inside your **ear canal** vibrates, it causes your **eardrum** to vibrate at the same rate.
3. Three tiny bones known as **ossicles** in your **middle ear** receive this vibration from your eardrum and then pass it to your inner ear.
4. Inside your inner ear, thousands of tiny hairs attached to nerve cells of the snail-shaped **cochlea** detect the vibration and send a message to your brain via your **auditory nerve**.
5. Your brain interprets the message as hearing sounds.

FIGURE 2.12 An electron micrograph of hair cells in the cochlea



wbk-12244
eles-2636
int-8176

FIGURE 2.13 Your ear contains specialised structures that help you to detect sound.



ear canal the tube that leads from the outside of the ear to the eardrum

eardrum a thin piece of stretched skin inside the ear that vibrates when sound waves reach it

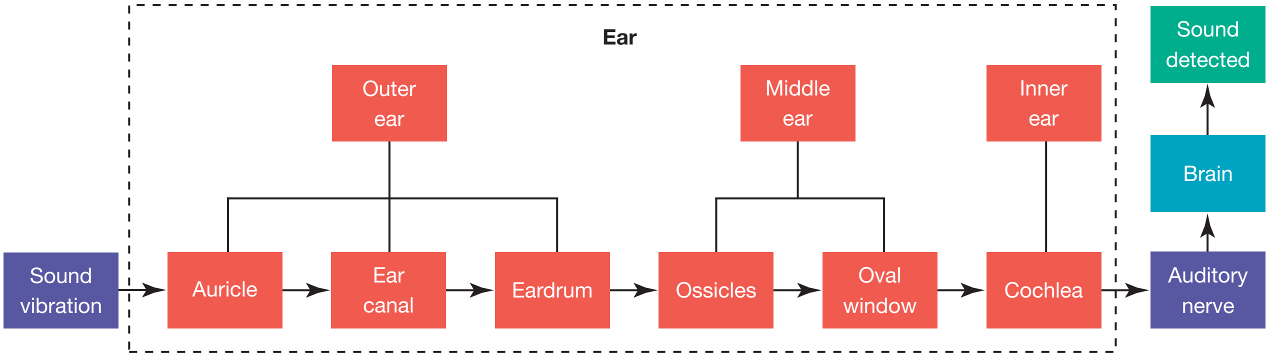
ossicles a set of three tiny bones that send vibrations from the eardrum to the inner ear

middle ear the section of the ear between your eardrum and the inner ear, containing the ossicles

cochlea the snail-shaped part of the inner ear in which receptors are stimulated

auditory nerve a large nerve that sends signals to the brain from the hearing receptors in the cochlea

FIGURE 2.14 Flow chart of the steps that allow us to hear



SCIENCE AS A HUMAN ENDEAVOUR: Cochlear implant — the 'bionic ear'

In the 1960s Australian surgeon and medical researcher Professor Graeme Clark from the University of Melbourne led the team that developed and implanted the first multi-channel cochlear implant, also known as the bionic ear. The first cochlear implant was implanted into a patient at the Royal Eye and Ear Hospital in Melbourne in 1978. Since then, Professor Clark's work has changed the lives of hundreds of thousands of people around the world, giving them the ability to hear and communicate with others.

A cochlear implant is an electronic device that is fitted to the head and sends signals to the nerves that allow us to hear (see figure 2.16a). It consists of two main parts: the receiver, which is placed under the skin near the ear, and the headpiece, which is worn on the outside of the head. The headpiece contains the transmitter, microphone and speech processor (figure 2.16b). A cochlear implant works differently to a hearing aid. Hearing aids amplify sound so that a damaged ear can detect them, whereas cochlear implants bypass damaged areas of the ear to directly stimulate the auditory nerve.

FIGURE 2.15 Professor Graeme Clark

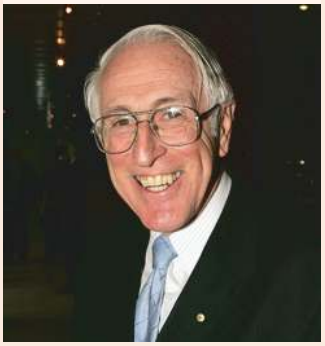
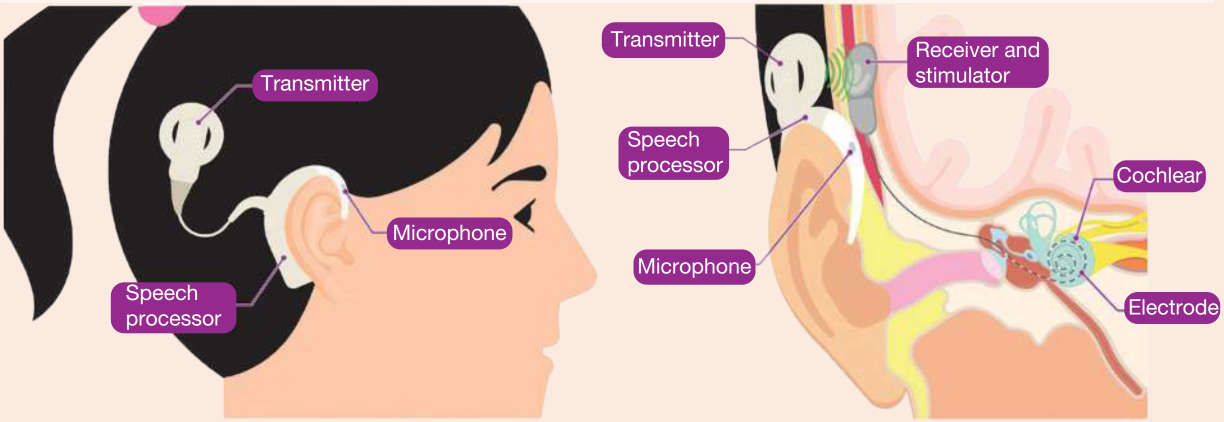


FIGURE 2.16 a. Individual fitted with a cochlear implant

FIGURE 2.16 b. Components of a cochlear implant



2.2.6 Taste receptors

The tongue is your sense organ for taste. **Tastebuds** located within bumps called **papilla** across your tongue have the ability to sense all flavours. This is because each of these tastebuds (see figure 2.17) contains cells with receptors for each type of flavour. Taste can be classified into five categories: sweet, salty, sour, bitter and umami.

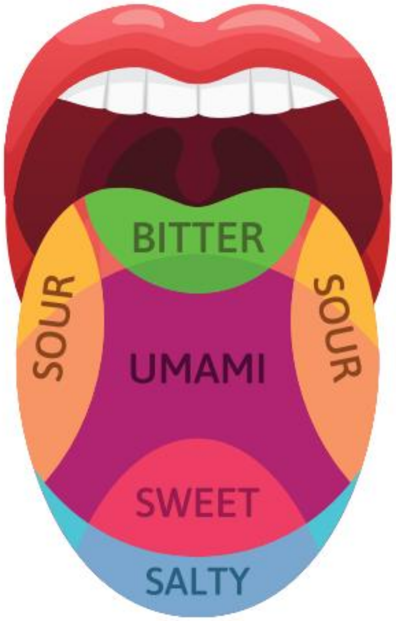
tastebuds nerve endings located in your tongue allowing you to experience taste

papilla bumps on your tongue that are thought to contain tastebuds

You may be familiar with the idea that different areas of the tongue are responsible for different tastes as seen in figure 2.18. This has been proven to be incorrect as all taste sensations come from all regions of the tongue, although different parts of the tongue are more sensitive to different tastes.

FIGURE 2.17 Tastebuds contain chemoreceptors (as shown here), which are sensitive to particular chemicals.

FIGURE 2.18 The idea that different parts of the tongue are responsible for different tastes has been proven wrong.



Resources

eWorkbook Skin (ewbk-12245)

ACTIVITY: Umami

Historically, we have classified taste into four main types: sweet, salty, bitter and sour. Recent findings suggest a fifth basic taste, known as umami. Find out what umami is and create a poster outlining the five basic tastes, including common foods in each category.

2.2 Activities

2.2 Quick quiz on | **2.2 Exercise**

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 4, 9	2, 6, 8, 10, 11	3, 5, 7, 12, 13

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. State the purpose of the sense organs.
2. Complete the following table.

TABLE Sense organs, stimuli and types of receptors

Sense organs	Stimuli	Types of receptors
		Photoreceptor
Ear		
	Smell	
Tongue		
	Touch	

3. Match each location to the type of receptor.

Location	Receptor
a. Tastebuds in mouth	**A.** Photoreceptor
b. Hot and cold receptors in skin	**B.** Mechanoreceptor
c. Rods and cones in the retina	**C.** Thermoreceptor
d. Hairs in the cochlea of ear	**D.** Chemoreceptor

4. Identify the location and function of the:
   a. optic nerve **b.** olfactory nerve.
5. Identify the type of receptor that would respond to the following stimuli:
   a. light **b.** sound **c.** chemicals **d.** temperature.

Apply and analyse

6. Describe the difference, relationship and function between:
   a. the pupil and iris in the eye **b.** rods and cones in the eye.
7. In which part of the human body is an observed image:
   a. formed **b.** interpreted?
8. If cats have rods, but no cones, what does that mean in terms of how they see the world?

Evaluate and create

9. **SIS** Describe the new model that is used to explain the involvement of our tongues in the sensation of taste. How is this different to the previous model?
10. Construct a flow chart or mind map that shows structures involved in:
    a. smell **b.** vision **c.** sound.
11. Suggest why:
    a. the thickest part of your skin is on the soles of your feet
    b. some parts of your skin, such as the back of your hand, are more sensitive to heat than others.

12. How do movement receptors receive a sensation of movement when they are well below the surface of the skin?
13. **SIS** Olfactory receptor cells are important in our ability to smell things. A human has about 40 million, whereas a rabbit has 100 million and a dog has 1 billion! What effect might this difference have on the chances of survival for these animals?

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

LESSON
2.3 Homeostasis

LEARNING INTENTION

At the end of this lesson you will be able to recall the five key features of a stimulus–response model, define homeostasis and explain the difference between negative and positive feedback mechanisms.

2.3.1 Stimulus–response model

You are a **multicellular organism** made up of many cells that need to be able to communicate with each other. They need to be able to let other cells know when they need help and support, when they need more of something or when they need to get rid of something.

All of your systems need to work together so that a comfortable stable environment for your cells is maintained. The nervous system (including nerves and **neurotransmitters**) and the endocrine system (including glands and **hormones**) are vital in helping your systems work together.

Homeostasis

The internal environment in which your cells live needs to be kept constant. Temperature, pH and concentrations of ions, glucose, water and carbon dioxide need to be within a particular range. Maintenance of this constant internal environment is called **homeostasis**.

To be able to achieve homeostasis, any changes or variations (stimuli) in the internal environment need to be detected (by receptors). If a response is required, this needs to be communicated to **effectors** to bring about some type of change or correction so the conditions can be brought back to normal. This is described as a **stimulus–response model**. The stimulus–response model (figure 2.19) involves two major functioning systems in the body: the nervous system and the endocrine system.

multicellular organism a living thing that is composed of many cells

neurotransmitters signalling molecules released from the axon terminals into the synapse between nerve cells (neurons)

hormone a signalling molecule that is produced in specialised cells and travels in blood to act on target cells to cause a specific response

homeostasis the maintenance by an organism of a constant internal environment (for example, blood glucose level, pH, body temperature)

effectors organs that respond to a stimuli to initiate a response

stimulus–response model a system in which a change (stimulus) is detected by receptors leading to a response, which acts to alter and return the variance to normal

FIGURE 2.19 The stimulus–response model

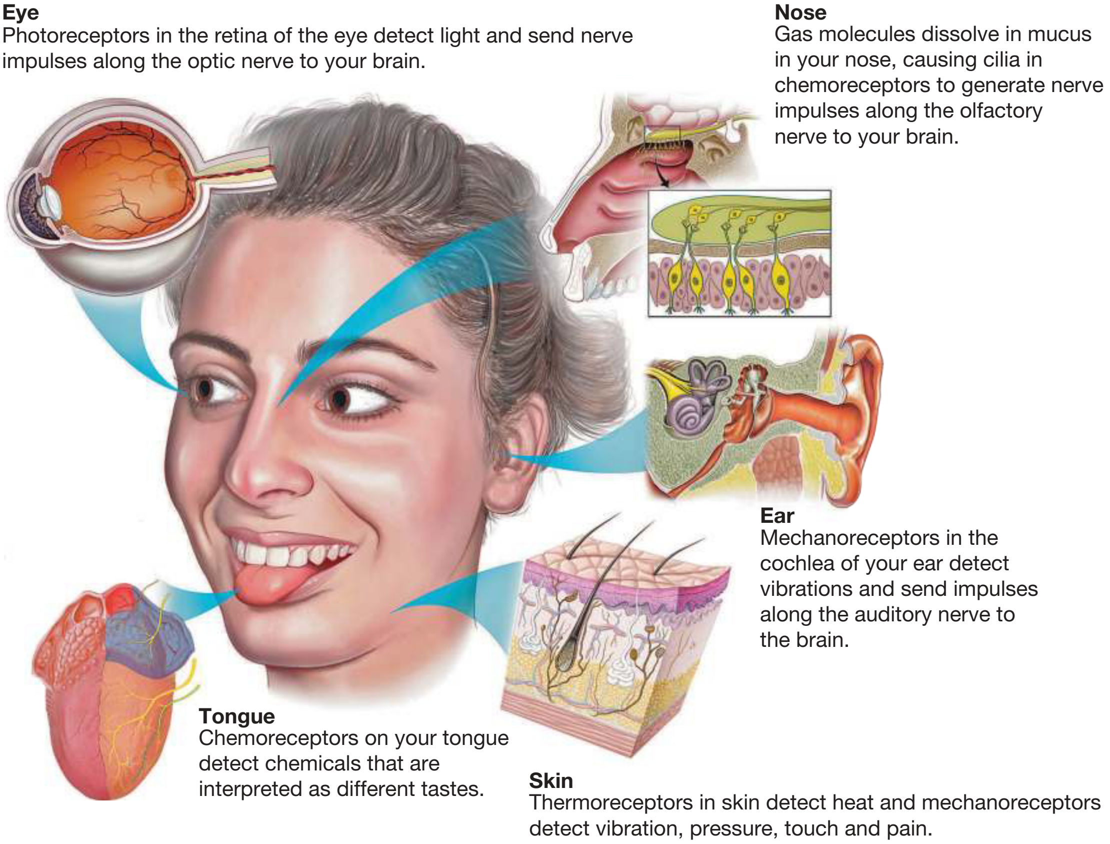
Stimuli

There are various stimuli that your body needs to detect and, if necessary, respond to. Some of these stimuli may be outside of your body, such as environmental temperature or potentially dangerous (for example, hot or sharp) objects. Other stimuli may be inside your body, such as changes in body temperature and blood sugar, pH or water levels.

Receptors

As discussed in lesson 2.2, receptors identify changes inside and outside your body. These special types of nerve cells may be located in sense organs such as your eyes, ears, nose, tongue and skin (figure 2.20).

FIGURE 2.20 Examples of the receptors in the human body



Control centre/modulator

Once a stimulus has been detected by a receptor, a message in the form of a nerve impulse travels to the central nervous system (brain and spinal cord). It is here that the message is processed to determine which response will be appropriate. A message is then sent to the appropriate effector.

Effectors

Effectors such as muscles or glands receive the message from the central nervous system to respond in a particular way. Their response depends on the original stimulus. For example, if your hand is too close to a candle flame, then muscles in your arm may respond to move your hand away from it. If your body temperature increases too much, your sweat glands produce sweat to help cool you down.

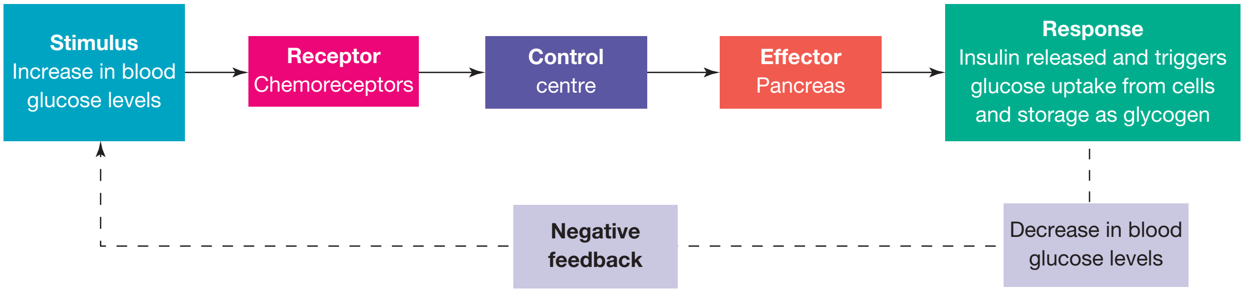
2.3.2 Feedback mechanisms

Stimulus–response models can also involve negative or positive feedback. Most biological feedback systems involve negative feedback.

Negative feedback

Negative feedback occurs when the response is in an opposite direction to the stimulus. It is a homeostatic mechanism that allows for the maintenance of variables within a set range. For example, if levels of a particular chemical in the blood were too high, then the response would be to lower them. Likewise, if the levels were too low, then they would be increased. The response is 'fed back' into the system, allowing for further adjustments to be made if required. Negative feedback mechanisms have five main key stages, as shown in figure 2.21. Examples of negative feedback mechanisms will be given in lessons 2.4 and 2.5.

FIGURE 2.21 Example of the negative feedback loop that happens when high blood glucose is detected.



2.3.3 How messages are sent in the body

To work together effectively, these systems require coordination. The two systems with this responsibility are the **nervous system** and the **endocrine system**. While both of these systems require signalling molecules to communicate messages throughout the body, they have different ways of going about it. The nervous system and endocrine system will be explored further in lessons 2.4 and 2.5. The nervous system uses a combination of electrical and chemical signals. The endocrine system uses hormones.

TABLE 2.2 Comparison of messages sent through the endocrine and nervous systems

Feature	Endocrine system	Nervous system
Speed of message	Slow	Fast
Speed of response	Usually slow	Immediate
Duration of response	Long lasting	Short
Spread of response	Usually slow	Very localised
How message travels through body	In circulatory system — in bloodstream	In nervous system — along nerves and across synapses
Types of message	Hormones (chemicals)	Electrical impulse and neurotransmitters (chemicals)

negative feedback a homeostatic mechanism that returns a stimulus back within its normal range

nervous system the body system in which messages are sent as electrical impulses (along neurons) and chemical signals (neurotransmitters across synapses)

endocrine system the body system composed of different glands that secrete signalling molecules (hormones) that travel in the blood for internal communication and regulation and to maintain homeostasis

on Resources

eWorkbook The stimulus–response model (ewbk-12249)

2.3 Activities

learnon

2.3 Quick quiz on

2.3 Exercise

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 2, 7, 10	3, 5, 8	4, 6, 9, 11

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. Match each of the following terms to its definition.

Term	Definition
a. Hormone	**A.** Command system of the body: brain, spinal cord and nerves
b. Neurotransmitter	**B.** The glands and organs that make hormones
c. Nervous system	**C.** Chemical responsible for controlling and regulating the activities of certain cells and organs
d. Endocrine system	**D.** Chemical messenger released by neurons

2. **MC** These detect or identify changes or variations on the inside or outside of your body.
A. Effectors **B.** Receptors **C.** Response **D.** Stimuli

3. **MC** These bring about a response to changes or variations in the internal environment of your body.
A. Effectors **B.** Receptors **C.** Response **D.** Stimuli

4. Give an example of homeostasis in regard to the human body.

5. Define each of the following terms:
a. Stimulus–response model
b. Control centre
c. Effector
d. Receptor

Apply and analyse

6. Identify each of the following as positive or negative feedback:
a. Blood glucose levels increase and insulin returns this back to normal levels.
b. During a fever, the body temperature continues to increase away from the set body temperature.
c. When your body temperature decreases, thyroxine acts to increase your metabolism and increase your body temperature.

7. Fill in the blanks using the following terms: effectors, receptors, response, stimuli.
The stimulus–response model describes how __________, such as changes in the internal environment of your body, are detected by __________, which may communicate the message to __________ to bring about some kind of __________ so that conditions are brought back to normal.

8. Give an example of a negative feedback mechanism in the human body.

9. Distinguish between:
a. receptors and effectors
b. negative and positive feedback
c. the endocrine system and the nervous system.

Evaluate and create

10. Construct a flow chart to show the relationship between the following: effector, response, control centre, stimulus, receptor.

11. **SIS** Research the regulation and stimulus–response model when the human body temperature is too low or too high and create a flow chart showing how the nervous and endocrine systems work to return the body temperature to normal.

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

LESSON
2.4 The nervous system

LEARNING INTENTION

At the end of this lesson you will be able to identify and explain the components of the nervous system, compare the roles of the somatic and autonomic nervous systems and describe how messages are transmitted from a stimulus to generate a response.

2.4.1 Components of the nervous system

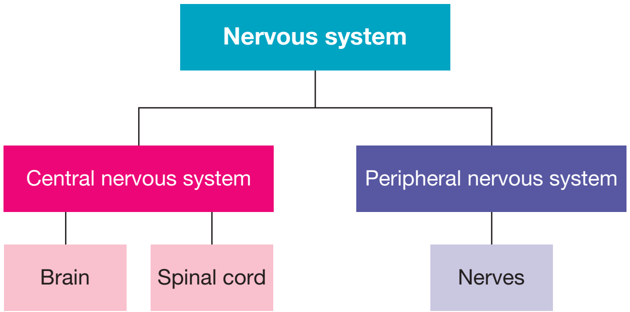
Your nervous system is composed of the:

- **central nervous system** (CNS) — contains brain and spinal cords
- **peripheral nervous system** (PNS) — contains the nerves that connect the central nervous system to the rest of the body.

Messages are sent by:

- **sensory neurons** — take messages to the central nervous system
- **motor neurons** — take messages away from the central nervous system.

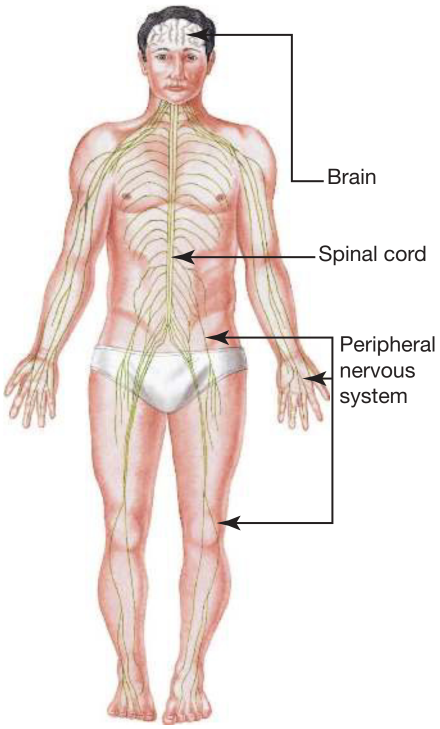
FIGURE 2.22 The components of the nervous system



The nervous system sends the message as an electrical impulse along a neuron and then as a chemical message (neurotransmitters) across the gaps (synapses) between them. We will discuss this in detail later in this topic.

eles-2632

FIGURE 2.23 The human nervous system



central nervous system the part of the nervous system composed of the brain and spinal cord

peripheral nervous system the part of the nervous system containing nerves that connect to the central nervous system

sensory neurons a nerve cell in the sensory organs that conducts a nerve impulse from receptors to the central nervous system

motor neuron a nerve cell that conducts a nerve impulse from the central nervous system to the effector, such as a muscle or gland so that it may respond to a stimulus

2.4.2 The central nervous system

The central nervous system (CNS) is responsible for receiving and processing information on changes to your environment. The CNS consists of the brain and spinal cord.

The brain is the control centre of all of your body's functions and is responsible for:

- intelligence
- creativity
- perceptions
- conscious reactions
- emotions and memories.

Your brain cells are organised into different areas within your brain. Although they may have different functions, they communicate and work together to keep you alive.

Components of the brain

- Your **hindbrain** is a continuation of your spinal cord. It develops into the pons and cerebellum, and the **medulla oblongata** (medulla).
- Extending through your hindbrain and midbrain is a network of fibres called the **reticular formation** — a network of neurons that opens and closes to increase or decrease the amount of information that flows into and out of the brain. The reticular formation helps regulate alertness (from being fully awake or deeply asleep), motivation, movement and some of the body's reflexes (such as sneezing and coughing).
- The **forebrain** develops into the cerebrum, **cerebral cortex** (outer, deeply folded surface of the cerebrum) and other structures such as the **thalamus**, hypothalamus and **hippocampus**.

hindbrain a continuation of the spinal cord

medulla oblongata (medulla) a part of the brain developed from the posterior portion of the hindbrain

reticular formation a network of neurons that controls the amount of information that flows into and out of the brain

forebrain consists of the cerebrum, cerebral cortex, thalamus and hypothalamus

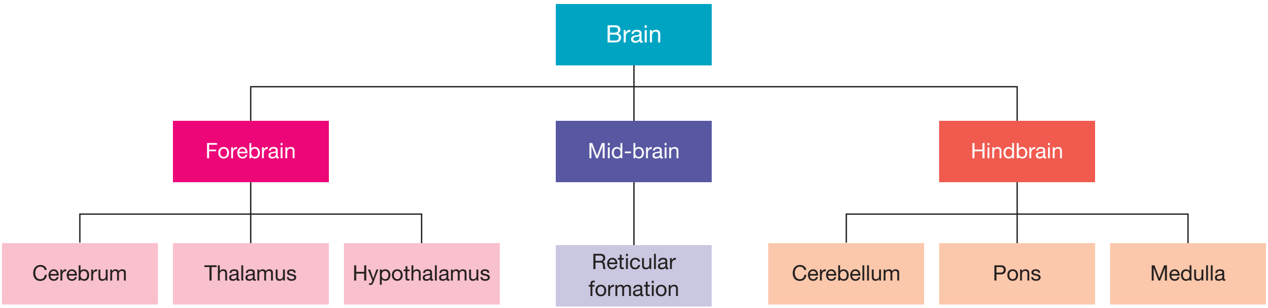
cerebral cortex the outer, deeply folded surface of the cerebrum

thalamus part of the brain through which all sensory information from the outside (except smell) passes before going to other parts of the brain for further processing

hippocampus part of the brain with a key role in consolidating learning, comparing new information with previous experience, and converting information from working memory to long-term storage

brain stem the part of the brain connected to the spinal cord, responsible for breathing, heartbeat and digestion

FIGURE 2.24 Components of the human brain



Brain stem (medulla)

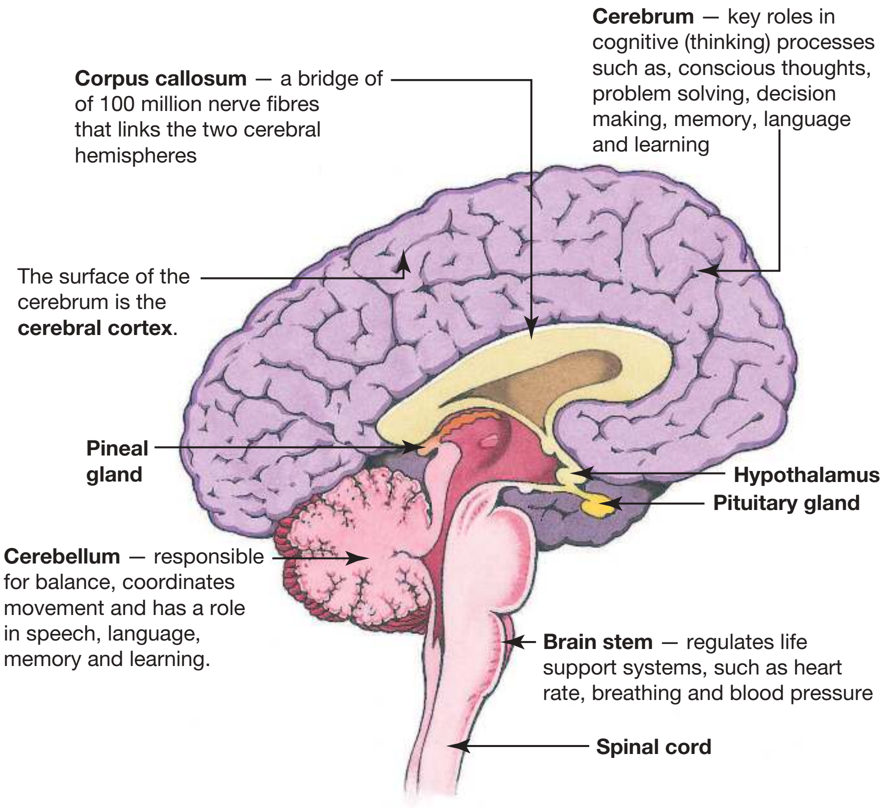
Not all actions in your body require conscious thought. These are called involuntary actions and you don't need to think about them for them to occur. Breathing, heartbeat, blood pressure, coughing, vomiting, sneezing and salivating are all examples of involuntary actions controlled by your **brain stem**.

Your brain stem (or medulla) is located between your spinal cord and your cerebrum. If this vital structure is damaged, death may result.

ewbk-12254

int-8229

FIGURE 2.25 The human brain



Cerebellum

Your **cerebellum** is located near the brain stem, underneath the cerebrum. Although it takes up only about 10 per cent of your brain's volume, the cerebellum contains over half of all of your brain's neurons. Your cerebellum has key roles in posture, coordination, balance and movement. Current research also suggests that it may also be involved in memory, attention, spatial perception and language.

The word *cerebellum* means 'little brain' in Latin. There are two halves (or hemispheres), one for each side of the brain. Each of these hemispheres consists of three lobes. There is a lobe that receives sensory input from your ears to help you to maintain your balance. Another lobe gets messages from your spinal cord to let your brain know what some other moving parts of your body are up to. There is even a lobe that communicates with your cerebrum, the thinking part of your brain.

Cerebrum

The **cerebrum** is the largest part of the brain and makes up about 90 per cent of your brain's total volume. The cerebrum is responsible for higher-order thinking (such as problem solving and making decisions) and controls speech, conscious thought and voluntary actions (actions that you control by thinking about them). The cerebrum is also involved in learning, remembering and personality.

The cerebrum is made up of four primary areas called lobes. Each of these lobes is associated with particular functions.

cerebellum the part of the brain that controls balance and muscle action

cerebrum the largest part of the brain responsible for higher order thinking, controlling speech, conscious thought and voluntary actions

Your cerebrum is divided into two **cerebral hemispheres** — the right cerebral hemisphere (mainly responsible for the left side of your body) and the left cerebral hemisphere (mainly responsible for the right side of your body). While each hemisphere is specialised to handle different tasks, they work together as an integrated whole, communicating with each other through a linking bridge of nerve fibres called the **corpus callosum**.

cerebral hemispheres the left and right halves of the brain

corpus callosum a bridge of nerve fibres through which the two cerebral hemispheres communicate

elog-2245

INVESTIGATION 2.3

Dissection of a mammal's brain

Aim

To investigate the structure of the brain

CAUTION

Handle dissecting instruments with care and ensure they are placed in a sterilising solution after use. Wear safety glasses and disposable gloves throughout the dissection and wash your hands thoroughly at the end.

Materials

- a semi-frozen sheep's brain
- dissecting board
- dissecting instruments (scalpel, forceps, scissors)
- plastic ruler
- paper towel
- disposable gloves

Method

1. Place the brain so that the cerebral hemispheres are at the top of the board and the brain stem is at the bottom.
2. Identify the external features of the brain: the cerebral hemispheres, cerebellum and brain stem.
3. Use your forceps and try to lift the meninges (membranes protecting the brain). You may be able to observe the cerebral fluid between these membranes and the hemispheres.
4. Carefully observe the overall appearance of each structure and, using a plastic ruler, measure its size (length, width and height). Include this information in a table in the results section.
5. Draw a diagram of the sheep's brain, labelling the external features.
6. Using your scalpel, cut the brain in half between the right and left hemispheres, and separate the two cerebral hemispheres.

7. Draw a cross-section of the brain. Be sure to label it!
8. Now make a second cut down through the back of one of the hemispheres to see inside the cerebellum and brain stem.

Results

1. Construct a table with the headings shown below and record your observations from the dissection.

TABLE Observations of different brain structures

	Appearance			
Brain structure	**Colour**	**Texture**	**Other features**	**Size**
Cerebrum				
Cerebellum				
Brain stem				

2. Sketch the sheep's brain, labelling the external features. On your diagram, identify and label the part of the brain that controls the sheep's:
   a. heart rate
   b. balance required for walking
   c. ability to locate its lamb.
3. Sketch a cross-section of the sheep's brain.

Discussion

1. a. Which structures contained the grey and white matter?
   b. Find out why these structures are different colours.
2. Which part of the sheep's brain is the biggest? Is this the same pattern in human brains?
3. The brain is usually protected by a bony skull. It is also covered with three layers of connective tissue called meninges and surrounded by cerebral fluid. Suggest how the meninges and cerebral fluid help protect the brain.
4. Identify strengths and limitations of your investigation of the brain and suggest improvements.

Conclusion

Summarise your findings for this investigation about the structures in the brain.

on Resources

eWorkbook The brain (ewbk-12255)
Weblink Neuroscience

2.4.3 The peripheral nervous system

The peripheral nervous system (PNS) consists of all the nerves located outside the central nervous system. The PNS is divided into two parts, the **somatic nervous system** and the **autonomic nervous system**.

The somatic nervous system

The somatic nervous system controls our voluntary actions via the skeletal muscles. This includes movement such as picking up an object or walking. It is composed of the sensory and motor neurons. The sensory neurons detect changes to our environment and send these messages to the CNS. Motor neurons relay messages from the CNS to the effectors, such as muscles or glands.

The autonomic nervous system

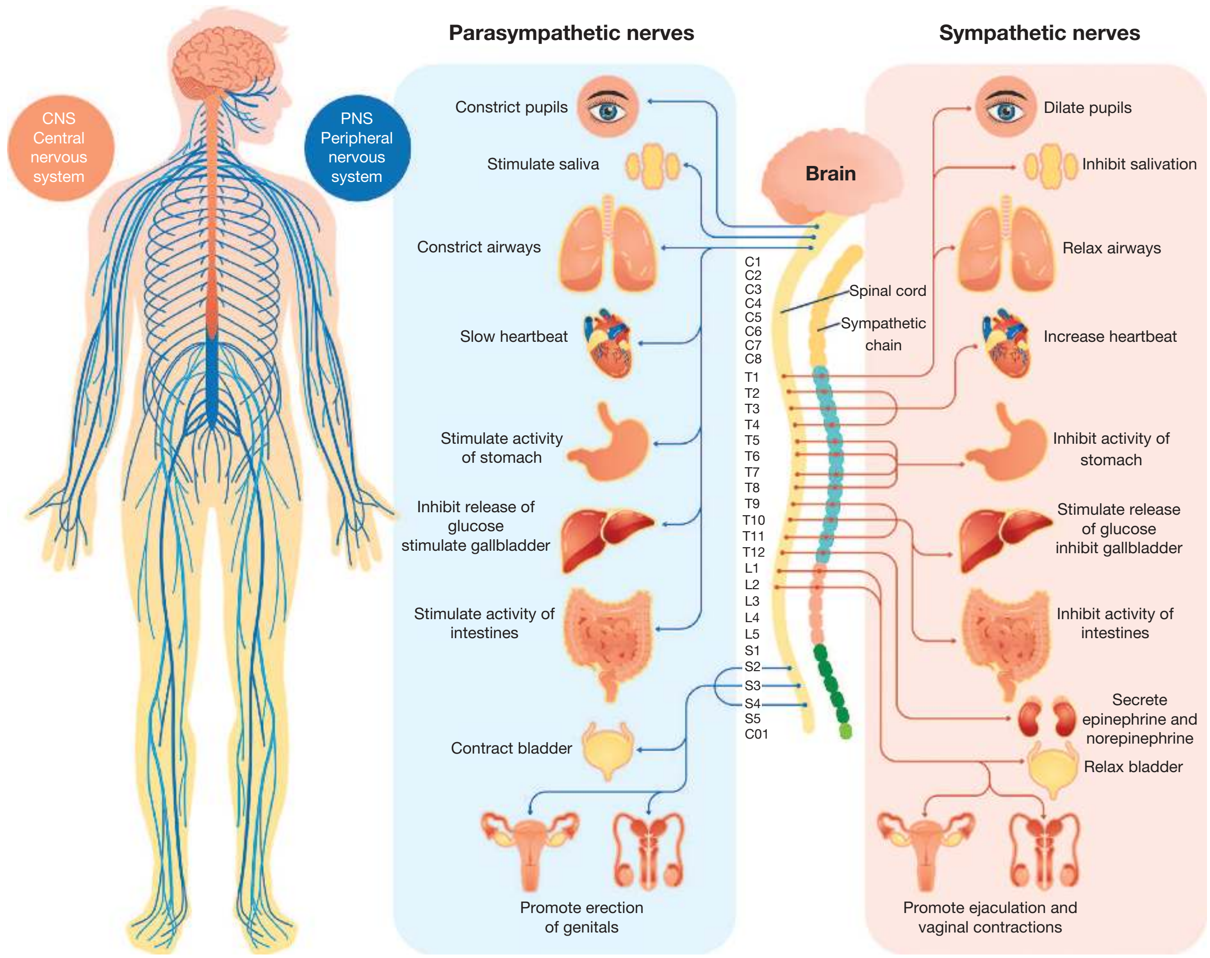
The autonomic nervous system controls are involuntary actions that control the functioning of our internal organs and functioning systems, including the heart and circulatory system. The autonomic nervous system can be further divided into the sympathetic and parasympathetic nervous systems. The sympathetic and parasympathetic nervous systems have opposite effects on the body; an example is the sympathetic nervous system increasing heart rate and the parasympathetic nervous system decreasing heart rate.

somatic nervous system part of the PNS that controls voluntary movement, such as walking

autonomic nervous system part of the PNS that controls involuntary movement, such as breathing or heartbeat

The sympathetic nervous system is responsible for our ‘flight or fight’ response (further discussed in section 2.5.2). Together these systems maintain homeostasis in the body (figure 2.26).

FIGURE 2.26 The location of the central nervous system (CNS) and peripheral nervous system (PNS) and comparison of the role of the sympathetic and parasympathetic nervous systems



2.4.4 Neurons

Whether you are catching a ball, breathing or stopping a fall, you need to be in control. You need to be able to detect and respond in ways that ensure your survival. This requires control and coordination. Your nervous system assists you in keeping in control, and coordinating other body systems so that they work together and function effectively.

Your nervous system is composed of the central nervous system (brain and spinal cord) and the peripheral nervous system (the nerves that connect the central nervous system to the rest of the body). These systems are made up of nerve cells called **neurons**. The axons of neurons are grouped together to form **nerves**.

Structure of a neuron

Neurons contain a **nucleus** and other cell **organelles**. They also contain a **cytosol** and cell membrane, as do other cells. However, the various types of neurons are all quite different. These differences mean that each particular neuron type is suited to its specific communication role in the nervous system. These differences are shown in table 2.3.

neuron another name for nerve cell, a specialised cell for transmitting a nerve impulse

nerve a bundle of neurons

nucleus roundish structure inside a cell that acts as the control centre for the cell

organelle small structure in a cell with a special function

cytosol the fluid found inside cells

Neurons are made up of three main parts as seen in figure 2.27:

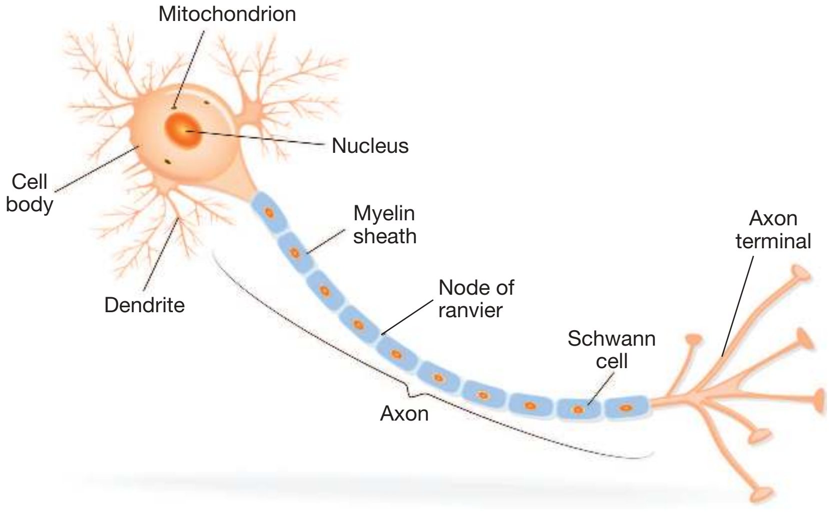
- a **cell body** — contains the nucleus of a neuron
- **dendrites** — highly sensitive branching extensions on the cell membrane of the cell body; these dendrites possess numerous receptors that can receive messages from the other cells
- **axon** — a long structure of the neuron that carries the electrical message from the dendrite and the cell body. This structure is often covered with a white insulating substance called **myelin**, which helps speed up the conduction of the message through the neuron.

The way an electrical impulse travels through a neuron can be seen in figure 2.28.

ewbk-12256

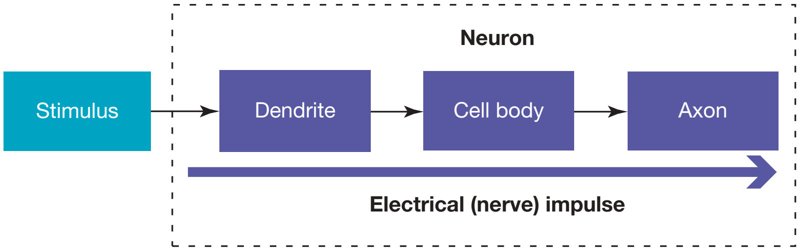
int-5762

FIGURE 2.27 The components of a neuron



int-0670

FIGURE 2.28 An electrical impulse moves in only one direction through a neuron.



Types of neurons

There are three types of neurons:

- sensory neurons, which carry the impulse generated by the stimulus to the central nervous system
- **interneurons**, which carry the impulse through the central nervous system
- motor neurons, which take the impulse to effectors such as muscles or glands.

cell body part of a neuron that contains the nucleus

dendrite structure that relays information towards the cell body of a neuron

axon long structure within a neuron through which the nervous impulse travels from the dendrite and the cell body

myelin a fatty, white substance that encases the axons of neurons

interneuron a nerve cell that conducts a nerve impulse within the central nervous system, providing a link between sensory and motor neurons

FIGURE 2.29 Relationship between the different neurons in the nervous system

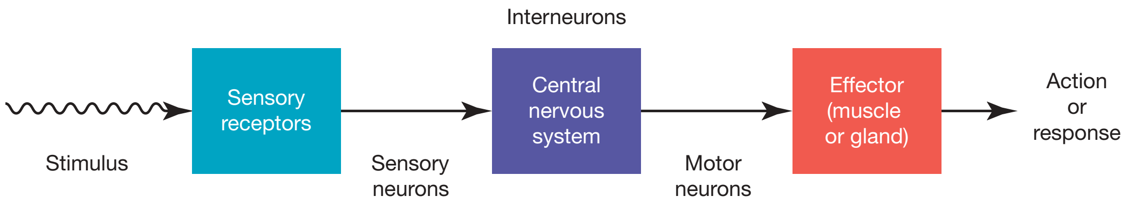
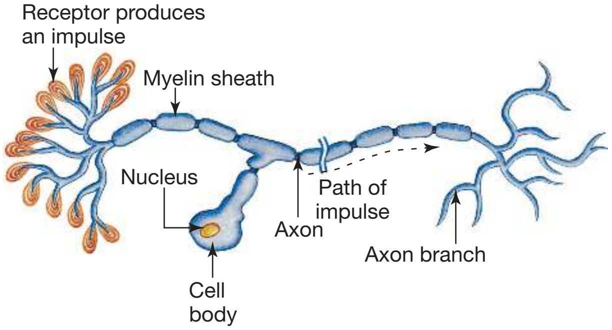
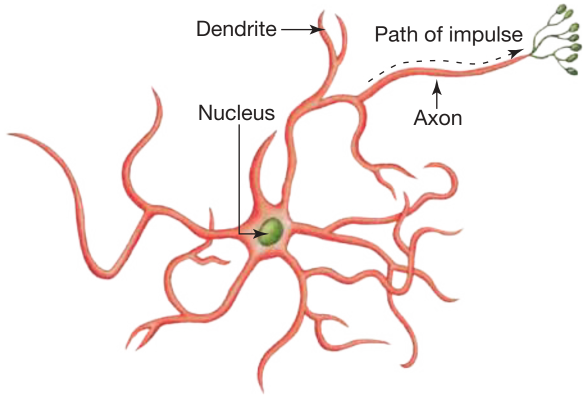
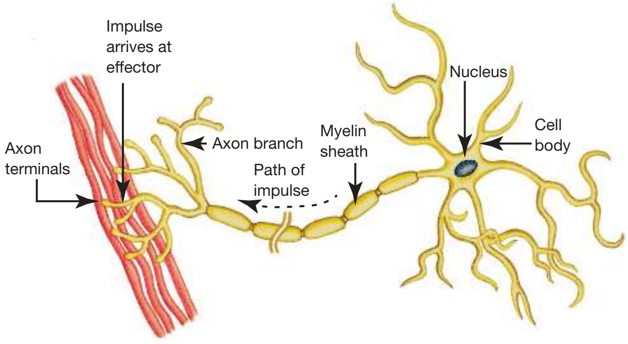


TABLE 2.3 The structure of different types of neurons

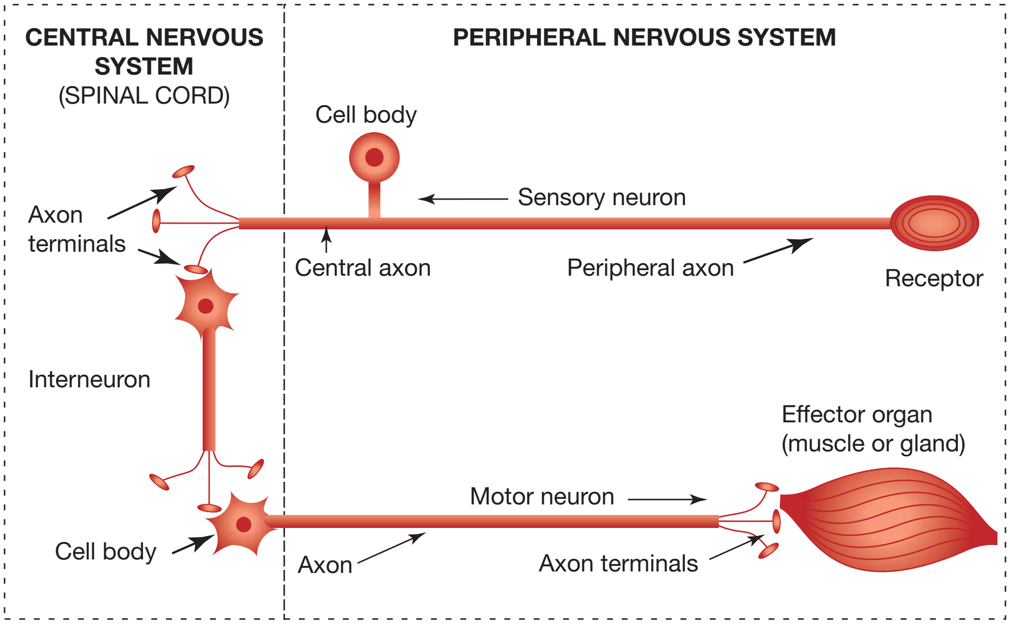
Type of neuron	Function	Structure
Sensory neurons	The sensory neurons in the sense organs detect changes in the environment. Messages about the changes are then relayed as impulses to an interneuron. Sensory neurons are part of the PNS.	
Interneurons	The interneurons carry impulses through the spinal cord and brain. So, they are part of the CNS. Interneurons are sometimes called connector neurons. Impulses are relayed from interneurons to motor neurons.	
Motor neurons	The motor neurons receive impulses from interneurons and cause a response in an effector organ such as a muscle or a gland. Motor neurons are part of the PNS.	

ACTIVITY: Neuron models

Make models of the different neuron types using balloons, string or cotton, straws and tape. Then try and connect them together using a large outline of the human body.

int-0670

FIGURE 2.30 Relationship between the different types of neurons



2.4.5 Synapses

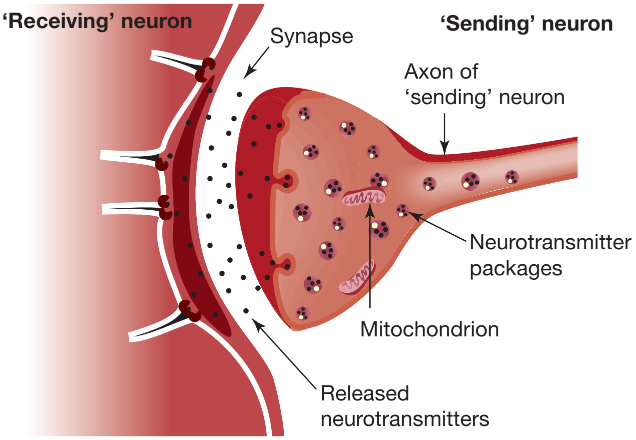
The gap between neurons is called a **synapse**. The nerve impulse cannot jump across the synapse so when the nervous impulse has reached the axon terminal of a neuron, tiny **vesicles** containing chemicals called neurotransmitters are transported to the cell membrane of the neuron. These chemicals are then released into the synapse, as seen in figure 2.31.

synapse the gap between adjoining neurons where neurotransmitters travel

vesicle a small fluid-filled, membrane-bound sac in a cell

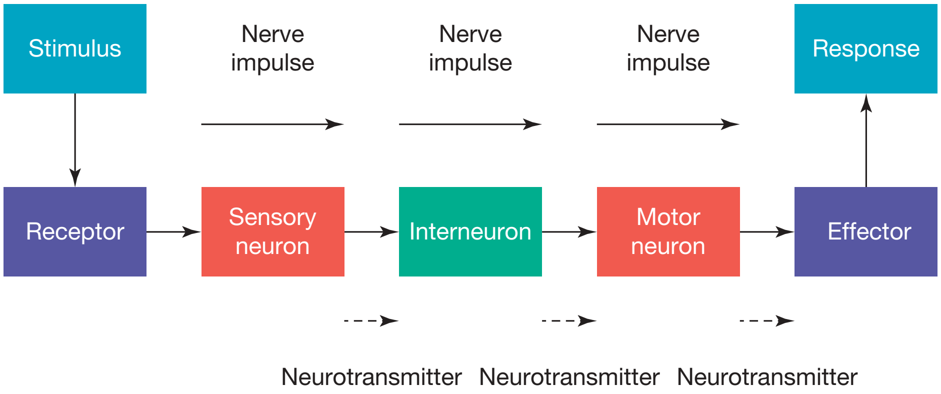
1. The neurotransmitters move across the synapse and bind to receptors on the membrane of the dendrites of the next neuron.
2. This may result in triggering the receiving neuron to convert the message into a nervous impulse and conduct it along its axon.
3. When it reaches the axon terminal, neurotransmitters are released into the synapse to be received by the dendrites of the next neuron.
4. This continues until the message reaches a motor neuron, which then communicates the message to an effector, such as a muscle or gland. The effector may then respond to the message; for example, a muscle cell may contract or a gland may secrete a chemical.

FIGURE 2.31 Neurotransmitters passing along the synapse to the next neuron



Your nervous system involves the use of both electrical signals (nerve impulses) and chemical signals (neurotransmitters) in order to detect a change in stimulus and initiate a response.

FIGURE 2.32 Your nervous system involves the use of both electrical signals (nerve impulses) and chemical signals (neurotransmitters).



EXTENSION: Neurotransmitters and your mood

Empathy

What happens when you feel upset, or feel upset for someone else? **Mirror neurons** are a group of neurons that activate when you perform an action and when you see or hear others performing the same action. Research is suggesting that these neurons are important in being able to feel **empathy** towards other people. If this theory is further supported, how could this connection increase the chances of the survival of our species?

Mood chemistry

Neurotransmitters are chemicals involved in passing messages between your nerve cells (refer back to section 2.4.5). Within your brain there are many neurotransmitters that influence how you feel and react: **serotonin**, **noradrenaline** (also known as norepinephrine) and **dopamine** are three examples. Imbalances of these neurotransmitters can contribute to a variety of mental illnesses.

- Serotonin acts like the brakes on your emotions. It can produce a calming effect and is important for maintaining a good mood and feelings of contentment. It also plays a role in regulating memory, appetite and body temperature. Low levels of serotonin can produce insomnia, depression and aggressive behaviour and are also associated with obsessive-compulsive and eating disorders.
- Noradrenaline can act like an accelerator. It can promote alertness, better focus and concentration. Your brain also needs this chemical to form new memories and to transfer them to your long-term storage.
- Dopamine is important for healthy assertiveness and autonomic nervous system function. Dopamine levels can be depleted by stress or poor sleep. Too much alcohol, caffeine and sugar may also lead to reduced dopamine activity in your brain. People with Parkinson's disease have a diminished ability to synthesise dopamine.

mirror neurons group of neurons that activate when you perform an action and when you see or hear others performing the same action

empathy the capacity to recognise and to some extent share feelings that are being experienced by other people

serotonin a common neurotransmitter involved in producing states of relaxation and regulating sleep and moods

noradrenaline also called norepinephrine; common neurotransmitter involved in arousal states

dopamine a neurotransmitter involved in producing positive moods and feelings

on Resources

eWorkbook	Labelling a synapse (ewbk-12251)
Video eLesson	Brain cell synapse (eles-2634)

2.4.6 Reflex actions

Sometimes you need to consciously think about what your body does. At other times actions happen without you having to think about them.

Have you ever had sand thrown in your eyes or touched something too hot? Or had a ‘knee-jerk’ reaction when a doctor sharply taps your knee? Sometimes you don’t have time to think about how you will react to a situation. Some actions need to be carried out very quickly — it may be a matter of survival! These actions are examples of reflex actions.

You also react to many internal stimuli using reflex actions. Breathing, for example, is a response regulated by chemoreceptors detecting changes in carbon dioxide levels in your blood. It’s very helpful that you don’t have to remember to breathe — imagine what would happen if you forgot to!

FIGURE 2.33 You don’t need to think what to do when you touch something hot.

Reflex actions may involve only a few neurons and require no conscious thought. Their pathway travels only to and from the spinal cord, and is called a **reflex arc**. An example of this process is outlined in figure 2.34.

1. A stimulus is encountered (in either the internal or external environment).
2. The stimulus is detected by a receptor.
3. The message is sent via the sensory neuron to the interneuron in the spinal cord.
4. Interneurons in the spine send the message to the motor neuron.
5. Motor neurons send the message to the effector to bring about a response.
6. The response occurs.

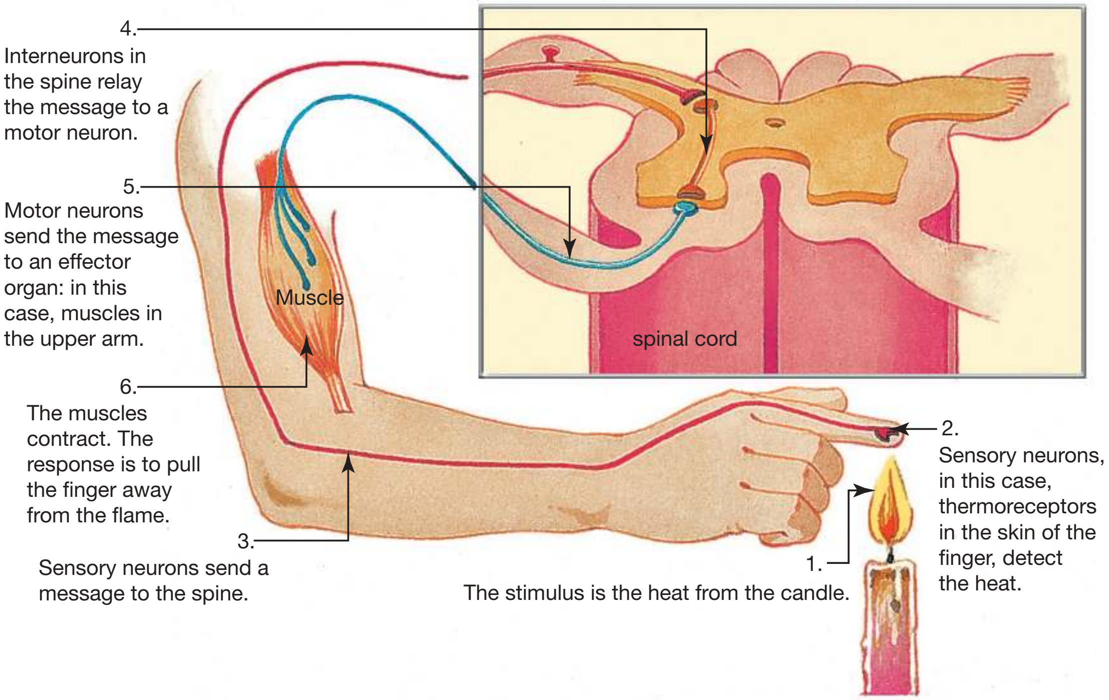
reflex arc a quick response to a stimulus that does not involve the brain (for example, knee jerk). The message travels from receptor to sensory neuron to interneuron in the spinal cord then directly via the motor neuron to the effector.

One important feature of the reflex arc is that a response occurs without the message needing to go to the brain.

ewbk-12252

int-0015

FIGURE 2.34 The reflex arc pathway does not go via the brain.



elog-2246

INVESTIGATION 2.4

How good are your reflexes?

Aim

To investigate some automatic responses

Materials

- well-lit room
- chair
- stopwatch or clock with a second hand
- 30 cm ruler

Method

Work in pairs for both parts of this activity. Decide who will be the experimenter and who will be the subject. Then swap roles and repeat both parts.

Part A: Kept in the dark

1. If you are the experimenter, look closely at the eyes of your partner, noting the size of their pupils.
2. Ask your partner to close their eyes for 60 seconds.
3. At the end of this time, monitor your partner's eyes for any changes.

Part B: Ruler drop

4. Hold out your thumb and first finger.
5. Have your partner hold the ruler from the 30 cm end, with the 0 cm end just above the gap between your thumb and first finger.
6. Your partner will randomly release the ruler and you will need to close your thumb and finger together to catch the ruler.
7. Run three trials and record where you catch the ruler.
8. Run different tests using your non-dominant hand and when distracted.

Results

Record your observations from Part A and Part B.

Discussion

Part A: Kept in the dark

1. What changes did you notice?
2. Identify the (a) stimulus and (b) response.
3. Why do you think this reflex action is important to our survival?
4. Can you control the size of your pupil?

Part B: Ruler drop

5. Identify the (a) stimulus, (b) response and (c) effector.
6. Identify any trends in your data the more trials you did.
7. Explain differences in your results for the different tests completed.
8. Suggest possible improvements to this experiment and suggest further relevant investigations that could be carried out.

Conclusion

Summarise the findings for this investigation about reflex actions.

SCIENCE AS A HUMAN ENDEAVOUR: Chemical weapons

Chemicals similar to those found in poisonous plants and animals have been used as agents of human warfare. These chemicals specifically target the nervous system. Nerve gas, for example, contains a substance that prevents neurotransmitters functioning properly at the synapses. The neurotransmitters accumulate, causing the nervous system to go haywire. Such chaos can result in death.

The first nerve gas, tabun, was initially developed when German scientists were developing a better insecticide. This has led to more deadly agents such as sarin and VX. All nerve gases block the body's production of an enzyme called acetylcholinesterase. This enzyme regulates the nerves controlling the action of particular muscles. A deficiency of acetylcholinesterase leads to tightening of your diaphragm, convulsions and death.

FIGURE 2.35 Scientists and experts working with dangerous chemicals that target the nervous system must use protective suits.

DISCUSSION

Is the use of chemical warfare ever justifiable? Discuss this with your class, recording all the various opinions and views.

on Resources

eWorkbook The nervous system (ewbk-12253)

2.4 Activities

learn**on**

2.4 Quick quiz on | **2.4 Exercise**

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 3, 6, 7, 10, 12	2, 4, 11, 13, 15, 16, 18	5, 8, 9, 14, 17, 19, 20, 21

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

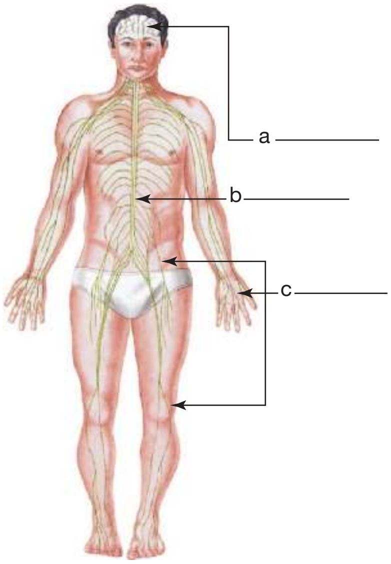
1. Fill in the blanks using the following terms.
Word bank: brain, central, nerves, peripheral.

The human nervous system is composed of the ____________ nervous system (____________ and spinal cord) and the ____________ nervous system (the ____________ that connect the central nervous system to the rest of the body).

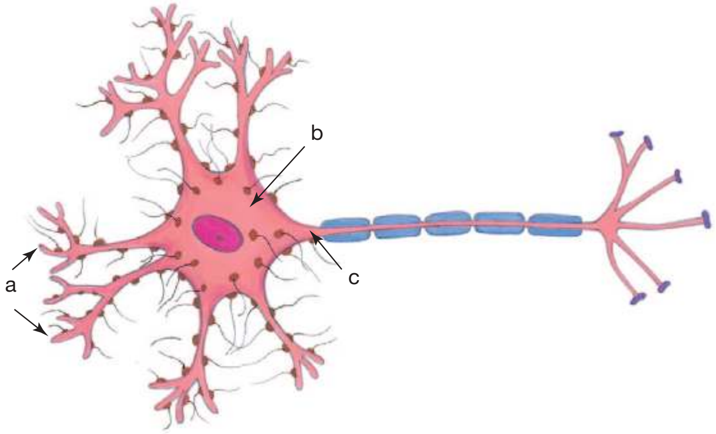
2. Match the term with its description in the table provided.

Term	Definition
a. Central nervous system	**A.** Gap between neurons
b. Motor neuron	**B.** Made up of neurons
c. Nerves	**C.** Nerves that connect the central nervous system to the rest of the body
d. Neuron	**D.** Takes messages to the central nervous system
e. Neurotransmitter	**E.** Made up of a cell body, dendrites and axon
f. Peripheral nervous system	**F.** Brain and spinal cord
g. Sensory neuron	**G.** Chemical messenger that carries messages from one neuron to another across a synapse
h. Synapse	**H.** Takes messages away from central nervous system

3. Identify the components of the nervous system and describe their function.



4. Label the cell body, dendrites and axon on the motor neuron and show the direction in which the impulse travels.



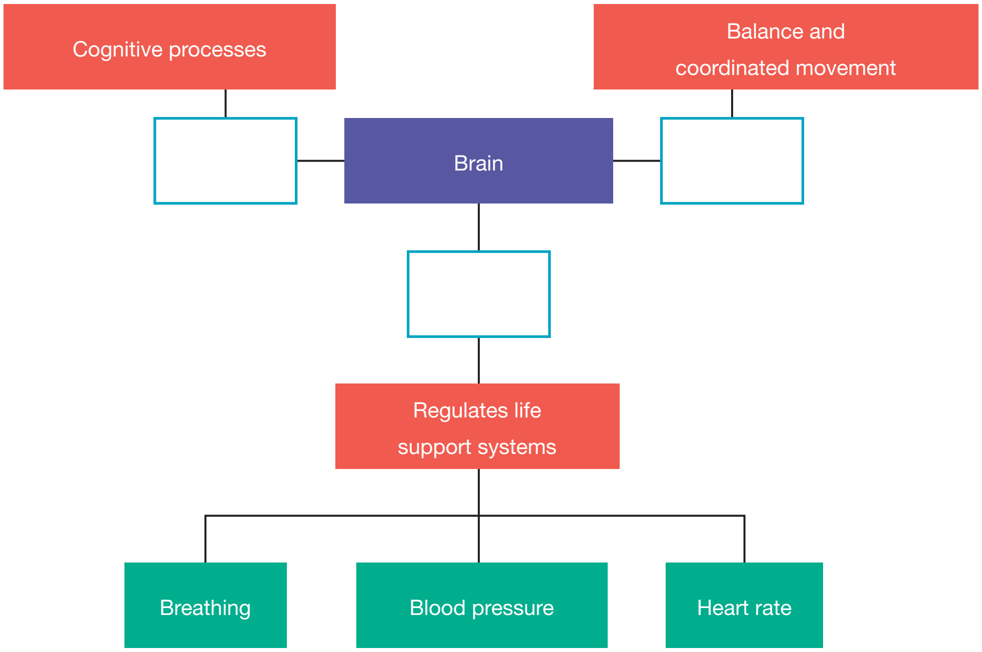
5. Distinguish between:
   a. a receptor and an effector
   b. a sensory neuron, an interneuron and a motor neuron
   c. a neuron and a nerve
   d. a reflex action and conscious reaction.
6. Name the organ that has been described as the control centre of your body.
7. Identify the part of your brain that does each of the following:
   a. takes up the greatest volume
   b. regulates heartbeat, breathing and blood pressure
   c. generates the most complex thoughts
   d. coordinates movement
   e. manages communication between left and right hemispheres.
8. Distinguish between:
   a. cerebrum and cerebellum
   b. left and right cerebral hemispheres
   c. cerebrum and cerebral cortex.

Apply and analyse

9. Suggest how the structure of the different types of neurons suits their function.
10. Describe the advantage of the presence of myelin on the axon of a neuron.
11. With reference to chemical and electrical signalling in nerve cells, describe one way in which paralysis can occur in animals.
12. a. Place a tick in the table provided for the responses that are reflex actions and those that are conscious responses:

Action	Reflex action	Conscious response
Sneezing		
Blinking		
Scratching your head		
Knee-jerk reaction		
Clapping		
Breathing		

   b. Explain how you decided if each action was a reflex or conscious reaction.
13. Copy the cluster map shown and insert ‘cerebrum’, ‘cerebellum’ and ‘brain stem’ into their appropriate location.



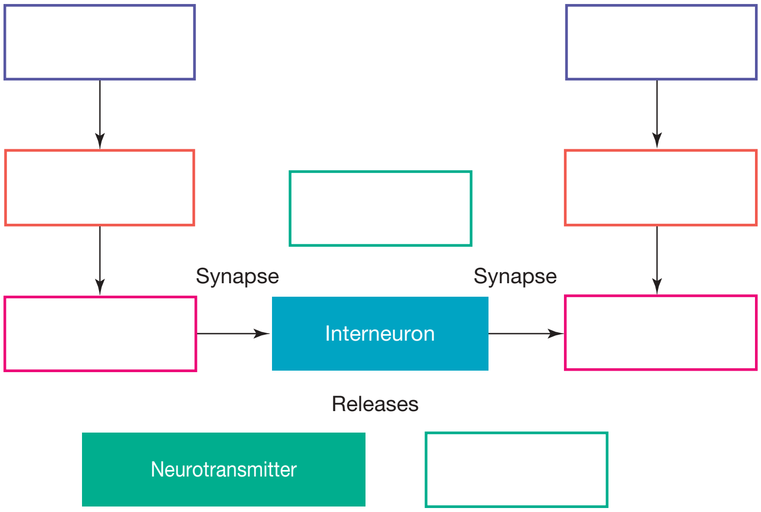
14. a. Explain the difference between the cerebral hemispheres.
    b. Outline how these hemispheres are able to work together.

Evaluate and create

15. Organise the terms below into a Venn diagram of the nervous system and the endocrine system.

Central nervous system	Electrical impulse
Endocrine gland	Glucagon
Insulin	Homeostasis
Hormone	Motor neuron
Neurotransmitter	Pancreas
Peripheral nervous system	Sensory neuron
Stimulus–response model	Negative feedback

16. Suggest how you could link the nervous system terms in the flow chart provided.
- Electrical impulse
- Motor neuron
- Sensory neuron
- Response
- Receptor
- Neurotransmitter
- Stimulus
- Effectors



17. a. SIS Suggest a reason why the pupil of your eye increases in size in dim light.
    b. Outline some triggers that may cause the size of your pupil to change in size.
18. How does blocking the production and action of neurotransmitters cause paralysis? Include a diagram to show this.
19. SIS Imagine that you are a scientist involved in researching the nervous system. Propose a relevant question or suggest a hypothesis for a scientific investigation and outline how you would design your investigation.
20. SIS There is a danger of chemical and biological weapons being used in acts of terrorism.
    a. Search the media for relevant examples of chemicals and their effects. Report on your findings of this.
    b. What sorts of strategies do we have in Australia to cope with threats of chemical warfare?
21. SIS 'Brains react to music like a drug.' This was a claim made in the media in 2011. It was based on a scientific study that used PET (positron emission tomography) and fMRI brain scans to record brain activity of volunteers while they listened to their favourite piece of music. The PET scan detected a release of dopamine (a neurotransmitter responsible for feeling a sense of reward and pleasure) in the volunteers' brains and the fMRI scan showed increased blood flow to the emotional response areas.
    a. For this investigation suggest:
        i. a hypothesis
        ii. the dependent variable(s) and independent variable
        iii. an appropriate control group
        iv. controlled variables.
    b. Find out more about similar investigations. Is the media claim supported by your findings? Explain.

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

LESSON
2.5 The endocrine system

LEARNING INTENTION

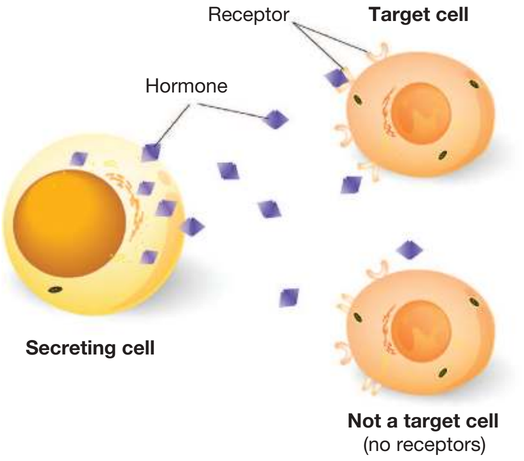
At the end of this lesson you will be able to explain how the endocrine system controls body functions through hormones released by various glands, and use the stimulus–response model and negative feedback loops to explain the role of the endocrine system in the regulation of body temperature and blood glucose by homeostatic mechanisms.

2.5.1 Hormones — chemical messengers

Thirsty? Too hot or too cold? Feeling different or noticing changes in how you look or act? Chemicals in your blood not only help to keep you balanced, but are also very important in controlling and coordinating your growth and development.

The nervous system is not the only means of controlling and coordinating activities in your body. The endocrine system uses chemical messengers called hormones. Cell communication is critical in maintaining homeostasis. As cells detect changes in our environment, it is important these cells can pass on the message to other cells in order to elicit a response. To communicate with one another, cells use signalling molecules, which can bind to target cells and initiate a response. An important group of signalling molecules in our body are hormones. They are produced in **endocrine glands** and released into the bloodstream. Although hormones travel via the bloodstream to all parts of the body, they only act on specific cells called **target cells**. Target cells contain receptors on their surface that are complementary to a hormone (figure 2.36). Therefore, cell communication via hormones is highly specific in response.

FIGURE 2.36 Hormones are released by secretory cells, located in endocrine glands. Hormones then bind to complementary receptors on the surface of target cells.



The endocrine system is made of many glands located around our body. Each gland is responsible for producing and secreting hormones into the bloodstream (table 2.4). Endocrine glands include the adrenal glands, pancreas and the ovaries and testes (figure 2.37).

TABLE 2.4 Examples of endocrine glands and their hormones

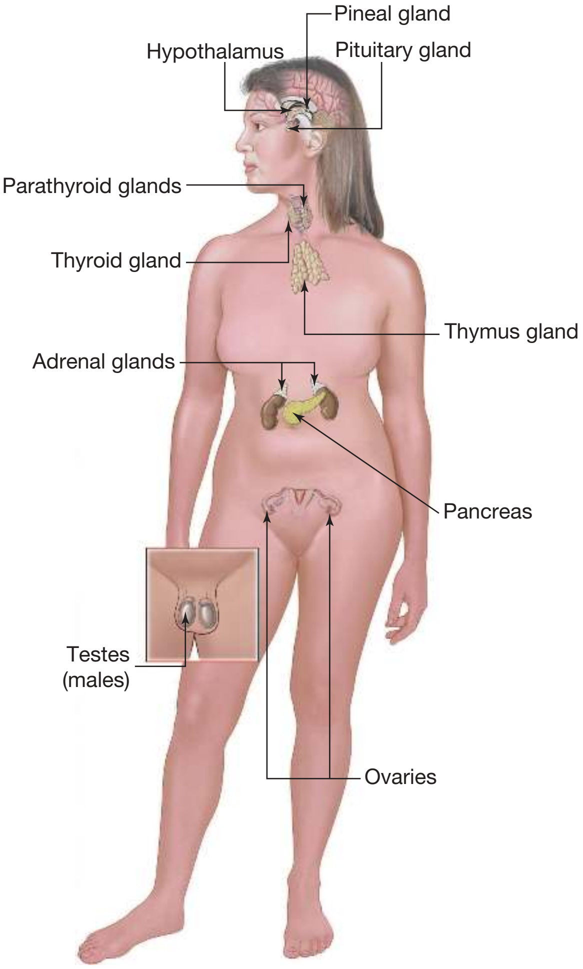
Endocrine gland	Example of hormone released	Response
Thyroid	Thyroxine	Raises basal metabolic rate
Adrenal	Adrenaline	Increases heart rate and blood pressure in times of stress
Pancreas	Insulin	Lowers blood glucose levels
Pituitary	Anti-diuretic hormone (ADH)	Reabsorption of water in kidneys
Ovaries	Progesterone	Controls menstrual cycle and pregnancy
Thymus	Thymosin	Stimulates the production of white blood cells to fight infection

endocrine glands organs that produce hormones, which are released into the bloodstream

target cells cells that contain receptors on their surface which are complementary to a specific hormone

eles-2633

FIGURE 2.37 The human endocrine system



Hormones control and regulate functions such as metabolism, growth, development and sexual reproduction. Like the nervous system, the endocrine system detects a change in a variable, and often acts using a *negative feedback* mechanism to counteract the initial change. The endocrine system also works with the nervous system to regulate your body's responses to stress. The effects of the endocrine system are usually slower and generally longer lasting than those of the nervous system.

2.5.2 Endocrine glands in your brain

Endocrine glands are located in various parts of your body, with three major glands located in the brain:

1. **Pituitary gland**: often referred to as your 'master gland' because it controls many other endocrine glands, stimulating them to release their own hormones. For example, your thyroid gland, ovaries and testes are all controlled by hormones released by this endocrine gland. Hormones released by the pituitary gland can control water balance, growth, development and reproduction-related processes.
2. Hypothalamus: sends hormones to the pituitary gland to control its release of hormones to other endocrine glands. It also releases hormones that control body temperature, growth, sex drive, thirst, hunger and sensations of pleasure and pain. The hypothalamus links your nervous system to your endocrine system and is used in reflex actions such as those involved in the beating of your heart and breathing.
3. **Pineal gland**: produces the hormone melatonin, which controls body rhythms such as waking and sleeping.

pituitary gland a small gland at the base of the brain that releases hormones

pineal gland gland that produces the hormone melatonin, which can make you feel drowsy

EXTENSION: Fight-or-flight response

Feeling angry? Is your heart racing, are your hands cold, do you have a sick feeling in your stomach? Anger can be one of our most primitive emotions. It is certainly a powerful one. Uncontrolled anger can lead to physical fights, arguments and self-harm. However, controlled anger can be a very useful emotion that can help motivate you to make positive changes.

When you feel angry, your hypothalamus responds by sending messages to your pituitary gland to instruct your **adrenal glands** to release **adrenaline** (also known as epinephrine). This hormone acts to:

- increase your heart rate
- dilate your pupils
- constrict skin blood vessels
- shut down digestion.

This helps you to see any threats better and provides your muscles with more glucose and oxygen, just in case you need to face the danger and *fight*, or take *flight* and escape it by running away (or you could *freeze* because you don't know what to do).

2.5.3 Thermoregulation

One factor under homeostatic control is our core body temperature. Body temperature is maintained around 37.5 °C. The control of our body temperature is known as **thermoregulation**. If our body temperature decreases or increases too far from this there can be severe consequences, including death. Our endocrine and nervous systems work together to ensure our body temperature is maintained within a narrow range because it is critical to our survival. Evidence suggests that a part of your brain called the hypothalamus contains a region that acts as your body's thermostat. It contains thermoreceptors that detect the temperature of blood that flows through it. Below is an example of how the endocrine system regulates a decrease in body temperature via negative feedback (figure 2.38).

1. The decrease in body temperature acts as the stimulus, which is detected by thermoreceptors in your body.
2. This message is taken to the hypothalamus, which activates warming mechanisms.
3. One of these mechanisms involves the **thyroid gland**. It responds by secreting the hormone thyroxine, which increases the metabolic rate of cells, releasing heat to warm you.
4. Raising body temperature reduces the need for the hypothalamus to direct the thyroid gland to secrete thyroxine.

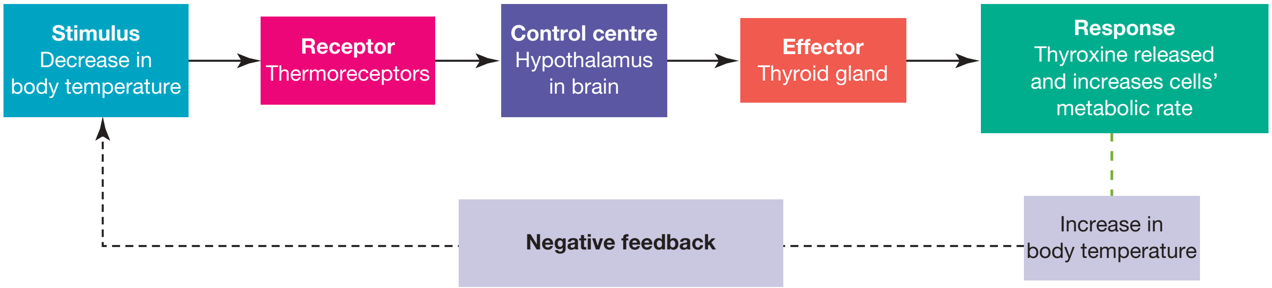
adrenal glands a pair of glands situated near the kidneys that release adrenaline and other stress hormones

adrenaline a hormone secreted in response to stressful stimuli, which readies your body for the fight-or-flight response

thermoregulation the control of body temperature

thyroid gland a small gland in the neck that helps regulate metabolism and growth

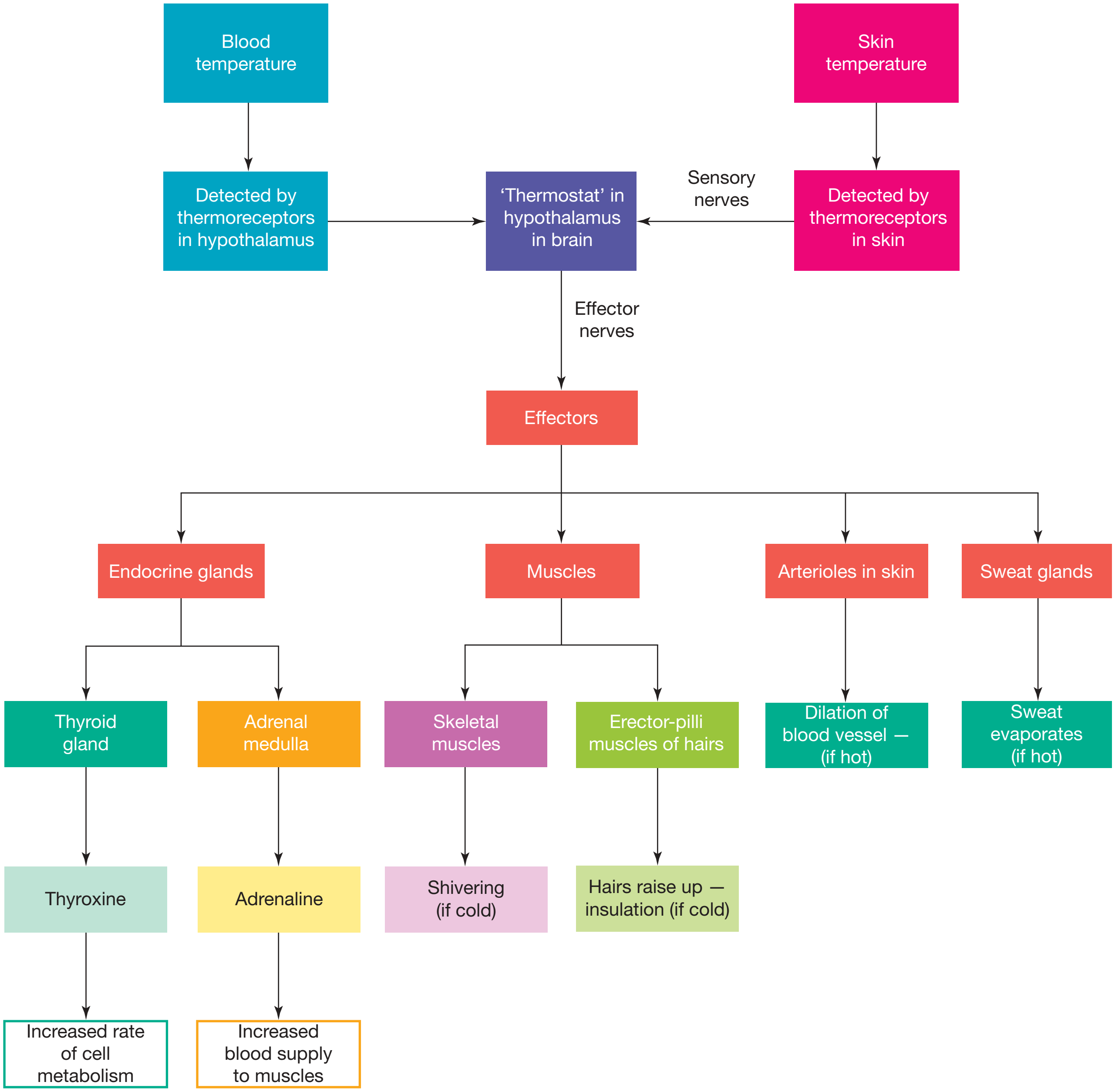
FIGURE 2.38 Negative feedback loop of thermoregulation



Endocrine and nervous systems working together

The endocrine and nervous systems can work together in the control of body temperature. When our body temperature increases or decreases from within a particular range, messages from thermoreceptors in your skin or hypothalamus trigger your hypothalamus to send messages to appropriate effectors. The effectors (such as those shown in figure 2.39) then bring about a response that may either increase or decrease body temperature back to within the normal range.

FIGURE 2.39 Temperature regulation is an example in which the nervous system and the endocrine system work together to maintain your body temperature within a range that is healthy for your cells.



2.5.4 Blood glucose regulation

Glucose is one of the human body's primary sources of energy. During cellular respiration, glucose is converted into ATP, the primary energy carrier in the body. Thus, it is critical that glucose levels are closely regulated. Homeostasis of blood glucose levels is maintained by two hormones produced by the pancreas: **insulin** and **glucagon** (table 2.5).

glucagon a hormone, produced by the pancreas, which increases blood glucose levels

glucagon a hormone, produced by the pancreas, which increases blood glucose levels

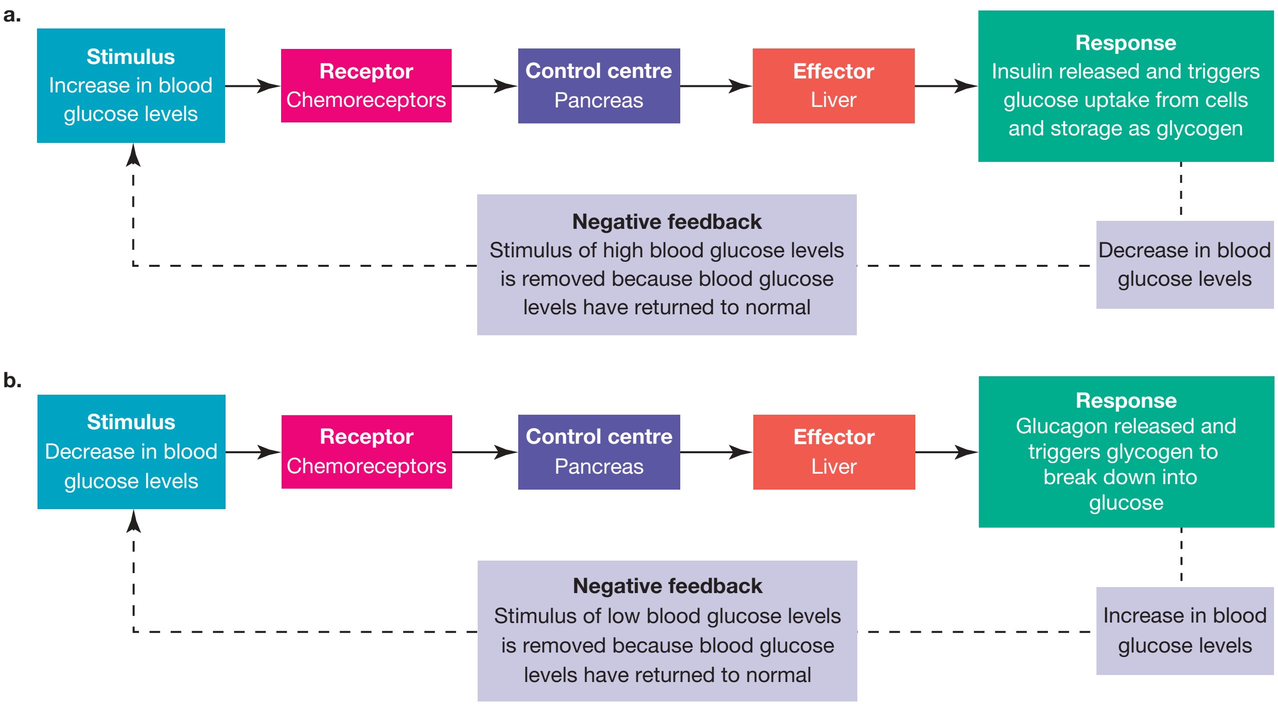
As seen in figure 2.40a, if an increase in blood glucose levels has been detected by receptors, the pancreas responds by secreting insulin, which may trigger an increased uptake of glucose by liver and muscle cells and the conversion of glucose into glycogen for storage. This decreases the blood glucose levels back to 'normal' levels.

If a decrease in blood glucose levels has been detected by receptors, the pancreas responds by secreting glucagon (figure 2.40b). Glucagon travels in the blood to the liver and muscle cells, stimulating the breakdown of glycogen into glucose. This increases the blood glucose levels back to 'normal' levels.

TABLE 2.5 Actions of insulin and glucagon

	Insulin	Glucagon
Stimulus	Increase in blood glucose levels	Decrease in blood glucose levels
Effector	Produced by the pancreas	Produced by the pancreas
Target cells	Liver and skeletal muscles	Liver
Response	Acts on the liver and skeletal muscles to increase the uptake of glucose from the bloodstream and storage as glycogen.	Acts on the liver to promote the breakdown of glycogen into glucose. Glucose is then released back into the bloodstream.
Outcome	Decrease in blood glucose levels to within normal range	Increase in blood glucose levels to within normal range

FIGURE 2.40 If your blood glucose levels are too high or low, your body will release hormones to bring it back to ideal levels. **a.** Negative feedback loop involved when high level glucose is detected **b.** Negative feedback loop of glucose regulation when low level glucose is detected



Increase in blood glucose levels

Figure 2.40 a is an example of how the endocrine system regulates an increase in blood glucose levels via negative feedback.

1. After you have eaten a lot of sugary food, your blood glucose levels increase.
2. This rise is detected by cells in your pancreas, which then secretes the hormone insulin.
3. Insulin travels in the bloodstream, and specific target cells in your liver and muscles respond by increasing the uptake of glucose into the cells and the conversion of glucose into glycogen, which is then stored.
4. The result is that blood glucose levels return to their 'normal' levels.

2.5.5 Reproductive hormones

The endocrine system also plays a key role in controlling and coordinating human reproduction and development.

Male reproductive hormone levels

When a male reaches puberty, the endocrine system releases several hormones.

1. The male's pituitary gland secretes **luteinising hormone** (LH).
2. LH acts on his testes to produce another hormone called **testosterone**. An increase in testosterone levels causes sex organs to grow and testes to begin to produce sperm. Secondary sex characteristics are increased muscle development, changes in voice, muscle and hair growth and hormones.

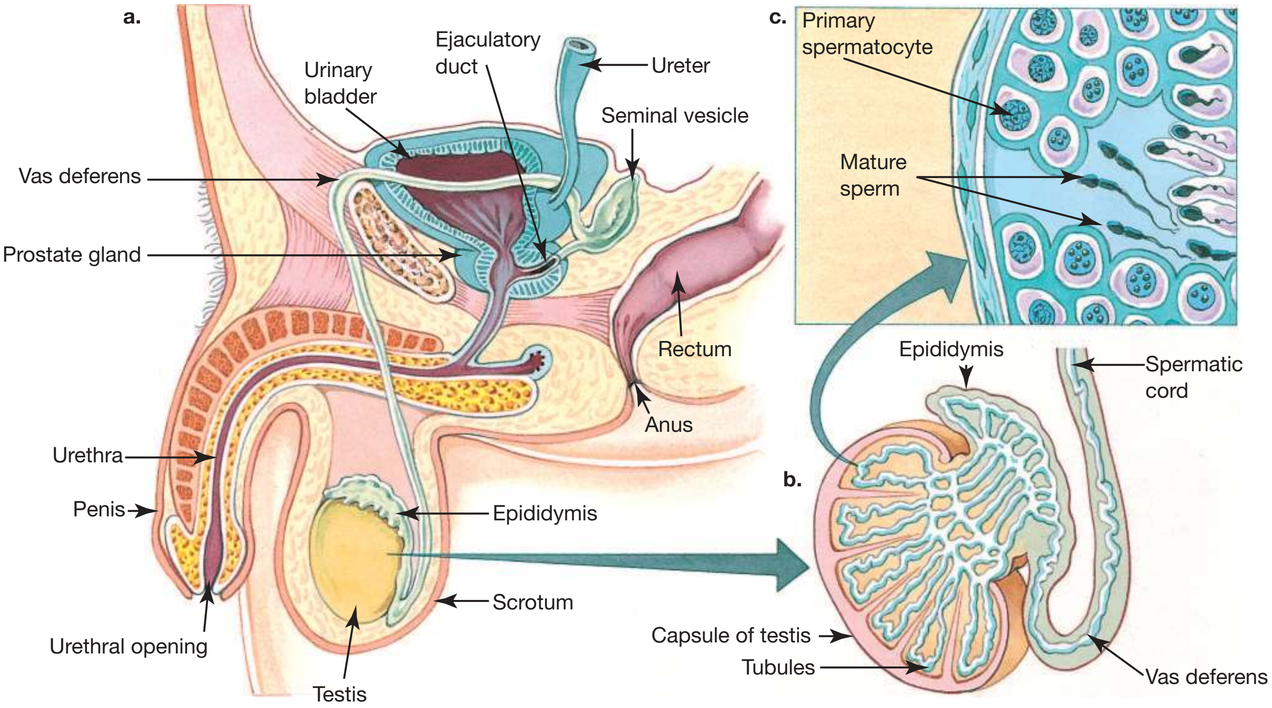
luteinising hormone (LH) hormone produced by the anterior pituitary gland that initiates ovulation, the production of progesterone and corpus luteum development in females and in the stimulation of production of testosterone in testes in males

testosterone male sex hormone

ewbk-12264

int-3032

FIGURE 2.41 a. The male reproductive system **b.** The internal structure of the testes **c.** An increase in the level of testosterone during puberty triggers the testes to produce sperm cells.



Female reproductive hormone levels

When a female reaches puberty, the endocrine system releases different hormones.

1. The female pituitary gland secretes **follicle-stimulating hormone (FSH)**.
2. FSH acts on ovaries to stimulate the **follicles** (structure in which the egg develops) to grow.
3. A hormone called **oestrogen** is secreted from the ovaries (and the placenta during pregnancy), which causes the thickening of the lining of the **uterus** to prepare it for a potential fertilised egg.
4. Increased levels of oestrogen also stimulate the hypothalamus to produce more FSH and LH.
5. Increasing levels of LH cause the follicle to swell. The mature follicle bulges on the surface of the ovary, ruptures, and the **ovum** (unfertilised egg cell) is released from the ovary into the fallopian tube. This process is called **ovulation**.
6. Following ovulation, the empty follicle from which the egg was released becomes a **corpus luteum**. This structure secretes another hormone called **progesterone**.
7. Progesterone continues to prepare the uterine lining for pregnancy.
8. If **fertilisation** does not occur, both the ovum and corpus luteum break down. This causes the progesterone levels to drop and hence the lining of the uterus (endometrium) to break down. Blood and uterine lining are discharged through the vagina in a process called **menstruation**.
9. When progesterone levels drop, the pituitary gland produces FSH and the cycle begins again. These cyclic changes in the ovaries and lining of the uterus as a result of changing hormone levels in the blood are called the menstrual cycle.

follicle-stimulating hormone (FSH) regulates the development, growth and reproductive processes of the body

follicles found in the ovary and contain a single immature ovum (egg)

oestrogen hormone secreted from the ovaries and the placenta with a variety of effects such as inducing puberty changes and thickening of the uterus lining

uterus the organ in which a baby grows and develops

ovum female sex cells produced in the ovaries

ovulation the release of an ovum

corpus luteum an endocrine structure that is involved in the production of progesterone

progesterone hormone produced in the ovaries that inhibits ovulation and prepares the lining of the uterus for pregnancy

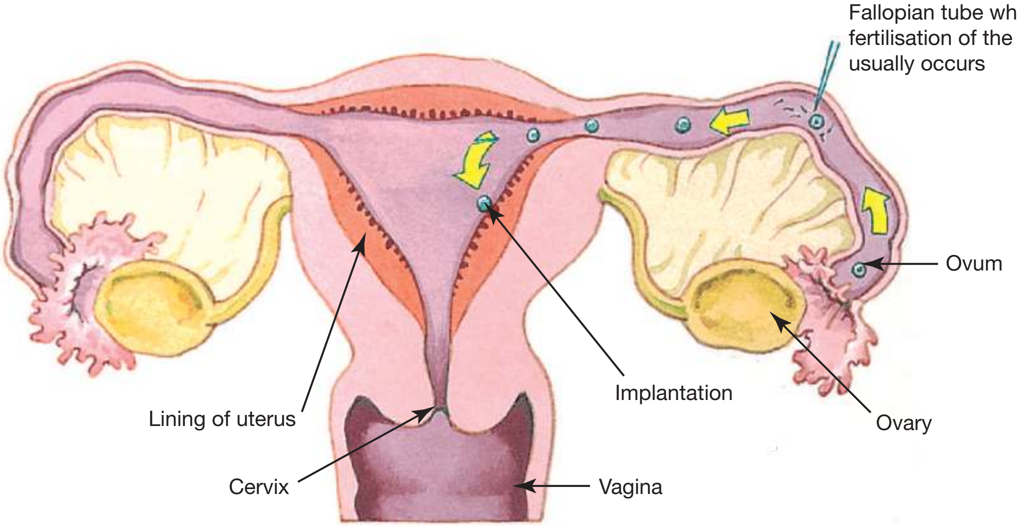
fertilisation fusion of the male sex cell (sperm) and the female sex cell (ovum)

menstruation monthly discharge of blood and other materials from the uterus lining through the vagina (also known as period)

ewbk-12265

int-3032

FIGURE 2.42 The female reproductive system showing the release of an ovum



SCIENCE AS A HUMAN ENDEAVOUR: Using hormones to control reproduction

Hormones can be harnessed to either increase or decrease fertility. There are a number of issues that have been expressed about the production, availability, uses and consequences of these hormones.

Hormones are used as contraceptives for females. Traditionally in pill form (figure 2.43), they are now appearing in patches, gels, implants and insertable vaginal rings. There is also a 'morning-before' pill, which can be used as an emergency contraceptive. This pill works by altering the ion content of the woman's reproductive tract for about 36 hours. The changes that it produces make it more difficult for the sperm to swim and hence less likely for them to reach the ovum to fertilise it.

FIGURE 2.43 Contraceptive pills contain different levels of hormones.

There are also plans to develop contraceptive drugs that target hormone receptors rather than altering hormone levels. These new contraceptives may work by tricking the egg into thinking that it is already fertilised so that it blocks sperm from penetrating it. Other new contraceptives may involve the development of hormones that prevent the fertilised egg from implanting in the uterus.

Scientists are working on developing male contraceptive pills. These are based on a combination of androgen and progesterone. Androgen blocks sperm development and progesterone blocks testosterone production. While combinations of these hormones may be used to prevent fertility, there are possible side effects that need to be considered.

In cases of abortion, an alternative to a surgery is the commercially produced hormone RU486 (Mifepristone). RU486 can terminate an early pregnancy by blocking the action of progesterone. This causes the lining of the uterus to break down so that the embryo is unable to implant into it. This pill is less invasive and has fewer side effects than a surgical abortion and it enables termination at a much earlier stage. In Australia, doctors must be a registered prescriber of RU486 to administer it to patients.

DISCUSSION

How might hormone replacement therapy help reduce the effects of menopause in women?

2.5.6 Malfunctions in the endocrine system — diabetes

Type 1 diabetes

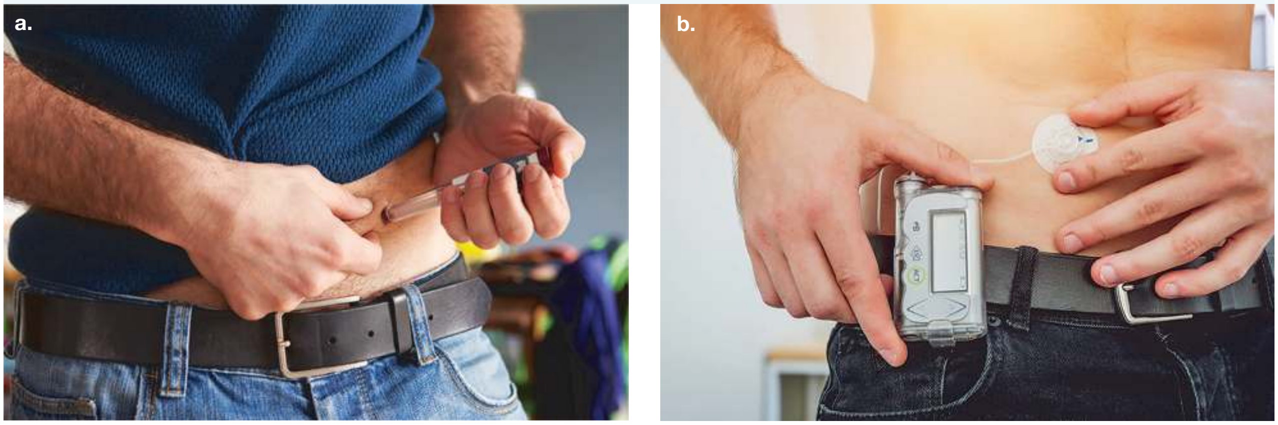
One of the most common malfunctions of the endocrine system is type 1 diabetes. Type 1 diabetes is an autoimmune condition that occurs when the insulin-producing cells of the pancreas are destroyed by the immune system, resulting in the inability to produce insulin. Type 1 diabetes typically develops in individuals under 30 years of age. The exact causes of type 1 diabetes are currently unknown, although there is evidence of genetic predisposition.

As there is no cure, people with type 1 diabetes must carefully monitor their blood glucose levels (up to six times a day) and undergo insulin replacement therapy. Insulin replacement uses artificially made insulin and is administered via injections or an insulin pump (figure 2.44). An insulin pump is a small device that stores insulin. Individuals wear the pump 24 hours a day. After a meal, insulin is injected into their body via a small needle inserted under the skin. If not carefully monitored, diabetes could lead to the development of **hyperglycaemia** or **hypoglycaemia**.

hyperglycaemia blood glucose levels above the normal range

hypoglycaemia blood glucose levels below the normal range

FIGURE 2.44 a. A diabetic person injects them self with insulin. **b.** A diabetic person with an insulin pump connected via the abdomen.



Type 2 diabetes

Type 2 diabetes accounts for 85–90 per cent of all cases of diabetes. Unlike type 1 diabetes, which is an autoimmune disease and cannot be prevented, type 2 diabetes is caused by both genetic factors and lifestyle (such as being overweight or obese, smoking or having a poor diet) and can be prevented. Type 2 diabetes generally forms in people later in life as a result of insulin resistance. Over a long period of time, insulin becomes ineffective at controlling blood glucose levels. To compensate for the ineffectiveness of insulin, the pancreas responds by producing even more insulin. This long-term over-production leads to damaged insulin-producing cells in the pancreas. Individuals with type 2 diabetes become hyperglycaemic due to a lack of insulin.

Effects of prolonged hyperglycaemia can include:

- kidney damage
- lack of circulation leading to numbness in feet and/or hands
- heart disease
- vision loss/blindness
- development of wounds that are difficult to heal.

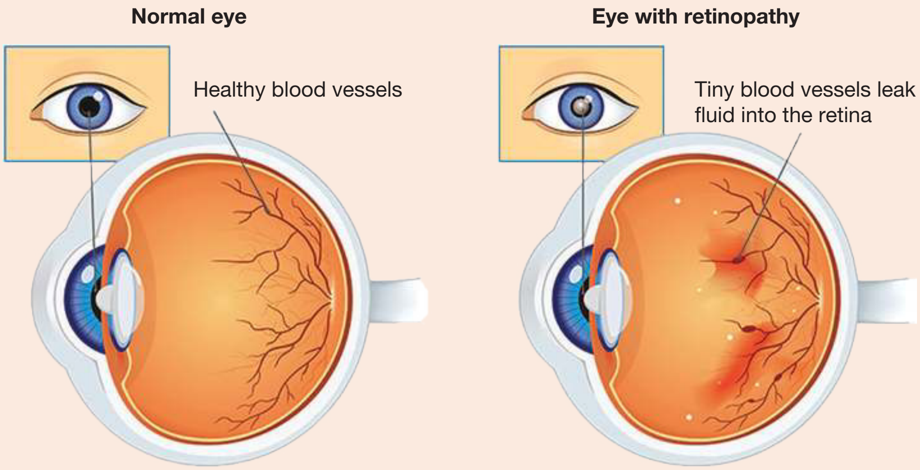
Type 2 diabetes can be managed with regular exercise and maintaining a healthy diet and lifestyle. In severe cases where blood glucose levels remain high, medication and insulin therapy may be required.

SCIENCE AS A HUMAN ENDEAVOUR: Diabetes-induced blindness

Diabetes-induced blindness, also known as diabetic retinopathy, is a common cause of blindness for people with type 1 or type 2 diabetes. It is an eye condition that causes damage to the blood vessels in the retina. As discussed in section 2.2.4, the retina contains photoreceptors called rods and cones that allow us to detect light and colour. If blood sugar levels have been elevated over a long period of time, this can result in the blockage of capillaries in the retina and diminished blood supply to the area. In an attempt to restore blood flow to the retina, new blood vessels are made. However, these blood vessels do not fully form and leak into the vitreous humour of the eye (figure 2.45b). In severe cases, scar tissue can form and pressure in the eye can increase, which leads to the detachment of the retina from the back of the eye.

Symptoms of diabetic retinopathy include headaches, blurred vision, eye strain and double vision. It is essential that individuals at higher risk of developing diabetic retinopathy carefully monitor their blood glucose levels. In Australia, diabetes is the main cause of preventable blindness, with around 25–35 per cent of Australians with diabetes developing diabetic retinopathy.

FIGURE 2.45 a. Blood vessels in a normal eye **b.** Damaged leaky blood vessels as a result of diabetic retinopathy



on Resources

eWorkbook The endocrine system (ewbk-12266)

2.5 Activities

2.5 Quick quiz on

2.5 Exercise

Select your pathway

🟩 LEVEL 1
1, 2, 5, 6, 8, 12

🟦 LEVEL 2
3, 7, 11, 13, 14, 16, 18

🟪 LEVEL 3
4, 9, 10, 15, 17

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

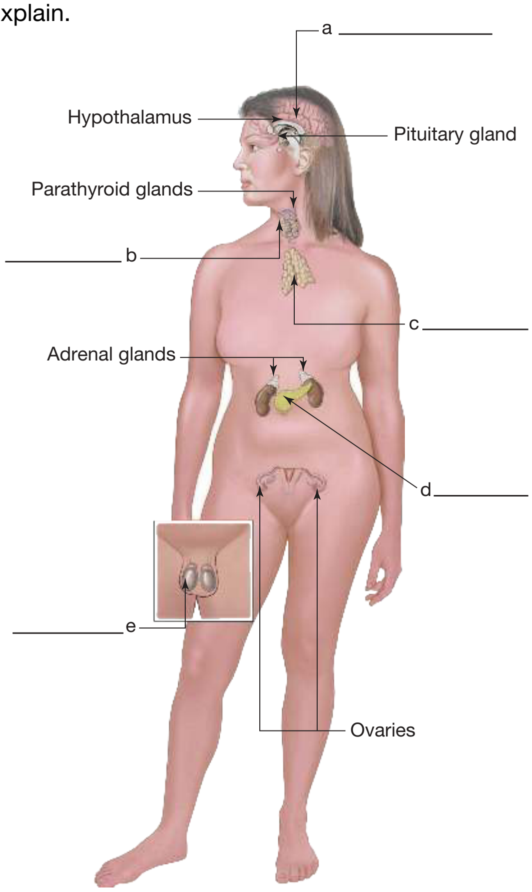
Find all this and MORE in jacPLUS

Remember and understand

1. Match the term with its description in the table provided.

Term	Definition
a. Anti-diuretic hormone (ADH)	**A.** Increases blood glucose levels
b. Glucagon	**B.** Lowers blood glucose levels
c. Insulin	**C.** Increases metabolic rate of cells
d. Oestrogen	**D.** Causes testes to produce sperm
e. Progesterone	**E.** Controls menstrual cycle and pregnancy
f. Testosterone	**F.** Causes thickening of the uterine lining
g. Thyroxine	**G.** Causes reabsorption of water in kidneys

2. Identify and describe the three endocrine glands located in your brain.
3. What are hormones, where are they produced and how are they transported through the body?
4. Are all parts of the body affected by a particular hormone? Explain.
5. Label the endocrine system in the figure provided.
6. Identify two ways in which the actions of the endocrine system differ from the nervous system.
7. Provide an example of negative feedback that includes the involvement of a hormone.



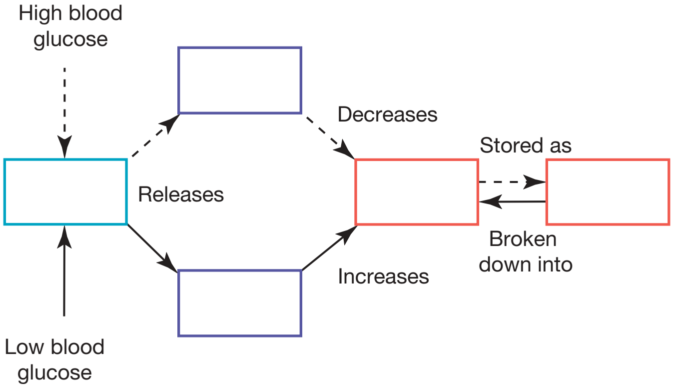
Apply and analyse

8. Distinguish between:
   - **a.** hormones and endocrine glands
   - **b.** menstruation and ovulation
   - **c.** endometrium and uterus
   - **d.** testes and sperm.
9. Describe the relationship between the:
   - **a.** pancreas, liver, glucose, glucagon, glycogen and insulin
   - **b.** pituitary gland, LH, testes, testosterone and sperm
   - **c.** pituitary gland, FSH, ovary, oestrogen, follicles, uterine lining, hypothalamus, LH, ovum, fallopian tube and ovulation
   - **d.** corpus luteum, uterine lining, progesterone and menstruation.
10. **a.** Other than pills, in which forms can hormone-based female contraceptives be used?
    b. Outline how these hormones can be used to prevent fertility.
11. **a.** Name the two hormones that may be used in a male contraceptive pill.
    b. Outline how these hormones can be used to prevent fertility.

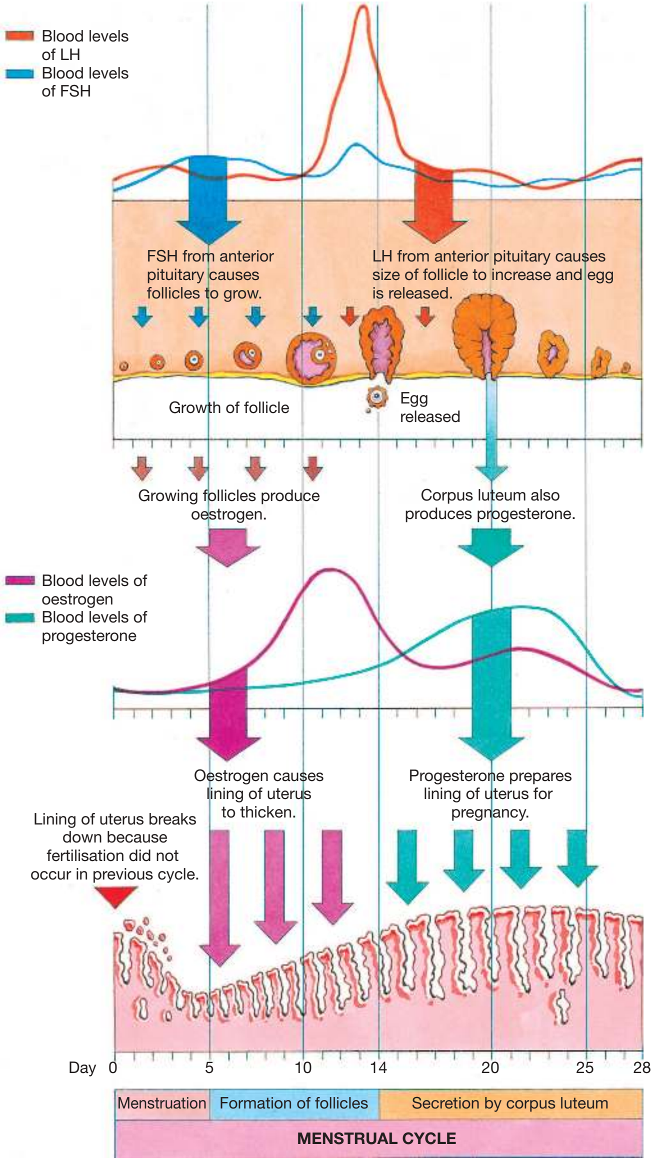
12. The nervous and endocrine systems both play a vital role in the maintenance of homeostasis in the body. Compare the speed and duration of response produced by the nervous and endocrine systems.
13. Compare and contrast the types of messages sent by the endocrine and nervous systems.

Evaluate and create

14. Complete the flow chart to link the listed terms.
    - Glucagon
    - Insulin
    - Pancreas
    - Glycogen
    - Glucose



15. Male and female fertility patterns are different. Find out the key differences and comment on how they may affect the development and use of effective hormone-based contraceptives.
16. **SIS** Ovulation occurs when the mature follicle ruptures on the surface of the ovary and the ovum is released. Use the diagram provided to answer the following questions.
    a. Which hormone in the diagram is at the highest level just prior to ovulation?
    b. When is ovulation likely to occur?
    c. When is progesterone at its highest level?
    d. At what stage in the cycle is the endometrium the thickest?
    e. Describe the changes in the concentrations of each of the hormones throughout the menstrual cycle.
    f. Research the changes in the levels of FSH (follicle stimulating hormone) and LH (luteinising hormone) throughout the menstrual cycle.
17. **SIS** Research the regulation and stimulus–response model when blood glucose levels are too high.
    a. Create a flow chart showing how the nervous and endocrine systems work to return blood glucose to normal.
    b. Describe why individuals with Type 1 diabetes cannot properly regulate blood glucose.
    c. Suggest some treatment options for individuals with Type 1 diabetes.
18. Create a graph to show how blood glucose levels could change over a 24 hour period from 7am.



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

LESSON

2.6 Malfunctions of the nervous system

LEARNING INTENTION

At the end of this lesson you should be able to explain some examples of technological and medical advances in the study of neural diseases and damage.

2.6.1 Damage to the nervous system

Damage to the spinal cord of the nervous system may be the result of a disease or an accident or be congenital (already present at birth). Whatever the cause, this type of damage can be devastating and debilitating.

Although there is currently no cure for spinal injury, teams of scientists around the world are involved in research that is aimed at improving the quality of life for those with this injury.

Paralysis and spinal injury

All of the nerves in your peripheral nervous system throughout your body connect to your spinal cord. Damage to this cord can prevent communication of messages between your brain and your body. This loss of communication can lead to **paralysis** (loss of movement).

Damage to different parts of the spinal cord results in different types of paralysis. For example, if you were in an accident in which the lower back section of your spine was completely crushed, messages would not be able to travel between your legs and feet and your brain. This loss of communication would mean that you would not be able to sense pain, heat, cold or touch in these parts of your body. You would also be unable to stand or walk as you would not be able to control the muscles in your legs and feet.

Christopher Reeve, an actor who played Superman in the 1970s and 80s, damaged his spinal cord in the neck region in a sporting accident. The consequence was that he was paralysed below the neck and required the use of a machine to breathe air into and out of his lungs as he was unable to breathe for himself. In the years following his accident he raised awareness of spinal injuries and increased public and political interest in related research. He died in 2004 as a result of complications from his paralysis.

FIGURE 2.46 Actor Christopher Reeve raised awareness for spinal injury research.

Paralysis and disease

A number of diseases can also result in paralysis. One such condition is motor neuron disease. Although the cause of this disease is still unknown, its effects are devastating. While the brain and the senses are usually unaffected, the person with the disease becomes increasingly paralysed.

paralysis loss of the ability to move

Motor neuron disease, as the name suggests, targets motor neurons and progressively destroys them. However, sensory neurons remain unaffected. This means that a person paralysed with motor neuron disease could hear and see a mosquito, feel it biting their arm, feel the itchiness, but be unable to move to scratch it or talk to tell someone to scratch it for them.

motor neuron disease a medical condition that progressively destroys motor neurons, resulting in progressive paralysis but leaving the brain and sense organs unaffected

People with motor neuron disease, such as Stephen Hawking (figure 2.47), sense their environment, but increasingly cannot respond to it. This paralysis eventually involves all muscles within the body. Sadly, motor neuron disease is fatal.

Stephen Hawking was an English theoretical physicist and cosmologist. He was diagnosed at the age of 21 with motor neuron disease (MND). MND soon claimed his physical body but it could never claim his intellect or wit. During his next 55 years he achieved extraordinary successes in the study of the physical nature of the Universe especially the theory of special relativity and quantum physics. He died in 2018.

Former Melbourne football coach and Essendon player Neale Daniher also suffers from MND. Daniher leads the way in raising funds for research into treatment and cures through the Big Freeze at the 'G for Fight MND. Other challenges, such as the Ice Bucket challenge, raised funds for MND.

FIGURE 2.47 Stephen Hawking suffered from motor neuron disease.

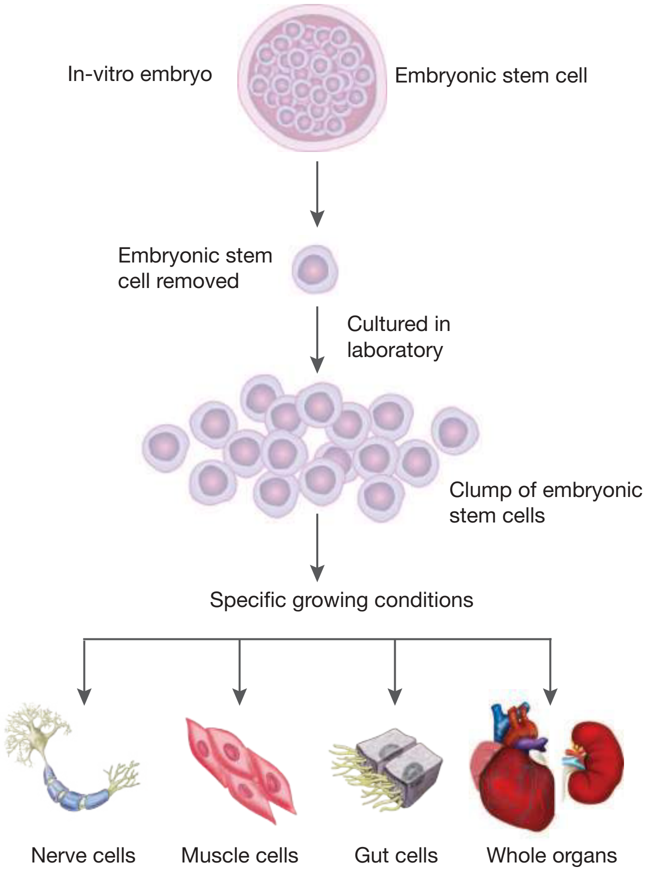
FIGURE 2.48 The Big Freeze at the 'G, started by Neale Daniher in 2015.

Stem cells — a possible treatment?

Embryonic stem cells have many properties that scientists find exciting. They can produce new cells for longer than other cells, and under the right conditions they can be made to differentiate into particular cell types. Some current research is investigating the injection of nerve cells produced from embryonic stem cells into the sites of spinal injury. Although it is early days for this research, it is hoped that it may lead to the recovery of muscle function in some cases.

Although the possible applications of this research are exciting, technologies involving the use of human embryonic stem cells must undertake strict bioethical procedures. The human embryos used in this research are obtained from the surplus embryos of couples undergoing IVF treatment.

FIGURE 2.49 The use of stem cells to treat (and possibly even cure) a variety of diseases is being investigated.



Brain-control interface technology

Currently making an entrance into the mass market are games and toys that utilise brain-control interface technology. In these applications, computer software in 'mindsets' are used to decode brain wave patterns and facial movements to bring about particular responses in the external environment (for example, moving an object by just thinking about it).

Broader applications of this technology, such as implanted electrodes and **neural prostheses**, are being researched and developed in order to provide assistance to people with a variety of disabilities. There have already been cases in which paralysed people have been able to move their wheelchairs by just thinking about the movement, or those who are unable to talk have been able to use their brain to result in their thoughts being spoken aloud. Cochlear implants are also examples of neural prostheses used to stimulate the auditory nerve in individuals with hearing loss.

FIGURE 2.50 Brain-control interface technology has many possible applications.

DISCUSSION

How else might brain-control interface technology be used? What other senses could be assisted using this technology? Could it be used to enable us to experience senses that humans do not currently possess?

neural prostheses technological devices that can replace a motor, sensory or cognitive structure

Resources

Weblinks Stem cells
Fight MND

2.6 Activities

learnon

2.6 Quick quiz on

2.6 Exercise

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 3, 4	2, 5, 7	6, 8

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. Define the term *paralysis*.
2. Outline the properties that make stem cells interesting to researchers.
3. Outline the cause and symptoms of motor neuron disease.

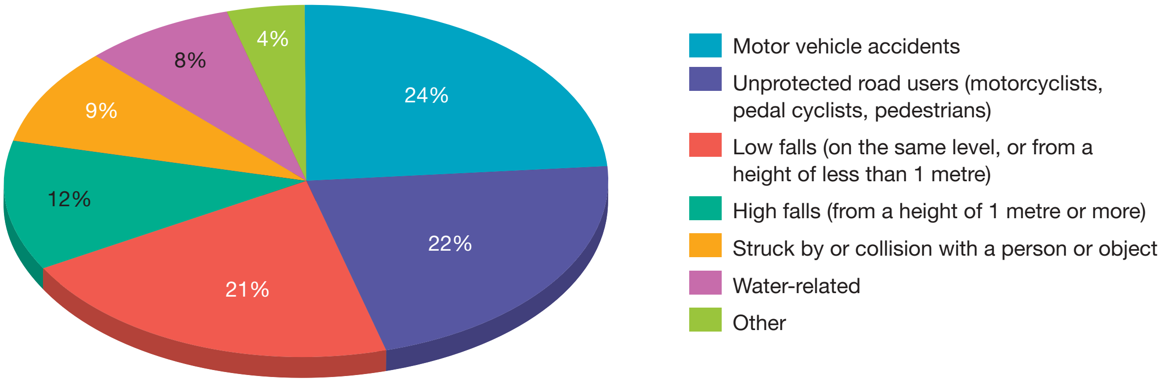
Apply and analyse

4. Outline how brain-control interface technology can bring about body responses.
5. Describe an application of implanted electrodes or neural prostheses.
6. Describe evidence that suggests that stem cells may one day be used to restore some mobility after a spinal injury.

Evaluate and create

7. **SIS** Use the graph showing the causes of spinal injury to answer the following questions.
   a. What are the two leading causes of spinal injury?
   b. What percentage of spinal injuries are sports related? Suggest which sports might have the highest risk of spinal injury.

Causes of spinal cord injury



8. a. Explain why an injury in the neck region of the spinal cord may result in quadriplegia, whereas an injury in the lower back region of the spinal cord may result in paraplegia.
   b. Research treatment options that are being investigated for different types of spinal cord injury.

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

LESSON
2.7 Review

Hey students! Now that it's time to revise this topic, go online to:

Review your results

Watch teacher-led videos

Practise questions with immediate feedback

Find all this and MORE in jacPLUS

Access your topic review eWorkbooks

on Resources

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-12272	ewbk-12273	ewbk-12274

2.7.1 Summary

Sense organs

- Sense organs detect stimuli (such as light, sound, touch, taste and smell) in your environment. Examples of human sense organs are your eyes, ears, skin, tongue and nose.
- Receptors respond to different stimuli. Receptors include thermoreceptors, mechanoreceptors, chemoreceptors, photoreceptors and pain receptors.

Homeostasis

- Multicellular organisms rely on coordinated and interdependent internal systems to respond to changes to their environment.
- Homeostasis is the constant maintenance of the internal body environment. Variables such as blood glucose, water and carbon dioxide need to be kept within a particular range for the body to remain healthy.
- The stimulus–response model is where any changes (stimuli) are detected (by receptors) leading to the initiation of a response by various body parts.
- Negative feedback occurs when the response is in an opposite direction to the stimulus.
- Positive feedback occurs when the response is in the same direction as the change in stimulus. The release of the hormone oxytocin during childbirth is an example of positive feedback.
- Both the endocrine and nervous systems work together to help maintain homeostasis and allow for responses to occur.

The nervous system

- The nervous system is composed of the central nervous system (CNS), which contains your brain and spinal cord, and the peripheral nervous system (PNS), which contains the nerves (neurons) that connect to the rest of the body.
- There are three types of neurons: sensory, interneuron and motor neuron.
- A synapse is a gap between neurons and is where neurotransmitters are released. Neurotransmitters are chemicals involved in passing messages between your neurons.
- Neurons are made up of three main parts: the dendrites, cell body and axon.
- Reflex responses require no conscious thought. A reflex arc is the nerve pathway followed by the reflex action.
- The brain is made up of three main parts: the forebrain (cerebrum, thalamus), the midbrain (reticular formation) and the hindbrain (medulla, pons and cerebellum).

- The reticular formation helps regulate your alertness (from being fully awake or deeply asleep), motivation, movement and some of your reflexes.

The endocrine system

- The endocrine system is composed of endocrine glands that secrete chemical substances called hormones into the bloodstream.
- Hormones control and regulate functions such as metabolism, growth, development and sexual reproduction.
- Hormones are a group of signalling molecules that travel via the circulatory system to act on target cells to produce a response.
- Hormones are involved in maintaining the homeostasis of a range of variables in the body including core body temperature and blood glucose levels.
- Insulin and glucagon, produced by the pancreas, are two important hormones involved in the regulation of blood glucose levels.
- LH and FSH play a key role in controlling and coordinating human reproduction and development.
- Diabetic retinopathy is a common cause of blindness in people with type 1 and 2 diabetes.

Malfunctions of the nervous system

- Paralysis is the loss of movement that can result from damage to the nervous system, particularly the spinal cord.
- Motor neuron disease targets motor neurons, resulting in progressive paralysis.

2.7.2 Key terms

adrenal glands a pair of glands situated near the kidneys that release adrenaline and other stress hormones
adrenaline a hormone secreted in response to stressful stimuli, which readies your body for the fight-or-flight response
auditory nerve a large nerve that sends signals to the brain from the hearing receptors in the cochlea
autonomic nervous system part of the PNS that controls involuntary movement, such as breathing or heartbeat
axon long structure within a neuron through which the nervous impulse travels from the dendrite and the cell body
brain stem the part of the brain connected to the spinal cord, responsible for breathing, heartbeat and digestion
cell body part of a neuron that contains the nucleus
central nervous system the part of the nervous system composed of the brain and spinal cord
cerebellum the part of the brain that controls balance and muscle action
cerebral cortex the outer, deeply folded surface of the cerebrum
cerebral hemispheres the left and right halves of the brain
cerebrum the largest part of the brain responsible for higher order thinking, controlling speech, conscious thought and voluntary actions
chemoreceptors special cells within a sense organ that are sensitive to particular chemicals
cochlea the snail-shaped part of the inner ear in which receptors are stimulated
cones photoreceptors located in the retina that respond to red, green or blue light
cornea the curved, clear outer covering of your eye
corpus callosum a bridge of nerve fibres through which the two cerebral hemispheres communicate
corpus luteum an endocrine structure that is involved in the production of progesterone
cytosol the fluid found inside cells
dendrite structure that relays information towards the cell body of a neuron
dopamine a neurotransmitter involved in producing positive moods and feelings
ear canal the tube that leads from the outside of the ear to the eardrum
eardrum a thin piece of stretched skin inside the ear that vibrates when sound waves reach it
effectors organs that respond to a stimuli to initiate a response
empathy the capacity to recognise and to some extent share feelings that are being experienced by other people
endocrine glands organs that produce hormones, which are released into the bloodstream

endocrine system the body system composed of different glands that secrete signalling molecules (hormones) that travel in the blood for internal communication and regulation and to maintain homeostasis
fertilisation fusion of the male sex cell (sperm) and the female sex cell (ovum)
follicles found in the ovary and contain a single immature ovum (egg)
follicle-stimulating hormone (FSH) regulates the development, growth and reproductive processes of the body
forebrain consists of the cerebrum, cerebral cortex, thalamus and hypothalamus
glucagon a hormone, produced by the pancreas, which increases blood glucose levels
hindbrain a continuation of the spinal cord
hippocampus part of the brain with a key role in consolidating learning, comparing new information with previous experience, and converting information from working memory to long-term storage
homeostasis the maintenance by an organism of a constant internal environment (for example, blood glucose level, pH, body temperature)
hormone a signalling molecule that is produced in specialised cells and travels in blood to act on target cells to cause a specific response
hyperglycaemia blood glucose levels above the normal range
hypoglycaemia blood glucose levels below the normal range
insulin hormone that reduces blood glucose levels
interneuron a nerve cell that conducts a nerve impulse within the central nervous system, providing a link between sensory and motor neurons
iris coloured part of the eye that opens and closes the pupil to control the amount of light that enters the eye
lens a transparent curved object that bends light towards or away from a point called the focus
luteinising hormone (LH) hormone produced by the anterior pituitary gland that initiates ovulation, the production of progesterone and corpus luteum development in females and in the stimulation of production of testosterone in testes in males
mechanoreceptors special cells within the skin, inner ear and skeletal muscles that are sensitive to touch, pressure and motion
medulla oblongata (medulla) a part of the brain developed from the posterior portion of the hindbrain
menstruation monthly discharge of blood and other materials from the uterus lining through the vagina (also known as period)
middle ear the section of the ear between your eardrum and the inner ear, containing the ossicles
mirror neurons group of neurons that activate when you perform an action and when you see or hear others performing the same action
motor neuron a nerve cell that conducts a nerve impulse from the central nervous system to the effector, such as a muscle or gland so that it may respond to a stimulus
motor neuron disease a medical condition that progressively destroys motor neurons, resulting in progressive paralysis but leaving the brain and sense organs unaffected
multicellular organism a living thing that is composed of many cells
myelin a fatty, white substance that encases the axons of neurons
negative feedback a homeostatic mechanism that returns a stimulus back within its normal range
nerve a bundle of neurons
nervous system the body system in which messages are sent as electrical impulses (along neurons) and chemical signals (neurotransmitters across synapses)
neural prostheses technological devices that can replace a motor, sensory or cognitive structure
neuron another name for nerve cell, a specialised cell for transmitting a nerve impulse
neurotransmitters signalling molecules released from the axon terminals into the synapse between nerve cells (neurons)
noradrenaline also called norepinephrine; common neurotransmitter involved in arousal states
nucleus roundish structure inside a cell that acts as the control centre for the cell
oestrogen hormone secreted from the ovaries and the placenta with a variety of effects such as inducing puberty changes and thickening of the uterus lining
olfactory nerve nerve that sends signals to the brain from the chemoreceptors in the nose
optic nerve large nerve that sends signals to the brain from the sight receptors in the retina
organelle small structure in a cell with a special function
ossicles a set of three tiny bones that send vibrations from the eardrum to the inner ear
ovulation the release of an ovum
ovum female sex cells produced in the ovaries

pain receptors special cells located throughout the body (except the brain) that send nerve signals to the brain and spinal cord in the presence of damaged or potentially damaged cells
papilla bumps on your tongue that are thought to contain tastebuds
paralysis loss of the ability to move
peripheral nervous system the part of the nervous system containing nerves that connect to the central nervous system
photoreceptor a special cell located in your eye that is stimulated by light
pituitary gland a small gland at the base of the brain that releases hormones
pineal gland gland that produces the hormone melatonin, which can make you feel drowsy
progesterone hormone produced in the ovaries that inhibits ovulation and prepares the lining of the uterus for pregnancy
pupil a hole through which light enters the eye
receptors chemical structures that receives and converts signals in the body
reflex arc a quick response to a stimulus that does not involve the brain (for example, knee jerk). The message travels from receptor to sensory neuron to interneuron in the spinal cord then directly via the motor neuron to the effector.
reticular formation a network of neurons that controls the amount of information that flows into and out of the brain
retina curved surface at the back of the eye
rods photoreceptors located in the retina that respond to low levels of light and allow you to see in black and white in dim light
sense organ a specialised structure that detects stimuli (such as light, sound, touch, taste and smell) in your environment
sensory neurons a nerve cell in the sensory organs that conducts a nerve impulse from receptors to the central nervous system
serotonin a common neurotransmitter involved in producing states of relaxation and regulating sleep and moods
somatic nervous system part of the PNS that controls voluntary movement, such as walking
stimulus–response model a system in which a change (stimulus) is detected by receptors leading to a response, which acts to alter and return the variance to normal
synapse the gap between adjoining neurons where neurotransmitters travel
target cells cells that contain receptors on their surface which are complementary to a specific hormone
tastebuds nerve endings located in your tongue allowing you to experience taste
testosterone male sex hormone
thalamus part of the brain through which all sensory information from the outside (except smell) passes before going to other parts of the brain for further processing
thermoreceptors special cells located in your skin, part of your brain and body core that are sensitive to temperature
thermoregulation the control of body temperature
thyroid gland a small gland in the neck that helps regulate metabolism and growth
uterus the organ in which a baby grows and develops
vesicle a small fluid-filled, membrane-bound sac in a cell

on Resources

eWorkbooks	Study checklist (ewbk-12275) Reflection (ewbk-12271) Literacy builder (ewbk-12276) Crossword (ewbk-12277) Word search (ewbk-12278)
Practical investigation eLogbook	Topic 2 Practical investigation eLogbook (elog-2239)
Solutions	Topic 2 Solutions (sol-1136)
Digital document	Topic 2 Key terms glossary (doc-40115)

2.7 Activities

2.7 Review questions

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 4, 6, 8, 10, 16, 17, 18, 21	3, 7, 9, 11, 14, 15, 19, 22	5, 12, 13, 20, 23, 24

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

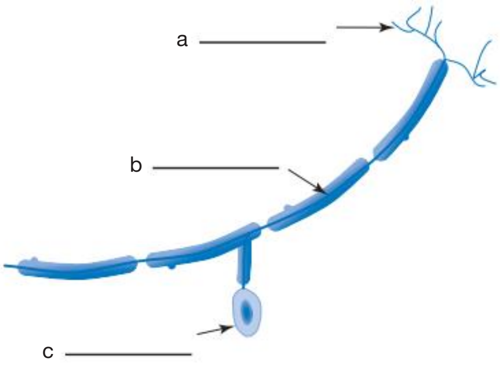
Remember and understand

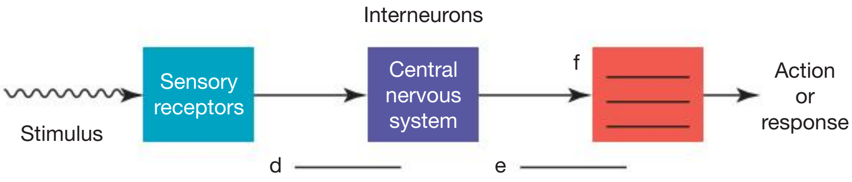
1. Construct a flow chart to show the stimulus–response model.
2. **MC** Identify the name given to the connections between neurons where the message is passed from one neuron to the next.
   A. Axon
   B. Dendrite
   C. Myelin
   D. Synapse
3. Copy and complete the following table.

TABLE Stimuli, receptors and sense organs

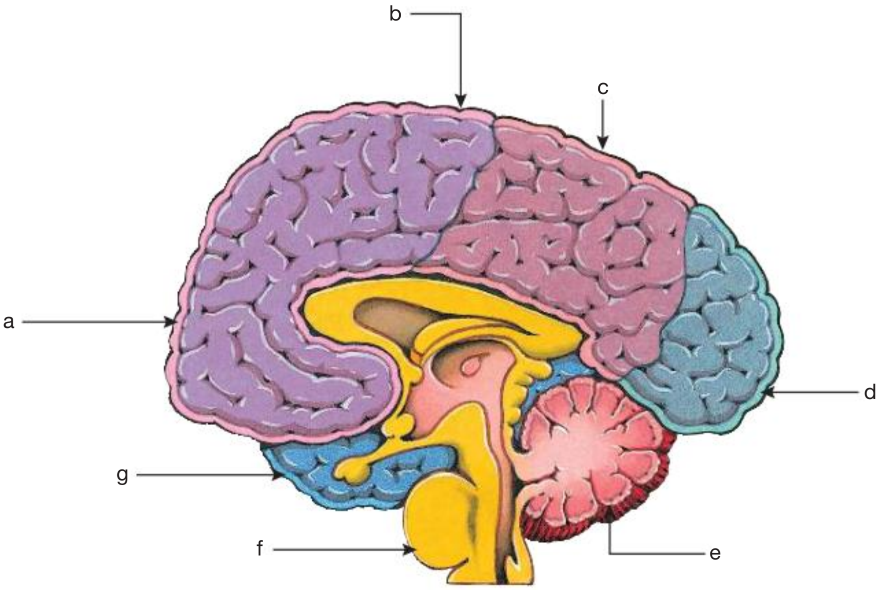
Stimulus	Receptor	Sense organ
		Eye
	Chemoreceptor	
Vibrations, pressure		
	Thermoreceptor	

4. Place the following labels in the correct places on the diagrams provided:
   - dendrite
   - sensory neurons
   - cell body
   - effector
   - axon
   - motor neurons





5. Label each of the parts of the brain and state one of the functions of each.



6. Match the hormone with the appropriate function.

Hormone	Function
a. Anti-diuretic hormone (ADH)	**A.** Causes reabsorption of water in kidneys
b. Glucagon	**B.** Causes testes to produce sperm
c. Insulin	**C.** Causes thickening of the uterine lining
d. Oestrogen	**D.** Controls menstruation cycle and pregnancy
e. Progesterone	**E.** Increases blood glucose levels
f. Testosterone	**F.** Increases metabolic rate of cells
g. Thyroxine	**G.** Lowers blood glucose levels

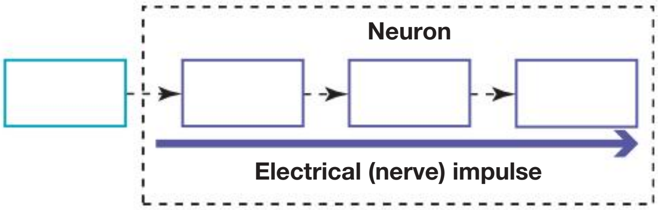
7. Match the terms with their appropriate description in the table provided.

Term	Definition
a. Central nervous system	**A.** Made up of a cell body, dendrites and axon
b. Motor neuron	**B.** Takes messages away from the central nervous system
c. Nerves	**C.** Takes messages to the central nervous system
d. Neuron	**D.** Brain and spinal cord
e. Neurotransmitter	**E.** Chemical messenger that carries messages from one neuron to another across a synapse
f. Peripheral nervous system	**F.** Nerves that connect the central nervous system to the rest of the body
g. Sensory neuron	**G.** Gap between neurons
h. Synapse	**H.** Made up of neurons

8. Fill in the blanks to complete the following sentence:
   Myelin _________ the speed at which the ____________ can move though the neuron and hence the speed at which the message is communicated.
9. Describe the relationship between the pituitary gland, the adrenal glands and adrenaline.
10. Explain how the release of adrenaline can increase your chances of survival.
11. a. Identify three neurotransmitters in your brain that can influence how you feel and react.
    b. Describe the effects that each of these neurotransmitters can have on your behaviour.

Apply and analyse

12. a. Underline the incorrect term in each sentence and replace it with the correct term.
    b. Write definitions of the incorrect words you replaced.
       i. The neuron carries hormones to target cells.
       ii. The master gland of the endocrine system is the adrenal gland.
       iii. The brain and spinal cord make up the peripheral nervous system.
       iv. Each molecule has tissues that carry out particular functions.
13. Outline the differences between each pair of terms.
    a. Positive feedback and negative feedback
    b. Thermoreceptor and chemoreceptor
    c. Axon and dendrite
    d. Hormone and neurotransmitter
    e. CNS and PNS
    f. Thalamus and hypothalamus
14. Place the terms in their appropriate position in the flow chart: cell body, axon, dendrite, stimulus

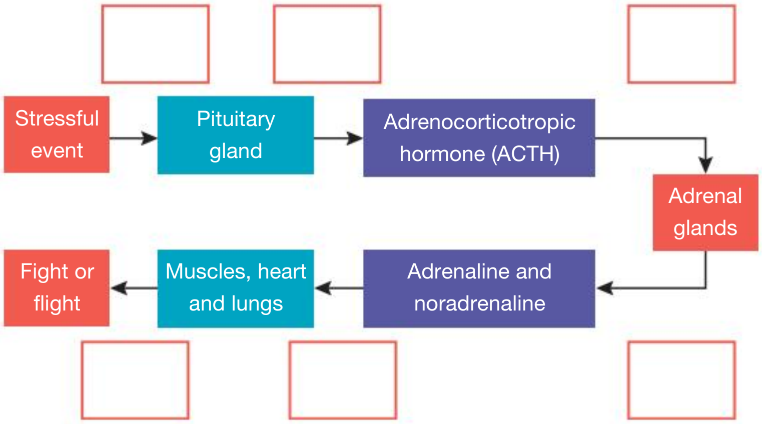


15. Describe the relationship between adrenaline, pituitary, adrenal cortex, heart rate, stress.
16. Recall three endocrine glands and hormones they produce. Describe a function of each of the hormones.
17. Provide an example of a negative feedback mechanism. Explain why it is important.
18. Compare type 1 and type 2 diabetes.
19. Explain how type 2 diabetes can lead to diabetic retinopathy.
20. **SIS** In 2020–21, one in twenty people in the Australian population (5.3 per cent) had type 2 diabetes. Rates of type 2 diabetes increase by 10.3 per cent in people aged 55–64 and by 14.9 per cent in people aged 65–74 years.
    a. The cause of type 1 diabetes is currently unknown. Research the causes of type 2 diabetes and explain how its development can be prevented.
    b. Discuss why type 2 diabetes normally develops in people later in life.

Evaluate and create

21. Construct a table to summarise the differences between the nervous and endocrine systems. Make sure you include the name of the information each system produces, how that information is carried throughout the body, and the speed and length of each system's response.
22. Draw a flow chart that outlines what happens when you sit on a chair that has a sharp object on it. Include both nervous and endocrine responses.

23. The flow chart shows a series of events that may occur when you encounter a stressful event. Suggest descriptions or labels for each of the links (shown as the blank boxes).



24. Explain the role of the nervous and endocrine systems in regulating body temperature and outline both voluntary and involuntary processes involved in thermoregulation.

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

Online Resources

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-12238)
- Student learning matrix (ewbk-12239)
- Starter activity (ewbk-12240)

Solutions
- Topic 2 Solutions (sol-1136)

Video eLesson
- Neurons in the brain (eles-2631)

Weblink
- Reaction time test

2.2 Sense organs

eWorkbooks
- Labelling the eye (ewbk-12243)
- Labelling the ear (ewbk-12244)
- Skin (ewbk-12245)

Teacher-led video
- Investigation 2.2: Dissection of a mammal's eye (tlvd-10798)

Practical investigation eLogbooks
- Investigation 2.1: Touch receptors on your skin (elog-2241)
- Investigation 2.2: Dissection of a mammal's eye (elog-2242)

Video eLessons
- Human eye anatomy and common eye defects (eles-2635)
- Sound waves vibrations are detected by the ear (eles-2636)

Interactivity
- Labelling parts of a human ear (int-8176)

Weblink
- The human eye

2.3 Homeostasis

eWorkbook
- The stimulus–response model (ewbk-12249)

2.4 The nervous system

eWorkbooks
- Labelling a neuron (ewbk-12256)
- Labelling a synapse (ewbk-12251)
- Labelling the reflex arc (ewbk-12252)
- The nervous system (ewbk-12253)
- Labelling the brain (ewbk-12254)
- The brain (ewbk-12255)

Practical investigation eLogbook
- Investigation 2.3 Dissection of a mammal's brain (elog-2245)
- Investigation 2.4: How good are your reflexes? (elog-2246)

Video eLessons
- The human nervous system (eles-2632)
- Brain cell synapse (eles-2634)

Interactivities
- A nervous response (int-0670)
- A bundle of nerves (int-0015)
- Neuron structure (int-5762)
- Labelling the human brain (int-8229)

Weblink
- Neuroscience

2.5 The endocrine system

eWorkbooks
- Labelling the male reproductive system (ewbk-12264)
- Labelling the female reproductive system (ewbk-12265)
- The endocrine system (ewbk-12266)

Video eLesson
- The male endocrine system (eles-2633)

Interactivity
- Reproductive system (int-3032)

2.6 Malfunctions of the nervous system

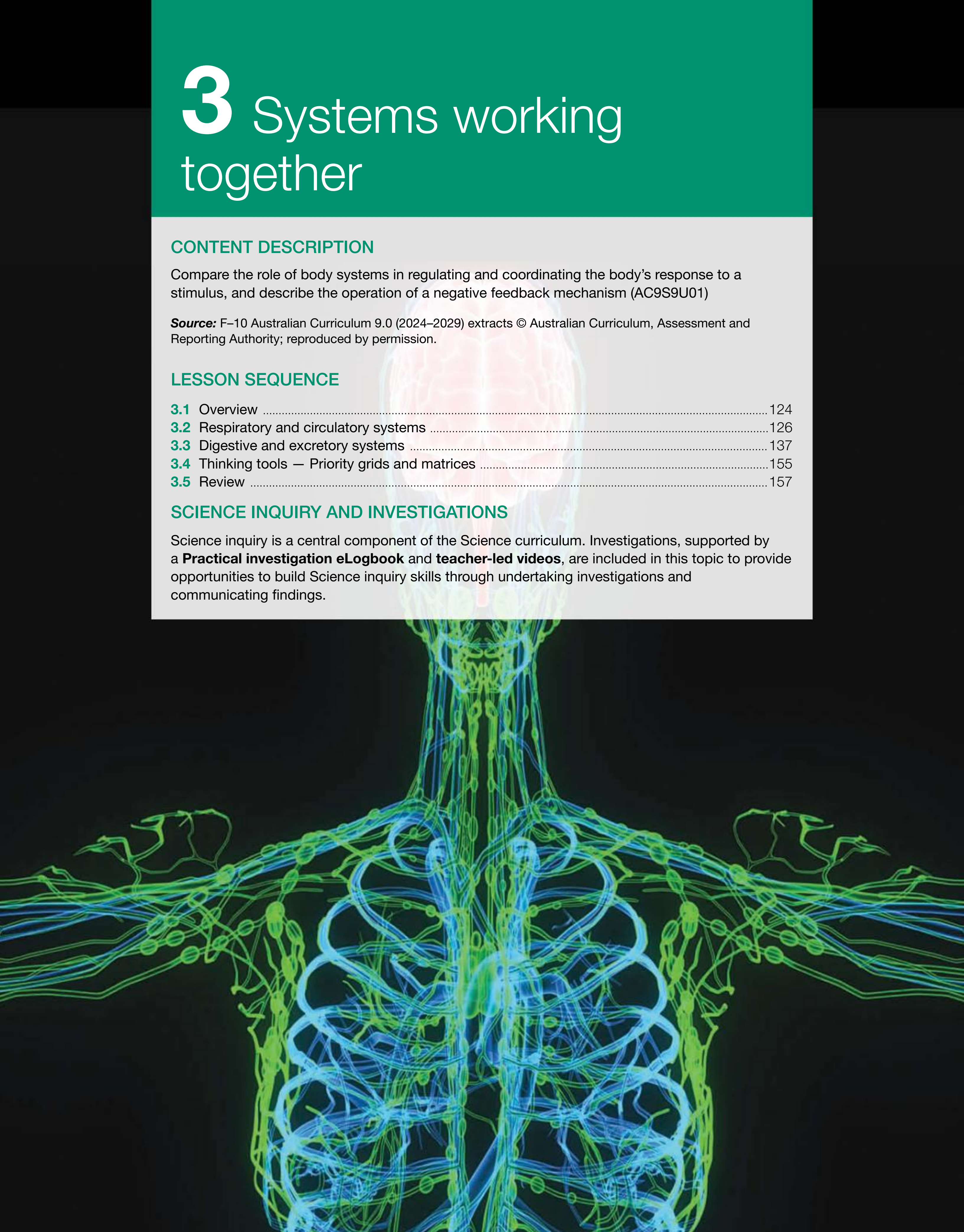
Weblinks
- Stem cells
- Fight MND

2.7 Review

eWorkbooks
- Topic review Level 1 (ewbk-12272)
- Topic review Level 2 (ewbk-12273)
- Topic review Level 3 (ewbk-12274)
- Study checklist (ewbk-12275)
- Reflection (ewbk-12271)
- Literacy builder (ewbk-12276)
- Crossword (ewbk-12277)
- Word search (ewbk-12278)

Digital document
- Topic 2 Key terms glossary (doc-40115)

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



3 Systems working together

CONTENT DESCRIPTION

Compare the role of body systems in regulating and coordinating the body's response to a stimulus, and describe the operation of a negative feedback mechanism (AC9S9U01)

Source: F–10 Australian Curriculum 9.0 (2024–2029) extracts © Australian Curriculum, Assessment and Reporting Authority; reproduced by permission.

LESSON SEQUENCE

SCIENCE INQUIRY AND INVESTIGATIONS

Science inquiry is a central component of the Science curriculum. Investigations, supported by a **Practical investigation eLogbook** and **teacher-led videos**, are included in this topic to provide opportunities to build Science inquiry skills through undertaking investigations and communicating findings.

LESSON
3.1 Overview

Hey students! Bring these pages to life online

Watch videos

Engage with interactivities

Answer questions and check results

Find all this and MORE in jacPLUS

3.1.1 Introduction

Like those of other multicellular organisms, your body systems work together to keep you alive. Each body system is made up of organs with specific functions. An important function of your body systems is to supply your cells with energy and nutrients, and to remove wastes that are produced. To achieve this, your body systems do not work independently of each other — they work together. This requires organisation, coordination and control.

FIGURE 3.1 Athletes rely on body systems that work in a coordinated manner. They need to have a supply of energy to keep them healthy and strong.

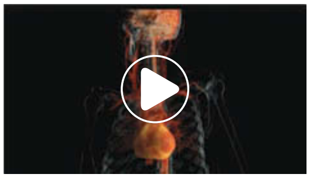
The nervous and endocrine systems were discussed in topic 2. This topic will focus on the interdependence of the circulatory system and respiratory system, and the digestive system and excretory system. The respiratory system allows gas exchange between cells and your environment; the circulatory system moves substances around and between body systems; the digestive system breaks down food and absorbs nutrients; and the excretory system helps the body to get rid of wastes from metabolism.

It is important to understand the none of our body's systems work in isolation. They are all connected and they work together. In the previous topic on the endocrine system, we learned about negative feedback mechanisms. Consider water regulation — as we dehydrate, anti-diuretic hormone (ADH) is released and we reabsorb more water from our blood as it passes through the kidneys. The endocrine system produces the hormone and the excretory system reacts to this. However, other systems are also needed for the body to function efficiently. The circulatory system is needed to deliver the hormone; the nervous system generates the feeling of thirst to encourage us to drink; the digestive system absorbs the water from that drink; the muscular system does this by using peristalsis, allows us to swallow the water and move it through our intestines. It requires energy to do so, and uses oxygen provided by the respiratory system. This working together of the systems is what we term a **coordinated response to stimuli** and is the basis on which complex, multi-cellular organisms are able to survive. None of these cells, tissues or systems could survive on their own. They all rely on each other.

on Resources

Video eLesson Body systems animation (eles-4171)

Watch this short animation demonstrating some of the major systems in the human body. How many systems and organs can you recognise?



3.1.2 Think about body systems

1. Is it the amount of oxygen or carbon dioxide in your blood that influences your breathing rate?
2. Does breathing rate differ at sea level or high in the mountains? What about during high intensity exercise?
3. In what form are old red blood cells excreted in faeces?
4. Which vitamin deficiency may result in poor blood clotting?
5. What's wrong with glucose in your urine?

3.1.3 Science inquiry

Design an organism

Have you ever wondered what the recipe for life is? Which ingredients would you blend together to make up a living thing? How could this mixture result in life?

Scientists have developed a whole range of different instruments and technologies to discover more about life processes. This has helped develop our knowledge and understanding of the structure of living things and how they work. Investigations give us more information about chemical processes that occur in cells and keep living things alive.

1. **a.** Identify an environment in which your organism will live.
   b. Describe the temperature, light intensity, water availability, food sources and other factors that you consider to be important to the survival of your organism.
2. Design your organism.
   a. Identify how your organism:
      i. obtains nutrients
      ii. obtains oxygen
      iii. removes its wastes.
   b. Identify how nutrients, oxygen and its wastes are transported within its body.
   c. Identify how the organism senses and responds to its environment.
3. Draw labelled diagrams of your organism's cells, tissues, organs and systems. Remember to think about the function of each of these when you are designing its structure.
4. Describe how each of your organism's systems work together to keep it alive.
5. Construct a model of your organism.
6. Construct a brochure that advertises what a magnificent life form your organism is. Think about who you are advertising your organism to. Is your target audience a zoo or a documentary film-maker or someone else?

FIGURE 3.2 *Grimpoteuthis*, one of the 15 species of umbrella (or dumbo) octopuses — they live in the deep sea in very cold water and without sunlight.

FIGURE 3.3 Tardigrades are half-a-millimetre-long water animals that have been found in rainforests, the Antarctic, in mud volcanoes and in the deep sea.

on Resources

eWorkbooks	Topic 3 eWorkbook (ewbk-12091) Student learning matrix (ewbk-12093) Starter activity (ewbk-12094)
Solutions	Topic 3 Solutions (sol-1123)
Practical investigation eLogbook	Topic 3 Practical investigation eLogbook (elog-2209)

LESSON
3.2 Respiratory and circulatory systems

LEARNING INTENTION

At the end of this lesson you will understand how the respiratory and circulatory systems work together to supply oxygen to your cells and remove carbon dioxide from them.

3.2.1 The respiratory system and the circulatory system

The respiratory system

The **respiratory system** is responsible for getting oxygen into your body and carbon dioxide, a waste product, out. This occurs when you inhale (breathe in) and exhale (breathe out). The main organ in this system is the **lungs**. It is in the alveoli (the tiny air sacs in the lungs) that gas exchange occurs (figure 3.4).

respiratory system the body system that includes the lungs and associated structures and is responsible for the gas exchange of getting oxygen into your body and carbon dioxide out

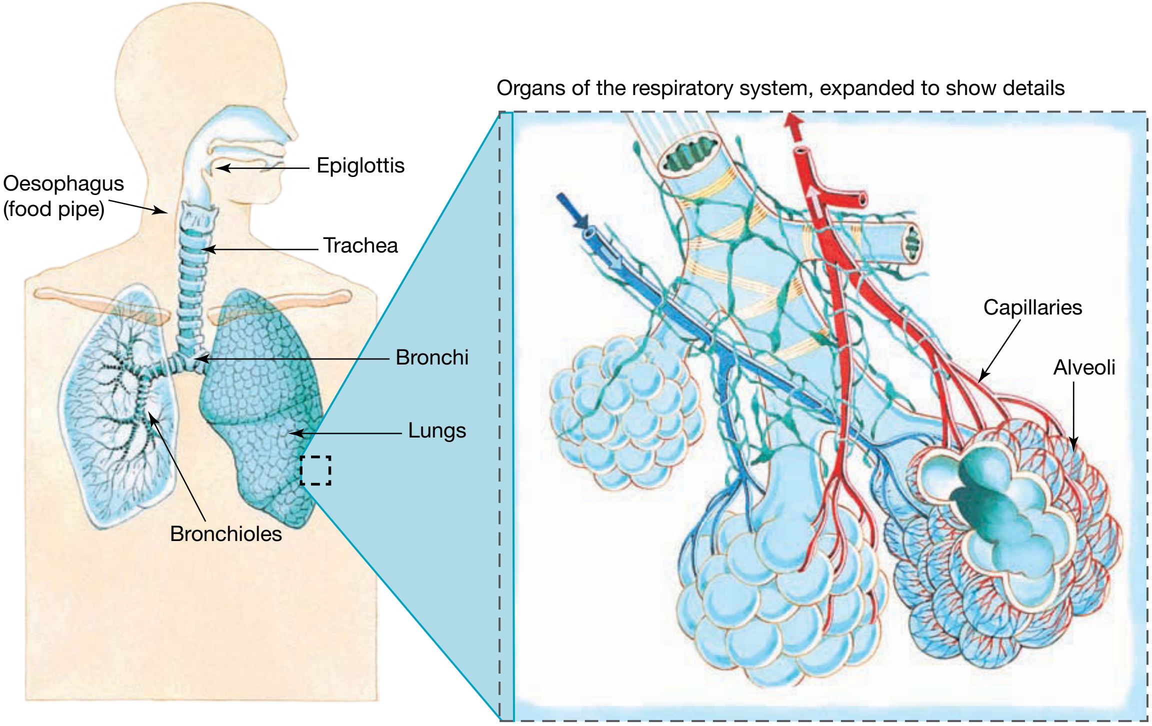
lungs the organ for breathing air. Gas exchange occurs in the lungs.

ewbk-12096

eles-2642

int-8233

FIGURE 3.4 The human respiratory system



The circulatory system

The **circulatory system**, also called the cardiovascular 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 (arteries, veins, and capillaries) and your heart. Arteries transport blood from the heart and veins transport blood back to the heart. Arteries are muscular narrower than veins, which means blood is under higher pressure in the arteries than in the veins. Capillaries are the site at which exchange of materials with the cells occurs (figure 3.6).

circulatory system the body system that includes the heart, blood and blood vessels and is responsible for circulating oxygen and nutrients to your body cells and carbon dioxide and other wastes away from them

The heart is actually two pumps. One side pumps oxygenated blood and the other pumps deoxygenated blood.

FIGURE 3.5 Heart and blood vessel flow chart

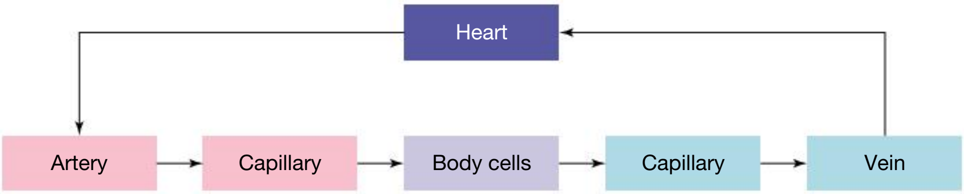
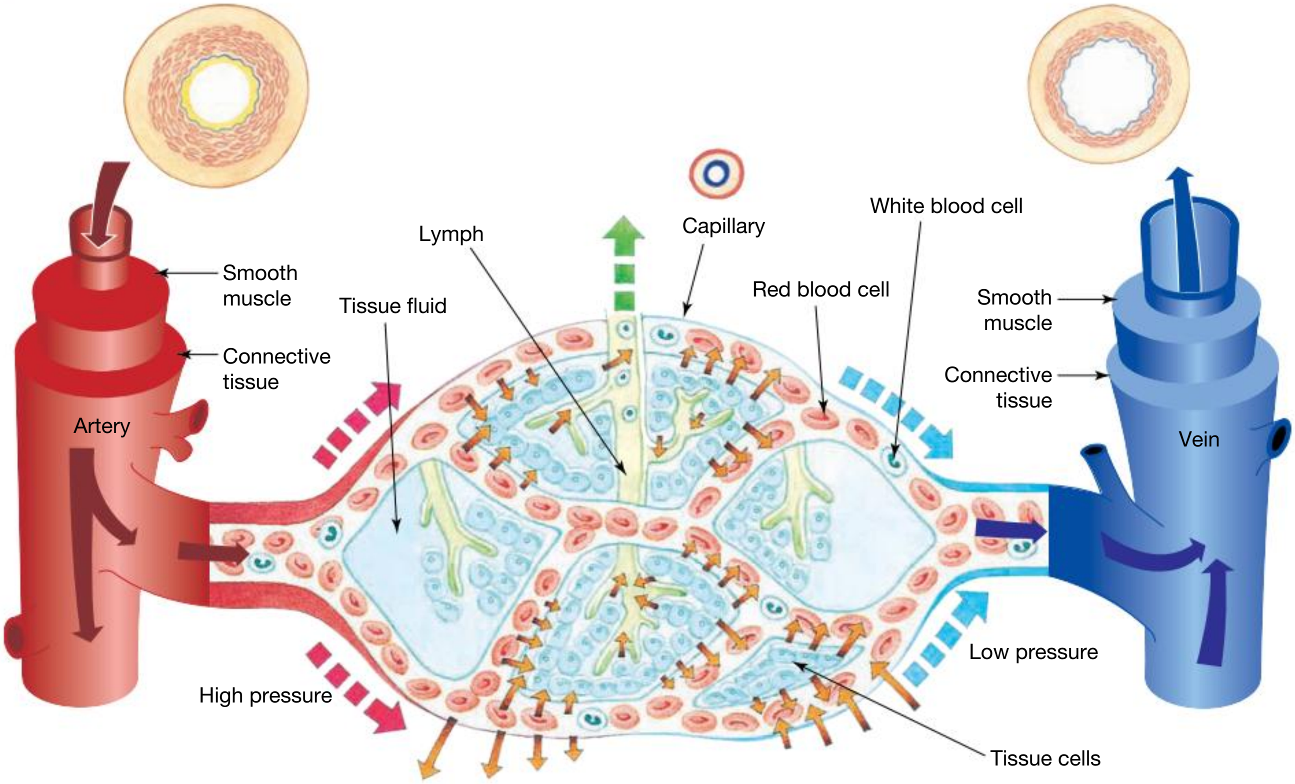


FIGURE 3.6 The oxygenated blood coming from the artery (red) moves into the finer capillaries where the thin walls allow an exchange of gases into the tissues. Carbon dioxide is released from the tissues to the bloodstream where the veins take the deoxygenated blood (blue) back to the heart and lungs.



3.2.2 Cells need energy!

Your circulatory and respiratory systems work together to provide your cells with **oxygen**, which is essential for the process of making energy. This process is called cellular respiration. It involves the breaking down of **glucose** so that energy is released and can be converted into a form that your cells can use. As can be seen in the cellular respiration equation below, **carbon dioxide** is produced as a waste product. The carbon dioxide then needs to be removed from your cells or it would result in their damage or death.

Cellular respiration

Cellular respiration is the breakdown of food (glucose) in the presence of oxygen, which releases energy that can be transformed into a form that cells can use. Carbon dioxide is a waste product.

$$\text{Glucose} + \text{oxygen} \rightarrow \text{carbon dioxide} + \text{water} + \text{energy}$$

EXTENSION: Details of cellular respiration

Cellular respiration actually occurs through a complex series of biochemical equations. It can be simplified as follows:

$$\begin{array}{ccccccccc} C_6H_{12}O_6 & + & 6O_2 & \rightarrow & CO_2 & + & H_2O & + & (\text{ATP}) \\ \text{Glucose} & + & \text{oxygen} & \rightarrow & \text{carbon dioxide} & + & \text{water} & + & \text{energy(ATP)} \end{array}$$

As this series of reactions give out energy, they are known as exergonic reactions, and the energy released is used to produce a usable form of energy known as ATP.

3.2.3 Transport in the respiratory and circulatory systems

Transport through your circulatory system

Your circulatory system is responsible for:

- transporting oxygen and nutrients to your body's cells
- transporting wastes such as carbon dioxide away from your body's cells.

This involves blood cells that are transported in your blood vessels and heart. The three major types of blood vessels are:

- **arteries** — transport blood from the heart
- **capillaries** — where materials are exchanged with cells
- **veins** — transport blood back to the heart.

oxygen tasteless and colourless gas in which molecules (0_2) are made up of two oxygen atoms. 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 of cellular respiration. The burning of fossil fuels also releases carbon dioxide.

arteries hollow tubes (vessels) with thick walls carrying blood pumped from the heart to other body parts

capillaries minute tubes carrying blood to body cells. Every cell of the body is supplied with blood through capillaries.

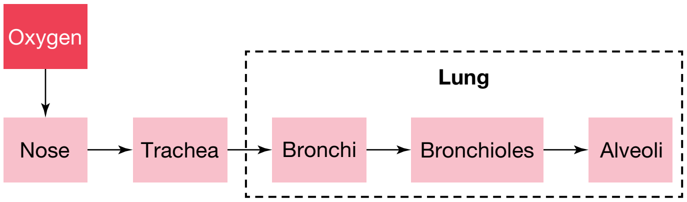
veins blood vessels that carry blood back to the heart. They have valves and thinner walls than arteries.

Inhaling — to get oxygen into your 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).

To get oxygen into your respiratory system, you breathe in, but you actually take in a mixture of gases (of which about 21 per cent is oxygen) from the air around you. The air moves down your **trachea** (or windpipe), then down into one of two narrower tubes called **bronchi** (bronchus), then into smaller branching tubes called **bronchioles,** which end in tiny air sacs called **alveoli** (alveolus).

FIGURE 3.7 Flow chart of the human respiratory system



Getting oxygen into your circulatory system

Your alveoli are surrounded by a network of capillaries. The alveolus wall and capillary walls are each one cell thick, the minimum possible for oxygen and carbon dioxide to cross by diffusion. These capillaries contain **red blood cells** (or **erythrocytes**) that contain **haemoglobin**, an iron-based pigment that gives your blood its red colour. Oxygen moves from the alveoli into the red blood cells in the surrounding capillaries and binds to the haemoglobin to form oxyhaemoglobin. It is in this form that the oxygen is transported to your body cells.

trachea narrow tube from the mouth to the lungs through which air moves

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

red blood cells living cells in the blood that transport oxygen to all other living cells in the body. Oxygen is carried by the red pigment haemoglobin.

erythrocytes red blood cells

haemoglobin the red pigment in red blood cells that carries oxygen

FIGURE 3.8 Flow chart of oxygen moving into the circulatory system

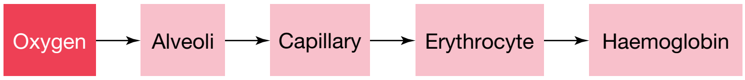
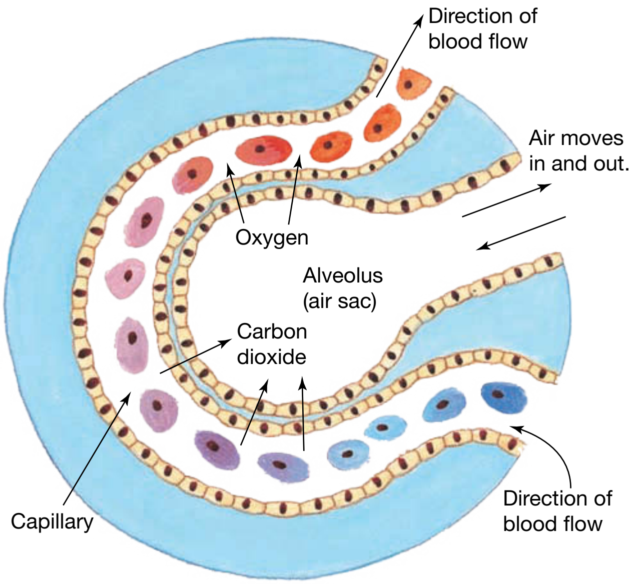


FIGURE 3.9 In an alveolus, oxygen diffuses into the blood and carbon dioxide diffuses out of the blood.



Transporting oxygen to your cells

Oxygenated blood travels in a path, as shown in figures 3.10 and 3.12. It 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 arteries transport the oxygenated blood to smaller vessels called **arterioles** and finally to capillaries through which oxygen finally diffuses into body cells for use in cellular respiration (figure 3.11).

FIGURE 3.10 Flow chart of oxygen moving through the circulatory system to the body's cells

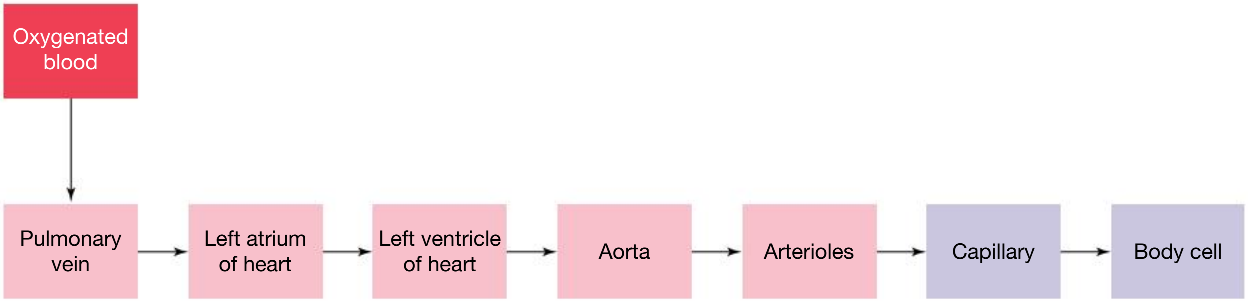
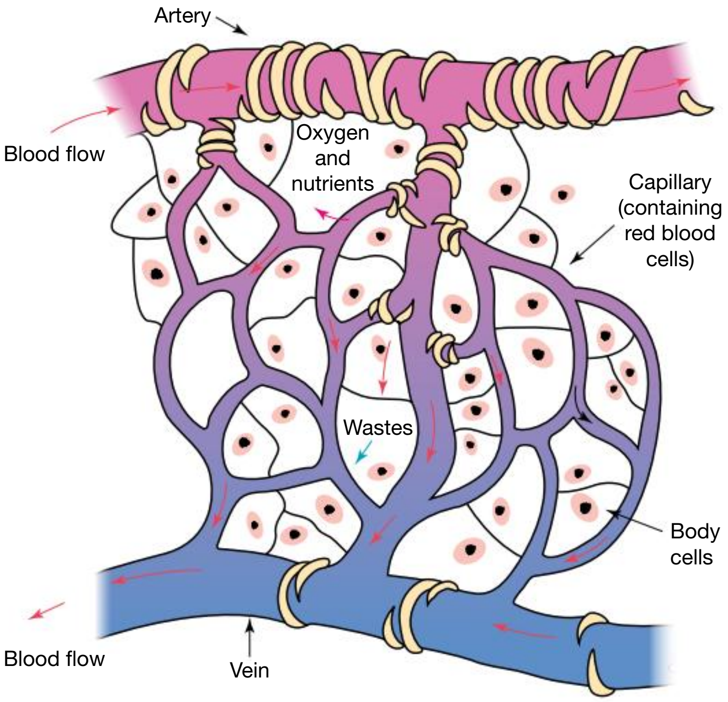


FIGURE 3.11 In the capillaries, oxygen diffuses out of the blood and waste produced by cells diffuses into the bloodstream.



pulmonary vein the vessel through which oxygenated blood travels from your lungs to the heart

left atrium upper left section of the heart where oxygenated blood from the lungs enters the heart

heart a muscular organ that pumps blood through the circulatory system so that oxygen and nutrients can be transported to the body's cells and wastes can be transported away

left ventricle lower left section of the heart, which pumps oxygenated blood to all parts of the body

aorta a large artery through which oxygenated blood is pumped at high pressure from the left ventricle of your heart to your body

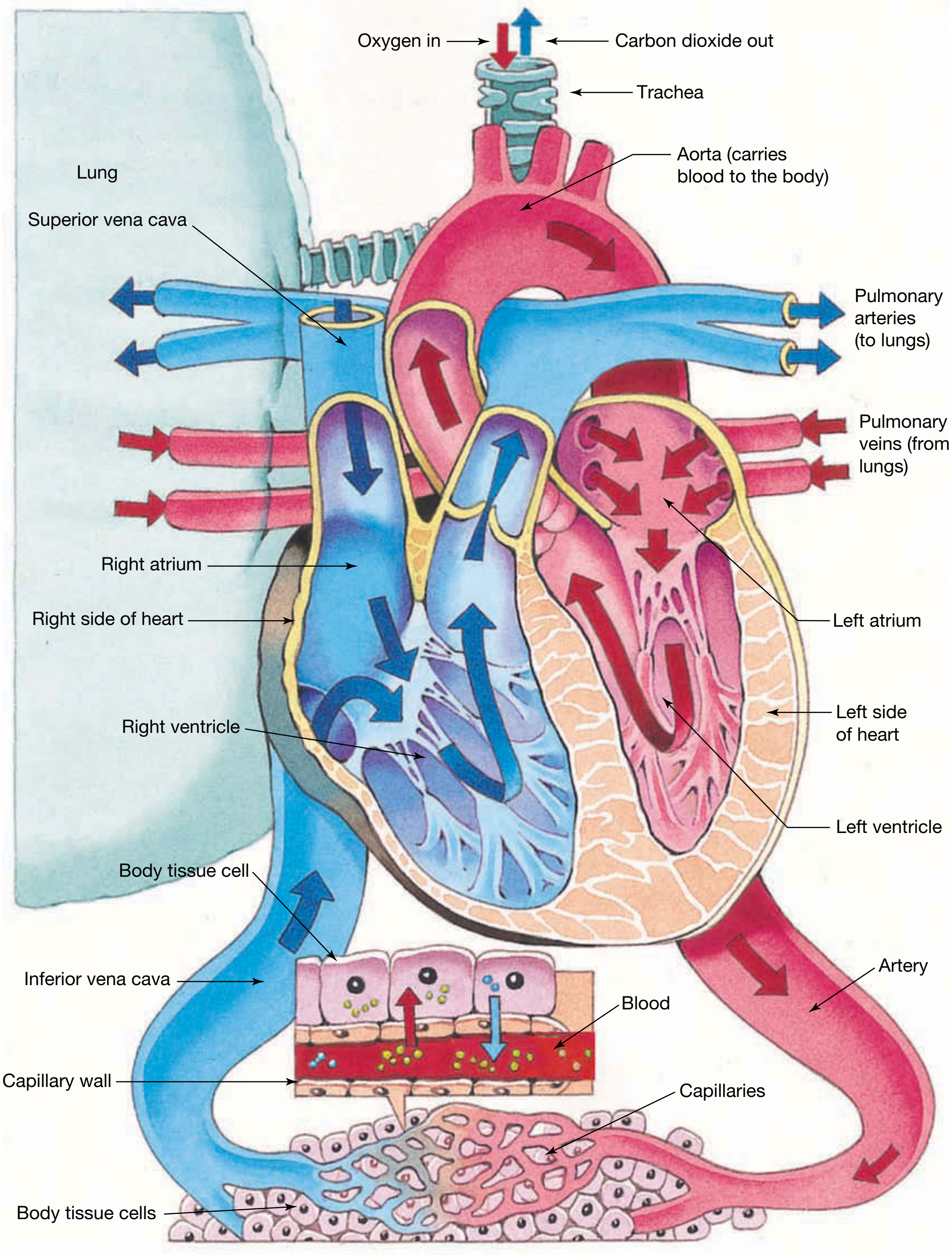
arterioles vessels that transport oxygenated blood from the arteries to the capillaries

ewbk-12098

eles-2049

int-0210

FIGURE 3.12 The path of oxygenated (red) and deoxygenated (blue) blood through the heart

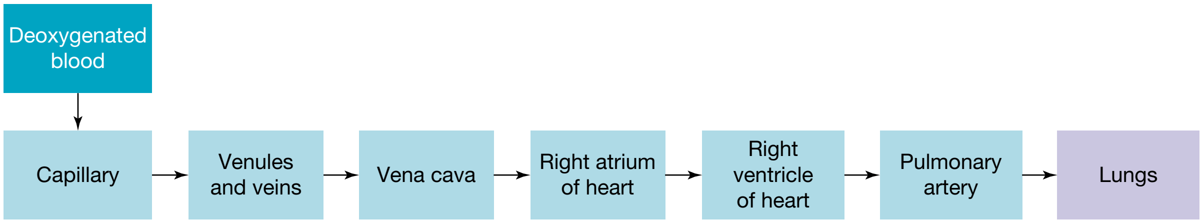


Transporting carbon dioxide away from your cells

When oxygen has diffused into the cell and the waste product of cellular respiration, carbon dioxide, has diffused out of the cell into the capillary, the blood in the capillary is referred to as **deoxygenated blood**.

The waste-carrying deoxygenated blood travels in a path (figures 3.12 and 3.13). It is transported via capillaries to **venules** (small veins) then to increasingly larger veins, before the largest veins – called the **vena cava** – deliver it to the **right atrium** of the heart. From here it travels to the **right ventricle** where it is pumped to your lungs through the **pulmonary artery**, so called because it is associated with your lungs. The pulmonary artery is the only artery that does not contain oxygenated blood.

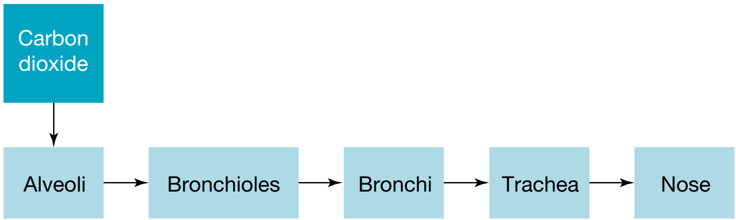
FIGURE 3.13 Flow chart of deoxygenated blood moving back to the lungs



Exhaling — to remove carbon dioxide from your respiratory system

To get rid of the carbon dioxide (CO_2) from the deoxygenated blood, your body needs to get carbon dioxide into your respiratory system and out of your body. Carbon dioxide in your capillaries diffuses into the alveoli in your lungs. It is then transported into your bronchioles, then your bronchi, and then into your trachea. From here, carbon dioxide is exhaled through your nose (or mouth) when you breathe out (figure 3.14).

FIGURE 3.14 Flow chart of carbon dioxide being released from the body



3.2.4 Working together

The respiratory system and the circulatory system work together to keep your cells alive. They achieve this by providing your cells with the oxygen required for cellular respiration and by removing its waste product carbon dioxide. In this lesson, you have followed the different pathways for the transport of oxygenated and deoxygenated blood through blood vessels and the heart. You have also seen where and how the exchange of oxygen and carbon dioxide occurs between the cells within the body, capillaries, and the alveoli of the lungs.

deoxygenated blood blood from which some oxygen has been removed

venules small veins

vena cava large vein leading into the top right chamber of the heart

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

pulmonary artery the vessel through which deoxygenated blood, carrying wastes from respiration, travels from the heart to the lungs

FIGURE 3.15 The respiratory and circulatory system work together.

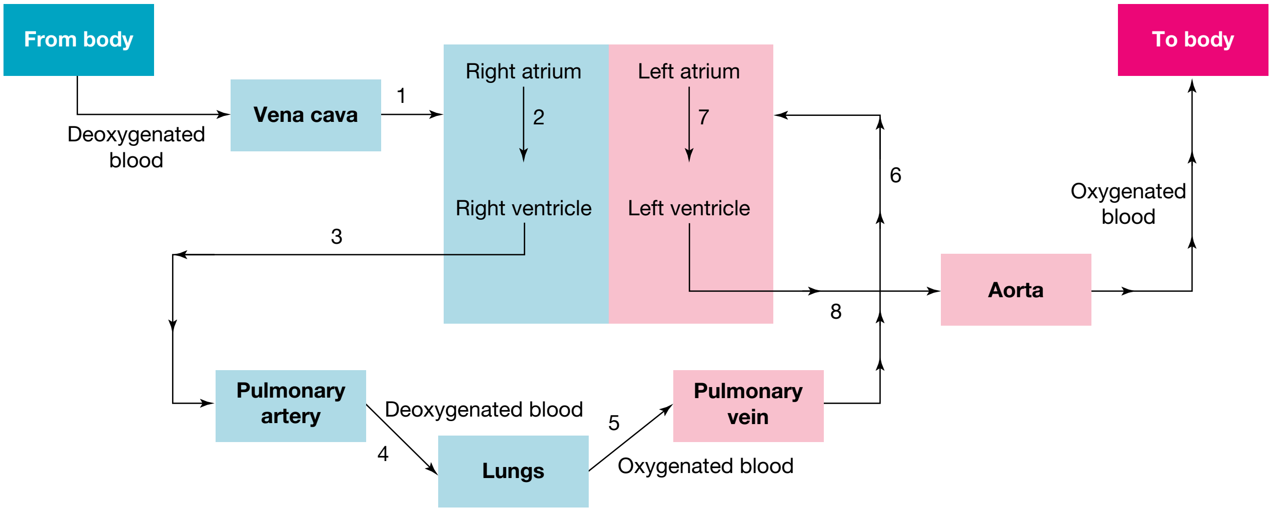
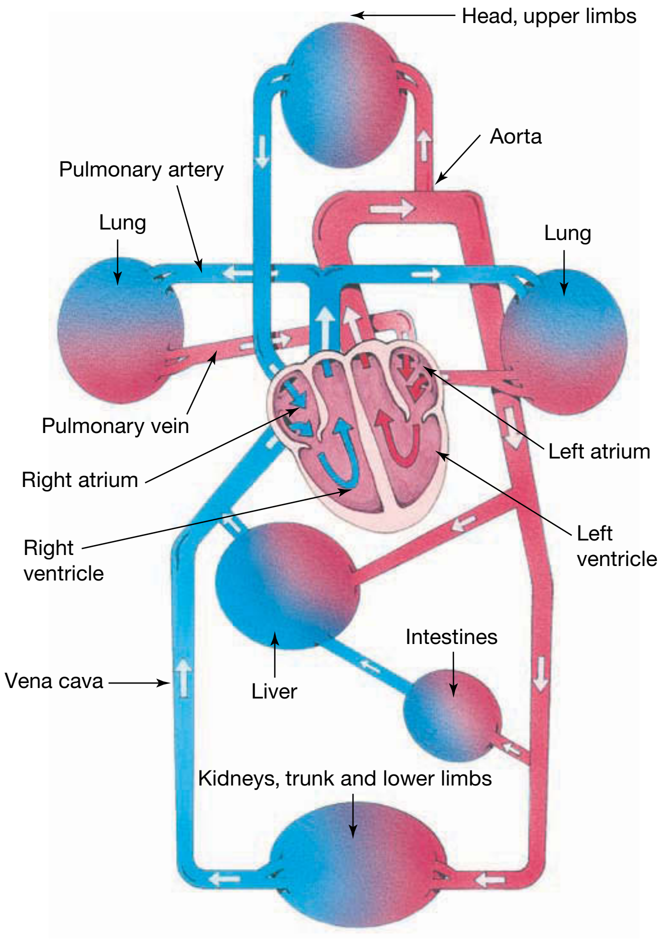


FIGURE 3.16 Connected highways — the routes for blood circulations



elog-2211

INVESTIGATION 3.1

The effect of exercise on the circulatory and respiratory systems

Aim

To investigate the response of the circulatory and respiratory systems to increasing levels of physical activity

Background

As the heart beats it sends a surge, or pulse, of blood through your blood vessels. The elastic walls of the arteries stretch and then relax as each surge of blood passes through them. We can feel each pulse passing through an artery wherever we have arteries close to the surface of the skin and can count these pulses to measure how fast our heart is beating. This is called our 'pulse rate' and is recorded in beats per minute.

A strong pulse can usually be felt in either the inside of the wrist, to the outside of the two tendons running up the inside of your arm near the base of your thumb, or in the neck, just below the hinge of the jaw. To record your pulse you should place the tips of your first and second fingers (NOT your thumb, as there is a faint pulse in your thumb that will interfere with your counting and give a false reading) where you can feel the pulse, count the number of pulses in 30 seconds and then double this number to calculate the number of beats in 1 minute.

A normal resting pulse rate can be anywhere between 50 and 100 beats per minute (bpm).

Prediction

Predict what you think will happen to your pulse rate and breathing rate as you increase your level of activity. Explain why you think this will happen.

Materials

- stopwatch
- oximeter (optional)

Method

1. Sit quietly at your desk for 2 minutes. Try to be as calm and relaxed as possible.
2. Have your partner count the number of breaths you take during the second minute and record this in your results table. Use the oximeter to record your pulse rate (if using).
3. At the end of your 2 minutes of 'activity', your partner will count your breathing rate for 30 seconds. Double this answer to get your breaths per minute and recorded it in your table.
4. In a suitable, safe, open space, such as the school yard, walk slowly for 2 minutes.
5. Repeat steps 2 and 3.
6. In a suitable, safe, open space, such as the school yard, walk briskly for 2 minutes.
7. Repeat steps 2 and 3.
8. In a suitable, safe, open space, such as the school yard, jog for 2 minutes.
9. Repeat steps 2 and 3.
10. In a suitable, safe, open space, such as the school yard, run at approximately 50 to 75 per cent of your maximum pace for 2 minutes.
11. Repeat steps 2 and 3.
12. In a suitable, safe, open space, such as the school yard, run at full pace for 2 minutes.
13. Repeat steps 2 and 3.

Results

Record your results.

TABLE Results of investigation 3.1

Level of activity	Breathing rate (breaths per minute)	Pulse rate (beats per minute)
Resting		
Slow walking		
Fast walking		
Jogging		
Running		
Sprinting		

Create a bar graph of your results. This could be two separate graphs for breathing rate and pulse rate, or a single graph with two alternative y-axes and two sets of bars on the same graph.

Discussion

1. What happened to your pulse rate as you increased your level of exercise?
2. What happened to your breathing rate as you increased your level of exercise?
3. What else changed about your breathing as you increased your level of exercise?
4. Why did these changes happen? Give as full an answer as you possibly can with as many reasons as you can think of.
5. Responding to changes in activity involves far more than just your respiratory and circulatory systems. Research the immediate, short-term responses to exercise of the musculoskeletal, digestive, excretory, nervous and endocrine systems.

3.2 Activities

learnon

3.2 Quick quiz on

3.2 Exercise

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 2, 7, 11	3, 4, 5, 10, 12	6, 8, 9, 13

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. Fill in the blanks, using the following words: alveoli, bronchi, bronchioles, trachea.
   When you breathe in, air moves down your ________then through the ________then through ________to tiny air sacs called ________.
2. Fill in the blanks to complete the sentences.
   The process of cellular respiration requires ________ and glucose, and produces energy in a form that the cell can use and ________ as a waste product.
3. State the word equation for cellular respiration.
4. Identify the molecule that the respiratory system and circulatory system work together to:
   a. supply to your cells
   b. remove from your cells.
5. a. MC Identify the name given to the blood vessel that takes oxygenated blood from the lungs to the left atrium of your heart.

   A. Pulmonary artery B. Pulmonary vein C. Aorta D. Vena cava

   b. MC Identify the name given to the blood vessel that takes deoxygenated blood from the right ventricle of your heart to your lungs.

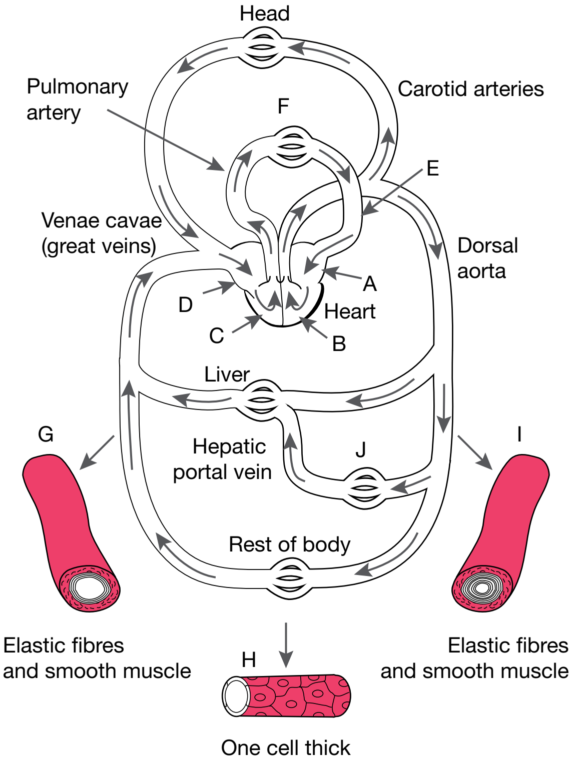
   A. Pulmonary artery B. Pulmonary vein C. Aorta D. Vena cava

6. Place the following sequence in order to show the pathway carbon dioxide travels from your body cells to your lungs:
   - a. Body cell
   - b. Capillary
   - c. Pulmonary artery
   - d. Right atrium
   - e. Right ventricle
   - f. Vena cava
   - g. Venules
   - h. Lungs
   - i. Arterioles
   - j. Capillary
7. a. Identify which of the following statements are true and which are false.
   - i. Oxygen is a product of cellular respiration.
   - ii. Arteries have thicker, more muscular walls than veins.
   - iii. Blood travels to the heart in arteries.
   - iv. Blood in the aorta is oxygenated.
   - v. Deoxygenated blood travels from your heart to your lungs in your pulmonary vein.

   b. Justify any false response.

Apply and analyse

8. Label the lettered parts (A–J) in the figure.



9. **SIS** Construct a flow chart to show how oxygen travels through the body.
10. **SIS** Construct a flow chart to show how deoxygenated blood travels from body cells to the lungs.
11. **SIS** Construct a flow chart to show how carbon dioxide travels from the lungs to be exhaled through the nose.

Evaluate and create

12. Use Venn diagrams to compare:
   - a. the right atrium and left atrium of the heart
   - b. the right ventricle and left ventricle of the heart
   - c. the left atrium and left ventricle of the heart
   - d. oxygenated blood and deoxygenated blood.
13. Use Venn diagrams to compare:
   - a. arteries and veins
   - b. oxygen and carbon dioxide
   - c. the pulmonary artery and pulmonary vein
   - d. the aorta and vena cava.

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

LESSON
3.3 Digestive and excretory systems

LEARNING INTENTION

At the end of this lesson you will understand the importance of the digestive and excretory organs and how they are coordinated as interdependent systems for the health of our bodies.

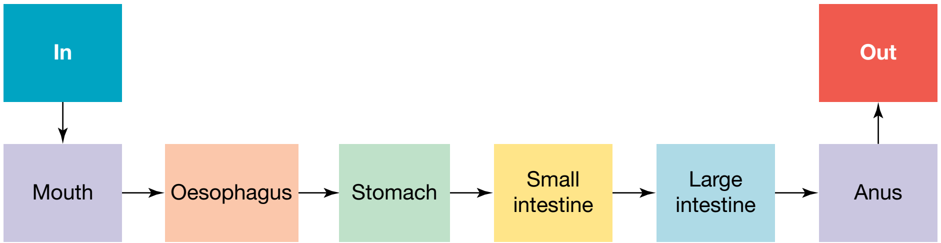
3.3.1 The digestive system — in we go!

The key role of your **digestive system** is to supply your body with the nutrients it requires to function effectively. It breaks down food into smaller particles, which are then absorbed into your tissues and cells. There are two types of digestion:

- **mechanical digestion** — the physical breakdown of food; it begins in the mouth as food is chewed
- **chemical digestion** — when food is broken down further into simpler compounds or nutrients used by cells.

The pathway of the digestive and excretory system is summarised in figure 3.17.

FIGURE 3.17 Flow chart of digestion and excretion



3.3.2 Digestive organs — down we go!

Mouth

The whole process of **digestion** starts with you taking food into your mouth.

- Chemical digestion of some of the carbohydrates begin in your mouth with **enzymes** (such as amylases) in your **saliva**, which are secreted by your **salivary glands**. (You can test this at home — the next time you eat a starchy food, such as pasta, bread, rice or potatoes, chew it, but don't swallow it. As you hold it in your mouth you should notice it starting to taste sweet as amylase in your saliva breaks down large starch molecules into small sugar molecules.)
- Mechanical digestion, uses your teeth to physically break down the food then your tongue rolls the food into a slimy, slippery ball-shape called a **bolus**.

digestive system a complex system of organs and glands that processes food in order to supply your body with the nutrients to cells so they can function effectively

mechanical digestion digestion that uses physical factors such as chewing with the teeth

chemical digestion the chemical reactions changing food into simpler substances that are absorbed into the bloodstream for use in other parts of the body

digestion breakdown of food into a form that can be used by an organism. It includes both mechanical digestion and chemical digestion.

enzymes special chemicals that speed up reactions but are themselves not used up in the reaction

saliva watery substance in the mouth that moistens food before swallowing and contains enzymes involved in the digestion of food

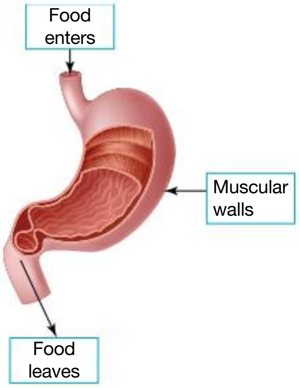
salivary glands glands in the mouth that produce saliva

bolus round, chewed-up ball of food made in the mouth that makes swallowing easier

Oesophagus to stomach

The bolus is then pushed through your **oesophagus** by muscular contractions known as **peristalsis**. From here the bolus is transported to your **stomach,** which secretes acids and enzymes for further digestion and then temporary storage.

FIGURE 3.18 The stomach is a large, hollow muscular organ.



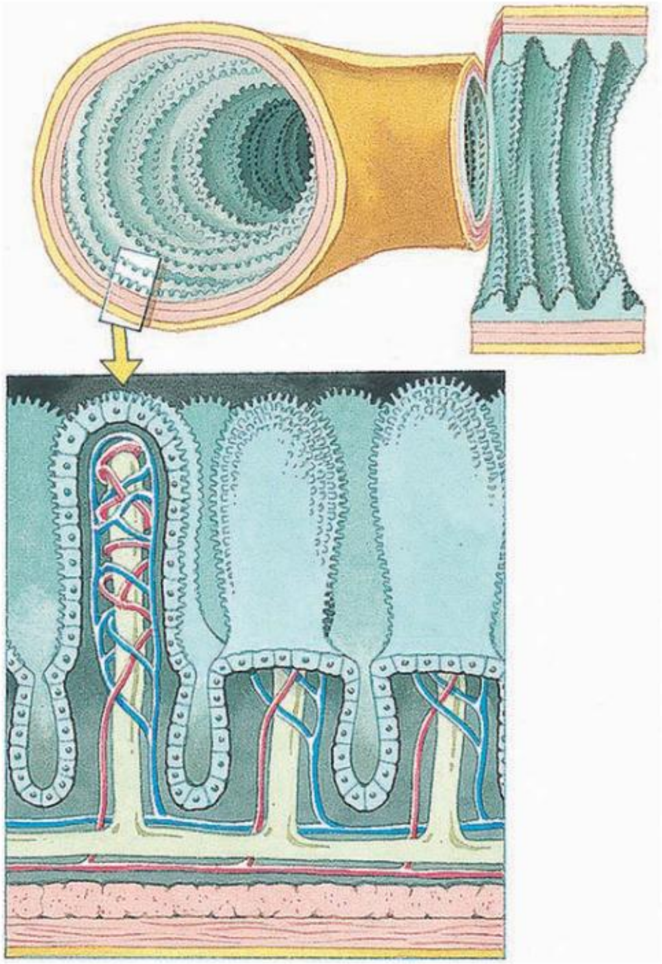
Stomach to small intestine

In your **small intestine**, more enzymes (including amylases, proteases and lipases) turn it into molecules that can be absorbed into your body. The small intestine has three parts: the duodenum, jejunum and ileum.

The **absorption** of these nutrient molecules in the small intestines has the following features:

- It occurs through finger-shaped **villi** in the small intestine (figure 3.19). Villi are shaped like fingers to maximise surface area to increase the efficiency of nutrients being absorbed into the surrounding capillaries.
- The absorption of most nutrients into your body occurs in the jejunum, the middle section of the small intestine.
- Once absorbed into the capillaries (of your circulatory system) these nutrients are transported to cells in the body that need them.
- Undigested material continues to the large intestine where water and **vitamins** may be removed.

FIGURE 3.19 The finger-like villi on the walls of the small intestine give it a large surface area that speeds up nutrient absorption.



oesophagus part of the digestive system composed of a tube connecting the mouth and pharynx with the stomach

peristalsis the process of pushing food along the oesophagus or small intestine by the action of muscles

stomach a large, hollow muscular organ that digests the bolus and secretes acids and enzymes for further digestion and temporary storage

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

vitamins organic nutrients required in small amounts; they include vitamins A, B, C, D and K

SCIENCE AS A HUMAN ENDEAVOUR: Publishing research

In 1984, Professor Barry Marshall and Dr Robin Warren's first major publication of their results into peptic ulcers hit some hurdles. This was because, at the time, there wasn't a great interest in their work, it wasn't seen as important, and they had difficulty convincing clinicians of the condition as it was believed that bacteria did not grow in the stomach. However, with persistence, their article was published in June 1984.

In 2005, their work was validated when they received the Nobel Prize in Physiology or Medicine.

FIGURE 3.20 Peptic ulcers are caused by sores in the stomach and small intestine caused by bacteria.

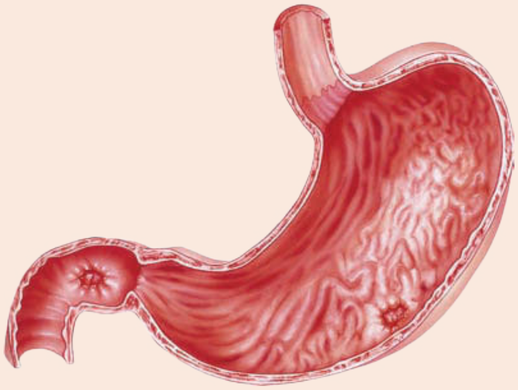
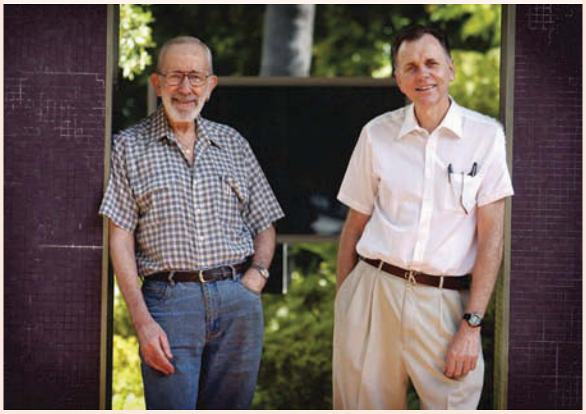


FIGURE 3.21 Dr Barry Marhsall (left) and Dr Robin Warren (right)



To have a paper published in a scientific journal requires a lot of time and can cost money. To determine which papers are published, editors check the language, what the paper is about, scientific accuracy and if the paper meets the editorial guidelines. Once it passes this stage, the editor will pick suitable peer reviewers who have expertise in the area to review the paper.

These reviewers will check the contents of the paper and submit a report to the editor, who will decide if the paper needs revisions, is to be rejected or is ready to publish. This is important to ensure consistent quality so readers understand the findings and can use the information in the paper in their own research.

Large intestine

All 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 accumulate here and add bulk to the undigested food mass.

The **rectum** is the final part of the large intestine and it is where faeces is stored before being excreted through the **anus** as waste.

colon the part of the large intestine where a food mass passes from the small intestine, and where water and other remaining essential nutrients are absorbed into your 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

rectum the final section of the digestive system, where waste food matter is stored as faeces before being excreted through the anus

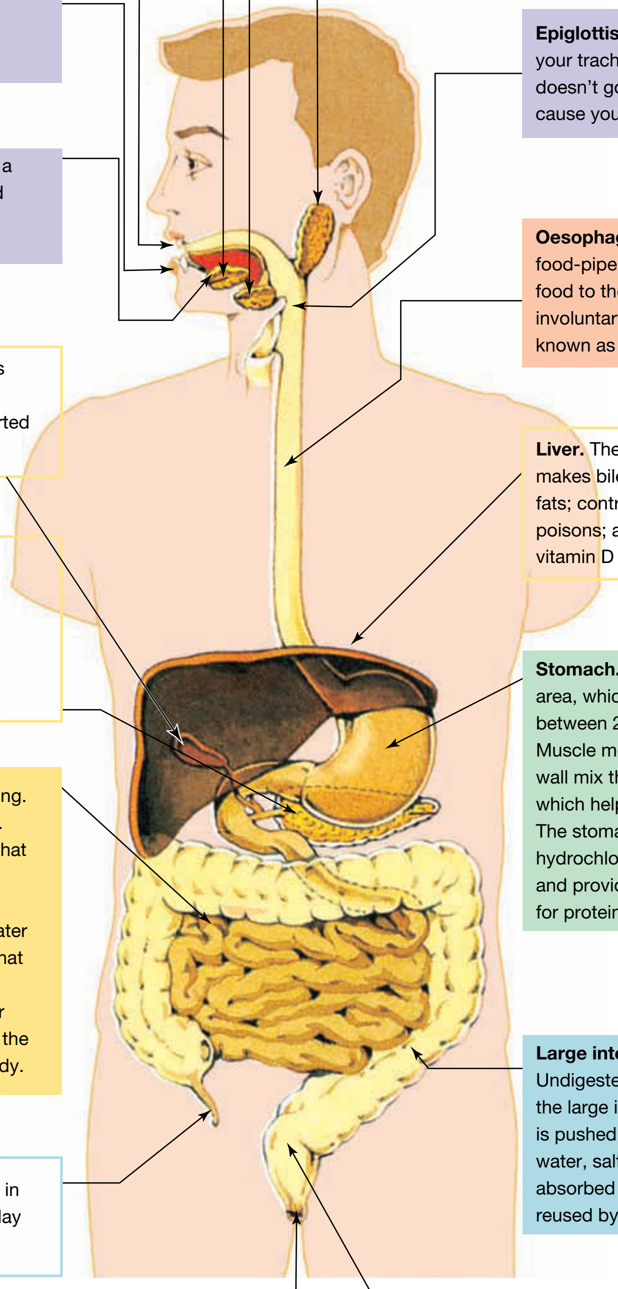
anus the final part of the digestive system, through which faeces are passed as waste

ewbk-12100

eles-2643

int-3398

FIGURE 3.22 The digestive system consists of many organs that work together to supply your body with the nutrients it requires.



Teeth. Used to bite and chew your food to break it down into smaller pieces.

Mouth. Food and saliva are mixed; teeth mechanically break food into smaller pieces.

Tongue. Involved in rolling food into a round ball (bolus) that is then pushed to the back of your mouth to be swallowed.

Gall bladder. Bile made in the liver is stored here; bile breaks up fats into droplets small enough to be transported to the rest of the body.

Pancreas. Makes pancreatic juice, which is alkaline (base dissolved in water) so it neutralises the stomach acid. Enzymes that break down proteins, fats and carbohydrates are also made here.

Small intestine. A tube about 6 m long. Food moves through it by peristalsis. The small intestine makes enzymes that complete the digestion process. The cells in the wall of the small intestine release over 5 litres of mucus and water each day. It is in the small intestine that nutrients from now almost totally digested food are absorbed into your bloodstream. The blood then carries the nutrients to all of the cells of your body.

Appendix. Plays no part in digestion in humans. However, it is believed to play a role in fighting some diseases.

Anus. The faeces pass through here when you go to the toilet.

Salivary glands. Make about 1.5 litres of saliva each day. Saliva contains enzymes that begin breaking down starch in food.

Epiglottis. A flap of tissue closes off your trachea (windpipe) so that food doesn't go down to your lungs and cause you to choke.

Oesophagus. Also known as the food-pipe or gullet. It carries the food to the stomach, using involuntary muscular contractions known as peristalsis.

Liver. The largest internal organ. It makes bile, which breaks down fats; controls blood sugar; destroys poisons; and stores vitamin A, vitamin D and iron.

Stomach. A temporary food storage area, which can expand to hold between 2 and 4 litres of food. Muscle movements in the stomach wall mix the food with gastric juice, which helps to break down proteins. The stomach also contains dilute hydrochloric acid, which kills germs and provides a suitable environment for protein digestion.

Large intestine (colon). Undigested material passes into the large intestine. As the material is pushed through it by peristalsis, water, salts, and vitamins are absorbed so that they can be reused by the body.

Rectum. The final part of the large intestine. This is where the faeces are stored.

Accessory digestive organs

Figure 3.22 shows all organs connected to form the digestive system. Other important organs involved in digestion are:

- **pancreas** — produces hormones such as insulin and glucagon which regulate the level of glucose in the blood. It also produces enzymes such as **lipases**, **amylases** and **proteases** (which break down lipids, carbohydrates and proteins respectively); these enzymes go into the small intestine to further chemically digest food materials (figures 3.23 and figure 3.25)
- **liver** — the largest internal organ with many functions; in digestion it produces bile that emulsifies lipids such as fats and oils so they can be broken down by lipases, and it plays a large role in the excretory system (see figure 3.24).
- **gall bladder** — where **bile** is stored before it is released into the small intestine.

FIGURE 3.23 The pancreas produces enzymes for digestion, and the gall bladder stores bile that emulsifies lipids.

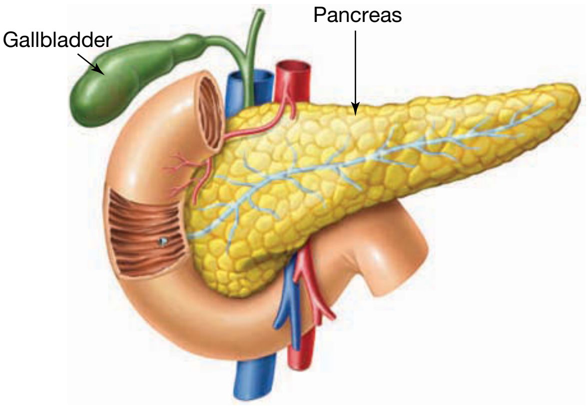


FIGURE 3.24 The liver is a large organ that is like a chemical factory and very important for the body. It is part of both the digestive and excretory system.

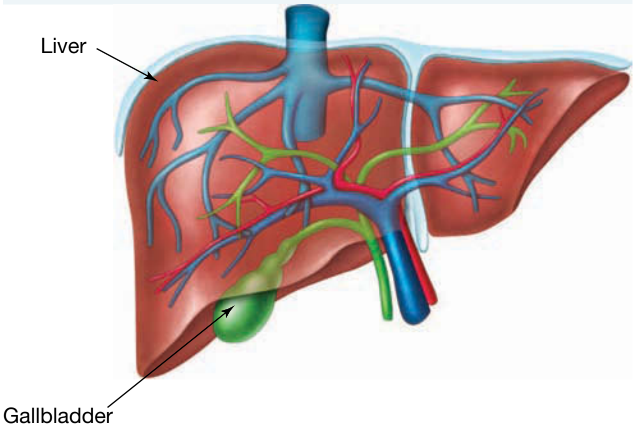
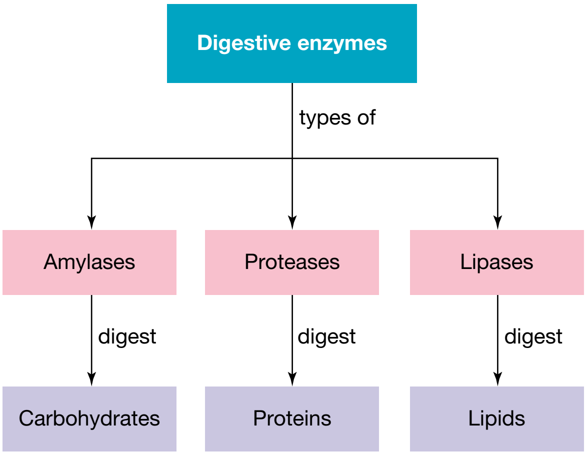


FIGURE 3.25 Different enzymes digest different types of nutrients.

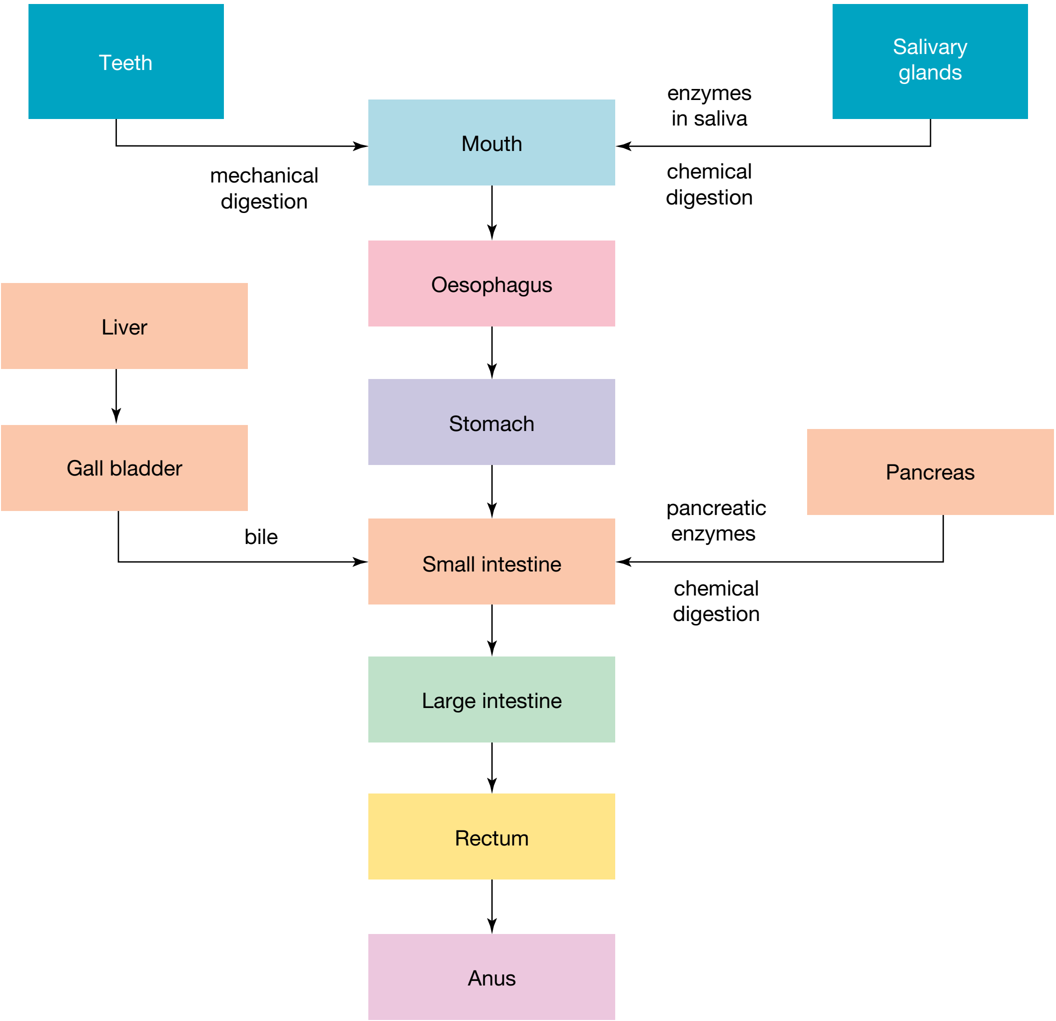


ACTIVITY: How does bile work?

To understand how bile breaks down lipids add 150 mL of water to a beaker, along with 20 mL of oil and record your observations. Then add a tablespoon of detergent, give it a gentle stir and record your observations.

pancreas	a large gland in the body that produces and secretes hormones such as insulin and glucagon and an important digestive fluid containing enzymes
lipases	enzymes that break fats and oils down into fatty acids and glycerol
amylases	enzymes in saliva that break down starch into sugar
proteases	enzymes that break proteins down into amino acids
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.
gall bladder	a small organ that stores and concentrates bile within the body
bile	a fluid made by the liver and stored in the gall bladder; it emulsifies fats to increase surface area for fat digestion

FIGURE 3.26 Digestion occurs within your digestive system in a systematic and organised manner.



on Resources

eWorkbook The digestive system (ewbk-2087)

3.3.3 The excretory system — out we go!

Your **excretory system** removes the waste products from a variety of necessary chemical reactions. It helps maintain the proper amount of water, nutrients and salts needed by the body. The main organs involved in human excretion are:

- **skin** — excretes salts and water as sweat
- **kidneys** — involved in excreting the unused waste products of chemical reactions (for example, urea) and any other chemicals that may be in excess (including water) so that a balance within our blood is maintained
- liver — involved in breaking down toxins for excretion
- lungs — excrete carbon dioxide (produced by cellular respiration) when you breathe out.

excretory system the body system that removes waste substances from the body

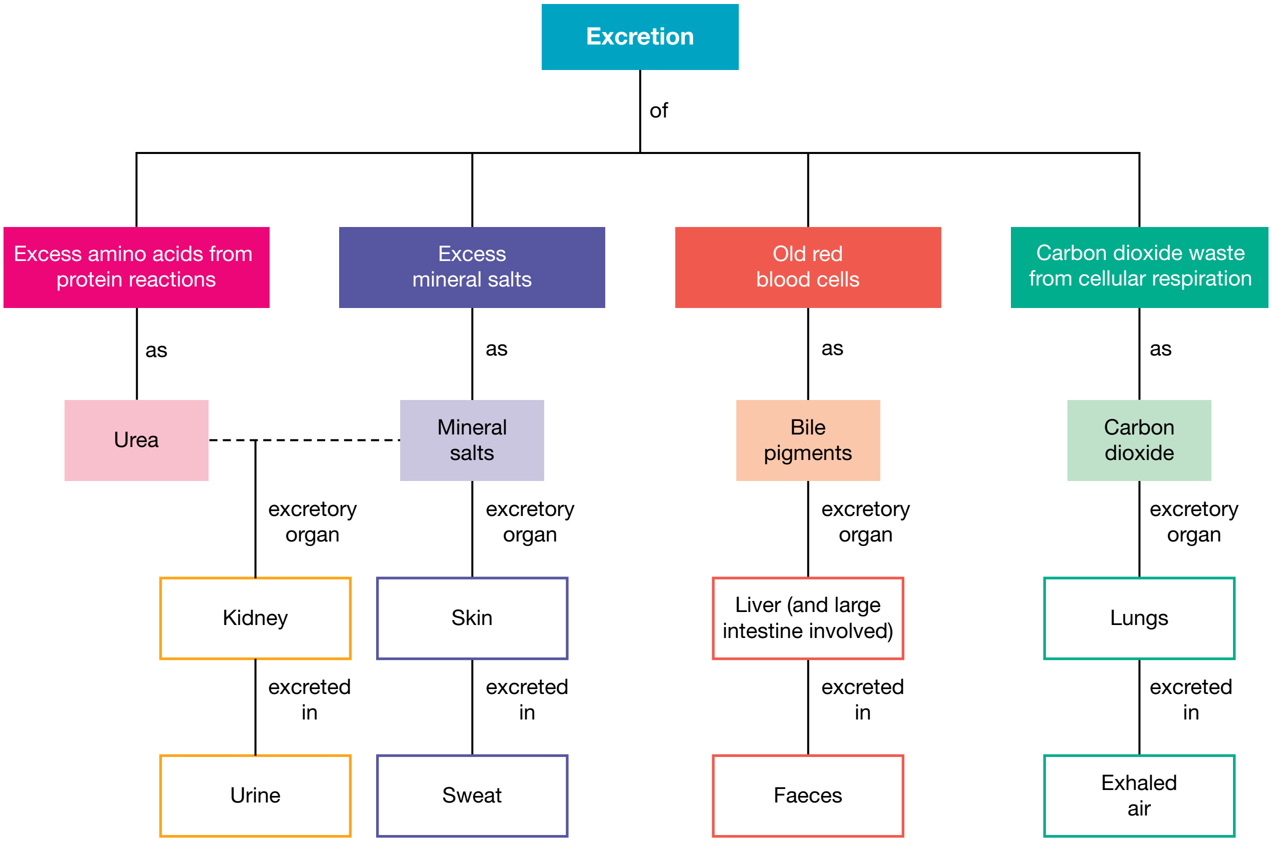
skin external covering of an animal body

kidneys body organs that filter the blood, removing urea and other wastes

Liver

Over a litre of blood passes through your liver each minute. Your liver is like a chemical factory, with more than 500 different functions. We have seen that it 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 3.27 Flow chart showing your excretory organs and the wastes they excrete.



Kidneys

Your kidneys play an important 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**.
- Nephrons are tiny structures that filter your blood, removing waste products and chemicals that may be in excess.
- Chemicals that are needed by your body are reabsorbed into capillaries surrounding them.
- The fluid remaining in your nephrons at the end of its journey then travels through to your **bladder** via your **ureters** for temporary storage until it is released as **urine**.

nephrons the filtration and excretory units of the kidney

bladder sac that stores urine

ureters tubes from each kidney that carry urine to the bladder

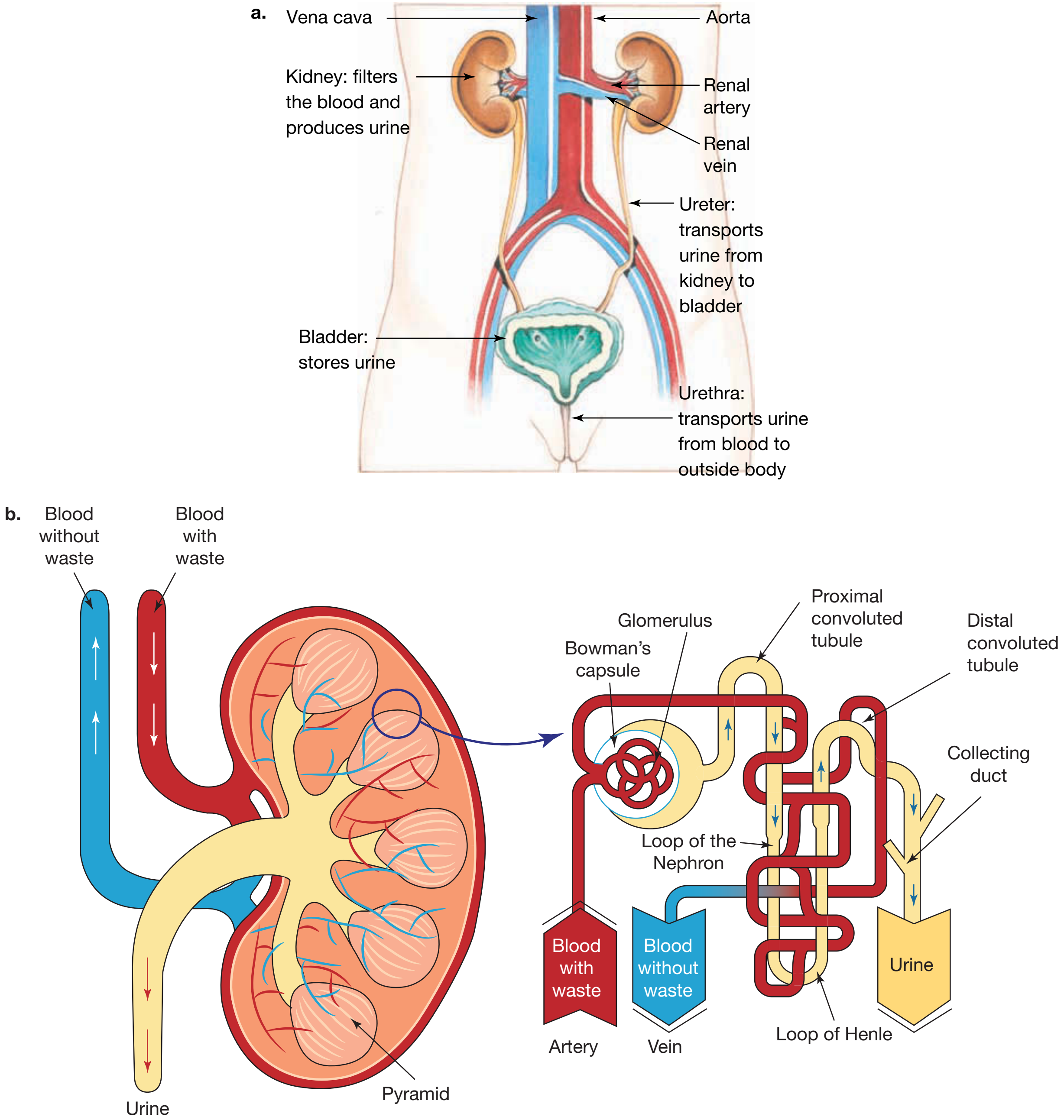
urine yellowish liquid, produced in the kidneys. It is mostly water and contains waste products from the blood such as urea, ammonia and uric acid.

ewbk-12803

eles-2644

int-8234

FIGURE 3.28 a. Your kidneys have an important role in the excretion of wastes from your body. **b.** Diagram of a nephron — each of your kidneys is made up of about a million nephrons.



3.3.4 Blood and urine

Both blood and urine are mostly made up of water. Water is very important because it assists in the transport of nutrients within and between the cells of the body. It also helps the kidneys do their job because it dilutes toxic substances and absorbs waste products so they may be transported out of the body.

The concentration of substances in the blood is influenced by the amount of water in it. If you drink a lot of water, more will be absorbed from your large intestine, and the 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.

3.3.5 Blood and carbon dioxide

Lungs

As described in section 3.2.3, your lungs remove carbon dioxide from your body through your respiratory system. Did you know that your body is more sensitive to changes in levels of carbon dioxide than oxygen? If there is too much carbon dioxide in your body, it dissolves in the liquid part of blood and forms an acid. The resulting acidic blood can affect the functioning of your body.

The amount of carbon dioxide in your blood influences your breathing rate. The level of carbon dioxide in the blood is detected by **receptors** in the walls of some arteries and in the brain. If the levels of carbon dioxide in your blood increase, your breathing rate will be increased so that carbon dioxide can be exhaled from your lungs and passed out of your body.

If you were to climb high up a mountain, you would need time for your body to adjust. Initially you would feel tired and out of breath because you would be restricted by the limited amount of oxygen available to your cells. Your breathing and heart rate would increase in an effort to get more oxygen around your body. In time, your body would begin to produce more red blood cells and hence more haemoglobin. After this, your breathing and heart rate would return to normal.

DISCUSSION

The amount of oxygen carried by haemoglobin varies with altitude. At sea level, about 100 per cent of haemoglobin combines with oxygen. However at an altitude of about 13 000 metres above sea level, only about 50–60 per cent of the haemoglobin combines with oxygen. This is why mountain climbers sometimes find it difficult to breathe during a climb. What would you suggest they could do to prepare themselves before they begin their climb?

Extension: Why do some athletes train for events in the mountainous regions?

FIGURE 3.29 Climbers on very high mountains, such as Mount Everest, may need to use oxygen stored in tanks.

Resources

eWorkbook Removing waste from the blood (ewbk-2089)

3.3.6 Systems working together to provide your cells with energy

We know that cells need energy. Glucose is an example of a nutrient that may be released from digested food. It is absorbed in your small intestine and then taken by the capillaries to cells for use in **cellular respiration**. As we saw in the respiratory system (section 3.2.2), glucose is combined with oxygen, and is then broken down into carbon dioxide (a waste product that needs to be removed from the cell) and water. During this reaction, energy in the form of ATP (adenosine triphosphate) is also released. ATP provides the cells with the energy needed to perform many of its activities and is essential to life.

receptors special cells that detect energy and convert it to electrical energy that is sent to the brain.

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

Cellular respiration:

$$\text{Glucose} + \text{oxygen} \rightarrow \text{carbon dioxide} + \text{water} + \text{energy (ATP)}$$

This is an example of systems working together. Glucose is supplied via the digestive system and oxygen is supplied via the respiratory system. The circulatory system transports nutrients (such as glucose) and oxygen to your cells and removes wastes (such as carbon dioxide) from your cells. These wastes are then removed from your body by your excretory systems. Without a supply of glucose and oxygen, cellular respiration could not occur. Without removal of wastes, your cells may die. If your systems did not work together like they do, you would not be able to stay alive.

3.3.7 Balancing blood glucose

Your cells need glucose to use in the process of cellular respiration to make **ATP** (adenosine triphosphate) molecules. ATP is used by cells in reactions that require energy. This glucose is obtained from the food that you eat. Glucose molecules are transported in blood in your circulatory system to cells throughout your body.

If you have high levels of glucose in your blood:

- Special cells in your pancreas detect this and release **insulin** into your bloodstream.
- Target cells in your muscles and liver receive this chemical message and glucose is taken out of the blood and converted into the storage polysaccharide **glycogen**.

If the levels of blood glucose are too low:

- Another hormone, **glucagon**, is released by the pancreas.
- Glucagon triggers the breaking down of glycogen into the monosaccharide glucose. This is how the glucose levels in the blood can be kept within a narrow range.

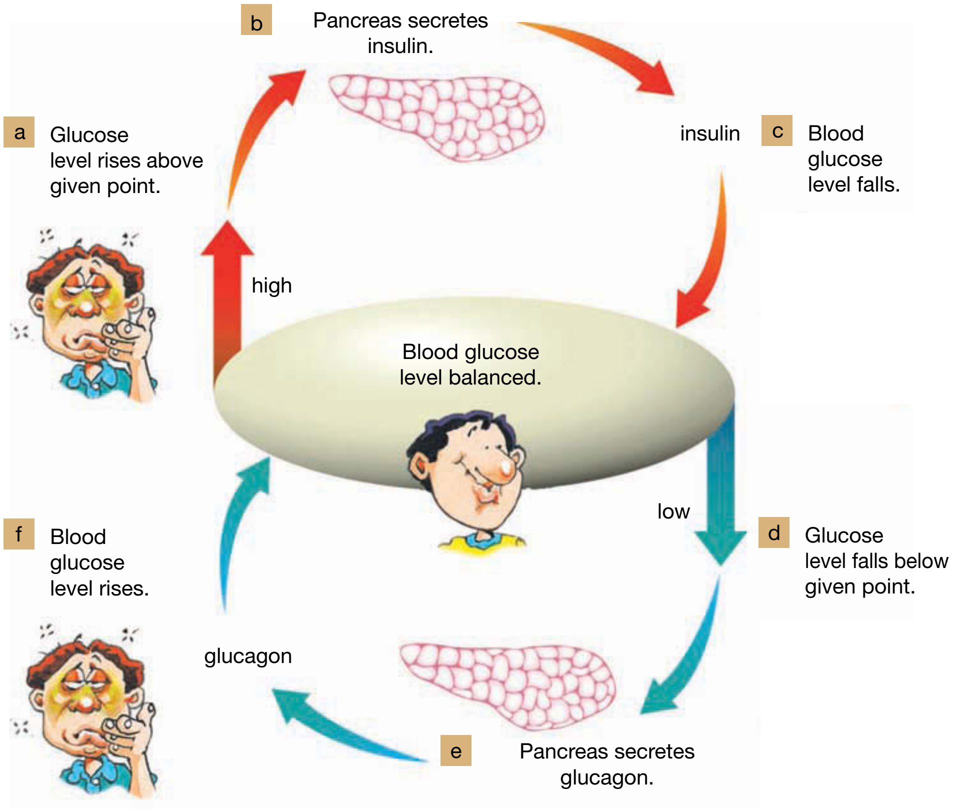
ATP molecule used by cells in chemical reactions that require energy. ATP is a product of cellular respiration.

insulin hormone that removes glucose from the blood and stores it as glycogen in the liver and muscles

glycogen the main storage carbohydrate in animals, converted from glucose by the liver and stored in the liver and muscle tissue

glucagon a hormone, produced by the pancreas, that increases blood glucose levels

FIGURE 3.30 The hormones insulin and glucagon are secreted by the pancreas to control glucose levels in your blood. This is an example of negative feedback.



CASE STUDY: Diabetes

Diabetes mellitus is an endocrine disorder. Features of diabetes include the following:

- It is caused by a deficiency of insulin or a loss of response to insulin in target cells (such as those in liver and muscle tissue).
- Deficiency or loss of response to insulin results in high blood glucose levels.
- Glucose levels can become so high that it is excreted by the kidneys and hence found in urine. Glucose in urine is one of the tests that are indicative of diabetes.
- The higher the glucose levels, the more water will be excreted with it. This results in the loss of large volumes of urine, which leads to persistent thirst; this is one of the warning signs for diabetes mellitus.

FIGURE 3.31 People with diabetes may need to inject insulin to control their blood glucose levels.

There are two main types of diabetes.

1. **Type 1 diabetes mellitus** usually starts in childhood and is an autoimmune disorder. In this case, the immune system mounts an attack against cells in the pancreas, destroying their ability to produce insulin. This type of diabetes requires treatment with insulin injections.
2. **Type 2 diabetes mellitus** usually starts later in life and is the most common form. It is characterised by either a deficiency of insulin or target cells that do not respond effectively to insulin. Type 2 diabetes has been linked to hereditary factors and obesity. It is usually controlled through exercise and diet.

Insulin was developed because it was understood that type 1 diabetes destroyed islets (cells in the pancreas) that were responsible for producing insulin, leading to a negative feedback loop that saw blood glucose levels become high. This understanding led to researching ways to extract insulin from the pancreas without it being destroyed or damaged in the process. In the 1920s, the extraction and testing of insulin had begun, and the first successful human trial saw a 14-year-old boy with high blood sugar levels drop within 24 hours of receiving an injection of insulin.

Since then, advances in technology have seen the development of insulin pens and insulin pumps to make it easier for people with type 1 diabetes to manage their condition.

CASE STUDY: How penguins survive the winter

When food supplies are scarce, or during hibernation, an animal's ability to store energy reserves greatly assists its chances of survival. Penguins, for example, use their fat reserves to provide them with energy when required. Male emperor penguins are able to keep eggs warm for nine weeks at a time without any food. Animals that live in cold regions also use their fat storage ability to insulate themselves against the very cold weather conditions. Whales and seals have a thick layer of fat cells called blubber, which serves as an insulation layer in their cold, watery habitats.

3.3.8 Fats, feasts and famines

Fats are particularly high in energy, providing about twice as much energy as the equivalent amount of carbohydrate or protein.

When more kilojoules of energy are consumed than required, the body tends to store the excess energy in the liver and muscle cells as glycogen. If glycogen stores are full and the energy intake still exceeds that required, the excess may be stored as fat in the form of fat cells just beneath the skin.

When extra energy is required, the liver glycogen is used first, then the muscle glycogen and finally the fat. Most people have enough fat cells stored to provide energy for 3–7 weeks. The human body tends to hoard fat, immediately storing fat molecules obtained from food.

diabetes mellitus a medical condition in which the liver cannot effectively convert glucose to glycogen

Type 1 diabetes mellitus a disease in which the pancreas stops producing insulin, so the body's cells cannot turn glucose into energy

Type 2 diabetes mellitus the most common form of diabetes, where the pancreas makes some insulin but does not produce enough

fats organic substances that are solid at room temperature and are made up of carbon, hydrogen and oxygen atoms

Most people should consume about 30–40 g of fat a day.

The amount of fat in your diet can have a more direct effect on weight gain than carbohydrates. Although fat hoarding can have a negative effect on our health today, it may have increased the chances of survival of your hunting and gathering ancestors. Recent discoveries suggest that the regulation of fat storage may be controlled by a hormone called leptin and several genes inherited from your parents.

elog-2213

tlvd-10799

INVESTIGATION 3.2

Measuring the energy in food

Aim

To compare the amounts of energy stored in a range of foods

Materials

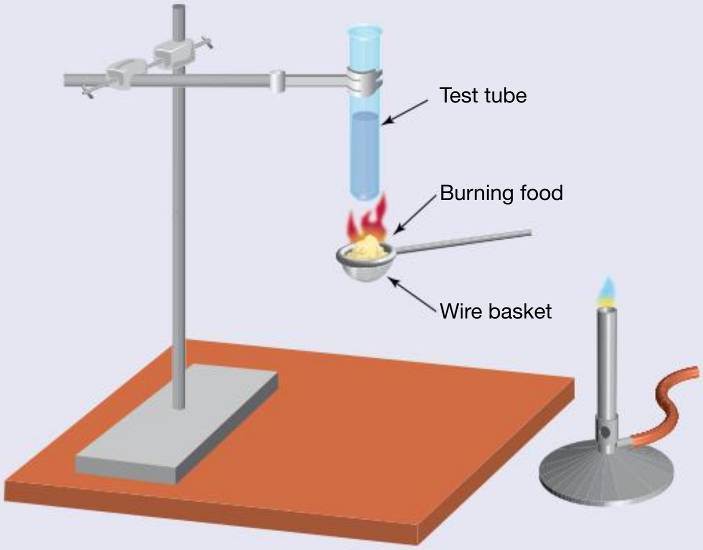
- small metal basket (used to fry food)
- samples of small biscuits, potato chips, uncooked pasta, crouton or small piece of toast
- safety glasses
- thermometer
- retort stand, bosshead and clamp
- large test tube
- Bunsen burner
- measuring cylinder
- water
- electronic balance

CAUTION

Before starting this experiment, read all the steps below and make a list of the risks associated with this activity and how you plan to minimise these risks. Avoid using biscuits with nuts at school due to allergies.

Method

1. Use the clamp to attach the test tube to the retort stand.
2. Measure 30 mL of water and pour it into the test tube.
3. Measure the temperature of the water.
4. Weigh the biscuit.
5. Place the small biscuit in the wire basket and set fire to it using the Bunsen burner. When the biscuit is alight, put the basket containing the biscuit underneath the test tube. The heat released from the burning biscuit will heat the water. Hold the basket under the test tube until the biscuit is completely burned. You can tell that the biscuit is completely burned if it is all black and will not re-ignite in the Bunsen burner flame.
6. Measure the temperature of the water again.



7. Repeat the steps above using the other food samples.

Results

1. Use the table to record your results

TABLE Results of investigation

Measurement	Biscuit	Chip	Pasta	Crouton/toast
a. Mass of food (g)				
b. Volume of water (mL)				
c. Initial temperature of water (°C)				
d. Final temperature of water (°C)				
e. Increase in temperature (= $d - c$)				
f. Energy in food (J) (= $4.2 \times 30 \times e$)				
g. Energy in food (kJ) (= $f \div 1000$)				
h. Energy per gram of food (kJ/g) (= $g \div a$)				

2. Calculate the amount of energy that was stored in the biscuit, using the following equation.

$$\text{Energy (in joules)} = 4.2 \times \text{volume of water (in mL)} \times \text{increase in temperature (in °C)}$$

3. Calculate the amount of energy per gram of food by dividing the amount of energy by the mass of the food in grams.

Discussion

1. Why was it necessary to calculate the amount of energy per gram of food?
2. Did all the heat from the burning food go into heating the water? Explain how this might have affected the validity of this experiment.

Conclusion

Write a conclusion to your experiment, referring back to your aim.

3.3.9 How much sugar?

To calculate how much sugar is in a can or bottle of drink you must first find the nutrition information section on the label. A typical non-diet soft drink might contain 11.04 grams in 100 mL.

To calculate the mass of sugar in one 375 mL can of drink, use the formula below:

$$\text{Mass of sugar} = \frac{11.04 \times \text{volume}}{100}$$

$$\text{So, mass of sugar} = \frac{11.04 \times 375}{100} = 41.4\text{g}$$

Since one teaspoon of sugar has a mass of approximately 4 grams, divide the mass of sugar in one can of drink by 4.

Therefore, one can of soft drink might contain more than 10 teaspoons of sugar.

$$\frac{41.4}{4} = 10.35 \text{ teaspoons}$$

FIGURE 3.32 Sugar content of some common drinks

DISCUSSION

Imagine being told ‘No treats for you! You will have spinach, capsicum and tomato on wholegrain bread and no butter!’ Who tells you what to eat? Should you listen? Do others really care what you put into your mouth?

In 2006, the Victorian government decided to address the types of food that are available to school students. One of the reasons for this was the growing concern about the number of obese children in the state. Soft drinks containing sugar were the first to be on their no-go list. Do you think the government has the right to make such a decision? What is your opinion on this issue?

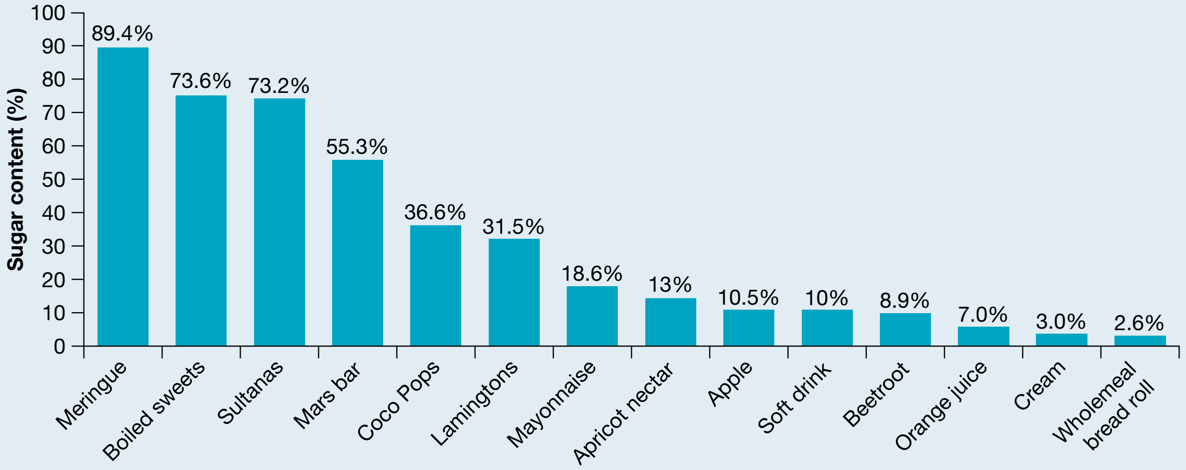
What other lifestyle habits should the government be involved in? How should they approach this? Provide reasons why you think they should be involved.

ACTIVITY: Fizz and tell

The aim of this activity is to increase awareness of the amount of sugar in soft drinks and other common foods. In this activity you will calculate the amount of sugar consumed in a week in your class, and you will analyse data.

1. Survey the class to find out:
   a. how much soft drink (or other sugary food) they consume in a week (in millilitres)
   b. which types of soft drinks are consumed.
2. Present your results in a format that can be shared with others.
3. Comment on your results. Were they what you expected or were you surprised? Were there patterns? What other sorts of information would you like to know to further analyse the data?
4. Comment on whether your data support the following statement: 'Almost 80 per cent of teenagers consume soft drinks weekly, with 10 per cent drinking more than one litre per day.'

FIGURE 3.33 Sugar content of some common foods



EXTENSION: More fizz and tell

This activity aims to extend your analysis of the amount of sugar consumed in a week. Here you will critically evaluate the relationship, if any, between soft drink consumption and teenage obesity.

Consider the following statement:

'Sugar-loaded soft drinks should be banned from all Australian schools to reduce teenage obesity.'

1. Construct a PMI chart on the statement.
2. Do you agree with this statement?
3. In the classroom, construct a human graph to show people's opinions on the statement. Stand in positions to indicate your feelings about the statement. For example:
   - Strongly disagree (0) — stand next to the left-hand wall.
   - Agree (2) — stand in the centre of the room.
   - Strongly agree (4) — stand next to the right-hand wall.
4. Have a discussion with students standing near you to find out the reasons for their opinion.
5. Listen to the discussions of students in other positions.
6. Construct a SWOT diagram to summarise what you have found out.
7. Record the results of the human graph.
8. a. What was the most popular attitude? Suggest a reason for this.
   b. What was the least popular attitude? Suggest a reason for this.
   c. Do you think this attitude pattern is representative of other Australians your age? Explain.
9. On the basis of your discussions, have you changed your attitude since the start of this activity? If so, how is it different and why?

3.3 Activities

learnon

3.3 Quick quiz on

3.3 Exercise

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 2, 3, 4, 10, 14, 16, 22	5, 6, 7, 11, 13, 15, 17, 19, 23, 25	8, 9, 12, 18, 20, 21, 24

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. Fill in the blanks to complete the sentence. Digestion involves the breaking down of food so that the __________ it contains can be absorbed into your __________and carried to ____________ in your _____________.
2. Place the following organs in the correct order.
   A. Anus
   B. Large intestine
   C. Mouth
   D. Oesophagus
   E. Small Intestine
   F. Stomach
3. MC Identify the name given to the slimy, slippery ball-shape your tongue rolls food into.
   A. Bile
   B. Bolus
   C. Peristalsis
   D. Villi
4. MC Identify the name given to the muscular contractions that push food through the oesophagus to the stomach.
   A. Bile
   B. Bolus
   C. Peristalsis
   D. Villi
5. MC In which part of the digestive system does most of the absorption of nutrients occur?
   A. Large intestine
   B. Mouth
   C. Small intestine
   D. Stomach
6. Match the organs of the digestive system with their function.

Organ	Function
a. Gall bladder	A. Stores faeces
b. Large intestine	B. Makes enzymes used in the small intestine
c. Liver	C. Temporary storage of food and where protein digestion begins
d. Oesophagus	D. Where the breakdown of starch and protein is finished and fat breakdown occurs
e. Pancreas	E. Tube that takes food to the stomach
f. Rectum	F. Stores undigested food and waste and absorbs water
g. Small intestine	G. Stores bile until needed by the small intestine
h. Stomach	H. Makes bile, stores glycogen and breaks down toxins

7. Match the organs of the excretory system with their function.

Organ	Function
a. Bladder	**A.** Watery fluid produced by kidneys that contains unwanted substances
b. Kidney	**B.** When urine moves from the bladder, through the urethra and out of the body
c. Ureter	**C.** Transports urine from bladder to outside body
d. Urethra	**D.** Filters the blood and produces urine
e. Urination	**E.** Stores urine
f. Urine	**F.** Transports urine from kidneys to bladder

8. Identify examples of types of enzymes involved in the digestion of:
   - **a.** carbohydrates
   - **b.** proteins
   - **c.** lipids.
9. Explain why the villi in the small intestine are the shape that they are.
10. Identify the part of the digestive system in which water is absorbed into your body.
11. Is cellulose digested? What happens to it?
12. **a.** Define the term *excretion*.
    - **b.** List examples of organs that are involved in human excretion.
13. Name the unit in which energy is often measured.
14. Explain why your cells need glucose.
15. Outline two ways in which fat storage assists the survival of animals.

Apply and analyse

16. Describe what happens when you drink a lot of water.
17. Suggest reasons why you can't live without your liver.
18. Identify the name given to the:
    - **a.** tiny structures that make up the kidney
    - **b.** fluid that travels from your kidneys to your bladder for excretion.
19. Construct flow charts to show the route travelled:
    - **a.** by nutrients (for example, glucose) as they are absorbed into your body
    - **b.** by undigested food material travelling from your mouth to your anus.
    - **c.** by water in the renal artery, through the nephron to the urethra.
20. Is your body more sensitive to changes in carbon dioxide or oxygen levels? Explain.
21. Compare and contrast:
    - **a.** Type 1 diabetes and Type 2 diabetes
    - **b.** carbohydrate storage and fat storage.

Evaluate and create

22. Use Venn diagrams to compare:
    - **a.** the digestive system and excretory system
    - **b.** the small intestine and large intestine
    - **c.** ingestion and egestion
    - **d.** proteases and lipases
    - **e.** cellulose and glucose
    - **f.** bile and enzymes
    - **g.** ureter and urethra
    - **h.** nephron and villi
    - **i.** the digestive system and respiratory system
    - **j.** the excretory system and circulatory system.

23. **SIS** Use the table and the other information in this lesson to answer the following questions.
   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?

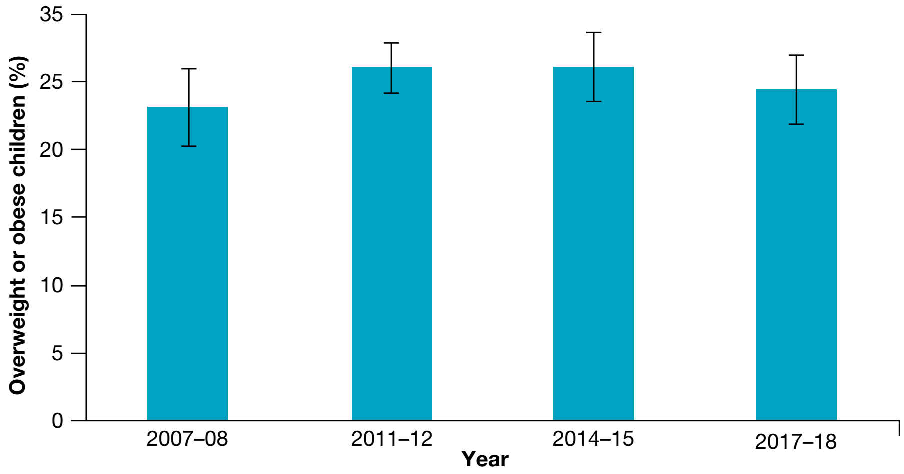
TABLE Substances in blood and urine as a percentage of total

	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

24. **SIS** An investigation is being conducted to explore how the function of the circulatory and excretory systems change during exercise.
   a. Write a suitable aim for this investigation.
   b. Identify the hypothesis for this investigation.
   c. Describe one piece of numerical (quantitative) data and one piece of visual (qualitative) data that can be collected.
   d. Explain two factors that may lead to differences in results between different students.
   e. Write a clear methodology for this investigation, with an explanation of how you will collect results.
   f. Which other body systems are needed to maintain a healthy body during exercise?

25. **SIS**

Overweight or obese children aged 5–14, 2007–08 to 2017–18



   a. In 2017–2018 what percentage of children in Australia were overweight or obese?
   b. Describe the trends in the incidence of childhood obesity in Australia from 2007–2008 to 2017–2018. Were any of the changes statistically significant? (*Hint*: Look at the error bars on the graph provided.)
   c. Based on the information given and your own knowledge, what are the advantages of maintaining a healthy weight?

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

LESSON
3.4 Thinking tools — Priority grids and matrices

3.4.1 Tell me

What is a priority grid?

A priority grid can help you prioritise or rank ideas, choices or activities in order. It can help you make decisions by showing the positives and negatives or how important each of the various ideas, choices or activities are, compared to how difficult or easy they are to finish. It can help you work out the best option to follow and why. It can also allow you to compare your views and judgements with others.

A priority grid is divided vertically and horizontally, which divides the grid into quarters.

- The vertical is used to rate the task. This could be, for example, whether it is a good result or a bad result, or if it is important or not important.
- The horizontal is used to rate whether it is difficult or easy to finish, or if the task is urgent or not urgent.

This allows the tasks to be ranked in order of priority.

A priority grid is also called a priorities grid or a decision grid.

What is a matrix?

A matrix also shows the positives and negatives of a topic. But it is used to compare topics or activities. It does not rank them as easy or difficult. It is used to compare features of different topics or activities.

FIGURE 3.34 Priority grid

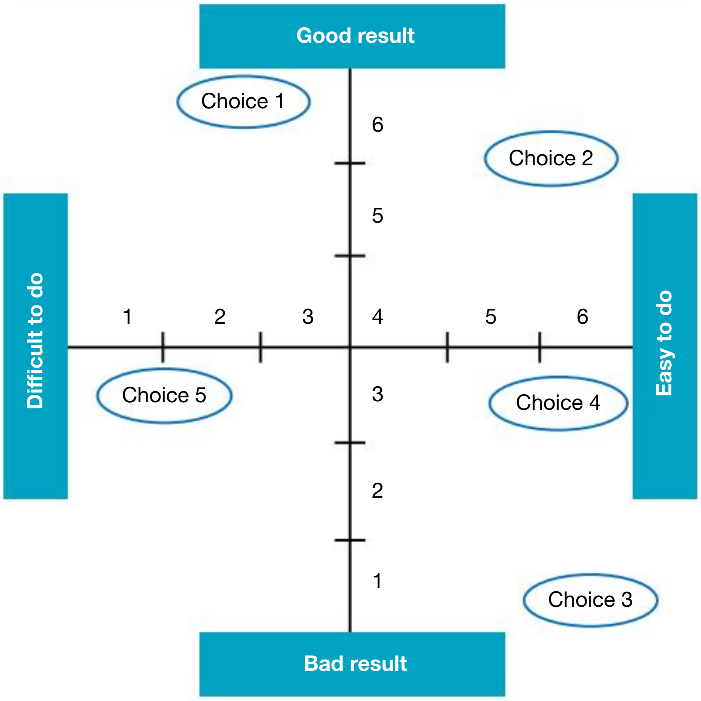


FIGURE 3.35 Matrix

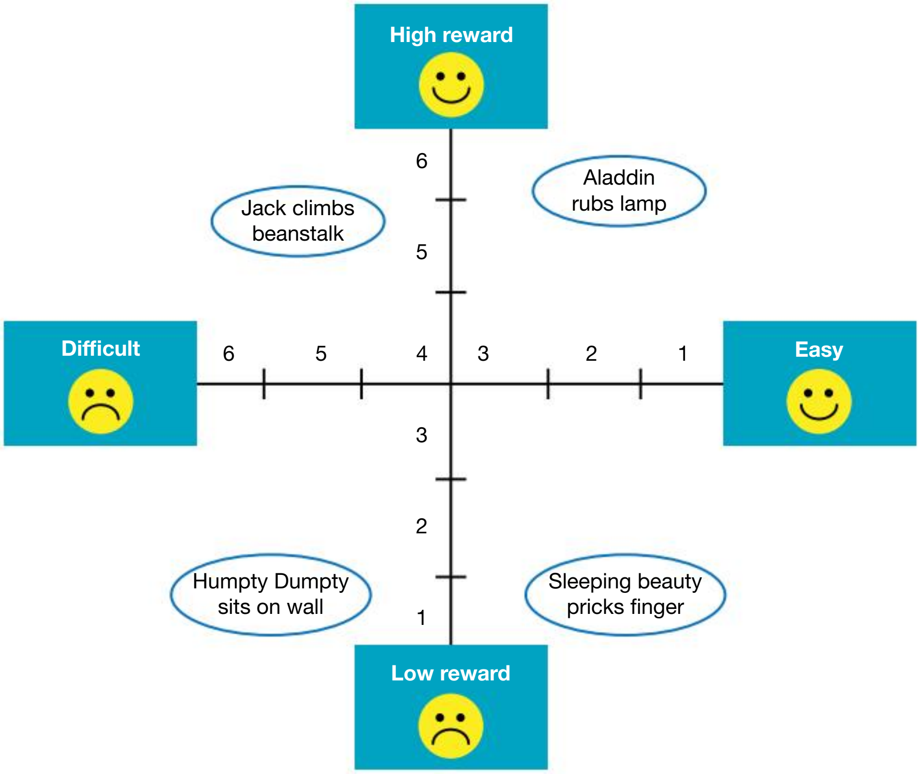
Topic	Feature A	Feature B	Feature C	Feature D	Feature E
1	✓		✓	✓	✓
2		✓			✓
3		✓		✓	✓

3.4.2 Show me

How to create a priority grid.

1. Draw two continuums that cross through each other at right angles.
2. Divide each line into six equal parts.
3. Put a label like ‘difficult’ on the left end of the horizontal line and ‘easy’ on the right.
4. Put a label like ‘high reward’ at the top of the vertical lines and ‘low reward’ at the bottom.
5. Think of an activity and assess it using these two lines, placing a mark where you think it fits best.
6. Compare and discuss your marked positions with those of others in your class. Share your ideas, values, views and judgements, and listen to those of others.

FIGURE 3.36 Priority grid of nursery rhymes



7. After your discussions and reflections, write your final positions directly onto the grid. You might use a priority grid to compare the outcome of different nursery rhymes.

3.4.3 Let me do it

3.4 Activity

1. **a.** Use a priority grid to evaluate some of the foods shown in figure 3.37.
   b. Describe the criteria that you used to make your decisions.
   c. In a team, brainstorm criteria that could be used to assist you in placing other foods on a priority grid. As a team, agree on your criteria.
   d. Construct a matrix with the agreed criteria in the first column and a variety of foods across the top row.
   e. Score each of the foods using your criteria, entering your results in the table.
   f. Use the data in your matrix to help you place these foods on a second priority grid.
   g. If you have any areas on the priority grid empty, suggest foods that may fit there. Share your reasoning with your team.
   h. Share and discuss your team grid with those of other classmates.

FIGURE 3.37 Different types of food

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

LESSON
3.5 Review

Hey students! Now that it's time to revise this topic, go online to:

Review your results

Watch teacher-led videos

Practise questions with immediate feedback

Find all this and MORE in jacPLUS

Access your topic review eWorkbooks

on Resources

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-12102	ewbk-12104	ewbk-12106

3.5.1 Summary

Respiratory and circulatory systems

- Multicellular organisms contain coordinated and interdependent systems that perform particular jobs within the body.
- Systems are made up of a variety of organs, that in turn consist of many tissues that in turn are composed of millions of cells.
- The main role of the respiratory system is to take oxygen into your body and carbon dioxide out.
- Organs of the respiratory system include the nose, trachea and lungs, which are made up of bronchi, bronchioles and alveoli.
- Cellular respiration is the breakdown of food in the presence of oxygen to produce energy in a form cells can use.

$$\text{Glucose} + \text{oxygen} \rightarrow \text{carbon dioxide} + \text{water} + \text{energy}$$

- Gases in the blood are exchanged in the alveoli, which are only one cell thick.
- Oxygen moves from the alveoli into the red blood cells in the surrounding capillaries and binds to the haemoglobin to form oxyhaemoglobin. This is known as oxygenated blood.
- Carbon dioxide diffuses out of the cell and into the capillary. This is deoxygenated blood.
- The circulatory system transports oxygen and nutrients to your body's cells and to remove wastes, such as carbon dioxide, away.
- Organs in the circulatory system include the blood, blood vessels (veins, arteries and capillaries) and the heart.
- Arteries transport oxygenated blood away from the heart to the body tissues. Their walls are rigid, thicker and muscular.
- Veins carry deoxygenated blood from body tissues to the heart. Their walls are thin and collapsible and contain valves so that blood does not flow backwards.
- Oxygenated blood moves through the body via the pulmonary vein to the left atrium of the heart, to the left ventricle, to aorta, to arterioles, to capillary, to the body cells.
- Deoxygenated blood flows back into the capillary to the venules, to the vena cava, to the right atrium of the heart, to the right ventricle of the heart, to the pulmonary artery and is finally expelled.

Digestive and excretory systems

- The main role of your digestive system is to supply your body with the nutrients it requires to function effectively.
  - Physical digestion is the mechanical breakdown of food. It begins in the mouth as food is chewed.
  - Chemical digestion is when food is broken down further into simpler compounds or nutrients by enzymes and used by cells.
- Organs of the digestive system: mouth, oesophagus, stomach, small intestine, large intestine, rectum, anus.
- Other important organs involved in the digestive system are pancreas, liver and gallbladder.
- The three main types of enzymes are:
  - amylase that digest carbohydrates
  - protease that digest protein
  - lipase that digest fats/lipids.
- The excretory system removes waste products of a variety of necessary chemical reactions.
- Organs involved in the excretory system are skin, kidneys, liver and lungs.
  - The kidneys are involved in excreting the unused waste products of chemical reactions (for example, urea) and any other chemicals that may be in excess (including water) so that a balance within our blood is maintained.
  - The liver is involved in breaking down toxins for excretion.
- Dehydration occurs to the body when we lose too much water.
- Constipation occurs when there is difficulty in releasing solid waste from the body due to insufficient water or fibre in the diet.

3.5.2 Key terms

absorption the taking in of a substance; for example, from the intestine to the surrounding capillaries

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

amylases enzymes in saliva that break down starch 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 your heart to your 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

ATP molecule used by cells in chemical reactions that require energy. ATP is a product of cellular respiration.

bile a fluid made by the liver and stored in the gall bladder; it emulsifies fats to increase surface area for fat digestion

bladder sac that stores urine

bolus round, chewed-up ball of food made in the mouth that makes swallowing easier

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

capillaries minute tubes carrying blood to 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 of cellular respiration. The burning of fossil fuels also releases 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

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 body system that includes the heart, blood and blood vessels and is 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 a food mass passes from the small intestine, and where water and other remaining essential nutrients are absorbed into your body

deoxygenated blood blood from which some oxygen has been removed

diabetes mellitus a medical condition in which the liver cannot effectively convert glucose to glycogen

digestion breakdown of food into a form that can be used by an organism. It includes both mechanical digestion and chemical digestion.

digestive system a complex system of organs and glands that processes food in order to supply your body with the nutrients to cells so they can function effectively

enzymes special chemicals that speed up reactions but are themselves not used up in the reaction

erythrocytes red blood cells

excretory system the body system that removes waste substances from the body

fats organic substances that are solid at room temperature and are made up of carbon, hydrogen and oxygen atoms

gall bladder a small organ that stores and concentrates bile within the body

glucagon a hormone, produced by the pancreas, that increases blood glucose levels

glucose a six-carbon sugar (monosaccharide) that acts as a primary energy supply for many organisms

glycogen the main storage carbohydrate in animals, converted from glucose by the liver and stored in the liver and muscle tissue

haemoglobin the red pigment in red blood cells that carries oxygen

heart a muscular organ that pumps blood through the circulatory system so that oxygen and nutrients can be transported to the body's cells and wastes can be transported away

insulin hormone that removes glucose from the blood and stores it as glycogen in the liver and muscles

kidneys body organs that filter the blood, removing urea and other wastes

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

lipases enzymes that break fats and oils down into fatty acids and glycerol

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

nephrons the filtration and excretory units of the kidney

oesophagus part of the digestive system composed of a tube connecting the mouth and pharynx with the stomach

oxygen tasteless and colourless gas in which molecules (0_2) are made up of two oxygen atoms. It is essential for cellular respiration for most organisms and is a product of photosynthesis.

pancreas a large gland in the body that produces and secretes hormones such as insulin and glucagon and an important digestive fluid containing enzymes

peristalsis the process of pushing food along the oesophagus or small intestine by the action of muscles

proteases enzymes that break proteins down into amino acids

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

receptors special cells that detect energy and convert it to electrical energy that is sent to the brain.

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. Oxygen is carried by the red pigment haemoglobin.

respiratory system the body system that includes the lungs and associated structures and is responsible for the gas exchange of 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 moistens food before swallowing and contains enzymes involved in the digestion of food

salivary glands glands in the mouth that produce saliva

skin external covering of an animal 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

stomach a large, hollow muscular organ that digests the bolus and secretes acids and enzymes for further digestion and temporary storage

trachea narrow tube from the mouth to the lungs through which air moves

Type 1 diabetes mellitus a disease in which the pancreas stops producing insulin, so the body's cells cannot turn glucose into energy

Type 2 diabetes mellitus the most common form of diabetes, where the pancreas makes some insulin but does not produce enough

ureters tubes from each kidney that carry urine to the bladder

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.

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

vitamins organic nutrients required in small amounts; they include vitamins A, B, C, D and K

on Resources

eWorkbooks	Study checklist (ewbk-12108) Reflection (ewbk-12115) Literacy builder (ewbk-12109) Crossword (ewbk-12111) Word search (ewbk-12113)
Solutions	Topic 3 Solutions (sol-1123)
Practical investigation eLogbook	Topic 3 Practical investigation eLogbook (elog-2209)
Digital document	Topic 3 Key terms glossary (doc-40098)

3.5 Activities

3.5 Review questions

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 3, 4, 9, 11	2, 6, 8, 12, 13	5, 7, 10, 14, 15

These questions are even better in jacPLUS!

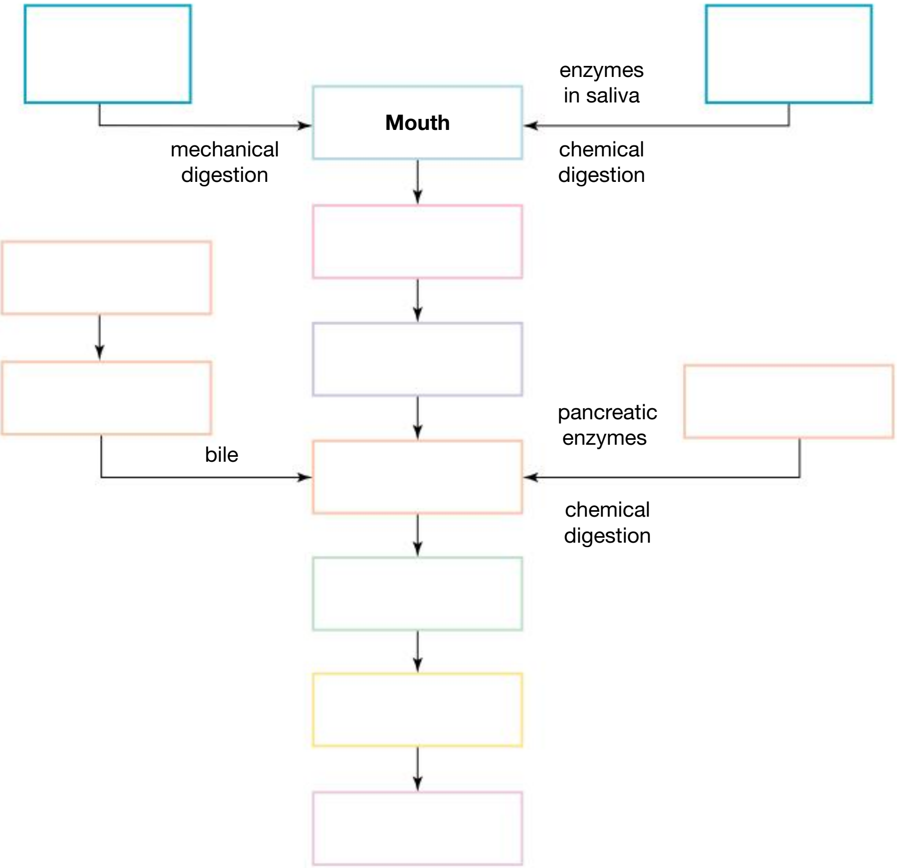
- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

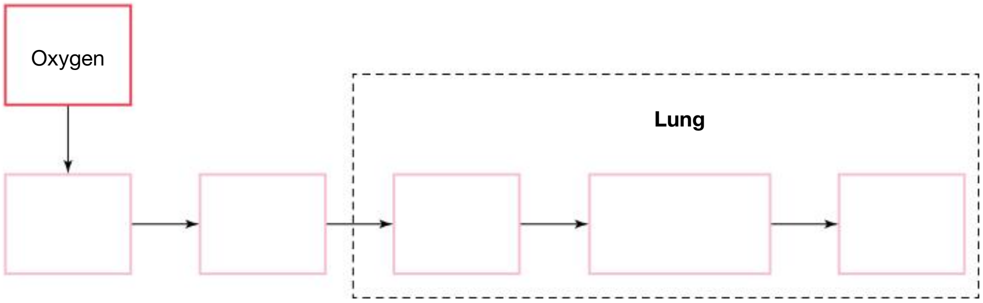
1. **a.** Identify whether the following statements are true or false.
    - **i.** Your circulatory and respiratory systems work together to provide your cells with carbon dioxide for cellular respiration.
    - **ii.** Arteries transport blood to the heart whereas veins transport blood away from it.
    - **iii.** Oxygen moves from the alveoli of your respiratory system into the red blood cells in the surrounding capillaries of your circulatory system.
    - **iv.** The left atrium of the heart contains oxygenated blood.
    - **v.** Oxygenated blood travels from your lungs via the pulmonary vein to the right atrium of your heart.

   b. Justify any false response.
2. Select the appropriate terms to complete the flow chart.
   oesophagus, teeth, salivary glands, stomach, large intestine, mouth, anus, small intestine, rectum, liver, gall bladder

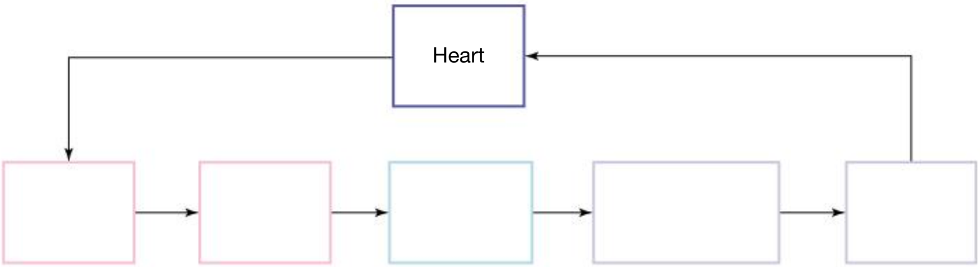


3. Select the appropriate terms to complete the flow charts shown below: trachea, bronchi, arterioles, pulmonary vein, artery, left atrium, capillary, alveoli, body cells, left ventricle, capillary, vein, nose, bronchioles.

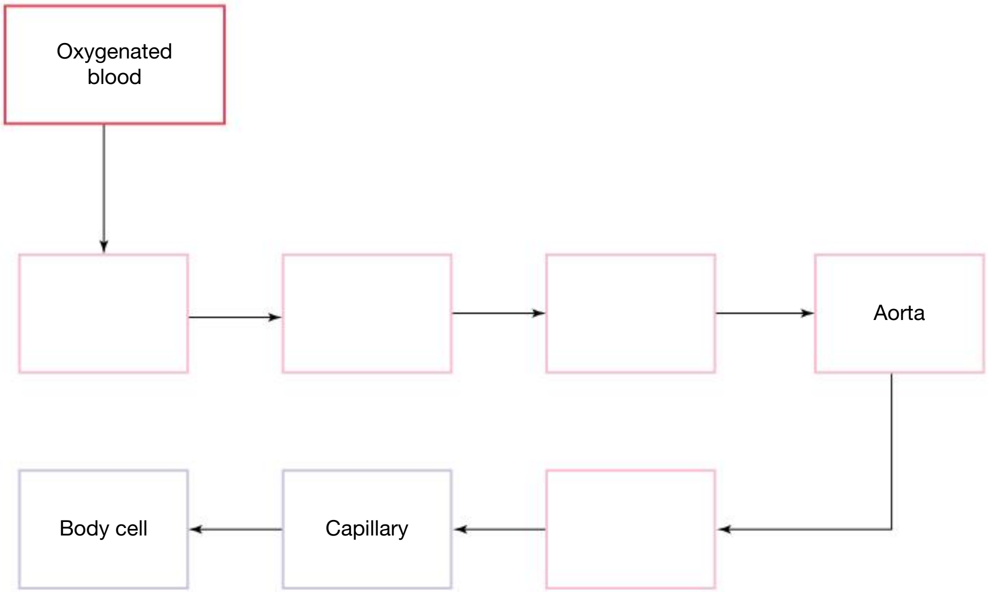
a.



b.



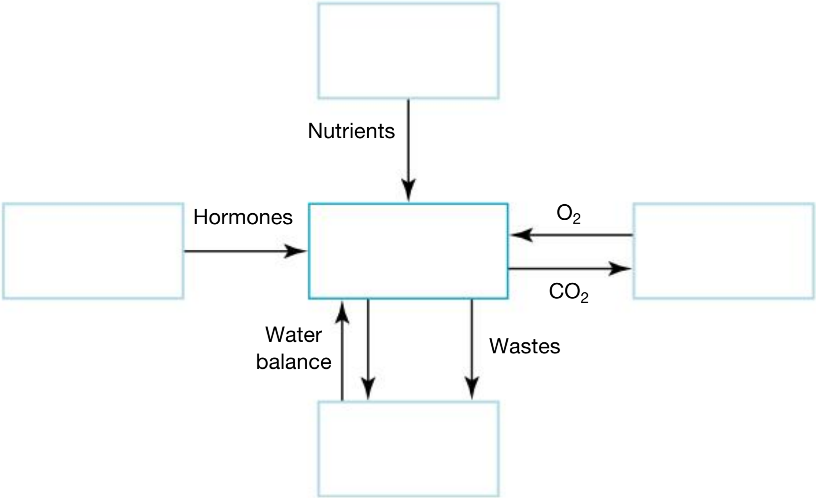
c.



4. Match the organ with the unwanted product or waste that it excretes.

Organ	Unwanted product or waste to be excreted
a. Kidney	**A.** Bile pigments from old red blood cells
b. Liver and large intestine	**B.** Carbon dioxide
c. Lungs	**C.** Urea

5. Suggest which body systems belong in each of the blank boxes in the figure.



6. Complete the sentences to describe each body system.

Term	Function
a. Respiratory system	To get ________________ into your body and ________________ out
b. Circulatory system	To transport ________________ and ________________ to your body cells, and wastes such as ________________ away from them
c. Digestive system	To supply your body with ________________ such as ________________ so that it functions effectively
d. Excretory system	To remove ________________ products of a variety of necessary chemical reactions
e. Endocrine system	Uses chemical messengers called ________________ secreted from special glands called ________________ throughout the body to control and coordinate at both cellular and system level
f. Nervous system	Uses ________________ and chemical messengers called ________________ to control and coordinate at both cellular and system level

7. Outline a way in which the liver is involved in digestion.
8. Describe how your:
   a. cells obtain glucose
   b. blood glucose levels are kept within a narrow range.
9. Explain what happens when we eat more kilojoules than we use.

Apply and analyse

10. Explain how the shapes of the following structures suit them to their function.
   a. Trachea
   b. Oesophagus
   c. Nephrons
   d. Villi
   e. Alveoli
11. Suggest why a supply of water is important to your cells.
12. Describe the relationship between:
   a. insulin and glucagon
   b. a diet high in kilojoules and no weight gain.

Evaluate and create

13. Describe the relationship between the respiratory, circulatory, excretory and digestive systems and cellular respiration.
14. Is it the level of oxygen or carbon dioxide in your blood that has the major influence on breathing rate? How are variations in blood concentrations detected?
15. **SIS** Use the data in the table, which shows recommended energy intakes, to answer the following questions.
    - a. Plot a graph to show how energy needs change with age. You will need to plot two lines: one for males and one for females. The age should be on the horizontal axis. (If a computer is available, you could use a spreadsheet.)
    - b. Suggest why females seem to need less energy.
    - c. Suggest why you need more energy as you approach your late teens.

TABLE Recommended energy intake per age group

	Recommended daily energy intake (kJ)		
Group	**Age (years)**	**Male**	**Female**
Children	1	5000	4800
	5	7600	6800
	9	9000	7900
Adolescents	12	9800	8600
	13	10 400	9000
	14	11 200	9200
	15	11 800	9300
Adults (height 190 cm)	18–30	12 000	10 600
	30–60	11 400	9500
	over 60	9700	8800

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

Online Resources

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-12091)
- Student learning matrix (ewbk-12093)
- Starter activity (ewbk-12094)

Practical investigation eLogbook
- Topic 3 Practical investigation eLogbook (elog-2209)

Solutions
- Topic 3 Solutions (sol-1123)

Video eLesson
- Body systems animation (eles-4171)

3.2 Respiratory and circulatory systems

eWorkbooks
- Labelling the human respiratory system (ewbk-12096)
- Labelling the heart (ewbk-12098)

Practical investigation eLogbook
- Investigation 3.1: The effect of exercise on the circulatory and respiratory systems (elog-2211)

Video eLessons
- Organs of the respiratory system (eles-2642)
- Blood flows through the heart (eles-2049)

Interactivites
- Beat it! (int-0210)
- Labelling the human respiratory system (int-8233)

3.3 Digestive and excretory systems

eWorkbooks
- Labelling the human digestive system (ewbk-12100)
- The digestive system (ewbk-2087)
- Labelling the kidneys (ewbk-12803)
- Removing waste from the blood (ewbk-2089)

Practical investigation eLogbook
- Investigation 3.2: Measuring the energy in food (elog-2213)

Teacher-led video
- Investigation 3.2: Measuring the energy in food (tlvd-10799)

Video eLessons
- The human digestive system (eles-2643)
- Urine formation in the kidney (eles-2644)

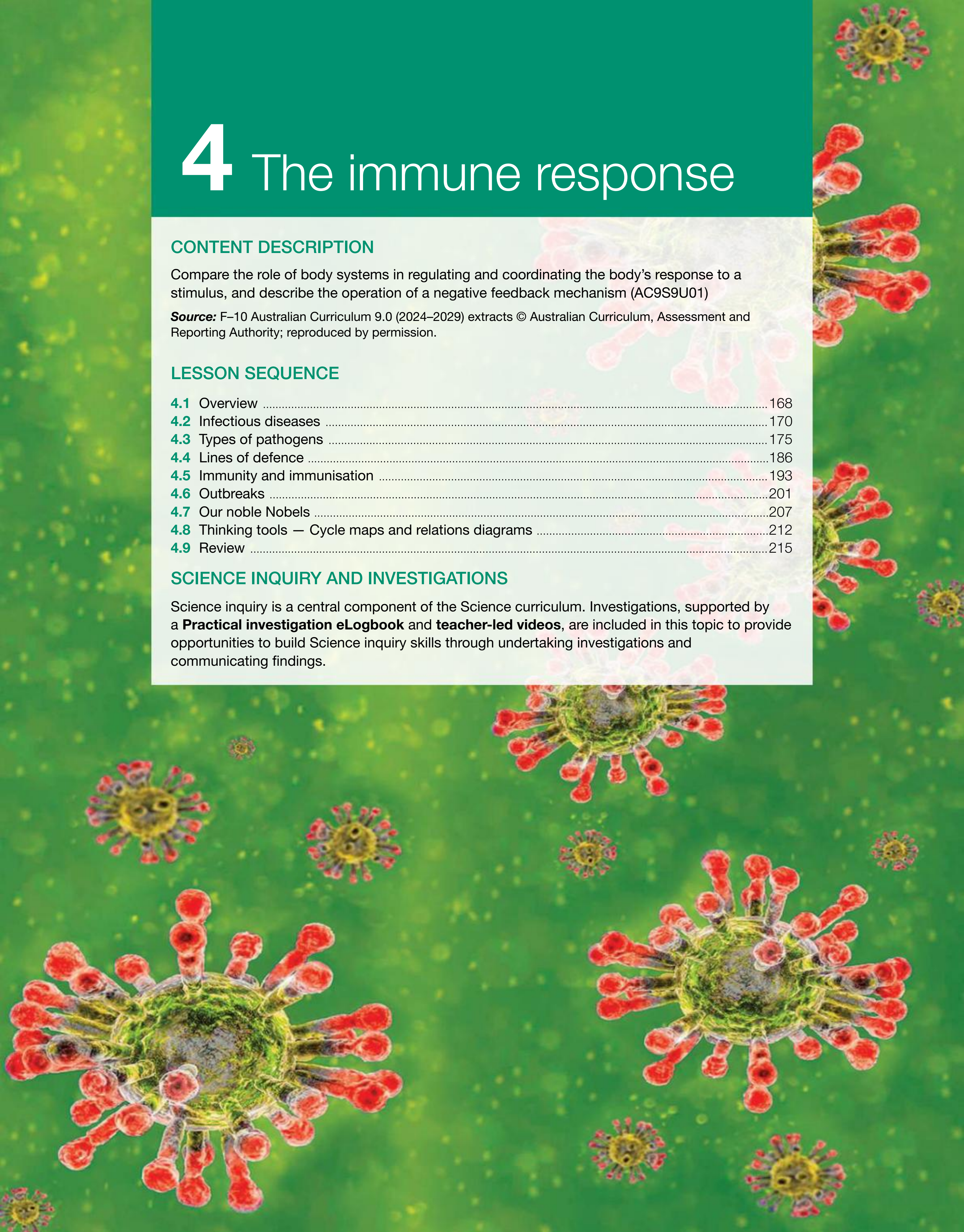
Interactivites
- The digestive system (int-3398)
- Labelling the kidneys (int-8234)

3.5 Review

eWorkbooks
- Topic review Level 1 (ewbk-12102)
- Topic review Level 2 (ewbk-12104)
- Topic review Level 3 (ewbk-12106)
- Study checklist (ewbk-12108)
- Literacy builder (ewbk-12109)
- Crossword (ewbk-12111)
- Word search (ewbk-12113)
- Reflection (ewbk-12115)

Digital document
- Topic 3 Key terms glossary (doc-40098)

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



4 The immune response

CONTENT DESCRIPTION

Compare the role of body systems in regulating and coordinating the body's response to a stimulus, and describe the operation of a negative feedback mechanism (AC9S9U01)

__Source:__ F–10 Australian Curriculum 9.0 (2024–2029) extracts © Australian Curriculum, Assessment and Reporting Authority; reproduced by permission.

LESSON SEQUENCE

SCIENCE INQUIRY AND INVESTIGATIONS

Science inquiry is a central component of the Science curriculum. Investigations, supported by a **Practical investigation eLogbook** and **teacher-led videos**, are included in this topic to provide opportunities to build Science inquiry skills through undertaking investigations and communicating findings.

LESSON
4.1 Overview

Hey students! Bring these pages to life online

Watch videos

Engage with interactivities

Answer questions and check results

Find all this and MORE in jacPLUS

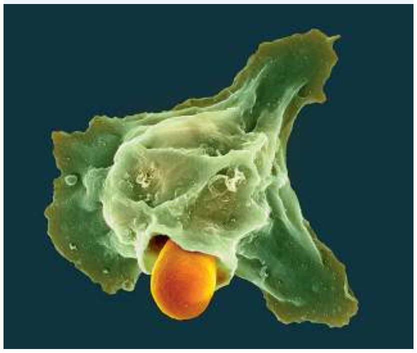
4.1.1 Introduction

Lines of defence, 'soldier cells' and chemical weapons all form a part of the amazing array of strategies used by our bodies to keep us healthy.

Figure 4.1 shows a coloured scanning electron micrograph of a lymphocyte (white blood cell, shown in green) engulfing a yeast cell (shown as orange). The lymphocyte is using projections of its cytoplasm to extend towards the yeast spore, which will be swallowed up and digested.

In this topic we will explore how infectious diseases have shaped the world and the medical breakthroughs that have been developed in response to these challenges. At the heart of these medical breakthroughs is the improved understanding of how our bodies respond to disease.

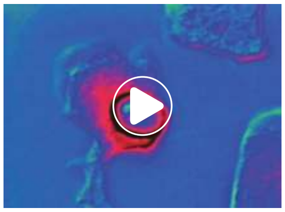
FIGURE 4.1 Your body has many ways to defend itself, including using 'soldier cells' such as this neutrophil white blood cell.



on Resources

Video eLesson The body at war (eles-4188)

Watch this light microscopy time-lapse footage of a white blood cell (entering from lower right) sensing, moving towards, and ingesting a yeast cell (centre). The white blood cell is a neutrophil, which are involved in defence against infections, in this case by a yeast fungus. Indicator dye has been added to demonstrate that the white blood cell is using its lethal oxidative ability to kill the yeast.



4.1.2 Think about the immune response

1. What is an infectious disease?
2. What are the differences between viruses and bacteria?
3. What is a parasite?
4. What is the Black Death and how does it spread?
5. Is immunisation necessary?
6. Which animal up to 10 metres long can live inside a living human body?
7. What does H5N1 have to do with birds?
8. How did COVID-19 become a global pandemic?
9. Is diabetes contagious?
10. Why are anthrax, cholera, botulism and smallpox attractive to terrorists?

4.1.3 Science inquiry

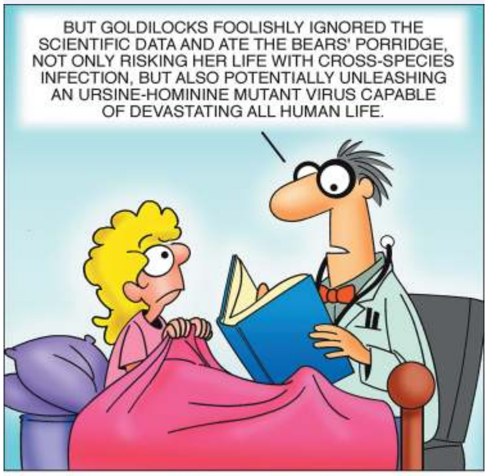
Using stories and rituals to pass on knowledge about food safety

Throughout history, stories and rituals have been used to pass knowledge about food and nutrition from one generation to the next.

Goldilocks and the three bears

1. Imagine that Goldilocks got sick after eating the porridge. Suggest some reasons why this may have happened.
2. The three bears did not cover their porridge while they went for their walk. Was this a good idea or not? Give reasons for your answer.
3. How long can porridge stay uncovered at room temperature before it is dangerous to eat? Find out the spoiling time of four other foods.
4. Create your own fairytale to teach young children about poisonous or spoiled food. Present your story as a PowerPoint presentation, storybook, pantomime or puppet play.

FIGURE 4.2 Why might it have been dangerous for Goldilocks to eat the bears' porridge?



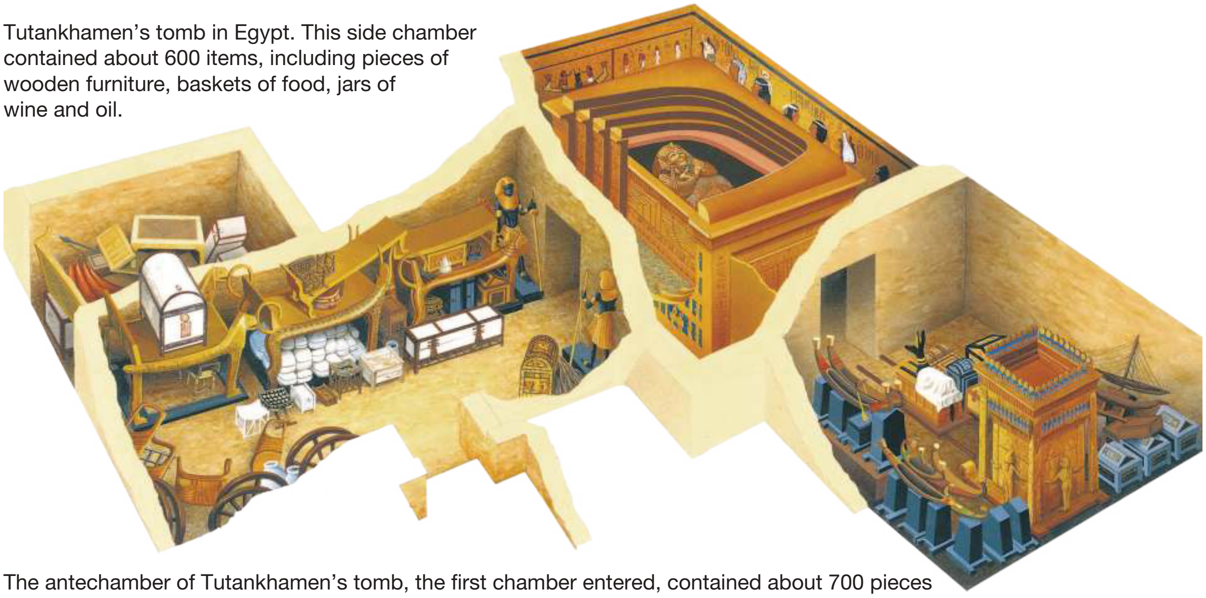
A Very Grimm Fairytale

Tutankhamen

Baskets of food, along with jars of wine and oil, were found in Tutankhamen's tomb in Egypt in 1922 (see figure 4.3). Other Egyptian tombs contained honey that was in a well-preserved state; when opened it retained some of its aroma. Today, most foods have a use-by or best-before date on the packaging.

5. For three different foods, find out what might happen, and why, if you used them well after their use-by date.
6. Sometimes canned food is unsafe to eat. Find out why.
7. Find out what strategies humans have to survive eating lots of different foods, some of which may cause food poisoning.

FIGURE 4.3 Inside the tomb of Tutankhamen



Tutankhamen's tomb in Egypt. This side chamber contained about 600 items, including pieces of wooden furniture, baskets of food, jars of wine and oil.

The antechamber of Tutankhamen's tomb, the first chamber entered, contained about 700 pieces of furniture, a chariot (in bits) and two black and gold life-size statues either side of the entrance. There were also jars of oil, lamps, vases, musical instruments, board games and clothing.

on Resources

eWorkbooks	Topic 4 eWorkbook (ewbk-12390) Student learning matrix (ewbk-12391) Starter activity (ewbk-12392)
Solutions	Topic 4 Solutions (sol-1137)
Practical investigation eLogbook	Topic 4 Practical investigation eLogbook (elog-2299)

LESSON

4.2 Infectious diseases

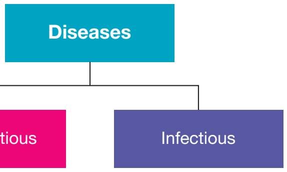
LEARNING INTENTION

At the end of this lesson you will be able to compare and describe the differences between non-infectious and infectious diseases, and understand how infectious diseases are spread and the range of strategies that can prevent or contain their spread.

4.2.1 Classifying diseases

A human **disease** can be defined as being any change that impairs the function of an individual in some way; it causes harm to the individual. Diseases can be classified as being infectious or non-infectious.

FIGURE 4.4 Diseases can be infectious or non-infectious.



Non-infectious diseases

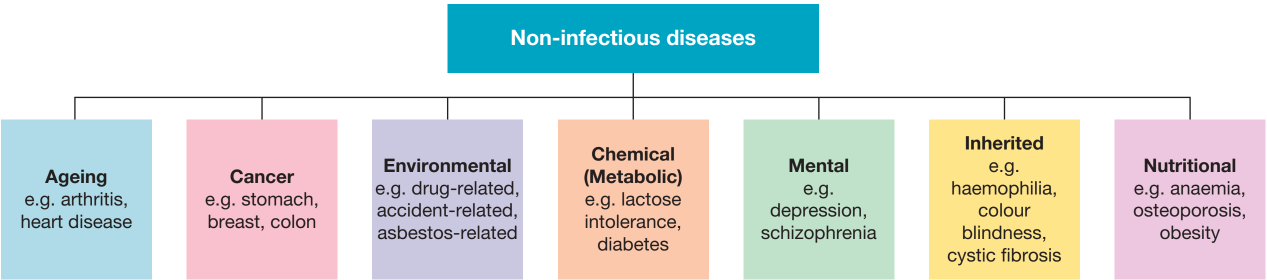
Non-infectious diseases cannot be spread from one person to another; they are not contagious (transferred from one organism to another). Obesity, rickets and scurvy are examples of non-infectious diseases that may be related to unbalanced diets or nutritional deficiencies. Inherited diseases such as haemophilia and cystic fibrosis and diseases related to exposure to particular poisons or drugs are also non-infectious. Although **viruses** have been implicated in some cancers (for example, cancer of the cervix), most cancers are considered to be non-infectious diseases.

disease any change that impairs the function of an organism in some way and causes it harm

non-infectious disease a disease that cannot be spread from one organism to another

virus a very simple microorganism that infects cells and may cause disease

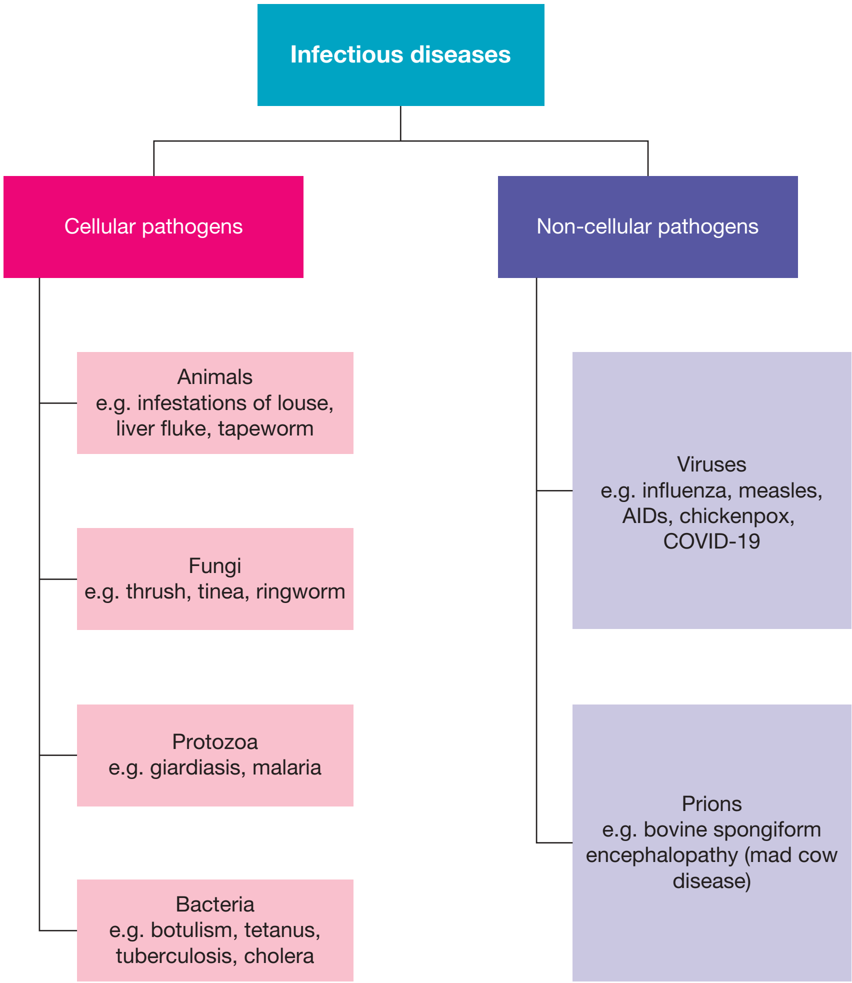
FIGURE 4.5 Non-infectious diseases include diabetes, heart disease and cancer.



Infectious diseases

Infectious diseases are diseases that are contagious and are caused by a **pathogen**. Tapeworms, head lice, liver flukes, fungi, protozoans and bacteria are examples of pathogens that are made up of cells and can be referred to as **cellular pathogens**. Some other pathogens, such as viruses, are not made up of cells and for this reason are sometimes referred to as **non-cellular pathogens**.

FIGURE 4.6 Infectious diseases in humans



4.2.2 Modes of transmission

The knowledge of how infectious diseases are transmitted is important if ways to control their spread are to be found. Some key ways in which pathogens may be transmitted include direct contact, vectors, contaminated objects or contaminated water supplies (figure 4.7).

Direct contact

Some diseases are spread by direct contact. Touching others or being touched is one way in which pathogens can be directly transferred from one person to another.

Another way is via airborne droplets that are produced when you cough, sneeze or talk. These droplets may contain pathogenic bacteria or viruses and may land on objects or people around you, which may result in disease.

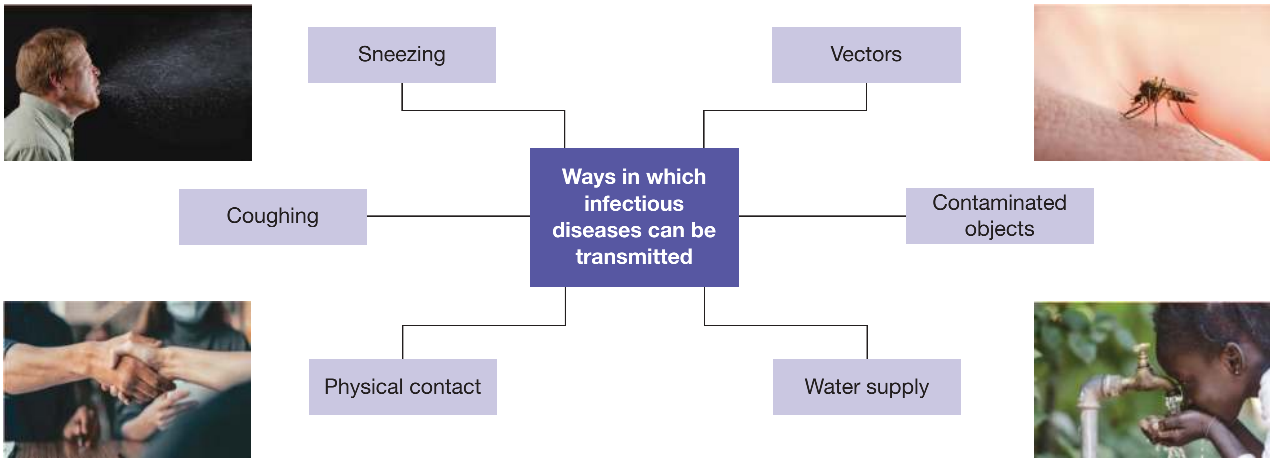
infectious disease a disease that is contagious (can be spread from one organism to another) and caused by a pathogen

pathogen a disease-producing organism

cellular pathogen a pathogen that is made up of cells, such as a tapeworm, fungus or bacterium

non-cellular pathogen a pathogen that is not made up of cells, such as a virus, prion or viroid

FIGURE 4.7 Different ways in which infectious diseases can be transmitted



Resources

Video eLesson Bacteria and viruses (eles-2645)

Interactivity Classifying diseases (int-5768)

Vectors

Some diseases are spread by vectors. **Vectors** are organisms that carry the disease-causing pathogen between organisms — without being affected by the disease themselves. Mosquitoes, houseflies, rats and mice are examples of organisms that can act as vectors to spread disease.

FIGURE 4.8 Mosquitoes are the vectors for many infectious diseases.

Contaminated objects

While fungal diseases such as tinea and ringworm can be spread by direct physical contact, they may also be transmitted by towels or surfaces that have been contaminated with skin cells of an infected person.

Food poisoning is often caused by contamination of food (or food utensils) with particular types of pathogenic bacteria called salmonella. This can cause diarrhoea and vomiting, usually within 2–24 hours after ingestion. This is why washing your hands is so important after going to the toilet and before touching food or being involved in food preparation.

Contaminated water

Many pathogenic organisms live in water and are carried about in it. Our domestic water supply is usually chemically treated to kill disease-causing micro-organisms within it. However, this may not be the case with water drunk directly from water tanks, rivers or creeks. This water may need to be boiled before it is drunk.

vector an organism that carries a pathogen between other organisms without being affected by the disease the pathogen causes

During the summer months, the Environment Protection Authority (EPA) measures the levels of *Escherichia coli* (*E. coli*) bacteria in water in coastal beaches. The level of *E. coli* in the water is used as an indicator of levels of potentially pathogenic bacteria, as it is found in faeces.

4.2.3 Preventing transmission of infectious disease

Preventing the spread of infectious diseases has been a challenge throughout history. The ancient Hebrews isolated those with disease by keeping them away from others or by sending them beyond the boundaries of the towns. In the Middle Ages, Mediterranean people refused to allow ships to dock for 40 days if they carried sick people. The separation of sick people from healthy people to avoid infection was the beginning of **quarantine**. Unfortunately these methods were not enough to stop large outbreaks of disease.

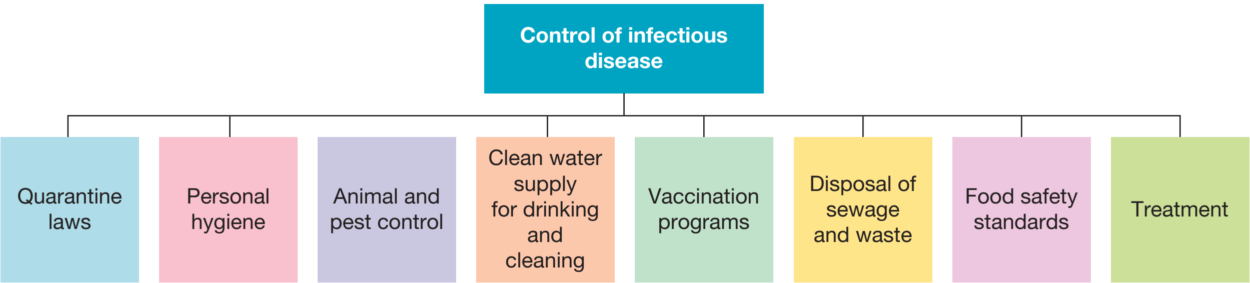
quarantine strict isolation of sick people from others for a period of time (originally 40 days) in order to prevent the spread of disease

WHAT DOES IT MEAN?

The word quarantine is derived from the Latin word ***quadrāgintā***, meaning 'forty'. In the Middle ages, sick people were strictly isolated for a period of 40 days in order to prevent the spread of disease.

There are a number of ways in which the spread of disease may be controlled.

FIGURE 4.9 Preventing the transmission of infectious disease



on Resources

eWorkbooks Infectious diseases (ewbk-12395)
Non-infectious diseases (ewbk-12396)

4.2 Activities

learnon

4.2 Quick quiz **on**

4.2 Exercise

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 5, 6	2, 3, 7, 8, 11	4, 9, 10, 12

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. Define the following terms and give one example for each of them.
   a. Disease
   b. Non-infectious disease
   c. Infectious disease
   d. Pathogen
   e. Contagious
   f. Vector
2. Identify three differences between non-infectious and infectious diseases.
3. Explain the difference between a pathogen and a disease.

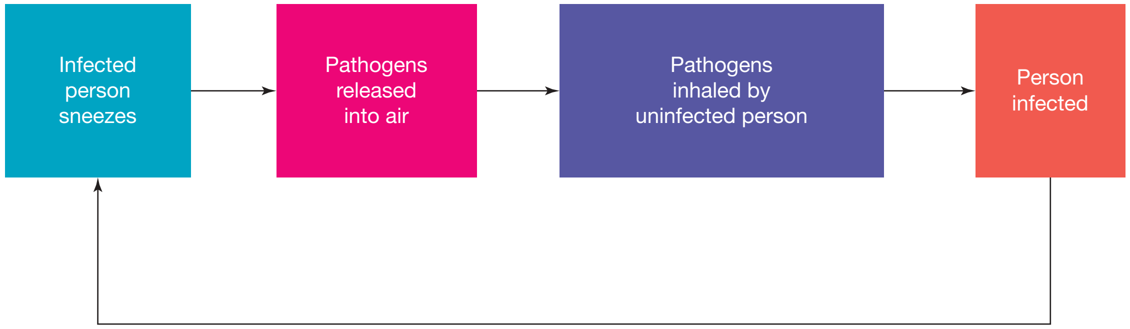
4. Bacteria causes tuberculosis, a virus causes Ebola and malaria is caused by a parasite. Explain why all three are considered infectious diseases. What do these infectious agents have in common in their structures and functions?
5. Match the type of pathogen with the infectious disease.

Type of pathogen	Infectious disease
a. Animal	**A.** Giardiasis
b. Bacteria	**B.** Tinea
c. Fungi	**C.** Tapeworm
d. Protozoans	**D.** Cholera
e. Viruses	**E.** Influenza

Apply and analyse

6. **a.** Media campaigns can be effective in improving our health by changing social behaviours. Explain how the social media campaign involving the DAB, which gained popularity as a dance move, impacted coughing etiquette and the spread of the common cold and influenza.
   b. List another five ways of preventing the spread of colds and flu.
7. The flow chart provided describes how disease can be spread by sneezing. Construct similar flow charts to show three other ways in which diseases can be spread.

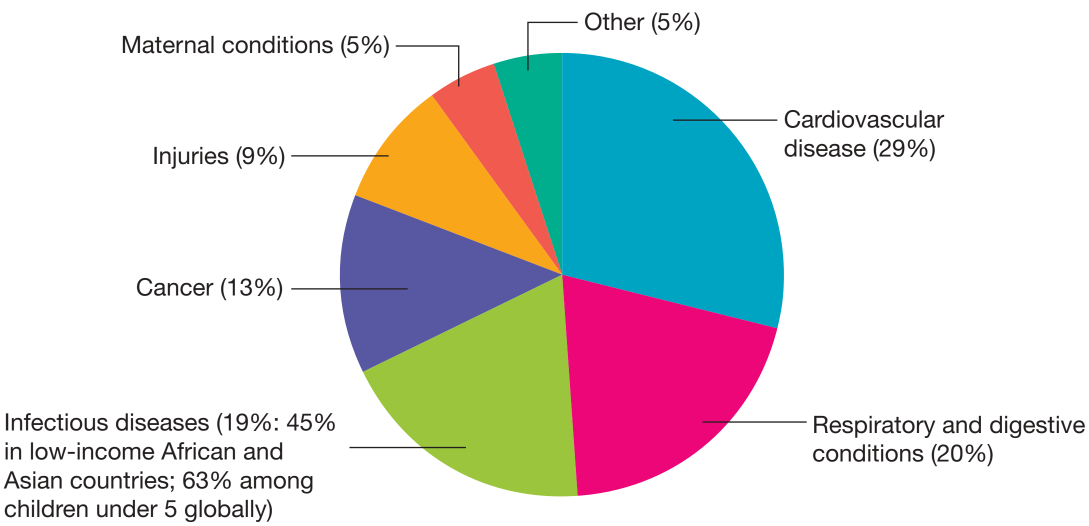
Some infectious diseases can be spread from one person to another via a sneeze.



Evaluate and create

8. **SIS** Study the pie chart provided. It shows the main causes of death worldwide in 2002.
   a. State the percentage of people who died from infectious diseases:
      i. worldwide
      ii. in low-income African and Asian countries.
   b. Suggest why there is such a large difference in the percentage of people who died from infectious disease between wealthier countries and poor countries.
   c. State the percentage of children who died before the age of five of infectious diseases. Suggest why this figure is so high. (*Hint*: Think about the other main causes of death and who they are likely to affect.)
   d. Draw a column graph to represent the data shown in the pie chart.
   e. If the same data was collected in 2020 and a similar graph was drawn, how do you think the two graphs would differ? Give reasons for your answer.

Main causes of death worldwide in 2002



9. Which pathogen is the most common cause of food poisoning due to consumption of undercooked chicken? What symptoms are observed? How many hours after consumption does it take for the onset of symptoms?
10. **SIS** Predict social or ethical issues that might arise in designing policies for disease prevention.
11. Describe the most common illness suffered by overseas travellers.
12. Suggest practical methods for avoiding traveller's diarrhoea. Consider as many influences — such as drinking water, the impact of water on food production and food preparation — as you can.

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

LESSON
4.3 Types of pathogens

LEARNING INTENTION

At the end of this lesson you will be aware that not all microorganisms cause disease, be able to describe the difference between cellular and non-cellular pathogens, be able to provide examples of some different types of pathogens that exist and be able to describe how pathogens can cause diseases in a host.

4.3.1 Microbiome — good bacteria

We do not live alone! There are trillions of microorganisms that live on us and in us, our **microbiome**. There are more of them than our own cells. We need them and they need us to survive. They even play a role in defending us from attack from outside invaders. Our microbiome is continually changing and no two people have the same microbiome. Development of our microbiome begins at birth, with the bacteria that colonises our intestines, and these are considered the normal **gut flora**. This gut flora varies depending upon whether the birth was a vaginal birth or a caesarean section, and is continued to be influenced by whether the baby is breast or bottle fed. We depend on our gut bacteria to obtain vitamins K and B.

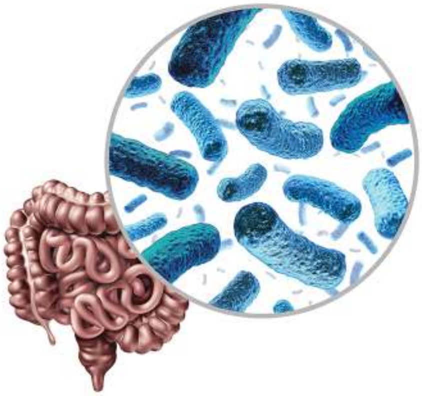
microbiome the community of microorganisms (such as bacteria, fungi, and viruses) living together in a particular habitat

gut flora bacteria and other organisms that live inside the intestines and help digest food

Other factors that change our gut flora include:

- antibiotics — using antibiotics destroys both pathogical and beneficial microbes, which can promote the growth of other pathogens
- the environment in which we live (rural, city, developing countries)
- diet — vegetarian diets are associated with healthy diverse gut microbiota. Diets high in sugar can slow the production of proteins, which inhibits the growth of beneficial gut microbes. Many people now choose to boost their gut flora by consuming probiotics, which are living organisms. Prebiotics can also be beneficial. These promote the activity or structure of the current gut microbiota.

FIGURE 4.10 Gut probiotic bacterium inside small intestine and digestive microflora inside the bowel



Bacteria do not live only in our gut, but all over our bodies. The skin under your armpits contains more than two million bacteria per square centimetre. The unpleasant smell is caused not by the bacteria themselves, but is the result of the bacteria breaking down the proteins in your sweat. The bacteria in your armpits can prevent pathogenic bacteria from colonising, and so keep you healthy.

4.3.2 Parasites

Some relationships between organisms may provide one with resources and cause harm to the other. An example of this relationship is that of a **parasite** and its host.

The organism that a parasite lives in or on is referred to as its **host**. The life cycle of parasites can involve one or more hosts. The **primary host** is the organism used for the adult stage and the **intermediate host** (or secondary host) is used for the larval stage (figure 4.11).

Parasites can be classified according to the part of your body in which they live.

- **Endoparasites**: parasites that live inside your body.
- **Ectoparasites**: parasites that live outside your body.

parasite organism that obtains resources from another organism (host) that it lives in or on, and can cause harm to

host organism living in a relationship with another organism

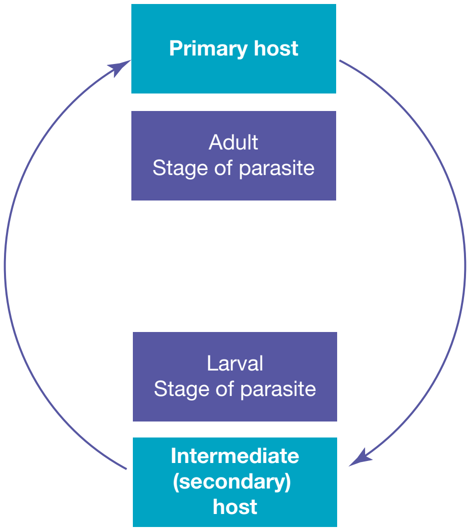
primary host the organism that a parasite lives in or on in its adult stage

intermediate host the organism that a parasite lives in or on in its larval stage; also known as secondary host

endoparasite parasite that lives inside the body of its host organism

ectoparasite parasite that lives outside the body of its host organism

FIGURE 4.11 The organism in which the parasite completes some part of its life cycle is referred to as its host.



Some parasites can harm their hosts and cause disease; these parasites are also considered to be pathogens. However, not all parasites kill their hosts. It's probably a very good idea if they don't, because they rely on their host for resources. Both animals and plants carry parasites; for example, fleas are a parasite that can be found living within the hair of a dog (figure 4.12).

FIGURE 4.12 Flea living in dog hair

4.3.3 Non-cellular pathogens

Infectious diseases are caused by pathogens. Pathogens may be cellular (made up of cells) or non-cellular.

- Cellular pathogens include disease-causing bacteria, protists, fungi and animal.
- Non-cellular pathogens include prions, viruses and **viroids**.

Non-cellular pathogens are considered to be non-living, as they are unable to undergo independent replication. In order to replicate, they must gain entry into a host cell.

viroid non-cellular pathogen comprised solely of a short circular RNA without a protein coat

prion an abnormal and infectious protein that converts normal proteins into prion proteins

transmissible spongiform encephalopathy (TSE) a degenerative neurological disease caused by prions

Prions

Prions are non-cellular pathogens. The word prion is derived from the terms protein and infection. They are abnormal and infectious proteins that can convert your normal protein into prion protein. When cells containing prions burst, more of these infectious proteins are released to infect other cells. The bursting of these cells can also result in damage to the tissues of which they are a part.

Prions are thought to be responsible for degenerative neurological diseases. These diseases are also called **transmissible spongiform encephalopathies (TSE)**. The term spongiform is included because of the tiny holes that result from the bursting of infected cells, giving the brain a spongy appearance. Examples of these diseases include kuru, Creutzfeldt-Jakob disease (CJD) and bovine spongiform encephalopathy (BSE).

FIGURE 4.13 Comparison between a normal prion protein and the disease-causing abnormal prion protein

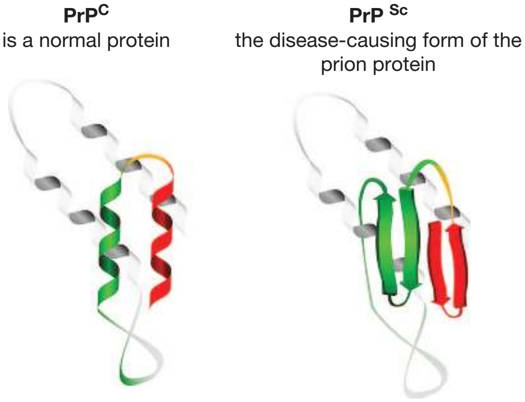
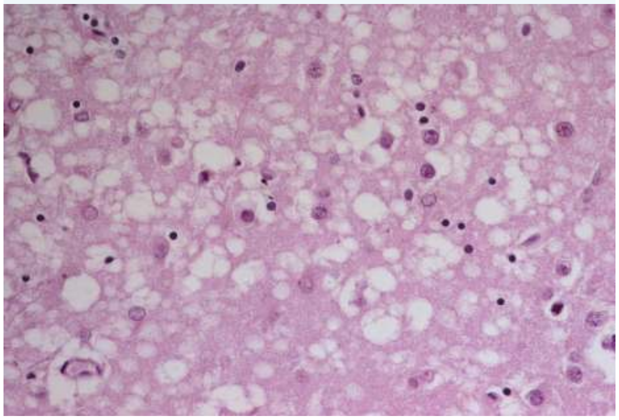


FIGURE 4.14 Brain tissue infected with Creutzfeldt-Jakob disease has a 'spongy' appearance, showing large holes due to cell damage.



BSE is commonly known as 'mad cow disease' because of the nervous or aggressive behaviour observed in infected cows. Mad cow disease was first discovered in the United Kingdom in 1986. Hundreds of thousands of cattle were destroyed when it was discovered that humans could become infected with this disease (giving them CJD) by eating meat from infected cows.

Viruses

Viruses are another example of non-cellular pathogens. Viruses are so small that they can only be seen with very powerful electron microscopes. Viruses come in many shapes and sizes (figure 4.15); however, all viruses contain the following features (figure 4.16):

- genetic material (**DNA** or **RNA**)
- protein coat (capsid).

Scientists debate whether viruses should be called living things, as they are **obligate intracellular parasites**. This means that they need to infect a host cell before they can reproduce; they cannot do it on their own (figure 4.17). As viruses cause damage to their host cell in the process, they are also classified as pathogens. Examples of infectious diseases caused by viruses include warts, rubella, mumps, poliomyelitis, influenza, AIDS, SARS-CoV-2 (the virus that causes COVID-19) and the common cold.

DNA (deoxyribonucleic acid) a substance found in all living things that contains genetic information

RNA (ribonucleic acid) complex compound that functions in cellular protein synthesis and replaces DNA as a carrier of genetic codes

obligate intracellular parasite a parasite that needs to infect a host cell before it can reproduce

FIGURE 4.15 Viruses come in many shapes and sizes.

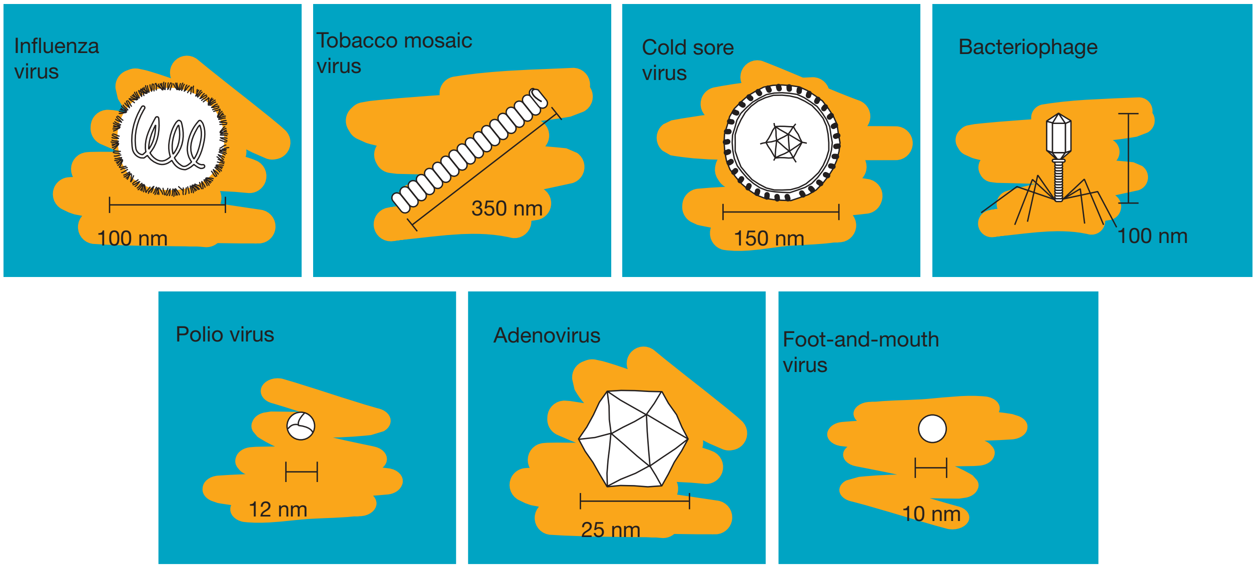


FIGURE 4.16 The influenza virus consists of RNA surrounded by protein and lipid layers. It is not cellular.

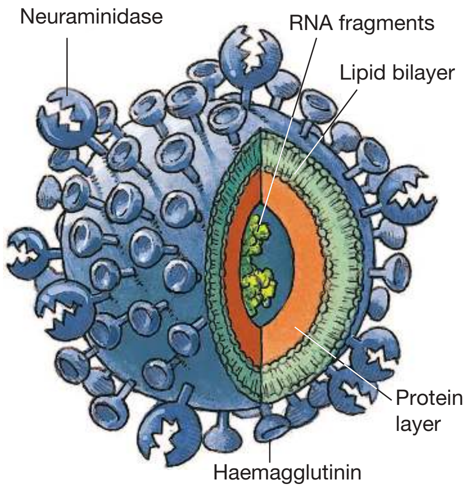
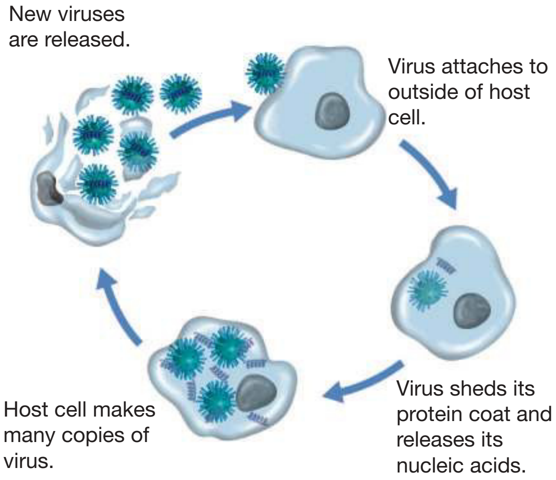


FIGURE 4.17 This cycle depicts how a virus is spread.



4.3.4 Cellular pathogens

Bacteria

Disease-causing bacteria are cellular pathogens that consist of a single cell. They can be classified on the basis of their cell shape, the organisation of colonies of bacteria and the presence or absence of structures (such as a flagellum) or particular chemicals in their cell wall. Some examples:

- Coccus — a spherical bacterium (for example, staphylococcus)
- Bacillus — a rod-shaped bacterium
- Spirochaete — a spiral-shaped bacterium

Diseases caused by bacteria include tetanus, pneumonia, food poisoning, gastroenteritis, cholera, gonorrhoea, leprosy, tetanus, scarlet fever, whooping cough, meningitis and typhoid.

FIGURE 4.18 Some types of disease-causing bacteria

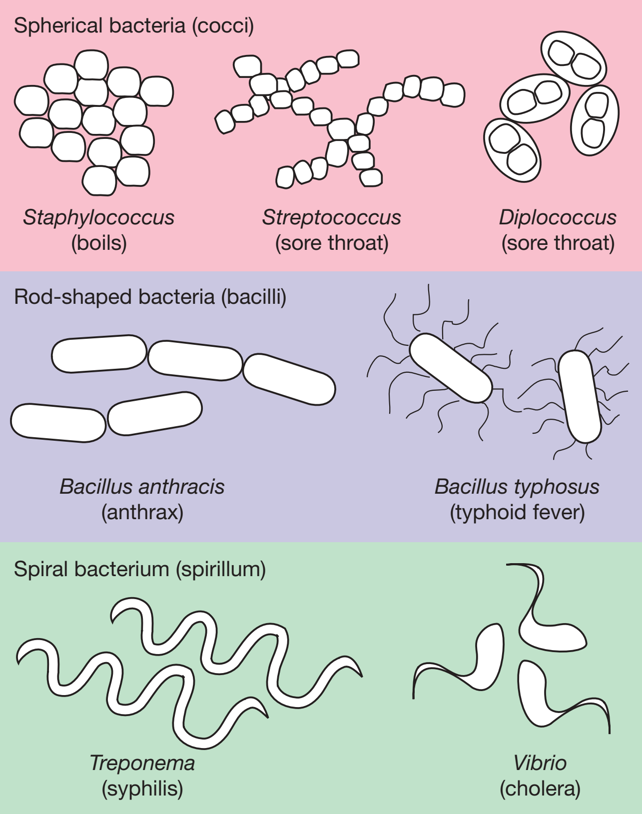


FIGURE 4.19 *Streptococcus* bacteria

CASE STUDY: Leprosy

Leprosy is rare in Australia, where it is known as Hansen's disease. It is caused by *Mycobacterium leprae*, a rod-shaped bacterium, and is a contagious disease that affects the skin, mucous membranes, and nerves, causing discolouration and lumps on the skin and, in severe cases, disfigurement and deformities. Leprosy is now mainly confined to tropical Africa and Asia. This disease is transmitted through droplets expelled by sneezes and coughs or by coming in contact with nasal fluids on surfaces.

Leprosy is curable with multidrug therapy, which involves treatment with two or more antibiotics over a period of around 6 months. In the past 20 years, 16 million people worldwide have been cured of leprosy.

FIGURE 4.20 Leprosy may cause disfigurement or deformities in severe cases.

SCIENCE AS A HUMAN ENDEAVOUR: Pasteurisation

Did you know that it is illegal for raw cow's milk to be sold in Australia for human consumption? This is because raw milk can contain dangerously high levels of bacteria such as *Brucella, Campylobacter, Cryptosporidium, E. coli*, *Listeria* and *Salmonella*, which can pose serious health risks.

Pasteurisation was first developed by Louis Pasteur in 1864. It kills harmful microorganisms responsible for such diseases as listeriosis, typhoid fever, tuberculosis, diphtheria, Q fever and brucellosis. Pasteurisation makes sure that milk is safe to drink (by killing any bacteria) and also helps to prolong its shelf life. The process of pasteurisation involves heating milk to 71.7 °C for at least 15 seconds, and no more than 25 seconds. Once the milk has been heated, it is then cooled very quickly to less than 3 °C. Unlike sterilisation, pasteurisation does not kill *all* microorganisms and their spores.

Protozoans

Parasitic protozoans are single-celled organisms that are usually found within their host's body. Infectious diseases caused by protozoans are common in tropical regions. Examples of diseases caused by protozoans include head lice, malaria (see the case study), amoebic dysentery and African sleeping sickness.

Fungi

Fungi belong to one of the biggest groups of organisms. They include some that are large, such as toadstools, and others that are microscopic, such as the **moulds** that grow on bread. Many fungi are parasites, feeding on living plants and animals, including humans. This often results in disease.

Common human diseases caused by fungi are tinea or athlete's foot, thrush and ringworm. Some fungi live in the mouth, the vagina and the digestive system at all times, without causing harm. However, if resistance to disease is low, the fungi in these places can become active and cause problems such as thrush.

fungi organisms, such as mushrooms and moulds — some help to decompose dead or decaying matter and some cause disease

moulds types of microscopic fungi found growing on the surface of foods

FIGURE 4.21 Two forms of fungi: **a.** mould (growing on an orange) **b.** athlete's foot (tinea)

Worms and arthropods

Larger parasites include endoparasites such as tapeworms, roundworms and liver flukes, and ectoparasites such as ticks, fleas and lice.

Tapeworms (figure 4.22) are the largest of the parasites that feed on the human body and can be up to 10 metres long! They have hooks and suckers to keep a firm hold on your intestine. Tapeworms don't have to worry about finding a mate. When they are reproductively mature, their end segment, which is full of eggs, along with their host's faeces, moves on to its next host.

Did you get an itchy bottom at night when you were little? You probably had a roundworm infection such as threadworm or pinworm. Although these worms usually live in the large intestine, when ready to lay her eggs the female worm moves down to lay them on the moist, warm skin of your anus. The sticky material they are covered with irritates your skin so that you scratch it, picking up some eggs in your nails. Better remember to wash your hands before you eat!

FIGURE 4.22 a. The head of a tapeworm showing its hooks and suckers **b.** A pork tapeworm with hooks that cling to the digestive track of the host

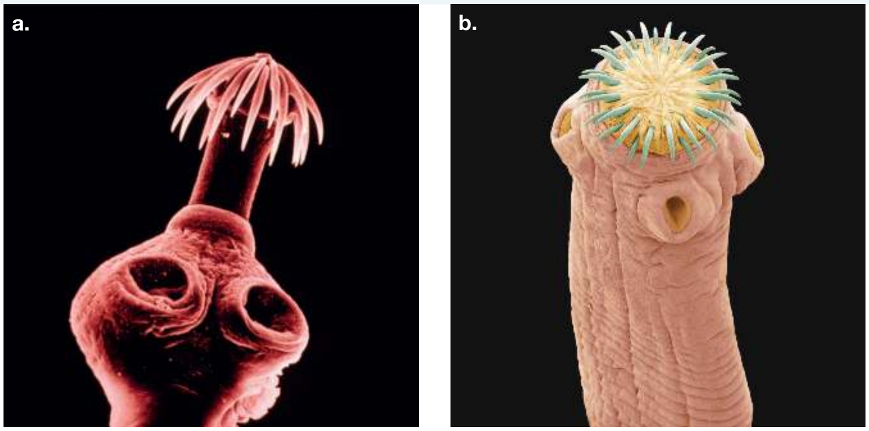


TABLE 4.1 Some common parasites that are also pathogens

Parasite	Condition caused	Source of infection
Amoeba	Amoebic dysentery	Contaminated food and drink
Malarial parasite	Malaria	Bite from infested mosquito
Tapeworm	Tapeworm	Raw or poorly cooked meats
Blood fluke	Schistosomiasis	Contaminated water
Tick	Skin infestation	Tick-infested areas
Louse	Pediculosis	Contact with human carrier, bedding, clothing
Flea	Skin irritation	Animal and human carriers

on Resources

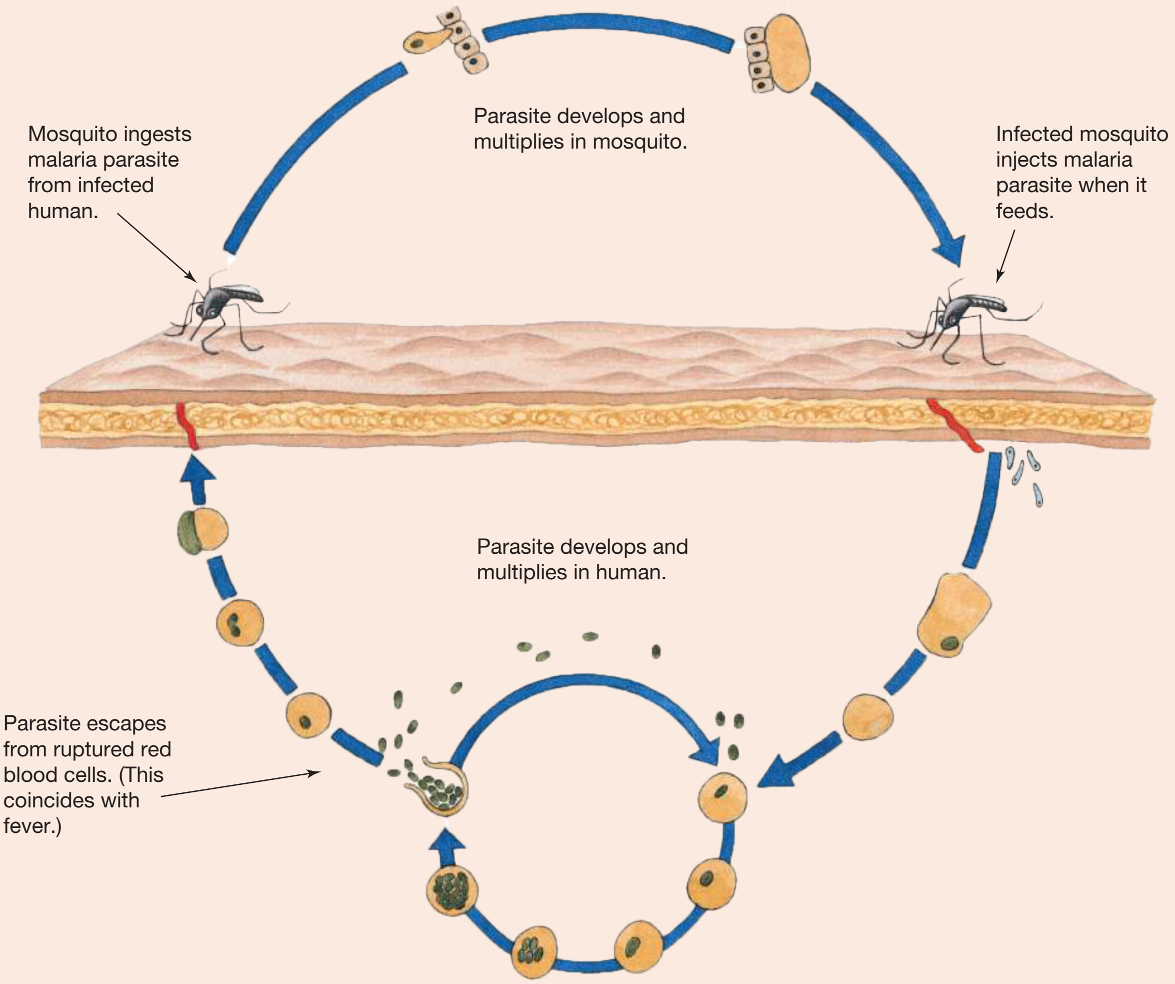
Video eLesson Human head lice on human hair (eles-2646)

CASE STUDY: Malaria

How do you catch malaria?

You catch malaria by being bitten by a female *Anopheles* mosquito that has been infected by the *Plasmodium* parasite. The parasite moves into the salivary glands of the mosquito and is passed into your bloodstream when it bites you.

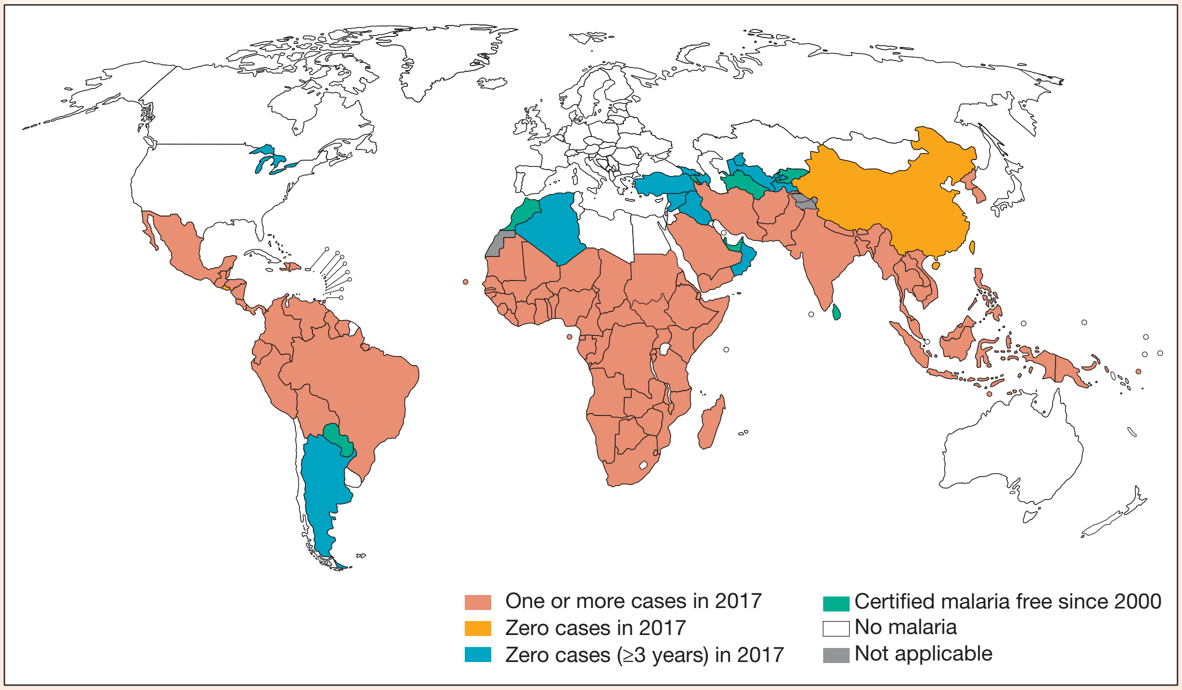
FIGURE 4.23 Malaria transmission cycle



How dangerous is malaria?

In 2017, the World Health Organization estimated that malaria caused 435 000 deaths worldwide. It is one of the most serious public health problems worldwide. It is a leading cause of death and disease in many developing countries, where pregnant women and young children are most affected. An infected mother can transmit the malaria parasite to her unborn child through the placenta.

FIGURE 4.24 Countries with malaria are decreasing, but 92 countries and 3.4 billion people are estimated to be still at risk.



How do you know if you have malaria?

Most people have high fevers, aches, pains, shivering and night sweats. Fatigue, low blood-cell counts and yellowing of the skin and whites of the eyes (caused by jaundice) may also result. Severe complications include cerebral malaria, anaemia and kidney failure, and can often result in death.

What causes malarial night sweats?

Once inside your body, malaria parasites grow and multiply first in your liver cells and then in your red blood cells. Successive broods of malaria parasites grow inside your cells until your red blood cells burst open and are destroyed. The new malaria parasites (or merozoites) seek other cells to infect and destroy. This causes night sweats.

What's new in malaria research?

In Australia, teams led by Professor Alan Cowman at the Walter and Eliza Hall Institute of Medical Research have studied how the malaria parasite uses genetic trickery to evade our immune systems. They have developed a novel class of compounds that target multiple stages of the parasite's life cycle, and may overcome existing drug resistance. In preclinical testing, the drug slowed growth of the parasite in the host, and also prevented transmission of the parasite back to mosquitoes. The R21 malaria vaccine is being rolled out in 2023 by the World Health Organization (WHO) to at least 250 000 children in Burkina Faso, Africa, which has the highest rate of malaria.

Watch out for the mozzies!

Mosquitoes are not only vectors for the malaria parasite, but can also transmit elephantiasis, dengue fever, yellow fever and Japanese encephalitis. That is why it's important to use insect repellents and bed nets to help prevent being bitten!

on Resources

Weblinks Malaria life cycle Part 1: Human host
Malaria life cycle Part 2: Mosquito host

elog-2301

tlvd-10806

INVESTIGATION 4.1

Microbes

Aim

To investigate the types of microbes in the air of the laboratory

Materials

- prepared agar plate
- marking pen
- sticky tape

Background

Agar is a jelly-like material made from seaweed. It provides a source of nutrients for microbes.

Health and safety guidelines

Do not open the tape seals after incubation and wash your hands thoroughly after making your observations.

Method

1. Take the lid off the agar plate to expose the agar to the air in your laboratory for about 5 minutes.
2. Seal the lid on the agar plate carefully, using the sticky tape.
3. Give the plate to your teacher to incubate at about 35 °C for two days.
4. After two days examine your incubated plate and record your observations. *Note:* Do not open the plate seals.
5. Give the unopened plates back to your teacher for proper disposal.

Results

1. Sketch your plate again after it has been incubated for 2 days.
2. Describe the general appearance, colour, size and shape of the groups or colonies on the agar plate.

Discussion

1. What can you conclude about the air in your science laboratory?
2. Do you think that the air in other parts of your school would be different? Explain.
3. Discuss the risks that could be associated with the experiment and ways to reduce these risks.
4. Formulate your own question or hypothesis about microbial growth, and design an experiment that could be used to investigate it. Include an explanation of your choice of variables and required specific safety precautions.

Conclusion

What can you conclude about the microbes in your school laboratory?

4.3 Activities

learnon

4.3 Quick quiz on

4.3 Exercise

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 4, 8, 9	2, 5, 7, 10, 12	3, 6, 11

Remember and understand

1. Distinguish between:
   a. pathogens, antigens and hosts
   b. prions, viruses and bacteria
   c. parasites, endoparasites and ectoparasites.
2. Our microbiome consists of trillions of microorganisms that live in us and on us. The bacteria that colonised the intestines after birth are important for development and function and are considered the normal flora of the gut. We depend on our gut bacteria to obtain vitamin K and vitamin B.
   a. Where do we obtain the bacteria that colonise our gut?
   b. Are any two people's gut microbiomes identical? Justify your response.
   c. Suggest factors that influence the composition of our gut microbiota over our lifetime.
3. Describe how our human microbiome protects us from pathogen attack.
4. Compare the ways in which viruses and bacteria reproduce by placing *Yes* or *No* in the table.

Feature	Bacteria	Virus
Invade host cell to reproduce		
Reproduction results in new cells		
Contain DNA or RNA		
Can only reproduce inside host cell using host cell machinery		

5. a. State the cause of leprosy and describe how it is transmitted.
   b. Is leprosy curable today? Justify your response.
6. a. Explain why many biologists consider viruses to be non-living.
   b. Explain why the cell that is invaded by a virus is called a host cell.

Apply and analyse

7. Construct a cycle map to show how prions replicate.
8. Explain why most milk is pasteurised rather than sterilised.
9. Describe the relationship between mosquitoes and malaria. Is there a vaccine to protect against contracting malarial disease?
10. After taking medication, antibiotics or being ill, people are often advised to eat yoghurt or other probiotics. Explain why yoghurt can be beneficial. Suggest some other foods that might be recommended and justify why.
11. The skin under your armpits contains more than two million bacteria per square centimetre.
    a. Explain why they do not cause disease more often.
    b. Explain what would happen if the same bacteria entered your bloodstream through a cut.

Evaluate and create

12. Explain why it is a good idea to read up on protozoans before you travel to tropical climates.

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

LESSON
4.4 Lines of defence

LEARNING INTENTION

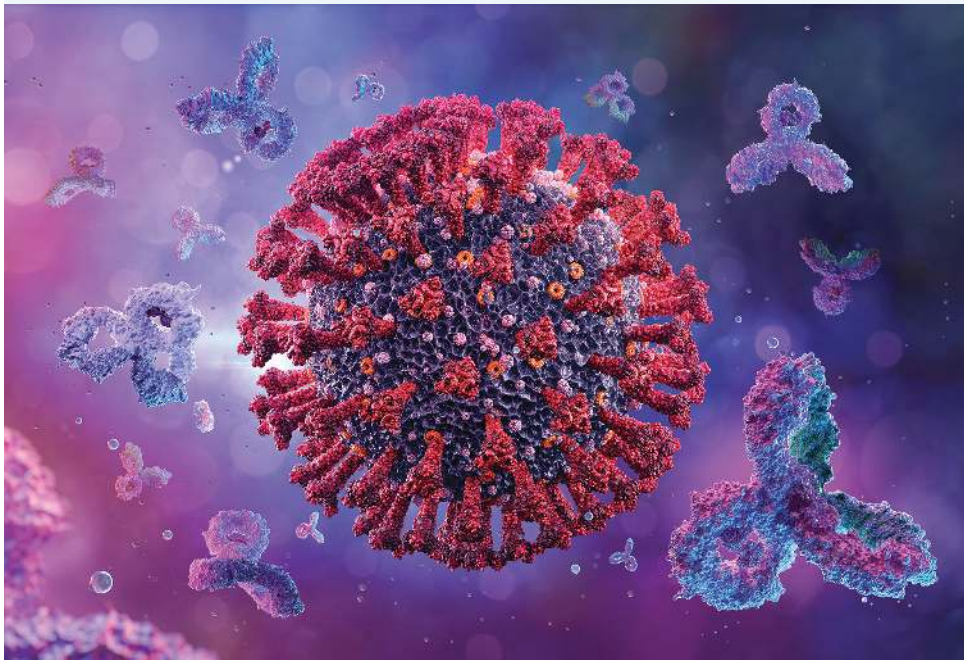
At the end of this lesson you will be able to identify the various chemical and physical barriers in the body's first line of defence, describe the process of inflammation and phagocytosis as a second line of defence, and outline the importance of B and T lymphocytes and the lymphatic system in the third line of defence.

4.4.1 Antigens

All cells from organisms contain molecules on their surface called **antigens**. Each antigen is unique, which allows our body to recognise antigens as being self or non-self (foreign) to your body. Non-self antigens trigger an immune response.

antigen a substance that triggers an immune response

FIGURE 4.25 Antigens (seen in red) on the surface of a virus



4.4.2 First line of defence

Pathogens can cause disease, preventing or stopping your body from working well. A healthy body helps you to defend yourself against infectious disease by setting up natural barriers, or lines of defence. The first and second lines of defence are described as being non-specific (also referred to as innate immune response). They fight the same way for all infections, regardless of whether they have encountered them before. The third line of defence is specific (also referred to as the adaptive immune response). It fights differently for different types of invaders and may react differently if it has been exposed to them before.

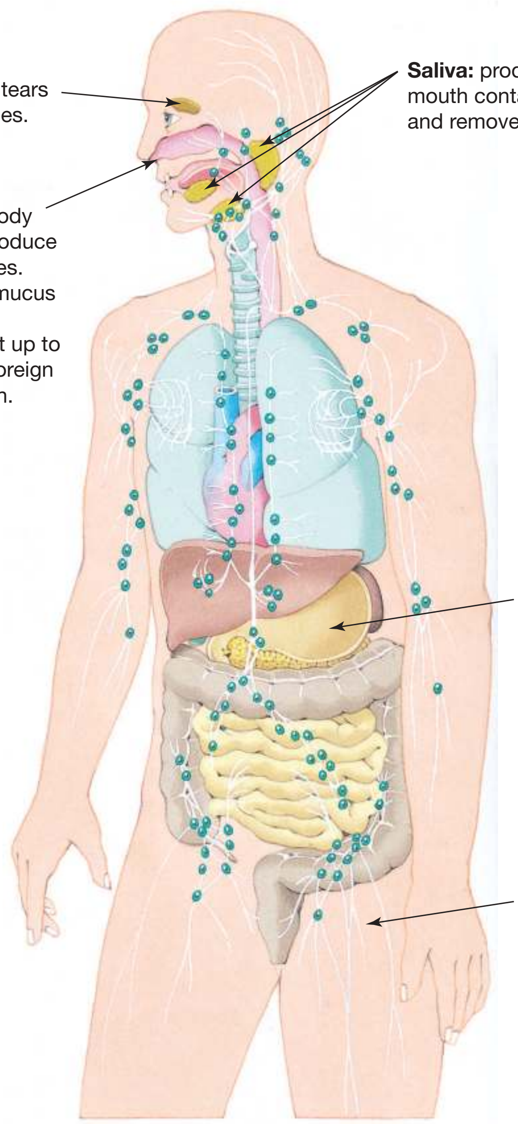
Your body's first line of defence is designed to prevent the entry of invading pathogens.

These defences (see figure 4.26) can be:
- physical barriers such as intact skin, cilia and nasal hairs
- chemical barriers — body fluids such as saliva, tears, stomach acid and acidic vaginal mucus.

ewbk-12399

int-5769

FIGURE 4.26 The body's first line of defence against disease



Lachrymal glands: near the eye produce tears to wash away dust, dirt and foreign particles.

Saliva: produced by the salivary glands in the mouth contains substances to help resist and remove microbes.

Mucous membranes: the linings of the body openings, such as the nose and throat, produce a sticky mucus to help trap foreign particles.
Cilia: small hairlike structures sweep the mucus (and trapped particles) out of the body.
Coughing: removes the mucus, bringing it up to your mouth to be swallowed so that any foreign material can be destroyed in your stomach.
Sneezing: ejects pathogens from your nasal cavity.

Stomach acid: kills many microbes before they reach the intestines.

Intact skin: surface barrier to most diseases. It is waterproof and if it is cut, the hole is sealed by a blood clot that then forms a scab to help protect you while it heals. It is also dry and slightly acidic — conditions that prevent the growth of many bacteria and fungi.

4.4.3 Second line of defence

If pathogens manage to get through your first line of defence, the second line of defence comes into play. The second line of defence is a non-specific immune response, meaning it will respond the same way with each exposure to a pathogen. This is because it has no 'memory' of the prior exposures.

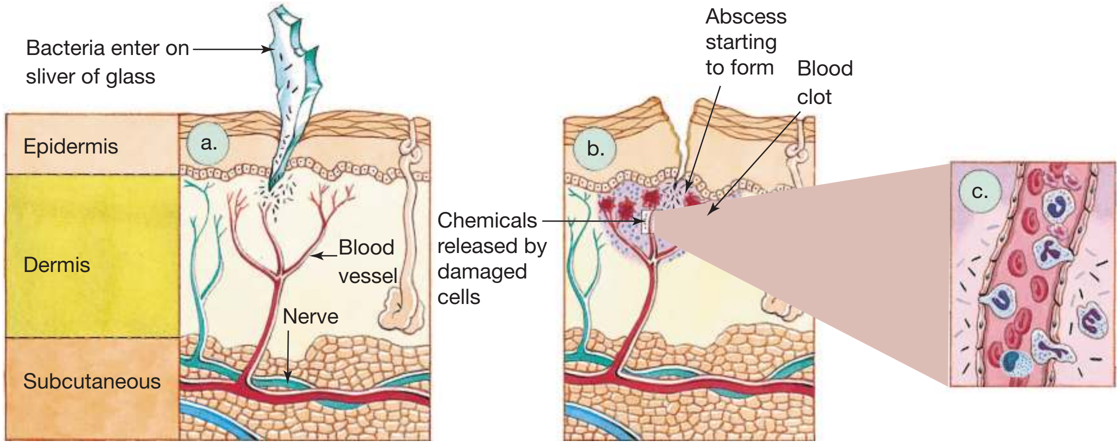
Inflammation

If you have had a cut that became infected you may have noticed that the area became red, warm and swollen (inflamed). The redness, caused by the increased blood flow to the area (vasodilation), and **inflammation** are signs that your second line of defence has been triggered (figure 4.27). The increase in blood flow is due to specialised cells located within the dermis of the skin, which when damaged release a chemical known as histamine. Histamine causes an increase in blood flow and **white blood cells** to the site of infection.

inflammation a reaction of the body to an infection, commonly characterised by heat, redness, swelling and pain

white blood cells living cells that fight bacteria and viruses

FIGURE 4.27 If a pathogen has breached your first line of defence, your skin, your second line of defence is activated.



Phagocytosis

Special types of white blood cells, **phagocytes**, that engulf and destroy pathogens and other foreign material move to the site of the infection. This action of engulfing and destroying materials is called **phagocytosis** (figure 4.28). Phagocytes have membrane-bound organelles called lysosomes, which contain a digestive enzyme, lysozyme. Lysozyme can break down foreign material (figure 4.29).

FIGURE 4.28 Phagocytes (such as some types of white blood cells) engulf and destroy materials. This action is called phagocytosis.

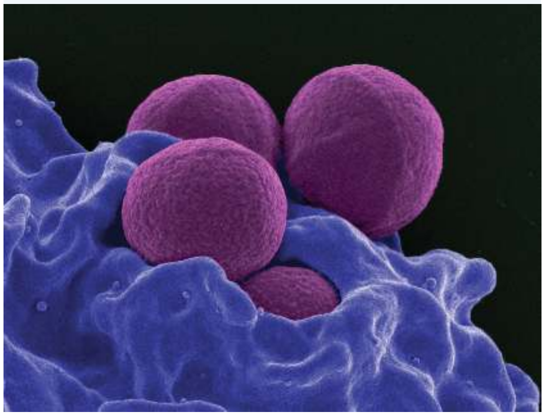
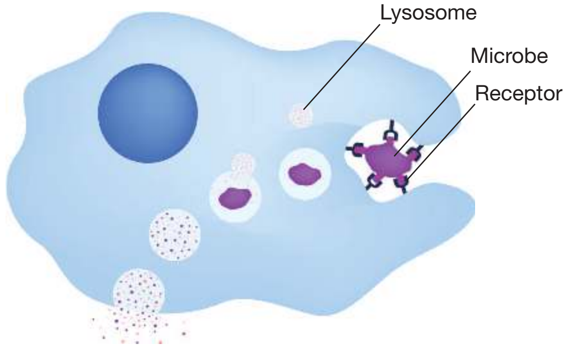


FIGURE 4.29 The process of phagocytosis: a phagocyte engulfs a pathogen, where it will fuse with a lysosome and undergo degradation.



4.4.4 Third line of defence

The lymphatic system

Have you ever felt swollen glands in your neck when you had an infection? These glands are part of a network of fine tubes running throughout your body called your **lymphatic system** (figure 4.30). Your lymphatic system contains lymph vessels, lymph nodes, lymph and white blood cells. Some of these white blood cells are **lymphocytes**. Two important types of white blood cells are the B and T lymphocytes. Both cells originate in the bone marrow, but play very different roles in the third line of defence. Unlike the second line of defence, the third line of defence is highly specific and forms the ability to remember pathogens.

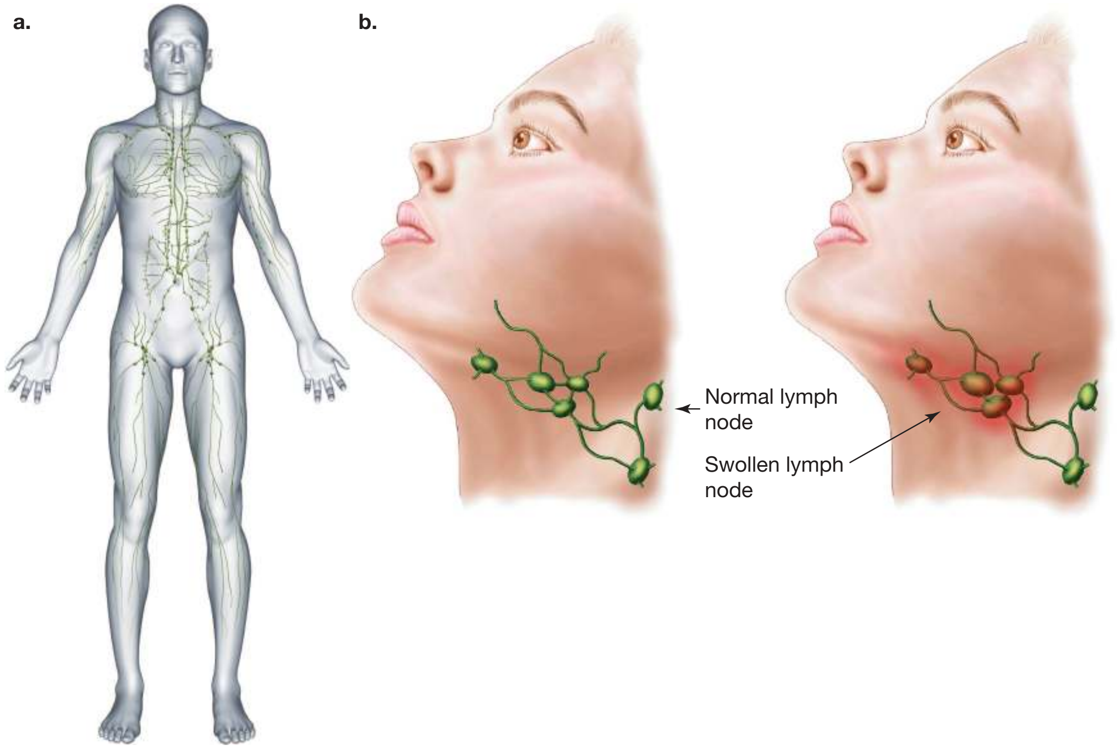
phagocyte white blood cell that ingests and destroys foreign particles, bacteria and other cells

phagocytosis the ingestion of solid particles by a cell

lymphatic system the body system containing the lymph vessels, lymph nodes, lymph and white blood cells that is involved in draining fluid from the tissues and helping defend the body against invasion by disease-causing agents

lymphocyte small, mononuclear white blood cells present in large numbers in lymphoid tissues and circulating in blood and lymph

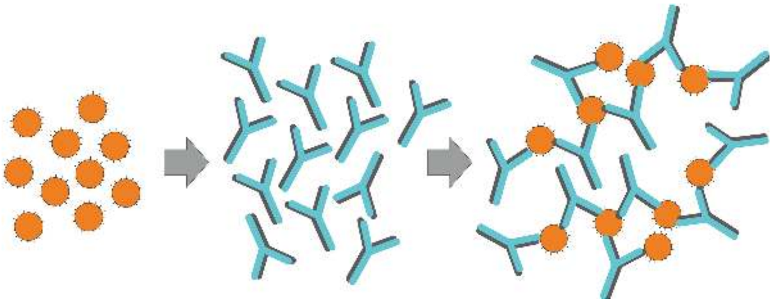
FIGURE 4.30 **a.** The lymphatic system containing lymphatic vessels and lymph nodes **b.** Swollen lymph nodes in the neck



B lymphocytes (humoral immunity)

B lymphocytes divide into **plasma cells**. Plasma cells produce chemicals called **antibodies** that are specific to the invader's antigens. These antibodies assist in the destruction of the invading pathogen. Antibodies (produced by B lymphocytes) can bind to antigens, causing pathogens to clump together (agglutination), as shown in figure 4.31. This clumping makes it easier for the phagocytes to engulf them.

FIGURE 4.31 **Humoral immune response**: antibodies (green) binding to the surface of the pathogen (orange) causing agglutination



B lymphocyte part of the third line of defence, these lymphocytes may be triggered by antigens to differentiate into plasma cells that produce and release specific antibodies against the antigen; also known as B cells

plasma cell *see* B lymphocyte

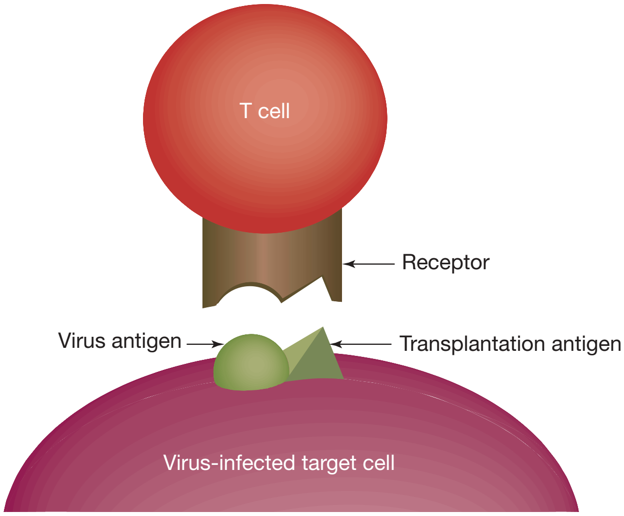
antibodies proteins that are produced by B lymphocytes as a result of the presence of a foreign substance in the body and that act to neutralise or remove that substance

humoral immune response immunity involving antibodies (which are specific to a particular antigen) that are produced and secreted by B lymphocytes that have differentiated into plasma cells

T lymphocytes (cell-mediated immunity)

T lymphocytes (or T cells) fight at a cellular level and are one of the main components of the adaptive immune system (see figure 4.32). These cells not only attack foreign invading cells, but may also attack your own cells that have been invaded. By destroying these infected cells, they also destroy the cause of infection and reduce the chance that it will be spread to other cells. There are four main types of T cells, which include T helper cells and natural killer T cells. Once T cells are activated, they secrete cytokines to directly attack infected or cancerous cells, and stimulate the growth of more T cells. The actions of lymphocytes can assist phagocytes in their duties. For example, some T lymphocytes produce substances that can attract or activate phagocytes.

FIGURE 4.32 Cellular immune response: a killer T lymphocyte (T cell) must identify both the virus antigen and the cells of the organism it is trying to protect. It makes a matched fit at the place where the antigen is attached to the host.



Your immune system can be so effective that you can be infected with a pathogen but not develop any symptoms. Lymphocytes can form **memory cells**, so that next time you encounter the same type of invader your immune response can be faster and stronger. Sometimes it is so fast and strong that, even though you may be infected with the pathogen, you may not show any symptoms of the disease that it could cause.

T lymphocyte part of the third line of defence, these lymphocytes fight the pathogens at a cellular level. Some T lymphocytes may also attack damaged, infected or cancerous cells.

cellular immune response immunity involving T lymphocytes (assisted by phagocytes) that actively destroy damaged cells or cells detected as non-self, such as those triggering an immune response

memory cells cells that may be formed from lymphocytes after infection with a pathogen — they 'remember' each specific pathogen encountered and are able to mount a strong and rapid response if that pathogen is detected again

4.4.5 Systems working together

Defence against disease is another example of how your systems work together. Your respiratory system's lining of mucus and ciliated tubes and your digestive system's enzymes and stomach acids help your fight against invaders. White blood cells produced in your bone marrow include those that will become phagocytes and lymphocytes. These defending cells will be circulated throughout your body in your circulatory system and lymphatic system to areas of infection, where they perform their task of destroying invaders. The remnants of these invaders are then excreted from your body via your excretory system.

EXTENSION: HIV attack on T cells

A type of T lymphocyte called the helper T lymphocyte (helper T cell) can be infected by the human immunodeficiency virus (HIV). This is the virus that causes AIDS (acquired immune deficiency syndrome). HIV destroys the helper T cells, and in doing so gradually damages the immune system of the infected person; this is why people with AIDS often die from diseases that a healthy immune system could normally defend itself from. HIV can be transmitted through body fluids such as blood, semen, vaginal fluid and breast milk. While there is currently no known cure, treatment for HIV is called antiretroviral therapy. This therapy aims to reduce the person's viral load to a level where HIV in the blood is too low to be detected by a viral load test. The viral load is reduced by HIV medicines, which prevent HIV from multiplying. By reducing the amount of HIV in the body, the immune system has a chance to recover and produce more T lymphocyte cells.

FIGURE 4.33 HIV (orange) attacking a T lymphocyte

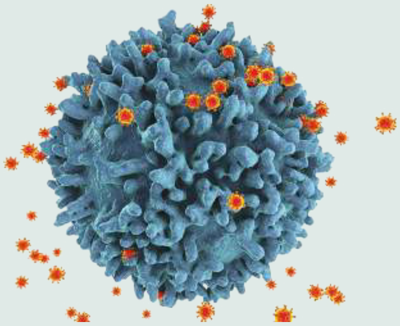
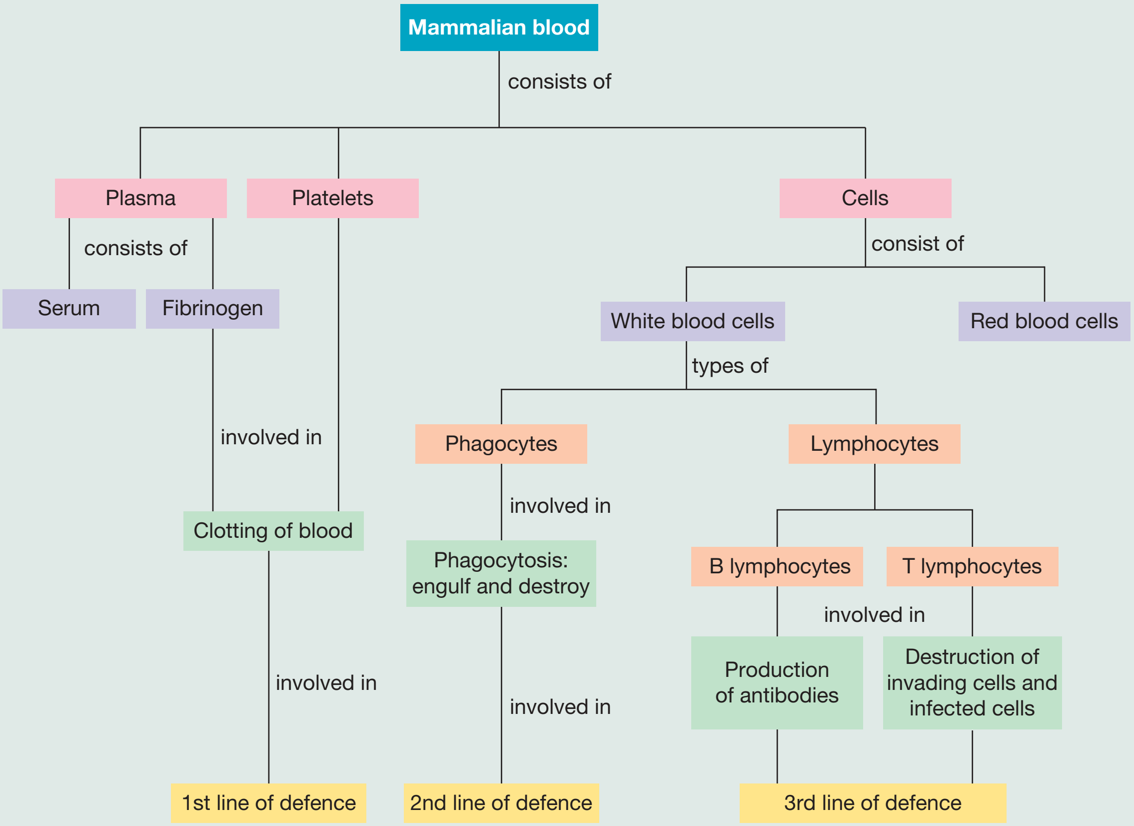


FIGURE 4.34 Your blood is involved in your body's defence against disease.



on Resources

Video eLesson Understanding HIV (eles-0125)

4.4 Activities

4.4 Quick quiz on

4.4 Exercise

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 4, 6, 7	2, 5, 8, 10	3, 9, 11

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. Explain how cilia, mucus, coughing and stomach acids can work together to help defend you against pathogens.
2. State three lines of defence that protect your body against pathogens and describe one key difference between each of them.
3. a. Explain why many species of bacteria and fungi find it difficult to grow on skin.
   b. Describe some of the microorganisms that typically reside on human skin (normal skin microbiota).
   c. Explain why they are of benefit to us and how they contribute to our first line of defence against pathogens.
4. Provide two examples of (a) physical barriers and (b) chemical barriers involved in the first line of defence.

Apply and analyse

5. Use labelled flow charts to show the relationship between:
   a. pathogens, phagocytes and phagocytosis
   b. antigens, pathogens, antibodies, lymphocytes and phagocytes.
6. Suggest three ways in which foreign particles might be able to enter your body.
7. Explain how you can be infected with a pathogen but not show any symptoms.
8. Explain how:
   a. T cells protect us from disease
   b. T cells recognise that a body cell has been infected by a virus.
9. Outline how your blood is involved in each line of defence against disease.

Evaluate and create

10. Use Venn diagrams to compare the following:
   a. First and second lines of defence
   b. Second and third lines of defence
   c. Physical and chemical barriers in the first line of defence
11. Use Venn diagrams to compare the following:
   a. Inflammation and phagocytosis
   b. Phagocytes and lymphocytes
   c. T lymphocytes and B lymphocytes

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

LESSON

4.5 Immunity and immunisation

LEARNING INTENTION

At the end of this lesson you will be able to explain what immunity is, compare the differences between active and passive immunity, and understand how immunity can be acquired naturally or artificially, and how the development of vaccines have positively affected the world in the fight against smallpox, polio and HPV.

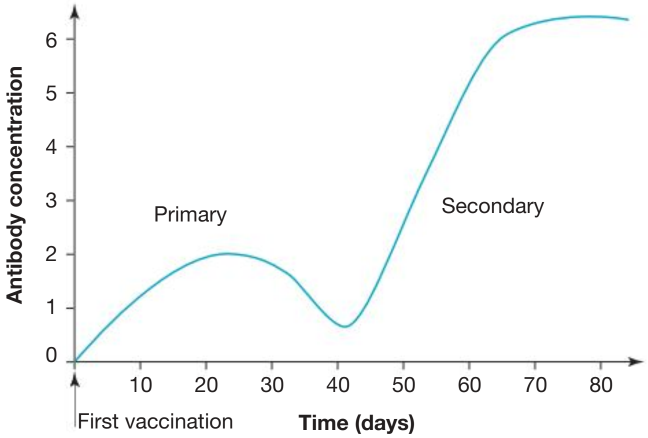
4.5.1 Immunity and immunisation

Immunity is resistance to a particular disease-causing pathogen. A person who is immune does not develop the disease.

If a person is exposed to the antigen of a particular pathogen, or non-self material, they may make specific antibodies against it. The next time they encounter that antigen, their response may be so fast and effective that they can resist infection (figure 4.35).

int-5770

FIGURE 4.35 On the second exposure to an antigen, the immune system is able to start producing antibodies more rapidly and in greater amounts.



Active and passive immunity

If your body makes antibodies to a specific antigen, this is described as **active immunity**. Your body has memory cells that remember the antigen and you can make more identical antibodies very quickly. You could also gain artificial (or induced) active immunity by producing antibodies after being injected with a toxoid or a killed or treated pathogen that contains the antigen.

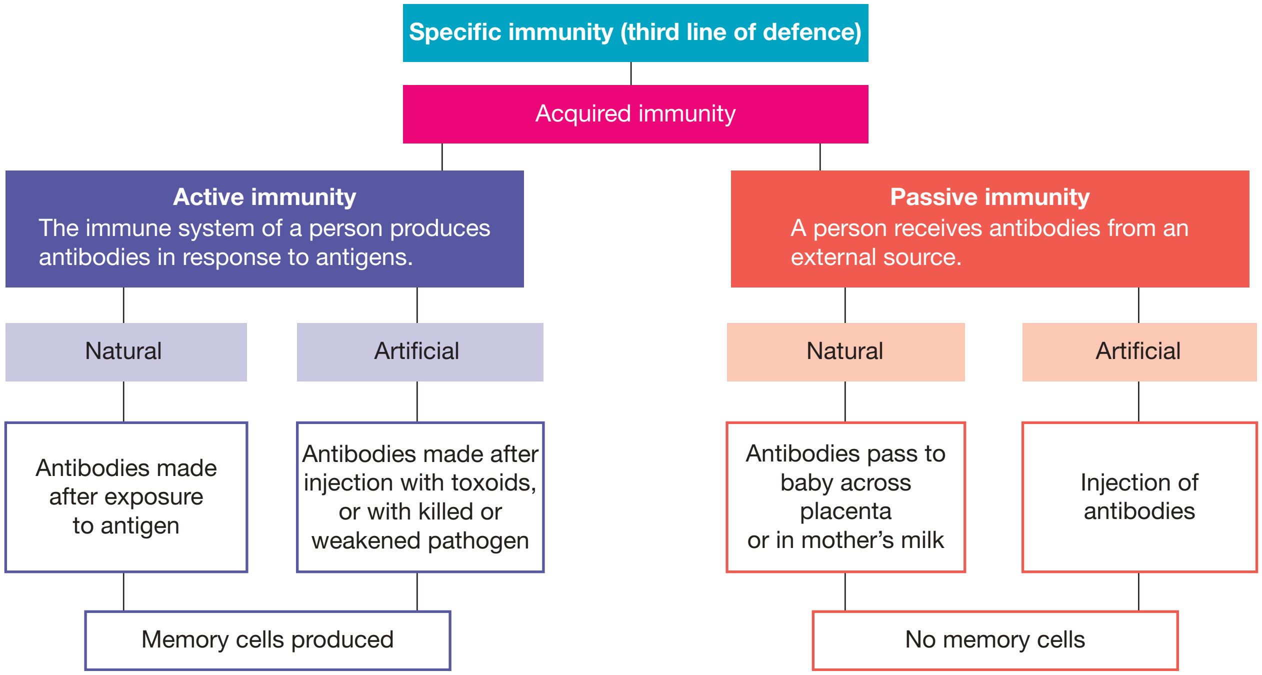
If you receive antibodies from an outside source, this is called **passive immunity**. In this case, you don't have memory cells for this infection so, if you were exposed to it again, your body would react as it did the first time. You could get passive immunity from your mother's milk, across the placenta or through an injection of antibodies.

active immunity immunity achieved by your body making antibodies to a specific antigen

passive immunity immunity achieved by your body receiving antibodies from an outside source, such as from your mother's milk or through vaccination

The development of one type of immunity involves the use of a vaccine. Vaccination or **immunisation** is the giving of a vaccine to produce a type of immunity called artificial immunity. Vaccination trains the immune response to fight a pathogen without being exposed to the dangers of the pathogen itself. Vaccination generates antibody responses against an immunological memory of the pathogen, mimicking the primary infection without being infected.

FIGURE 4.36 Immunity can be active or passive, and acquired naturally or artificially.



Tetanus vaccination

In the case of tetanus, a safe part of the tetanus toxin produced by *Clostridium tetani*, called tetanus toxoid, is used as the antigen to generate a protective immune response (generation of antibodies) against the deadly toxin. When someone who has been vaccinated against tetanus is exposed to it, these pre-existing antibodies bind rapidly to the tetanus toxin and prevent the toxin from binding to and affecting the nerves and muscles. This prevents paralysis and death. Memory cells respond quickly (within a few days) rapidly removing the bacteria and producing higher levels of antibodies against the toxin (see example in figure 4.35). An unvaccinated person has no pre-existing antibodies to bind the toxin which would kill the person in 1–2 days. The antibody response would take weeks to occur without prior vaccination (primary response).

Herd immunity

Herd immunity is the protection that exists when a high proportion of the population has been immunised against a disease. Herd immunity is vital to limit the spread of a disease and protect vulnerable individuals within the community. As vaccinations are not 100 per cent effective it is important that vaccination rates are high among the population for a program to be successful. Herd immunity allows the protection of individuals who are unable to be vaccinated, such as those with a weakened or suppressed immune system, babies and the elderly.

The higher the proportion of the population that is immune, the lower the chance that an unimmunised individual will encounter an infected individual. Over time, the pathogen will have a decreased chance of finding a suitable host and eventually the disease will not be able to spread.

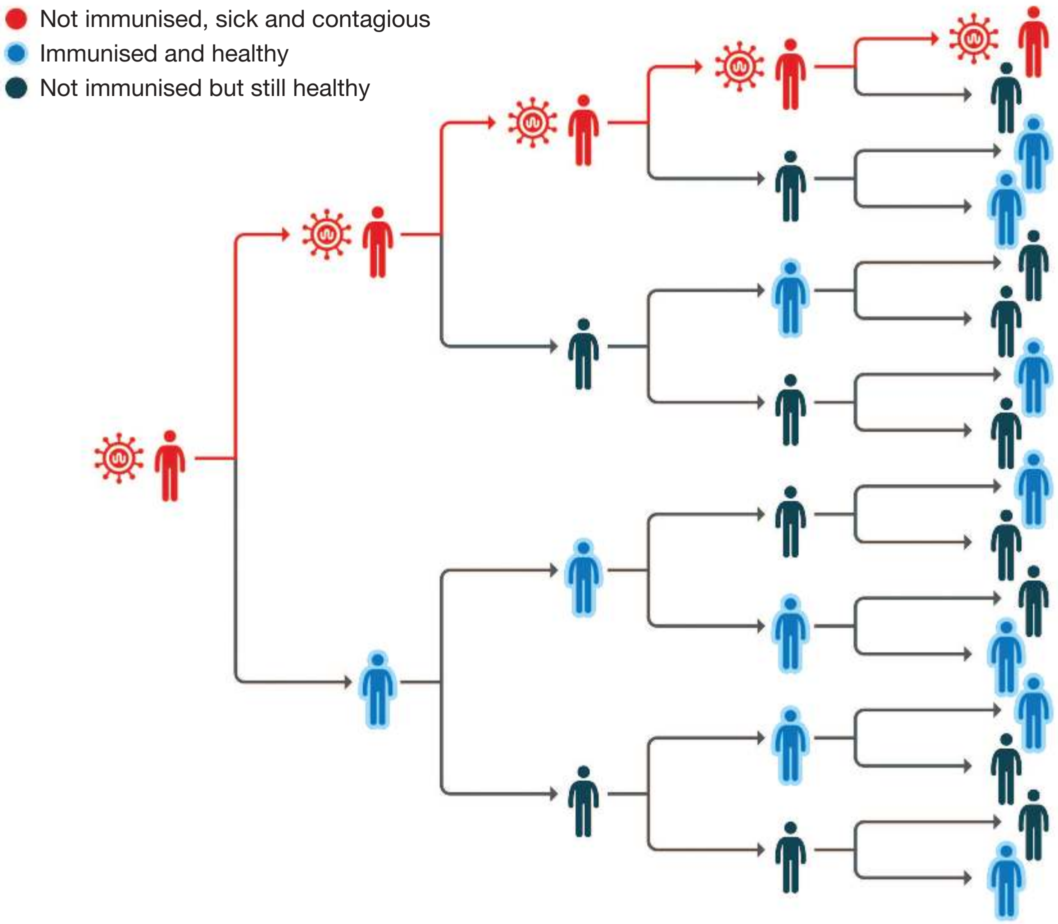
immunisation administering an antigen, such as in a vaccine, with the aim of producing enhanced immune response against the antigen in a future exposure

herd immunity protection against an infectious disease; describes a high proportion of the population being immune to a disease, via vaccination, reducing the spread of the disease and protecting individuals who are not immune

Vaccination programs have led to herd immunity for many infectious diseases, successfully reducing transmission. In some cases, herd immunity has resulted in the worldwide elimination of smallpox and rinderpest. Several other diseases, such as polio, are close to worldwide elimination but still have local outbreaks.

Scientists are now focused on COVID-19 and the vaccination rates required to achieve herd immunity. Currently, we are unsure how long immunity lasts after infection or a vaccination, and booster vaccinations are required to provide longer-lasting immunity. At the beginning of the pandemic in 2020, herd immunity was the desired outcome; however, since then many new variants of COVID-19 have emerged.

FIGURE 4.37 Herd immunity reducing the spread of a disease



SCIENCE AS A HUMAN ENDEAVOUR: The development of vaccines

Smallpox

Throughout history, people noticed that, once infected, a survivor of a disease often did not catch that disease again. A long time before vaccination had been created in England, the Chinese used this observation as a basis for a process called **variolation**.

variolation deliberate infection of a person with smallpox (Variola) in a controlled manner so as to minimise the severity of the infection and also to induce immunity against further infection

In the case of smallpox, variolation involved transferring material from the lesions of those infected with smallpox to healthy individuals. The transference was achieved by inserting infected material under the skin or inhaling the infected powder. The relative success of this process in reducing mortality and morbidity rates resulted in its spread to other countries.

It was an English aristocrat and writer, Lady Mary Wortley Montagu (1689–1762), who was responsible for bringing variolation to England from Turkey around 1721. She had been scarred by smallpox herself and had also lost close relatives to it. Although variolation was used by some of the aristocracy (including the royal family), it was not until 1797 that Edward Jenner (1749–1823) refined this method. Jenner noticed that people who had contracted cowpox, a much less serious disease, did not seem to ever develop smallpox. Jenner took some pus from an infected cow and deliberately gave a person cowpox. Some time later he exposed this person to smallpox, but the person never showed signs of the illness. Jenner had successfully produced an immunity to smallpox. He called the method **vaccination**, from the Latin word for cow, *vacca*. Jenner's vaccination method was able to be used by wider populations, and occasionally its use was enforced. By 1980, because of the use of vaccination, the World Health Organization (WHO) was able to announce the elimination of smallpox from our planet.

FIGURE 4.38 Smallpox leaves the sufferer with scarred skin.

FIGURE 4.39 Lady Mary Wortley Montagu

Polio

Poliomyelitis (polio) is a disease caused by the *Picornaviridae* virus. This disease is highly infectious and consequences can include complete recovery, limb and chest muscle paralysis, or death. It is not contagious, but spreads by consuming contaminated water or food.

A vaccine for polio was developed by Jonas Salk in 1955 using a dead virus. However, this vaccine required a booster shot about every 3 years and occasionally a live virus contaminated the vaccine. One batch in 1955 infected 44 children with polio; this resulted in some fear within the population about its use. In 1956, Polish-American doctor Albert Sabin announced that his oral live virus polio vaccine was ready for mass testing. Public mistrust in the safety of a vaccine using a live virus resulted in Sabin using Soviet (Russian) school children in his large population tests. His tests indicated that this vaccine was not only safer, but also more effective, providing lifelong immunity — and it was cherry-flavoured and could be taken by mouth! By 1961, Sabin's oral polio vaccine was adopted as the standard in the USA. In 1966, Australia also introduced this oral vaccine, and the entire western Pacific region (including Australia) has been declared polio-free since 2000. One case was reported in 2007, in a traveller who acquired polio overseas. Given the extent of travel around the world, polio vaccination remains an important part of Australia's immunisation schedule.

vaccination administering a vaccine to stimulate the immune system of an individual to develop immunity to a disease

poliomyelitis a highly infectious disease caused by the *Picornaviridae* virus that can have consequences including complete recovery, limb and chest muscle paralysis, or death

FIGURE 4.40 Dr Albert Sabin and his vaccine against polio

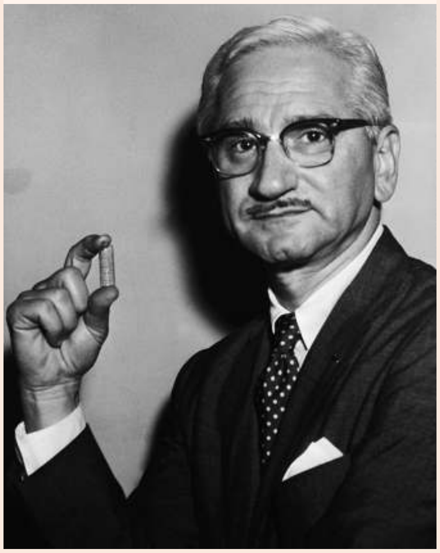


FIGURE 4.41 People suffering with polio may become paralysed.

Cervical cancer

Human papillomavirus (HPV) is the cause of greater than 90 per cent of cervical cancers. Cervical cancer was responsible for the deaths of more than 300 Australian women each year. A vaccine against the papillomavirus was developed by Professor Ian Frazer from the University of Queensland's Centre for Immunology and Cancer Research. He was recognised as Australian of the Year in 2006 for his involvement in this development. Vaccination against HPV began in 2007 for girls aged 12–13 years and has resulted in a significant decrease in the cervical cancer rate of women who have been vaccinated. This vaccine may assist in the prevention and eventual eradication of cervical cancer, which currently affects more than half a million women worldwide each year.

In years gone by, women had a Pap test every 2 years, which was used to detect pre-cancerous and cancerous cells. In Australia, this has been replaced by the cervical screening test in women aged 25–75. This test detects the presence of HPV before the cells have become cancerous. Predictive modelling indicates that if screening and vaccination rates remain at current levels, cervical cancer could be eliminated as a public health issue in Australia by 2035.

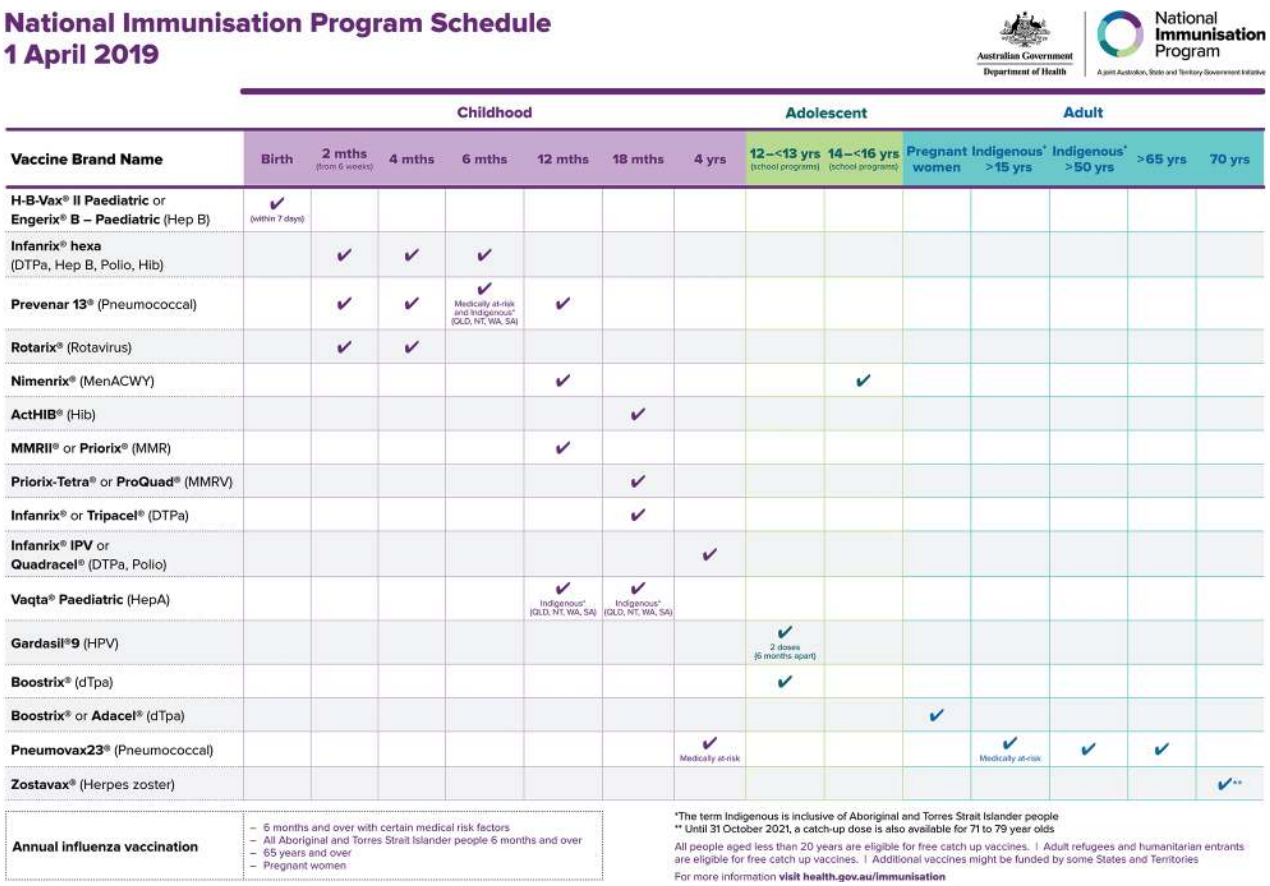
FIGURE 4.42 Ian Frazer developed the HPV vaccine, which may help eradicate cervical cancer.

4.5.2 Vaccination in Australia

Vaccinations have been developed by scientists against many diseases and are available to the majority of Australians. Community health programs ensure that children are vaccinated to protect them against infectious diseases such as tetanus, rubella, mumps, diphtheria, poliomyelitis and whooping cough. Many of these diseases have now been controlled so are rarely seen in Australia.

Alarmingly, there is an increasingly low child immunisation rate in some areas in Australia. This has resulted in the government taking steps to boost the numbers of children immunised.

TABLE 4.2 Vaccine program schedule



National Immunisation Program Schedule
1 April 2019

Australian Government
Department of Health

National Immunisation Program
A joint Australian, State and Territory Government Initiative

	Childhood							Adolescent		Adult				
Vaccine Brand Name	Birth	2 mths (from 6 weeks)	4 mths	6 mths	12 mths	18 mths	4 yrs	12–<13 yrs (school programs)	14–<16 yrs (school programs)	Pregnant women	Indigenous* >15 yrs	Indigenous* >50 yrs	>65 yrs	70 yrs
H-B-Vax® II Paediatric or **Engerix® B – Paediatric** (Hep B)	✓ (within 7 days)													
Infanrix® hexa (DTPa, Hep B, Polio, Hib)		✓	✓	✓										
Prevenar 13® (Pneumococcal)		✓	✓	✓ Medically at-risk and Indigenous* (QLD, NT, WA, SA)	✓									
Rotarix® (Rotavirus)		✓	✓											
Nimenrix® (MenACWY)					✓				✓					
ActHIB® (Hib)						✓								
MMRII® or **Priorix®** (MMR)					✓									
Priorix-Tetra® or **ProQuad®** (MMRV)						✓								
Infanrix® or **Tripacel®** (DTPa)						✓								
Infanrix® IPV or **Quadracel®** (DTPa, Polio)							✓							
Vaqta® Paediatric (HepA)					✓ Indigenous* (QLD, NT, WA, SA)	✓ Indigenous* (QLD, NT, WA, SA)								
Gardasil®9 (HPV)								✓ 2 doses (6 months apart)						
Boostrix® (dTpa)								✓						
Boostrix® or **Adacel®** (dTpa)										✓				
Pneumovax23® (Pneumococcal)							✓ Medically at-risk				✓ Medically at-risk	✓	✓	
Zostavax® (Herpes zoster)														✓**

Annual influenza vaccination	– 6 months and over with certain medical risk factors – All Aboriginal and Torres Strait Islander people 6 months and over – 65 years and over – Pregnant women

*The term Indigenous is inclusive of Aboriginal and Torres Strait Islander people
** Until 31 October 2021, a catch-up dose is also available for 71 to 79 year olds

All people aged less than 20 years are eligible for free catch up vaccines. | Adult refugees and humanitarian entrants are eligible for free catch up vaccines. | Additional vaccines might be funded by some States and Territories

For more information **visit health.gov.au/immunisation**

Travel vaccinations

If you are planning an overseas trip, it's recommended that you research the conditions in your holiday destination carefully. Otherwise you may bring back more than you expect!

Although many travellers are aware that immunisations to travel to certain countries are recommended, the most common illness suffered by overseas travellers is diarrhoea. While this may cause a little discomfort in the short term, it may be lethal if it continues for a long time. It is responsible for the deaths of almost five million children in tropical regions each year. There are no vaccines to protect you against it, but you can reduce your risk of getting diarrhoea by following a few simple precautions. These include avoiding uncooked foods that may have been washed with contaminated water or handled unhygienically. Only bottled or boiled water may be safe to drink.

Vaccines are currently available for some strains of hepatitis, typhoid, yellow fever, Japanese encephalitis, cholera, influenza, rabies and bacterial meningitis.

If you are travelling to a region where malaria is a problem, you are advised to begin a course of antimalarial tablets before leaving. This preventative action should be continued for at least a month after your return. Some countries require proof of a vaccination against yellow fever before you are allowed to enter the country.

FIGURE 4.43 Proof of vaccination against yellow fever

EXTENSION: No more needles? Vaccine delivery via patch

Since 1853, the syringe has been the main delivery system for vaccines. Professor Mark Kendall and his team of researchers at the University of Queensland have developed a game changer for vaccine delivery — a painless tiny skin patch that doesn't require trained doctors and nurses to deliver it, and doesn't need refrigeration. Find out more about the Vaxxas nanopatch, then consider the following points:

- How does the nanopatch deliver the vaccine antigens? Which cells are targeted in the person being vaccinated?
- How will the nanopatch benefit African countries? Compare and contrast with the benefits for Australia.
- What is the first vaccine being trialled using this new technology in conjunction with the World Health Organization (WHO)?

on Resources

eWorkbooks	Immunity (ewbk-12401) Vaccination (ewbk-12402)
Video eLesson	Immunisation in Australia (eles-0126)

4.5 Activities

learnon

4.5 Quick quiz on

4.5 Exercise

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 3	2, 4, 5	6, 7

Remember and understand

1. Describe a way in which each of the following people contributed to the fight against disease.
   a. Lady Montagu
   b. Edward Jenner
   c. Jonas Salk
   d. Albert Sabin
2. Distinguish between the following:
   a. Immunity and immunisation
   b. Antigen and antibody
   c. Active immunity and passive immunity
   d. Natural passive immunity and artificial passive immunity
   e. Natural active immunity and artificial active immunity

Apply and analyse

3. **SIS** Whooping cough, caused by *Bordetella pertussis*, is a very serious infection of the respiratory system. It can cause violent coughing fits. The cough has a distinctive whooping sound, which led to the disease name. Whooping cough is most harmful for young babies and can be deadly.
   a. Look at the vaccination schedule in table 4.2. Pertussis (whooping cough) is vaccinated against using the DTP (diphtheria, tetanus and pertussis) vaccine. When are children vaccinated against whooping cough?
   b. Explain how unborn babies and newborn babies can be protected against whooping cough before they are old enough for their first vaccination.
   c. Should people visiting babies in hospitals and homes, including grandparents, be required to be vaccinated? Give reasons for your answer.
   d. Does the vaccine provide life-long protection? If not, how often should people be given a booster shot of the vaccine to remain protected?

4. ‘No Jab, No Play’ is the name of legislation that requires all children to be fully vaccinated, unless they have a medical exemption, in order to be enrolled in childcare or kindergarten in Victoria. Who else is vulnerable to harm and potential death from this disease in our community?
5. a. Describe herd immunity.
   b. Explain why the World Health Organization states that 95 per cent of the population needs to be vaccinated against a pathogen to maintain herd immunity.
   c. Predict what happens when vaccination rates drop to 80 per cent of the population.

Evaluate and create

6. **SIS** The following table shows statistics of the number of people infected with vaccine-preventable diseases in Victoria from January 2019 to January 2020.

TABLE Infections of preventable diseases in Victoria, 2019

Vaccine preventable diseases	128 (current)
Diphtheria	0
Haemophilus influenzae type B infection	0
Influenza	63
Measles	1
Meningococcal infection	0
Mumps	0
Pertussis	54
Invasive pneumococcal disease (IPD)	10
Rotavirus infection	0
Rubella	0
Tetanus	0
Varicella zoster infection (chickenpox)	0
Varicella zoster infection (shingles)	0
Varicella zoster infection (unspecified)	0

   a. Use the table to identify how many whooping cough infections there were from January 2019 to January 2020. Suggest why there were so many whooping cough infections when cases of other vaccine-preventable diseases were not occurring in the same 12-month period.
   b. Do you think we will ever be able to eradicate whooping cough from the planet, as was done with smallpox?
7. **SIS** a. Draw a flow chart showing the effect of *Clostridium tetani* infection on the human body systems. Include the time it would take for a person to die from tetanus if unvaccinated.
   b. Explain why a person who has been vaccinated against tetanus does not die when they are infected with *Clostridium tetani*. Refer to figure 4.35.
   c. Compare the response in part b to an unvaccinated person.

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

LESSON
4.6 Outbreaks

LEARNING INTENTION

At the end of this lesson you will be able to understand how epidemics and pandemics have shaped human history and why the world's population is more vulnerable to infections than in earlier times.

4.6.1 Epidemics and pandemics

Disease has shaped our human history. It could be argued that we are who we are because of and in spite of disease.

Throughout history there have been records of **plagues** — contagious diseases that have spread rapidly through a population and resulted in high death rates. There are also other terms used to describe the spread of disease. **Epidemics** occur when many people in a particular area have the disease in a relatively short time and **pandemics** are diseases that occur worldwide.

plagues contagious diseases that spread rapidly through a population and results in high mortality (death rates)

epidemic a disease affecting a large number of people in a particular area in a relatively short period of time

pandemic a disease occurring throughout an entire country or continent, or worldwide

bubonic plague an infectious, epidemic disease, caused by the *Yersinia pestis* bacteria and carried by fleas from rats; also known as the Black Death

Black Death *see* bubonic plague

The Black Death — bubonic plague

The Plague of Justinian in the sixth century was one of the first recorded pandemics. It is thought to have been the result of **bubonic plague**. Of all of the plagues throughout history, the bubonic plague (known as the **Black Death** in Europe) has been the most widespread and feared. Its name is due to the presence of black sores on the skins of victims. The cause of the disease is the bacteria *Yersinia pestis*. These bacteria were transmitted by fleas that had bitten an infected rat and then bitten a human, infecting the human with the disease.

Bubonic plague was first recorded in the north-eastern Chinese province of Hopei in 1334, where it is thought to be responsible for the death of about 90 per cent of the people. By 1348, bubonic plague had reached Europe. Within 5 years, an outbreak of this disease had resulted in the death of almost one-third of Europe's population. After this time, plague visited England another six times before the end of the century.

Nearly all those infected died within 3 days of their first symptoms appearing. Lack of medical knowledge and great fear resulted in the development of a diverse range of methods being used to fight the condition. Some people tried special diets or were cut or bled in the hope that the disease would leave their bodies along with their bodily fluids. Others (flagellants) whipped themselves to show their love of god, hoping to be forgiven their sins and spared the disease. Most importantly, bodily wastes and the bodies and clothes of those infected with the disease were burned in deep pits. In some areas, improved public sanitation resulted from these outbreaks.

The last recorded epidemic of the Black Death was around 1670. A victim of its own success, it had killed so many so quickly that those remaining had either immunity or genetic resistance. While it could still infect, its hosts were able to fight back and destroy it. Its demise paved the way for another disease, smallpox, to take over as the number one infectious disease.

FIGURE 4.44 Plague doctors wore protective clothing that included a long beak filled with antiseptic substances.

4.6.2 Crossing boundaries

Recent years have seen not only the discovery of new infectious agents, but also the emergence of some of our old infectious enemies. Some of these new diseases are crossing the species barrier and are now infecting species that they previously did not affect. Increasing resistance of many pathogens to antibiotics or vaccines has also raised concerns about the potential for sudden outbreaks of infectious diseases around the world.

Some of the new diseases and pathogens that have been identified as having crossed the species barrier over the past few decades include Lyme disease, rabies, henipavirus, bovine spongiform encephalopathy (mad cow disease), Legionnaire's disease, HIV, Marburg virus, hantavirus, SARS, H5N1, Ebola virus and SARS-CoV-2 (the virus that causes COVID-19).

FIGURE 4.45 The bacteria causing the Black Death was transmitted by fleas.

Increased travel between continents brought new knowledge and discoveries. It also brought death. At the turn of the century, around 1500 expeditions by Columbus and other explorers brought venereal diseases, smallpox and influenza to areas that had no history of them. This resulted in the deaths of millions of native people, who had no prior exposure to enable them to develop immunity. In some areas, up to 95 per cent of the native population died. This drop in population from introduced diseases was so significant it can be seen in a global fall in carbon dioxide levels around the globe (as preserved in Antarctic ice core records). Carbon dioxide levels fell so significantly because farming across the American continent nearly stopped entirely, which resulted in re-growth of forests, which in turn consumed more carbon dioxide. This event is recognised globally and has been suggested to mark the start of a new geological era known as the Anthropocene — the age of humans.

surface protein a protein molecule occurring on the surface of a virus

Spanish influenza a strain of influenza caused by the H1N1 subtype of influenza virus, which spread across the world in 1918–1920

4.6.3 Viral diseases

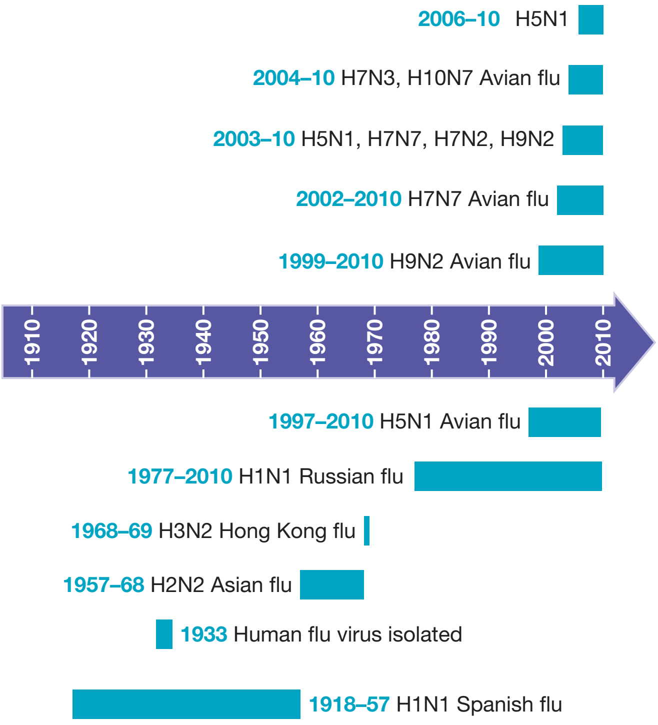
Why are viruses so effective at infecting large populations? Let's consider some of the major viruses that have affected the world in modern times.

Influenza

Throughout history, there have been numerous outbreaks of influenza. The influenza virus constantly evolves, and pandemics happen every few decades when the flu virus gets new **surface proteins** that people have little immunity to, generally because they come from an animal strain.

By the end of 1918, more than 25 million people had died from a virulent strain of **Spanish influenza** (H1N1). In 1919, the League of Nations Health Organisation was established, with the aim of preventing and controlling disease around the world.

FIGURE 4.46 A timeline of influenza outbreaks

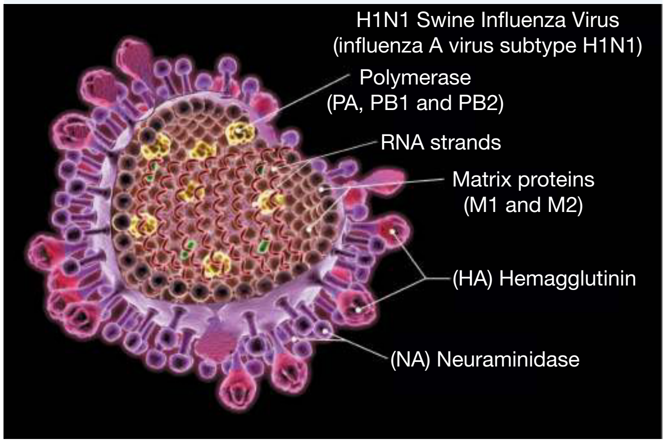


The **Asian influenza** (H2N2) pandemic emerged in 1957, followed by a series of others over the next decades. **Avian influenza** (H5N1) made its debut in 1997 in a form that was highly contagious among birds and also infected humans. Since that time, it has devastated East Asian poultry industries. By 2006, a particular strain of H5N1 had been transmitted to humans and had caused a number of fatalities. H5N1 was dangerous because its H5 surface protein was totally new to humans — this is why it has killed more than half of the people who have been infected with it.

Swine flu

In 2009 there was a **swine flu** (H1N1) pandemic, which killed several thousand people. This strain of influenza contained a mixture of genes from the swine flu, human flu and avian flu viruses. It was of particular concern because it was thought that this new strain might have surface proteins that the human immune system may not recognise.

FIGURE 4.47 The swine flu (H1N1) virus contains a mixture of genes from the swine flu virus, human flu virus and avian flu virus.



Asian influenza a strain of influenza caused by the H2N2 subtype of influenza virus, which spread across parts of the world in 1956–58

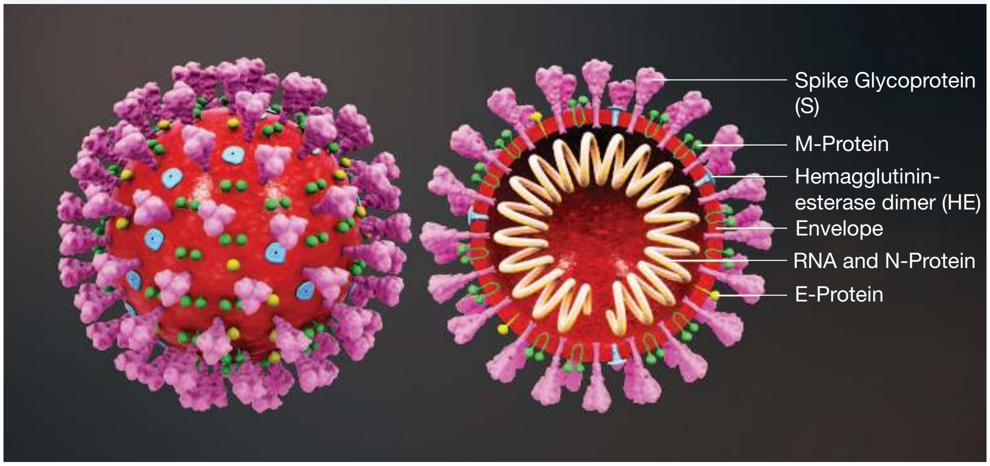
avian influenza a strain of influenza caused by the H5N1 subtype of influenza virus that is highly contagious in birds and has caused over 300 fatalities in humans since 2003

swine flu a strain of influenza caused by the H1N1 subtype of influenza virus, containing a combination of genes from the swine, human and avian flu viruses

Coronaviruses

Coronaviruses are named for the 'corona' or crown of spikes on their viral envelope, which gives them their characteristic shape. These spikes bind to specific receptors on the host cell. Coronaviruses have a strand of RNA surrounded by a viral envelope with spike proteins. In humans and some other animals, coronaviruses cause respiratory tract infections. They were first discovered in the 1930s in a respiratory tract infection in domesticated chickens.

FIGURE 4.48 Morphology of a coronavirus



There have been three coronaviruses that have produced severe symptoms in humans.

SARS-CoV: Severe Acute Respiratory Syndrome Coronavirus

During 2002–2004 this virus infected around 8000 people, with a mortality rate of approximately 10 per cent. In 2017, scientists traced the cause of the virus from a population of horseshoe bats in China, which passed the virus through the intermediary species of civets (a small, nocturnal mammal native to Asia and Africa), and then on to humans. No cases have been recorded since 2004.

MERS-CoV: Middle East Respiratory Syndrome-related Coronavirus

Another virus throught to have originated in bats; humans are typically infected through contact with camels or camel products. Spread between humans is not common, and requires close contact. Between its discovery in 2012 and 2020, there have been approximately 2500 cases, but it has a mortality rate of 35 per cent. There is currently no vaccine.

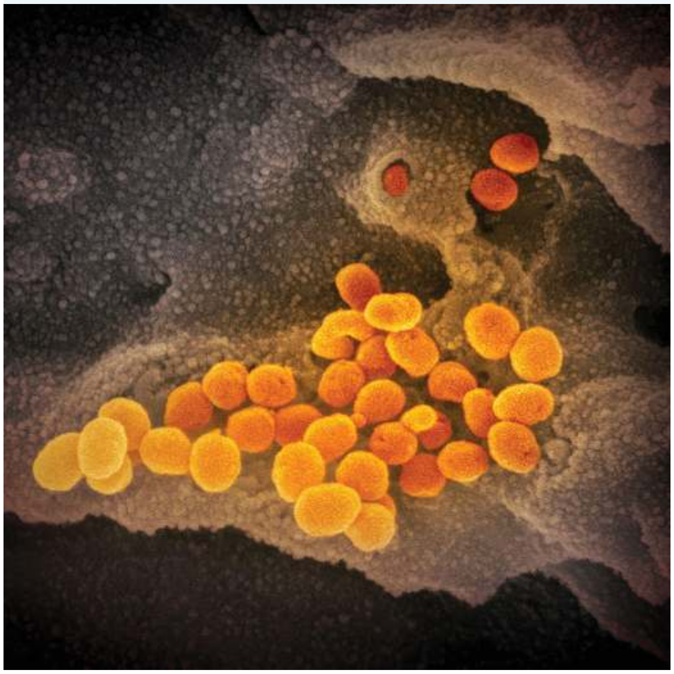
SARS-CoV-2: Severe Acute Respiratory Syndrome Coronavirus 2

This is the virus that causes COVID-19. It was recognised as a global pandemic and the World Health Organization (WHO) designated it a Public Health Emergency of International Concern. Initial scientific investigations suggest it has an animal origin due to its genetic similarity to bat coronaviruses, and may have passed through pangolins as an intermediate species in its spread to humans. China was the first country to report the disease to the WHO in late December 2019, and it is currently thought to have originated in Wuhan, China, in people working in a market. By 2022, there were more than 500 million confirmed cases of COVID-19 around the world, and the mortality rate is thought to be less than 5 per cent. While it is thought to cause less severe illness in the majority of cases compared to SARS-CoV, it appears to be much more infectious.

The shape of SARS-CoV-2 is much like other coronaviruses, and it is approximately 50–200 nanometres in diameter. It has four structural proteins as shown in figure 4.48. The spike protein is what allows it to attach to the cell membrane of the host cell. The virus is thought to infect a patient in the following way:

- An infected person expels droplets with the virus and they are absorbed through the mucous membranes (inhaled, or perhaps even through touching the eyes or mouth).
- Cells in the nose have a cell-surface receptor called ACE2, which the virus attaches to and then enters the cell, and starts making many copies of itself. Although they are infectious, patients may not even have symptoms at this point, or they may develop a fever, dry cough, sore throat or a loss of smell and taste.
- If the body does not fight off the invading virus at this point, the virus moves down the windpipe and enters the lungs. The tiny air sacs in the lungs (the alveoli) are lined with a single layer of cells that are also rich in ACE2 receptors. The virus populates the alveoli and the patient can struggle to breathe.

FIGURE 4.49 A scanning electron microscope image of SARS-CoV-2 (orange) emerging from the surface of cells (grey) cultured in a laboratory

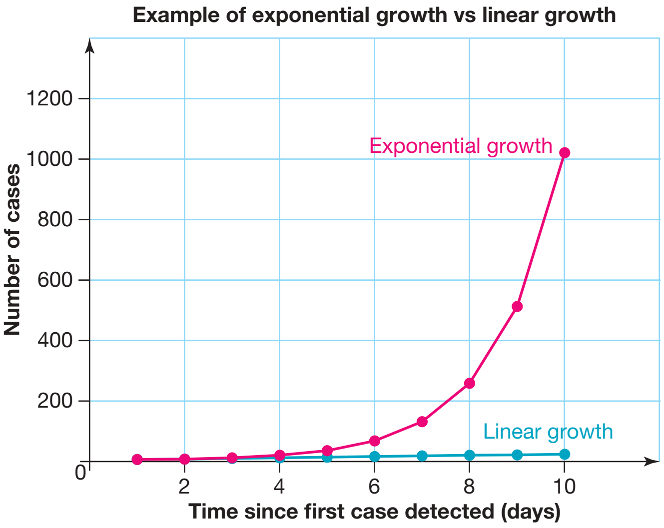


- White blood cells try to fight off the virus, and encourage more immune cells to grow, killing the virus but leaving fluid and dead cells (pus) in the lungs, which can fill the lungs and leave patients struggling to breathe.
- In severe cases the immune system overreacts to the virus causing a 'cytokine storm' and the immune system starts to attack healthy cells. Blood pressure drops, blood vessels leak and blood clots form, which can lead to severe damage to, and even failure of, other organs such as the heart, liver, kidneys and intestines.

These severe symptoms require high levels of care in hospitals, and that is why the world's population was placed under instructions to minimise physical contact, to ensure hospitals were not overwhelmed by severe cases of COVID-19. This public health strategy became known as 'flattening the curve' of new infections. Due to the infectiousness of this virus, the curve of new infections could be defined by a mathematical phenomenon known as exponential growth, where infections were doubling every three days.

Exponential growth is difficult to visualise. The graph at figure 4.50 compares linear growth and exponential growth.

FIGURE 4.50 A comparison of exponential growth and linear growth



The World Health Organization has identified a likely series of steps that allow viruses to spread across the world:

- An influenza virus in birds or animals develops the ability to infect humans and cause serious disease. Humans need close contact with animals for this to occur.
- The virus mutates (changes its genetic makeup), which allows it to pass from human to human.
- The virus is able to transmit readily between humans because of its short incubation period and how easily it can be spread (contact with body fluids, coughing sneezing etc.) As we saw with COVID-19, rapid global spread occurs through international travel.

Since the emergence of the virus, scientists around the world have been working in collaboration to understand COVID-19.

FIGURE 4.51 Scientist wearing protective clothing while studying samples of COVID-19

FIGURE 4.52 There are many ways to help stop the spread of contagious diseases.

on Resources

Weblink COVID-19 data

ACTIVITY: Indigenous rangers

Biosecurity measures are important when people and products enter Australia as it stops diseases and pests from damaging Australia's primary industries.

Indigenous rangers play a crucial role as they combine traditional knowledge with conservation training.

1. Research the role of Indigenous rangers and the jobs they undertake. Explain how they prevent the transfer of certain diseases and pests.
2. How do they use their traditional knowledge to protect and manage their land, sea and culture?

4.6 Activities

learnon

4.6 Quick quiz on

4.6 Exercise

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 2, 3, 8	4, 5, 9, 10	6, 7, 11, 12

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

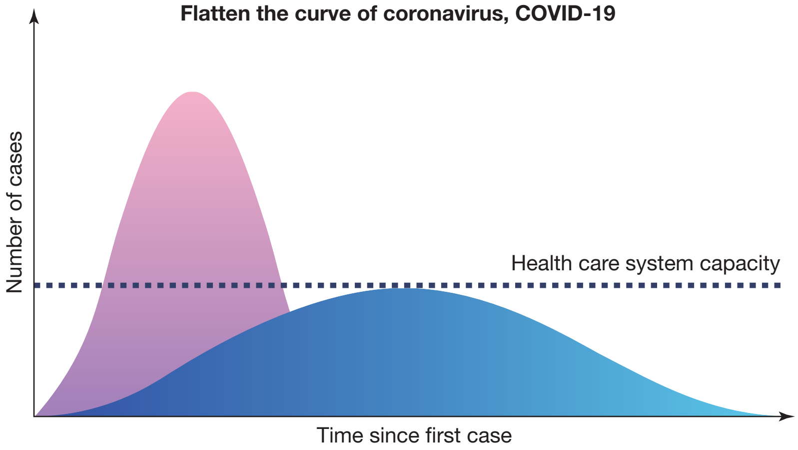
1. Define the term *plague* and give one example.
2. State two differences between an epidemic and a pandemic. Give one example for each of them.
3. Suggest why bubonic plague is often referred to as the Black Death.
4. Suggest why the last recorded epidemic of bubonic plague was around 1670.
5. Provide three examples of new infectious diseases that have been identified over the last few decades.

Apply and analyse

6. Construct a flow chart to show the relationship between the bubonic plague pathogen, fleas and rats.
7. Names of human diseases can change over time for various reasons. Hendra virus was originally called equine morbillivirus, but after further investigation was found not to be a morbillivirus. It was re-named after the Brisbane suburb where the first outbreak occurred. The 1918 'Spanish flu' did not originate from Spain. The swine flu outbreak had a significant impact on the meat and pork trade and the virus is now referred to as influenza A H1N1.
   In 2015 the WHO identified a best practice for naming new human diseases. Diseases are no longer named after geographical location, animals, individuals or groups of people. Explain why you think this change was made.
8. Explain the relationship between international travel and pandemics.
9. Explain why you think COVID-19 spread so rapidly around the world.
10. Suggest three actions that can help control the spread of a virus.

Evaluate and create

11. **SIS** The graph shows the relationship between the number of cases of COVID-19 and the time since the first case was identified.



   a. Describe the shape of the two curves with reference to health care system capacity.
   b. Explain why it is important to ‘flatten the curve’ of infections.

12. Suggest how COVID-19 is different from SARS.

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

LESSON
4.7 Our noble Nobels

LEARNING INTENTION

At the end of this lesson you will be able to provide examples of some of the contributions that our Australian Nobel Prize winners have made to scientific knowledge and understanding.

4.7.1 Australian Nobel Prize winners

Australian scientists have made significant contributions to disease control and to the quality of life that we enjoy today. Sir Howard Florey, Sir Frank Macfarlane Burnet and Professor Peter Doherty each won a Nobel Prize in Medicine.

One hundred years ago, many children died from both infectious diseases and bacterial infections. A small scratch was sometimes enough to allow deadly bacteria to enter the body and cause swelling, the formation of pus and severe pain. Children born today can avoid the harsh consequences of most bacterial infections.

Understanding and finding cures for infectious diseases has been a long process involving the efforts of many scientists around the world. Some of the key researchers in the discovery and development of penicillin, and their ideas and breakthroughs, are listed in tables 4.3 and 4.4. If it were not for their contributions, we may not have the antibiotic medicines that we take for granted today.

TABLE 4.3 Australian Nobel Prize–winning scientists

Year of Nobel Prize	Scientist	Contribution to our understanding of disease
1945	Howard Florey (1898–1968)	Isolation and manufacture of penicillin and discovery of its curative effect in various infectious diseases
1960	Frank Macfarlane Burnet (1899–1985)	Discovery of acquired immunological tolerance
1996	Peter Doherty (1940–)	Discoveries about the specificity of the cell-mediated immune defence
2005	Barry Marshall (1951–) and Robin Warren (1937–)	Discovery of the involvement of the *Helicobacter pylori* bacterium in stomach ulcers and gastritis

TABLE 4.4 Other notable Nobel Prize–winning scientists

Scientist	Field	Contribution to our understanding of disease
Louis Pasteur (1822–1895)	French chemist	Discovered that infectious diseases are spread by bacteria. Observed that mould stopped the spread of anthrax
Joseph Lister (1827–1912)	British surgeon	Noted that samples of urine contaminated with mould prevented bacterial growth
Alexander Fleming (1881–1955)	Scottish bacteriologist	In 1928, while studying the influenza virus, Fleming went on holiday and left several discarded Petri dishes on his bench. He had been using them to grow bacteria in nutrient jelly. When he returned, he noticed that where some of the mould had fallen, the bacteria had been killed. He called this substance penicillin but was unable to extract it and did not pursue it further.

4.7.2 Howard Florey — penicillin

Howard Florey was born in Adelaide in South Australia in 1898. He was a keen student who loved sport and chemistry. He studied medicine at the University of Adelaide where he won a Rhodes scholarship to Oxford University, England. While in England he led the team who finally extracted **penicillin** in 1940. In 1945 he shared his Nobel Prize withAlexander Fleming and Ernst Chain. In speaking of his discovery, he modestly stated, ‘All we did was to do some experiments and have the luck to hit on a substance with astonishing properties.’

FIGURE 4.53 Howard Florey

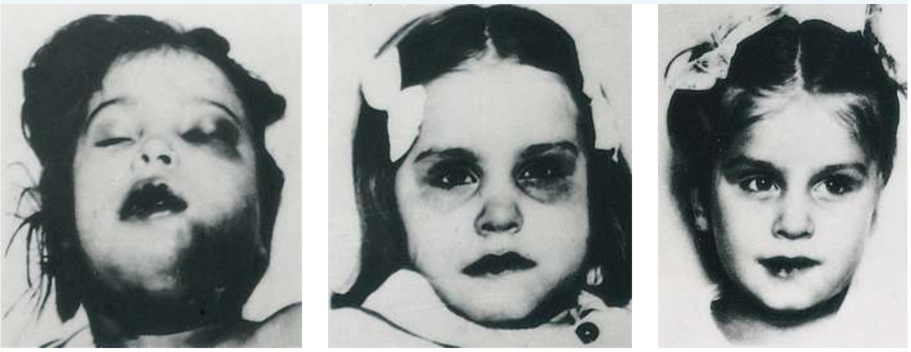
Penicillin was so successful in saving lives that population control became an issue for medical researchers. Florey later worked on contraception research. In honour of his contribution to medicine, he was knighted in 1944. His likeness appeared on an Australian $50 banknote and a suburb of Canberra was named after him.

Penicillin is an antibiotic and is a chemical made by the mould (fungus) *Penicillium* If you leave oranges for too long in the fruit bowl, you will sometimes find them growing a greenish mould. This is *Penicillium*. Antibiotics destroy bacteria, and they are widely used to treat diseases caused by bacteria. In the human bloodstream, penicillin works by stopping bacteria from forming cell walls as they try to divide. Natural penicillin must be given by injection as otherwise it is destroyed by stomach acid. Some people are allergic to penicillin, but luckily there are now several different antibiotics to choose from. There are few people in the community who have not taken antibiotics at some time in their lives.

penicillin a powerful antibiotic substance found in moulds of the genus *Penicillium* that kills many disease-causing bacteria

While penicillin has saved millions of lives, there are now strains of bacteria that are becoming resistant to penicillin. These include *Staphylococcus aureus* (‘golden staph’ or MRSA) and *Neisseria gonorrhoeae* (the cause of gonorrhoea).

FIGURE 4.54 These photographs from 1942 show how serious a bacterial infection can be. After being treated with penicillin, the patient's condition improved and she recovered fully.



This resistance develops due to mutations (or changes) to the bacteria that result in the bacteria being able to affect the penicillin before it has a chance to work. This resistance is thought to be due to overuse of antibiotics, which allows the bacteria to mutate. These mutations in the bacteria affects penicillin in different ways:

- the bacteria can break down the antibiotic through degradation by enzymes
- changes to the bacterial proteins that are the targets for the antibiotic
- changes in membrane permeability of the bacteria to antibiotics.

4.7.3 Frank Macfarlane Burnet — immunology

Frank Macfarlane Burnet, known as 'Mac', was born in Traralgon, Victoria, in 1899 and died in 1985. As a boy, he loved science and spent hours exploring the bush near his home searching for beetles. Charles Darwin was his hero. After graduating from the University of Melbourne as a medical researcher, he started work at the Walter and Eliza Hall Institute (WEHI) in Melbourne. He then worked in England for many years, returning to Australia in 1944 to become director of the WEHI. He was knighted in 1951 and received his Nobel Prize in 1960. In 1961 he was named Australian of the Year, and 4 years later he was elected President of the Australian Academy of Science.

Immunology, the science that deals with protection from diseases, was Mac's speciality and he spent most of his career studying viruses. His doctorate thesis was on the **phage**, a type of virus that infects and kills bacteria. Scientists of the time thought there was only one species of phage. Mac showed that there are, in fact, several species.

FIGURE 4.55 Mac demonstrates his method of growing viruses by injecting them into eggs to a class of US postgraduate students.

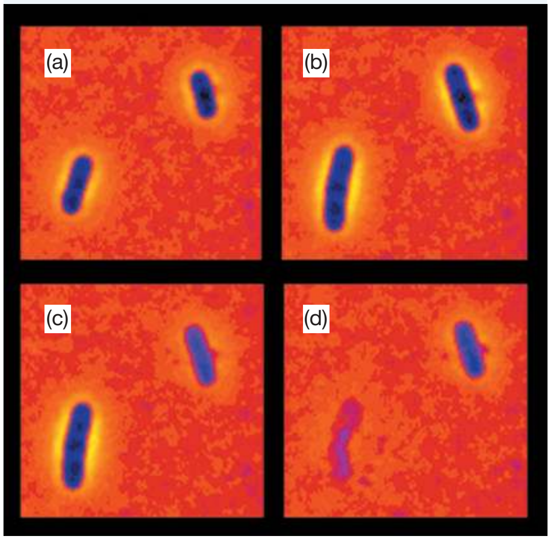
In 1928, there was public hysteria against vaccination when 12 children died after receiving their diphtheria injections. Mac was part of a team that investigated this tragedy. His experiments showed that contamination of the vaccine caused the deaths, rather than the vaccine itself. This no doubt saved many further lives as people regained their confidence in vaccination.

immunology the branch of science that deals with immunity from disease

phage a type of virus that infects and kills bacteria

Influenza strains

FIGURE 4.56 In these photographs, bacteria were grown in penicillin for 30 minutes. The bacteria grow longer as shown at **(b)**, but eventually rupture **(d)**, unable to divide due to the influence of the penicillin.



While in England, Mac worked on the human influenza (flu) virus and developed a successful method of growing high concentrations of the virus using fertilised chickens' eggs. This work led to the development of an influenza vaccine. Mac determined that there were several strains of influenza. This meant a new vaccine had to be developed each year once the particular strain of influenza had been identified. His work laid the foundation for the discovery by Dr Peter Coleman from CSIRO that all influenza viruses had a common part. Researchers then focused on ways to attack this common part and were able to produce drugs that can kill all strains of influenza virus. Now, people in high-risk categories are encouraged to be vaccinated each autumn to avoid contracting the disease.

Mac was so dedicated to his work that he was willing to risk his life to show others what he knew. In the early 1950s, CSIRO released the myxomatosis virus so it would infect and reduce the rabbit population in Australia. At the same time, there was an outbreak of encephalitis that made hundreds of people sick. The public started to blame myxomatosis. Mac knew how the myxoma virus worked and that it could not affect humans. He set up an experiment where he and two colleagues, Professor Frank Fenner and Dr Ian Clunies Ross, injected themselves with live myxoma virus. When it was shown that their health was not affected, the panic died down.

4.7.4 Peter Doherty — understanding the immune system

Professor Peter Doherty was born in Brisbane in 1940. He received a veterinary science degree from the University of Queensland and a graduate medical degree from the University of Edinburgh. He shared his Nobel Prize in 1996 with Rolf Zinkernagel when they described the way the **immune system** recognises virus-infected cells. In 1997 Peter Doherty was named Australian of the Year. Doherty and Zinkernagel worked at the John Curtin School of Medical Research in Canberra from 1973 to 1975.

immune system a network of interacting body systems that protects against disease by identifying and destroying pathogens and infected, malignant or broken-down cells

The immune system uses special white blood cells called T lymphocytes, or T cells, to protect an organism from infection by eliminating invading microbes. T cells have to be smart enough to avoid damaging their own organism. They need a recognition system so that they can identify the parts they must destroy and those they must protect. The body also needs to know when to activate them.

FIGURE 4.57 Laureate Professor Peter Doherty

Doherty and Zinkernagel studied mice to learn how their immune systems (particularly their T cells) protect them against the virus that causes meningitis. They discovered that mice can make killer T cells that protect them. However, when these T cells were placed in a test tube with infected cells from another mouse, they did not work. Doherty and Zinkernagel developed a model to explain why this happened. They said that each T cell carries a marker that allows it to recognise the cell of the organism it is protecting, as well as the antigen of the invading microbe. At the spot where the antigen attaches itself to the host, the T cell can make a matched fit and destroy the antigen. It works like two interlocking pieces of a jigsaw puzzle.

When your body is exposed to a microbe, it develops T cells that give it immunity. If there are enough of the right type of T cells, these can eliminate the microbes faster than they can reproduce and you remain well. Your body keeps some of these T cells as immunity against future attacks from the same microbe.

This work has had a major impact on our understanding of organ transplantation and vaccines. Scientists now realise they must try to match both tissue and immune system types for a successful transplantation. Laureate Professor Peter Doherty is now the patron and namesake of the Doherty Institute for Infection and Immunity, which is a research facility between the University of Melbourne and the Royal Melbourne Hospital. He is still active in Science, and has also written a number of popular Science books, including *The Beginners Guide to Winning the Nobel Prize*.

4.7 Activities

4.7 Quick quiz on

4.7 Exercise

Select your pathway

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

Remember and understand

1. Who discovered that infectious disease was spread by bacteria?
2. Sir Howard Florey, Sir Frank Macfarlane Burnet and Professor Peter Doherty are Australians who have received a Nobel Prize for their contributions to medical research.
   a. Which Nobel Prize did each win and in what year?
   b. In which area of science did each one specialise?
3. Are there any strains of bacteria that are resistant to penicillin?

Apply and analyse

4. Explain what would have happened to you if you had a bacterial infection in the time before penicillin was discovered?
5. Explain how antibiotic resistance develops.

Evaluate and create

6. **SIS** Howard Florey infected eight mice with streptococcus. Four of the mice that were given a penicillin injection survived the infection and those that did not receive penicillin died from the infection.
   a. Explain why the mice given the penicillin injection survived the infection. Explain how penicillin works.
   Following the success of penicillin in treating infection in mice, Florey and his team of scientists produced cultures of *Penicillium notatum* as a source of penicillin in the 'fungus juice' to try to slow or counteract bacterial infections in humans. In 1940, Oxford Police Constable, Albert Alexander, was hospitalised following infection with streptococcus and staphylococcus, resulting from a rose bush's scratch to his face. Howard Florey's wife, Ethel, a pharmacologist, brought Albert's plight to his attention, as other treatments were failing and Albert's face was covered in abscesses. Albert lost his eye to the infection. Within 24 hours of injection with penicillin, Albert was showing signs of recovery. After 5 days of treatment the penicillin ran out. They had even been extracting penicillin from Albert's urine to prolong his treatment.
   b. Suggest why the penicillin treatment was successful in mice but was unable to save Albert.
   c. Suggest reasons why the young girl pictured in figure 4.54 with a serious infection in 1942 fully recovered after treatment with penicillin.
   d. Investigate improvements in the production of penicillin that have led to the drop in the death rate from infections during World War II and beyond.

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

4.8 Thinking tools — Cycle maps and relations diagrams

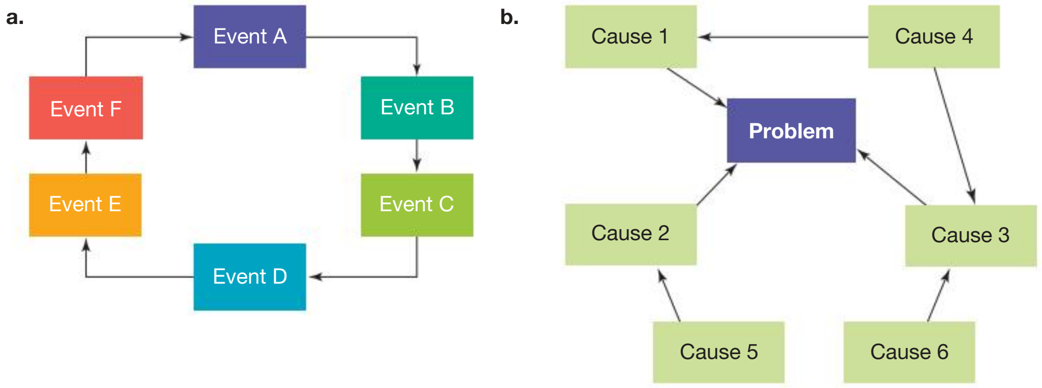
4.8.1 Tell me

What are cycle maps and relations diagrams?

A cycle map is a diagram that is useful for showing a circular or repeating event or process. It helps you arrange a complex sequence of events that contains a number of steps, which each depend upon the previous step being completed. They are also known as cycle charts or cyclical maps.

A relations diagram also shows an event or process that has a number of different steps, but these steps do not always depend upon the previous step being completed. Relations diagrams identify and represent relationships between causes of events; cycle maps just sequence them. Both diagrams help you see patterns in the events.

FIGURE 4.58 **a.** A cycle map **b.** A relations diagram



4.8.2 Show me

Follow these steps to create a cycle map or a relations diagram.

Choose a topic that has a number of events, which rely upon the occurrence of the previous step.

1. List actions or steps that are relevant to a particular cycle on small pieces of paper.
2. Order your pieces of paper and then position the steps in a circle.
3. Review your cycle — are any steps in the wrong order, missing or irrelevant? If so, make changes.
4. Write your cycle with each step placed in a box and the boxes joined by arrows within your circle.

FIGURE 4.59 Cycle map of life cycle of a dog flea

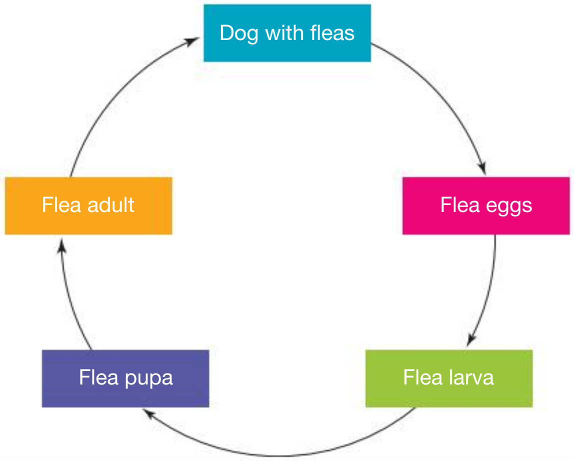
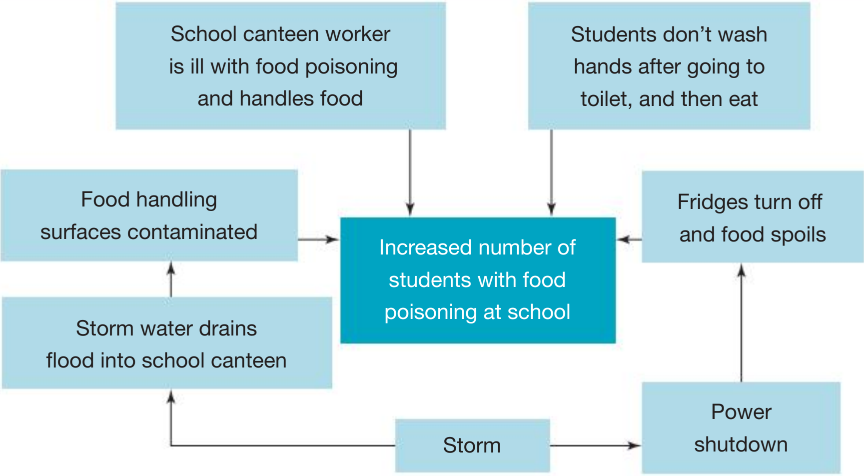


FIGURE 4.60 Relations diagram to show how food poisoning could occur in a school canteen

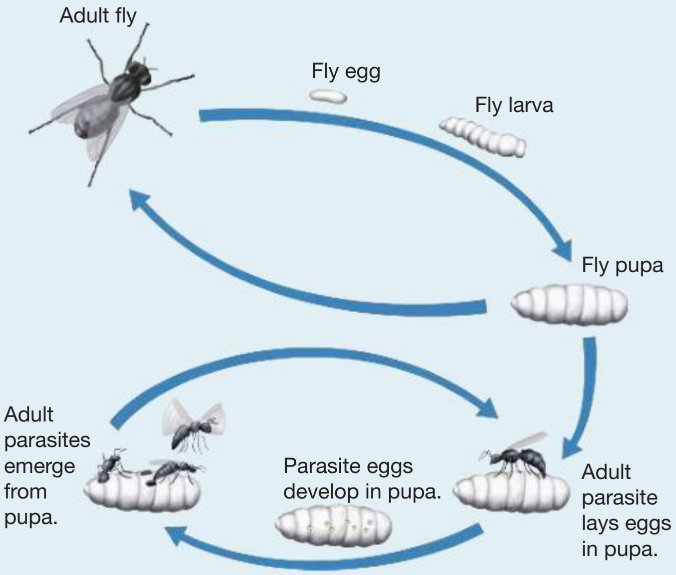


4.8.3 Let me do it

4.8 Activity

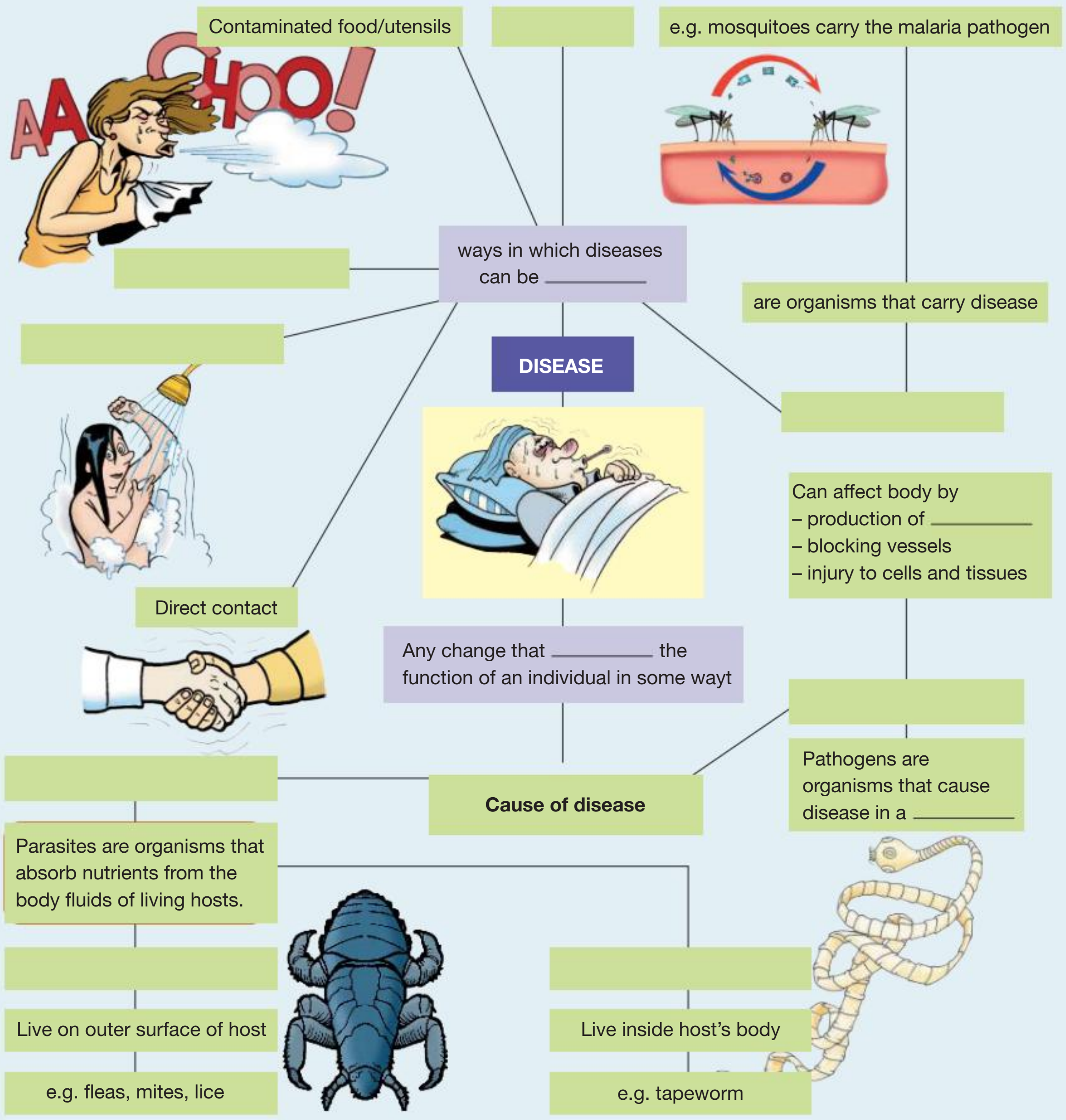
1. Use a cycle map or a relations diagram to show why the area around an infected cut becomes red and inflamed (swollen).
2. Biological control is a method of using one living organism to control another by interfering with its life cycle in some way. An example of this is using parasites to control fly populations. Use the diagram to answer the following questions.
   a. At which stage in the life cycle of the fly do the parasites invade?
   b. Suggest how the use of this method may control the fly population.
   c. Find out more about the use of biological control to reduce fly populations.

Parasites that use flies as hosts can be used to help control fly populations.



3. Examine the relations diagram below. Find out where the words in the top box fit in the relations diagram.

water
ectoparasites
air
vectors
endoparasites
transmitted
impairs
parasites
toxins
pathogen
blood
host



Contaminated food/utensils

e.g. mosquitoes carry the malaria pathogen

ways in which diseases can be ________

are organisms that carry disease

DISEASE

Can affect body by
– production of ________
– blocking vessels
– injury to cells and tissues

Direct contact

Any change that ________ the function of an individual in some wayt

Cause of disease

Pathogens are organisms that cause disease in a ________

Parasites are organisms that absorb nutrients from the body fluids of living hosts.

Live on outer surface of host

e.g. fleas, mites, lice

Live inside host's body

e.g. tapeworm

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

LESSON
4.9 Review

Hey students! Now that it's time to revise this topic, go online to:

Review your results

Watch teacher-led videos

Practise questions with immediate feedback

Find all this and MORE in jacPLUS

Access your topic review eWorkbooks

on Resources

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-12406	ewbk-12407	ewbk-12408

4.9.1 Summary

Infectious diseases

- Disease can be defined as any change that impairs the function of an individual in some way; it causes harm to the individual.
- Infectious diseases are diseases that are contagious and are caused by a pathogen.
- Non-infectious diseases cannot be spread from one person to another; they are not contagious (transferred from one organism to another).
- Some of the ways in which pathogens may be transmitted include direct contact, vectors, contaminated objects or contaminated water supplies.
- The spread of disease may be controlled by personal hygiene; care with food preparation; proper disposal of sewage and rubbish; chemical control of vectors; chemical treatment of clothes, surfaces and water; pasteurisation of milk; public education programs; quarantine laws; and the use of drugs such as antibiotics.

Types of pathogens

- There are trillions of microbiomes that live on us and in us; we need them, and they need us to survive.
- Parasites can cause harm to their hosts as they obtain resources from them.
- Parasites that can cause disease are also considered to be pathogens.
- Endoparasites live inside the body of a host organism.
- Ectoparasites lives outside the body of a host organism.
- Pathogens may be cellular (made up of cells) or non-cellular.
- Cellular pathogens include disease-causing bacteria, protists, fungi and animals.
- Non-cellular pathogens include viruses, prions and viroids.
- Malaria is one of the most serious public health problems worldwide. It is a leading cause of death and disease in many developing countries.
- Mosquitoes are not only vectors for the malaria parasite, but can also transmit elephantiasis, dengue fever, yellow fever and Japanese encephalitis.

Lines of defence

- Pathogens possess specific chemicals that are recognised as being non-self or foreign to your body, referred to as antigens, and trigger your immune response.

- The first and second lines of defence involve non-specific responses: they react the same way to all infections and as they have no ‘memory’ of prior infections, their level of response will be the same for each infection with the same pathogen.
- The first line of defence, which is designed to prevent the entry of invading pathogens, involves physical barriers (skin, coughing, sneezing, cilia and nasal hairs) and chemical barriers (body fluids such as saliva, tears, stomach acid and acidic vaginal mucus).
- The second line of defence comes into play when pathogens have managed to get through your first line of defence and involves inflammation and special types of white blood cells called phagocytes.
- Phagocytes engulf and destroy pathogens using a process called phagocytosis.
- The lymphatic system contains lymph vessels, lymph nodes, lymph and white blood cells. Some of these white blood cells are lymphocytes.
- The third line of defence involves specific responses: it reacts in a specific way to each infection and as it retains a ‘memory’ of prior infections there is a much greater response in future infections by the same pathogen.
- In the third line of defence, the presence of antigens can trigger some B lymphocytes to differentiate into plasma cells to produce and release specific antibodies against the antigen.
- T lymphocytes are involved in the third line of defence and fight the pathogens at a cellular level. They also attack damaged and cancerous cells.
- In the third line of defence, memory cells may be formed from lymphocytes after infection with a pathogen — they ‘remember’ each specific pathogen encountered and are able to mount a strong and rapid response if that pathogen is detected again.

Immunity and immunisation

- Immunity is resistance to a particular disease-causing pathogen. A person who is immune does not develop the disease.
- Vaccination or immunisation is the giving of a vaccine to produce a type of immunity called artificial immunity.
- Herd immunity is when a high proportion of the population has been immunised against a disease. It is important in preventing the spread of disease and provides protection to young and vulnerable people, such as the elderly.
- Poliomyelitis is a highly infectious disease caused by the *Picornaviridae* virus that can have consequences including complete recovery, limb and chest muscle paralysis, or death.
- Active immunity is achieved by your body making antibodies to a specific antigen.
- Passive immunity is achieved by your body receiving antibodies from an outside source, such as from your mother’s milk or through vaccination with antibodies.
- Human papilloma virus (HPV) is the cause of greater than 90 per cent of cervical cancers.
- Professor Ian Frazer from the University of Queensland’s Centre for Immunology and Cancer Research developed a vaccine for the HPV, which may eradicate cervical cancer.

Outbreaks

- Plagues are contagious diseases that have spread rapidly through a population and resulted in high death rates.
- Epidemics occur when many people in a particular area have the disease in a relatively short time.
- Pandemics are diseases that occur worldwide.
- Spanish influenza is a strain of influenza caused by the H1N1 subtype of influenza virus, which spread across the world in 1918–1920.
- Asian influenza is a strain of influenza caused by the H2N2 subtype of influenza virus, which spread across parts of the world in 1956–58.
- Avian influenza is a strain of influenza caused by the H5N1 subtype of influenza virus, which is highly contagious in birds and has caused more than 300 fatalities in humans since 2003.
- Swine flu is a strain of influenza caused by the H1N1 subtype of influenza virus, containing a combination of genes from the swine, human and avian flu viruses, which killed several thousand humans in 2009.

- Coronaviruses are named for the ‘corona’ or crown of spikes on their viral envelope; these spikes bind to specific receptors on the host cell and cause respiratory tract infections.

Our noble Nobels

- Penicillin is a powerful antibiotic substance found in moulds of the genus Penicillium that kills many disease-causing bacteria without harming the body’s natural defences.
- In 1945, Howard Florey shared the Nobel Prize with Alexander Fleming and Ernst Chain for extracting penicillin.
- Antibiotics destroy bacteria, and they are widely used to treat diseases caused by bacteria.
- Immunology is the branch of science that deals with immunity from disease.
- The immune system is a network of interacting body systems that protects against disease by identifying and destroying pathogens and infected, malignant or broken-down cells.
- Professor Peter Doherty shared the Nobel Prize in 1996 with Rolf Zinkernagel for describing the way the immune system recognises virus-infected cells.

4.9.2 Key terms

active immunity immunity achieved by your body making antibodies to a specific antigen
antibodies proteins that are produced by B lymphocytes as a result of the presence of a foreign substance in the body and that act to neutralise or remove that substance
antigen a substance that triggers an immune response
Asian influenza a strain of influenza caused by the H2N2 subtype of influenza virus, which spread across parts of the world in 1956–58
avian influenza a strain of influenza caused by the H5N1 subtype of influenza virus that is highly contagious in birds and has caused over 300 fatalities in humans since 2003
B lymphocyte part of the third line of defence, these lymphocytes may be triggered by antigens to differentiate into plasma cells that produce and release specific antibodies against the antigen; also known as B cells
Black Death *see* bubonic plague
bubonic plague an infectious, epidemic disease, caused by the *Yersinia pestis* bacteria and carried by fleas from rats; also known as the Black Death
cellular immune response immunity involving T lymphocytes (assisted by phagocytes) that actively destroy damaged cells or cells detected as non-self, such as those triggering an immune response
cellular pathogen a pathogen that is made up of cells, such as a tapeworm, fungus or bacterium
disease any change that impairs the function of an organism in some way and causes it harm
DNA (deoxyribonucleic acid) a substance found in all living things that contains genetic information
ectoparasite parasite that lives outside the body of its host organism
endoparasite parasite that lives inside the body of its host organism
epidemic a disease affecting a large number of people in a particular area in a relatively short period of time
fungi organisms, such as mushrooms and moulds — some help to decompose dead or decaying matter and some cause disease
gut flora bacteria and other organisms that live inside the intestines and help digest food
herd immunity protection against an infectious disease; describes a high proportion of the population being immune to a disease, via vaccination, reducing the spread of the disease and protecting individuals who are not immune
host organism living in a relationship with another organism
humoral immune response immunity involving antibodies (which are specific to a particular antigen) that are produced and secreted by B lymphocytes that have differentiated into plasma cells
immune system a network of interacting body systems that protects against disease by identifying and destroying pathogens and infected, malignant or broken-down cells
immunisation administering an antigen, such as in a vaccine, with the aim of producing enhanced immune response against the antigen in a future exposure
immunology the branch of science that deals with immunity from disease
infectious disease a disease that is contagious (can be spread from one organism to another) and caused by a pathogen

inflammation a reaction of the body to an infection, commonly characterised by heat, redness, swelling and pain

intermediate host the organism that a parasite lives in or on in its larval stage; also known as secondary host

lymphatic system the body system containing the lymph vessels, lymph nodes, lymph and white blood cells that is involved in draining fluid from the tissues and helping defend the body against invasion by disease-causing agents

lymphocyte small, mononuclear white blood cells present in large numbers in lymphoid tissues and circulating in blood and lymph

memory cells cells that may be formed from lymphocytes after infection with a pathogen — they 'remember' each specific pathogen encountered and are able to mount a strong and rapid response if that pathogen is detected again

microbiome the community of microorganisms (such as bacteria, fungi, and viruses) living together in a particular habitat

moulds types of microscopic fungi found growing on the surface of foods

non-cellular pathogen a pathogen that is not made up of cells, such as a virus, prion or viroid

non-infectious disease a disease that cannot be spread from one organism to another

obligate intracellular parasite a parasite that needs to infect a host cell before it can reproduce

pandemic a disease occurring throughout an entire country or continent, or worldwide

parasite organism that obtains resources from another organism (host) that it lives in or on, and can cause harm to

passive immunity immunity achieved by your body receiving antibodies from an outside source, such as from your mother's milk or through vaccination

pathogen a disease-producing organism

penicillin a powerful antibiotic substance found in moulds of the genus *Penicillium* that kills many disease-causing bacteria

phage a type of virus that infects and kills bacteria

phagocyte white blood cell that ingests and destroys foreign particles, bacteria and other cells

phagocytosis the ingestion of solid particles by a cell

plagues contagious diseases that spread rapidly through a population and results in high mortality (death rates)

plasma cell *see* B lymphocyte

poliomyelitis a highly infectious disease caused by the *Picornaviridae* virus that can have consequences including complete recovery, limb and chest muscle paralysis, or death

primary host the organism that a parasite lives in or on in its adult stage

prion an abnormal and infectious protein that converts normal proteins into prion proteins

quarantine strict isolation of sick people from others for a period of time (originally 40 days) in order to prevent the spread of disease

RNA (ribonucleic acid) complex compound that functions in cellular protein synthesis and replaces DNA as a carrier of genetic codes

Spanish influenza a strain of influenza caused by the H1N1 subtype of influenza virus, which spread across the world in 1918–1920

surface protein a protein molecule occurring on the surface of a virus

swine flu a strain of influenza caused by the H1N1 subtype of influenza virus, containing a combination of genes from the swine, human and avian flu viruses

T lymphocyte part of the third line of defence, these lymphocytes fight the pathogens at a cellular level. Some T lymphocytes may also attack damaged, infected or cancerous cells.

transmissible spongiform encephalopathy (TSE) a degenerative neurological disease caused by prions

vaccination administering a vaccine to stimulate the immune system of an individual to develop immunity to a disease

variolation deliberate infection of a person with smallpox (Variola) in a controlled manner so as to minimise the severity of the infection and also to induce immunity against further infection

vector an organism that carries a pathogen between other organisms without being affected by the disease the pathogen causes

viroid non-cellular pathogen comprised solely of a short circular RNA without a protein coat

virus a very simple microorganism that infects cells and may cause disease

white blood cells living cells that fight bacteria and viruses

on Resources

eWorkbooks	Study checklist (ewbk-12409) Reflection (ewbk-3038) Literacy builder (ewbk-12410) Crossword (ewbk-12411) Word search (ewbk-12412)
Solutions	Topic 4 Solutions (sol-1137)
Practical investigation eLogbook	Topic 4 Practical investigation eLogbook (elog-2299)
Digital document	Key terms glossary (doc-40132)

4.9 Activities

learnon

4.9 Review questions

Select your pathway

■ LEVEL 1	■ LEVEL 2	■ LEVEL 3
1, 2, 3, 9, 10, 15	4, 5, 6, 11, 14, 16, 17, 21	7, 8, 12, 13, 18, 19, 20, 22

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. Identify which type of diseases can be transmitted from one person to another.
2. **MC** Identify the term used for the cause of an infectious disease.
   A. Accidents B. Ageing C. Nutritional deficiency D. Pathogen
3. **MC** Identify the term used for any foreign particles that stimulate an immune response.
   A. Antibodies B. Antigens C. Lymphocytes D. Vaccination
4. **MC** Identify chemical barriers involved in the first line of defence against disease.
   A. Inflammation and fever B. Lymphocytes and antibodies
   C. Saliva and stomach acid D. Skin, cilia and nasal hairs
5. **MC** Identify the type of specific proteins that are produced rapidly and in great amounts during the secondary exposure response.
   A. Antibodies B. Antigens C. Lymphocytes D. Vaccination
6. **MC** Identify a way of tricking your immune system into acting as though it has met the pathogen before.
   A. Antibodies B. Antigens C. Lymphocytes D. Vaccination
7. **MC** Identify the type of acquired immunity in which a person makes their own antibodies after exposure to the antigen.
   A. Active artificial immunity B. Active natural immunity
   C. Passive artificial immunity D. Passive natural immunity
8. **MC** Identify the type of acquired immunity in which antibodies are injected into a person.
   A. Active artificial immunity B. Active natural immunity
   C. Passive artificial immunity D. Passive natural immunity
9. a. All parasites are pathogens. True or false? b. Justify your response.
10. Match the infectious disease with the type of pathogen that causes it.

Type of pathogen	Infectious disease
a. Bacteria	A. Malaria
b. Fungi	B. Measles
c. Protozoans	C. Ringworm
d. Viruses	D. Scarlet fever

11. Identify the types of cells that can divide into plasma cells and produce antibodies.

12. Describe what helper T cells signal B cells to do.
13. Match the human blood component to its line of defence.

Line of defence	Blood component
a. First line of defence	**A.** Lymphocyte
b. Second line of defence	**B.** Phagocyte
c. Third line of defence	**C.** Platelet

Apply and analyse

14. Sequence the following cyclic events by placing them in order beginning with the infected person sneezing.
    - **A.** Person infected
    - **B.** Pathogens inhaled by uninfected person
    - **C.** Infected person sneezes
    - **D.** Pathogens released into air
15. Draw a flow chart to describe the host type in the life cycle of a parasite.
16. Draw a labelled diagram to show the cycle of how a virus is spread.
17. Draw a labelled diagram to describe the malaria transmission cycle.
18. Explain how vaccines work.

Evaluate and create

19. Explain why are viruses such as HIV, cold, and flu are so difficult to cure.
20. Construct your own summary mind maps or concept maps on the following topics, using the terms suggested (as well as any others that may be relevant).
    - **a.** Infectious disease: contagious, infected, pathogen, cellular pathogens, non-cellular pathogens, quarantine, direct contact, vectors, contaminated objects, contaminated water, sneezing, coughing, physical contact, antibiotics, personal hygiene, tapeworms, head lice, fungi, protozoans, bacteria, viruses, prions
    - **b.** Pathogens and parasites: parasite, host, primary host, intermediate host, endoparasite, ectoparasite, pathogen, non-cellular pathogen, cellular pathogen, prions, kuru, mad cow disease, viruses, obligate intracellular parasites, mumps, AIDS, warts, influenza, bacteria, coccus, bacillus, *Streptococcus*, cholera, pneumonia, typhoid, whooping cough, Gram stain, protozoans, malaria, amoebic dysentery, fungi, tinea, ringworm, thrush, worms and arthropods, tapeworm, liver fluke
21. Construct your own summary mind maps or concept maps on the following topics, using the terms suggested (as well as any others that may be relevant).
    - **a.** Putting up defences: lines of defence, first line of defence, second line of defence, third line of defence, antigen, non-self, specific, non-specific, physical barriers, chemical barriers, inflammation, phagocytosis, phagocytes, white blood cells, inflammation, cilia, skin, acid, enzymes, nasal hairs, sneezing, coughing, lymphocytes, B lymphocytes, plasma cells, antibodies, T lymphocytes, lymphatic system, lymph, lymph vessels, memory cells
    - **b.** Immunity: vaccine, vaccination, immunisation, active immunity, passive immunity, artificial immunity, natural immunity, antibodies, active natural immunity, active artificial immunity, passive natural immunity, passive artificial immunity
22. **SIS** Design an experiment that would show which disinfectants and antiseptics are most effective against the growth of bacteria in your kitchen.

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

Online Resources

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-12390)
- Student learning matrix (ewbk-12391)
- Starter activity (ewbk-12392)

Practical investigation eLogbook

- Topic 4 Practical investigation eLogbook (elog-2299)

Video eLesson

- The body at war (eles-4188)

4.2 Infectious diseases

eWorkbooks

- Infectious diseases (ewbk-12395)
- Non-infectious diseases (ewbk-12396)

Video eLesson

- Bacteria and viruses (eles-2645)

Interactivity

- Classifying diseases (int-5768)

4.3 Types of pathogens

Practical investigation eLogbook

- Investigation 4.1: Microbes (elog-2301)

Teacher-led video

- Investigation 4.1: Microbes (tlvd-10806)

Video eLessons

- Human head lice on human hair (eles-2646)

Weblink

- Malaria life cycle Part 1: Human host
- Malaria life cycle Part 2: Mosquito host

4.4 Lines of defence

eWorkbook

- Labelling the body's first line of defence against disease (ewbk-12399)

Video eLesson

- Understanding HIV (eles-0125)

Interactivities

- The first line of defence (int-5769)

4.5 Immunity and immunisation

eWorkbooks

- Immunity (ewbk-12401)
- Vaccination (ewbk-12402)

Video eLesson

- Immunisation in Australia (eles-0126)

4.6 Outbreaks

Weblink

- COVID-19 data

4.9 Review

eWorkbooks

- Topic review Level 1 (ewbk-12406)
- Topic review Level 2 (ewbk-12407)
- Topic review Level 3 (ewbk-12408)
- Study checklist (ewbk-12409)
- Literacy builder (ewbk-12410)
- Crossword (ewbk-12411)
- Word search (ewbk-12412)
- Reflection (ewbk-12405)

Digital document

- Key terms glossary (doc-40132)

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

5 Reproduction

CONTENT DESCRIPTION

Describe the form and function of reproductive cells and organs in animals and plants, and analyse how the processes of sexual and asexual reproduction enable survival of the species (AC9S9U02)

Source: F–10 Australian Curriculum 9.0 (2024–2029) extracts © Australian Curriculum, Assessment and Reporting Authority; reproduced by permission.

LESSON SEQUENCE

SCIENCE INQUIRY AND INVESTIGATIONS

Science inquiry is a central component of the Science curriculum. Investigations, supported by a **Practical investigation eLogbook** and **teacher-led videos**, are included in this topic to provide opportunities to build Science inquiry skills through undertaking investigations and communicating findings.

LESSON
5.1 Overview

Hey students! Bring these pages to life online

Watch videos

Engage with interactivities

Answer questions and check results

Find all this and MORE in jacPLUS

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 reproduce, as do plants, fungi and bacteria, 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 also have male and female reproductive cells and 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 its life, beginning as a male and then becoming female; the oysters switch genders over and over again to improve their chances of successful reproduction. Although many animals and plants reproduce sexually there are lots of 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.

FIGURE 5.1 Dandelions use the wind to help them to disperse their seeds.

organisms living things

offspring the young born of a living organism

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. They 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-2305

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-12345) Student learning matrix (ewbk-12347) Starter activity (ewbk-12348)
Solutions	Topic 5 Solutions (sol-1138)
Practical investigation eLogbook	Topic 5 Practical investigation eLogbook (elog-2303)

LESSON
5.2 Asexual reproduction

LEARNING INTENTION

At the end of this lesson 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.

Asexual means 'without sex'. Asexual reproduction does not use specialised sex cells (**gametes**) to bring information from two parents together. Instead, all the information (**genes**) comes from one parent. This means that all the offspring produced are identical to each other — and to their parent. However, there are some issues that can arise from being genetically identical. Because there is a lack of variation in the genetic information, a disease would be detrimental to the whole population, not just some. Also, any errors that occur in the genetic information would be passed on to all offspring.

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.

asexual reproduction a type of reproduction that does not require the fusion of sex cells (gametes)

gametes reproductive cells (sperm or ova) containing half the genetic information of normal cells

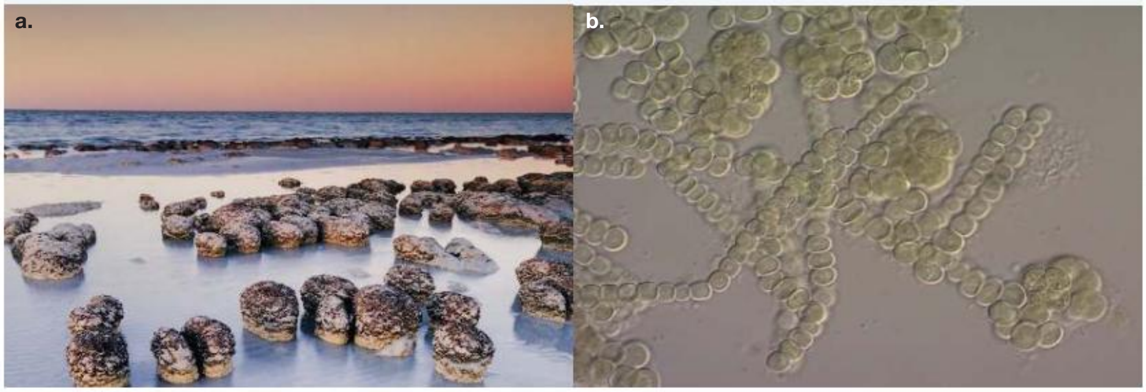
genes a coded set of instructions within DNA that determines the characteristics of an organism

cloning the process used 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. These were 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.

FIGURE 5.3 First life on Earth. **a.** *Stromatolites* might look like rocks; however, they are 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 things on Earth and have been living and reproducing for longer than any other organisms.



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. 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.

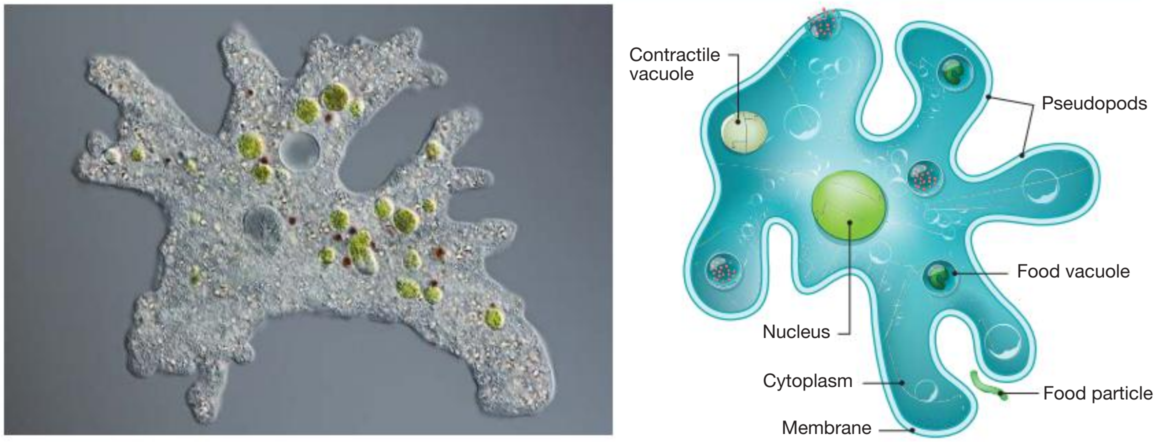
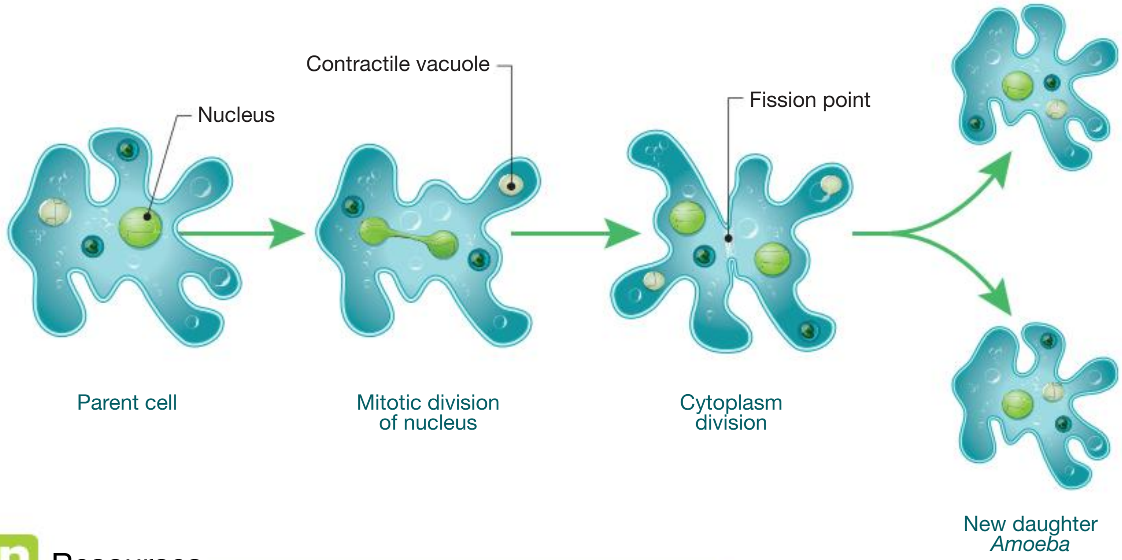


FIGURE 5.5 Binary fission in amoeba. This simple yet effective life form reproduces by duplicating all of the essential parts of the cell, such as the nucleus and mitochondria, to ensure the offspring have their own genetic information and can turn food into energy. The amoeba then divides into two daughter cells which are genetically identical to the parent cell. This is called binary fission.



on Resources

Video eLesson Binary fission (eles-2306)

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 5.6) and also in freshwater hydra (figure 5.7). The initial swelling is called a bud and hence this process is often called **budding**.

FIGURE 5.6 Yeast are unicellular organisms from the same kingdom as mushrooms and mould, kingdom Fungi. Yeast reproduce by budding off their offspring from the parent cell.

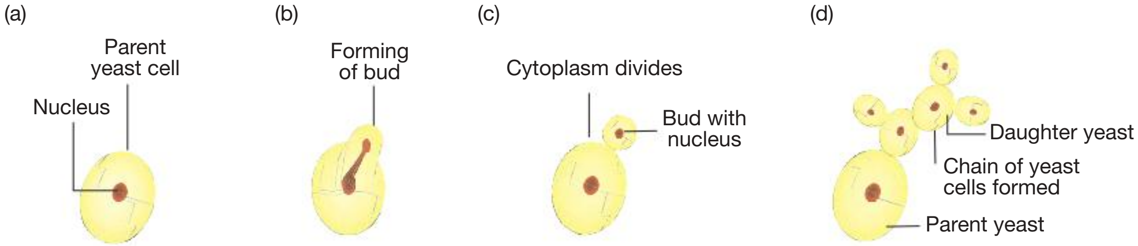
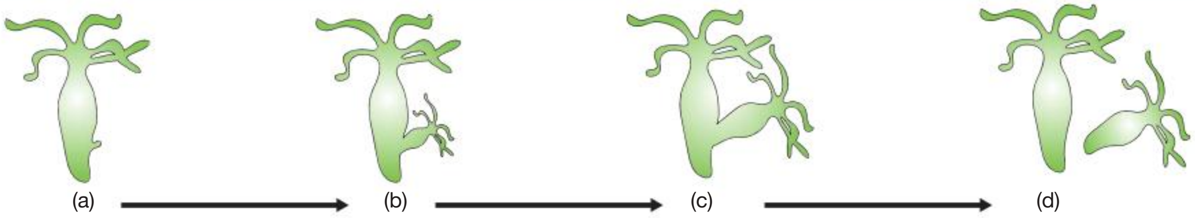


FIGURE 5.7 Hydra are a small multicellular freshwater organisms, from the phylum cnidaria, that also reproduce by budding.



Jellyfish, such as the common *Aurelia aurita*, reproduce both sexually and asexually (figure 5.8). The mature medusa (figure 5.9a) 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 as seen in figure 5.9b.

FIGURE 5.8 Jellyfish reproduce both sexually and asexually.

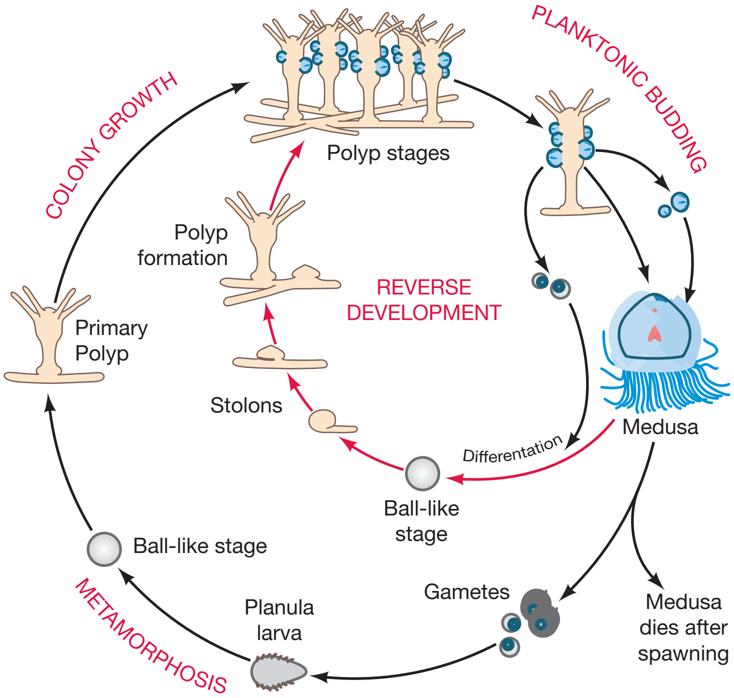
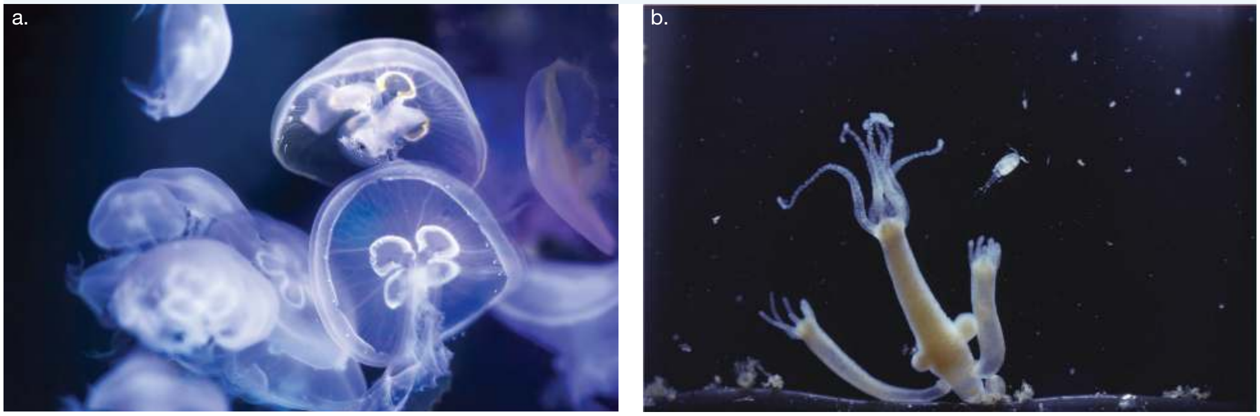


FIGURE 5.9 a. Mature medusa **b.** Miniature medusae formed from budding.



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 5.10 Mould spores on berries, which may develop into offspring genetically identical to the parent fungi.

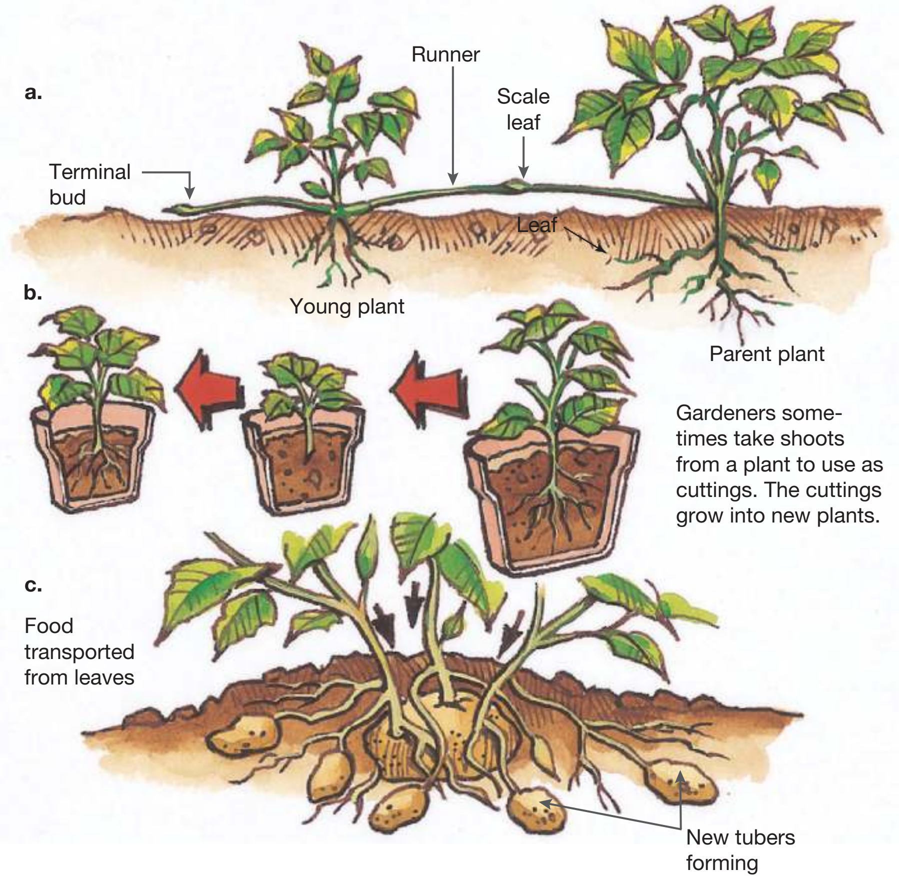
5.2.5 Vegetative propagation

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).

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

FIGURE 5.11 Examples of vegetative propagation: **a.** runners, **b.** cuttings and **c.** tubers



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 5.12 Tiny new starfish growing at the end of a discarded *Linckia* starfish arm

5.2.7 Parthenogenesis

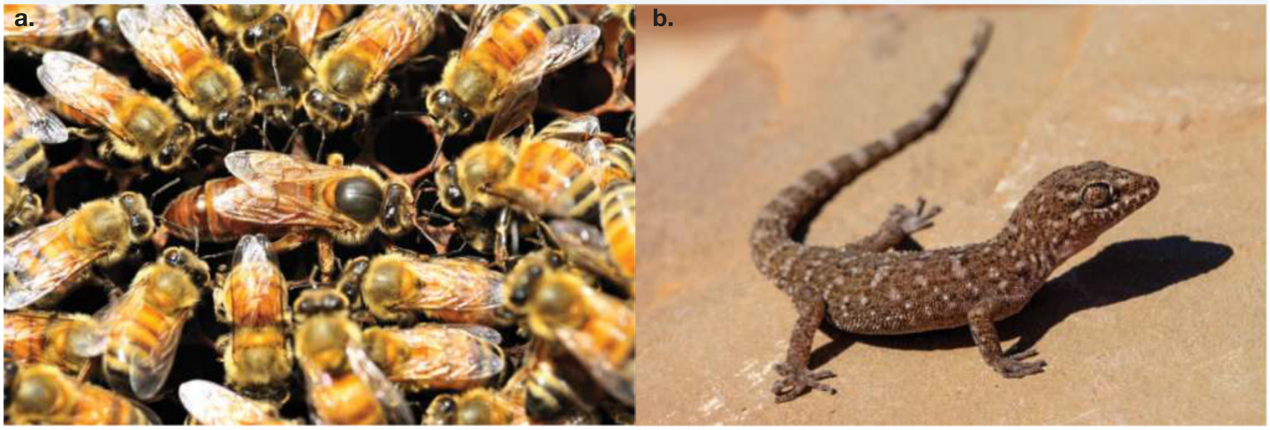
In some animals, the females produce eggs, but these develop into embryos without fertilisation taking place. The scientific name for the development of new individuals from an unfertilised egg is **parthenogenesis**. Worker bees, for example, develop from unfertilised eggs laid by the queen bee (figure 5.13a). This allows the most number of offspring to be produced in the least amount of time.

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 (figure 5.13b). 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**.

parthenogenesis the development of new individuals from unfertilised eggs

virgin births births that do not involve the joining of eggs and sperm

FIGURE 5.13 a. Worker bees develop from unfertilised eggs laid by the queen bee (parthenogenesis).
b. Bynoe's gecko.



on Resources

eWorkbook Asexual reproduction (ewbk-12350)

elog-2307

INVESTIGATION 5.2

Asexual reproduction

Aim

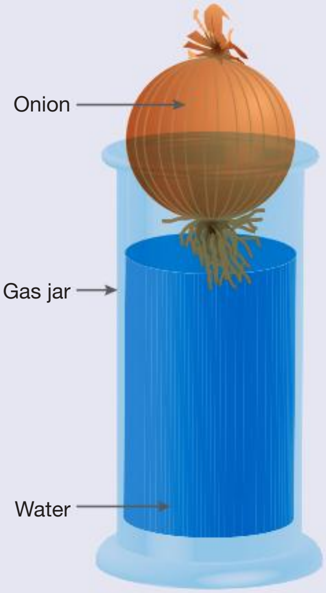
To observe asexual reproduction in plants

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. Explain why each of the examples in the table above are forms of asexual reproduction.
3. What are the advantages of growing plants using one of the techniques described above rather than growing them from seeds?
4. Suggest improvements to the design of the investigation.

Conclusion

Summarise the findings from this investigation about asexual reproduction.

5.2 Activities

learnon

5.2 Quick quiz on | **5.2 Exercise**

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 2, 4, 6, 10	3, 5, 7, 11	8, 9, 12

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

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. a. Identify whether each of the following statements are true or false.

Statement	True or false?
i. The processes involved in binary fission in prokaryotes and eukaryotes are the same.	
ii. A population of Bynoe's gecko lizards (*Heteronotia binoei*) would contain only males.	
iii. Worker bees develop from unfertilised eggs laid by the queen bee.	
iv. Births that result without any meeting between eggs and sperm are often referred to as virgin births.	

b. Justify any false responses.

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.

LESSON
5.3 Sexual reproduction in flowering plants

LEARNING INTENTION

At the end of this lesson 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.

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**.

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)

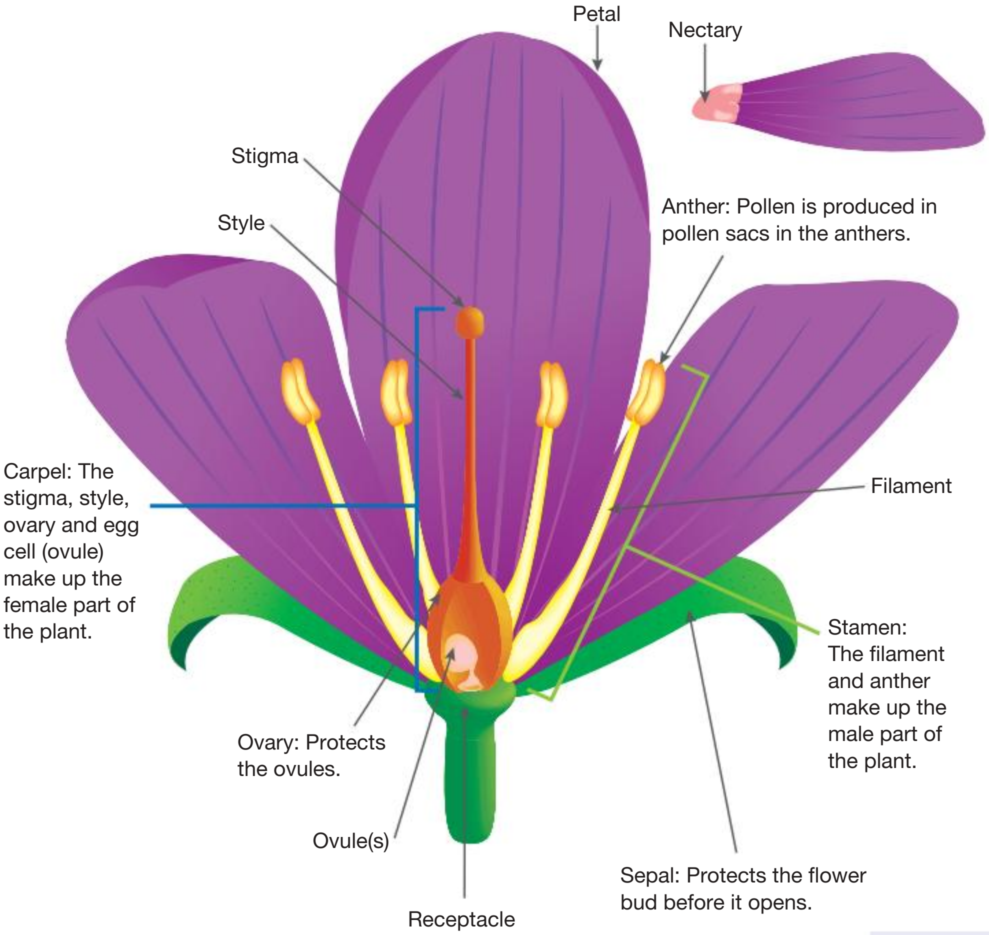
stigma the female part of a flower, at the top of the carpel, that catches the pollen during pollination

FIGURE 5.14 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-12356

FIGURE 5.15 Each part of a flower has a specific function that allows the flower to bloom, fruit or seed.



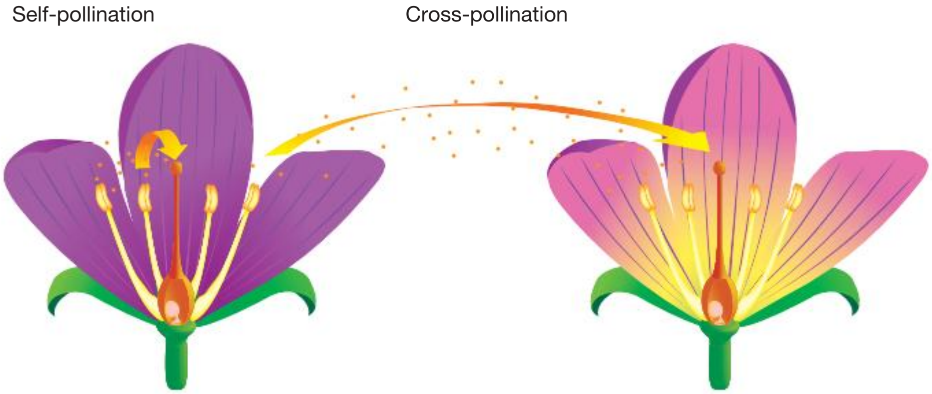
Pollination describes the way in which pollen grains reach the stigma. Plants may pollinate themselves (**self-pollination**). More often, however, they obtain the pollen from the flower of a different plant of the same species (**cross-pollination**). Cross-pollination increases the genetic variation among the offspring and gives them a better chance of survival. This is because if a disease passes through the population, some may have natural immunity that will allow them to survive and pass this resistance on to its offspring. The pollen grains may be transferred to other flowers by wind, insects or other animals.

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

FIGURE 5.16 The difference between self-pollination and cross-pollination



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 5.17 A sunflower is an example of an insect-pollinated flower.

FIGURE 5.18 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 5.19). 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 5.19 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)

zygote a cell formed by the fusion of two gametes; fertilised ovum before it starts to divide into more cells

endosperm the food supply for the embryo plant in a seed

seed a product of a fertilised ovule

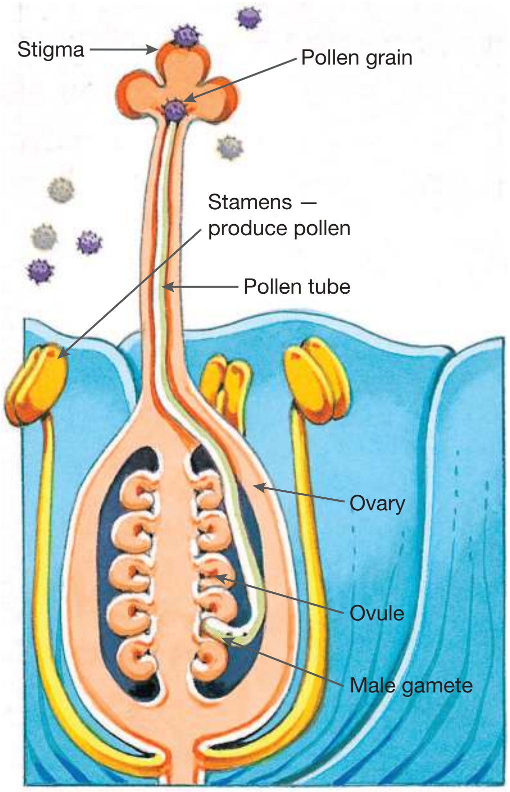
seed coat the protective layer around a seed

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 5.20 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**.

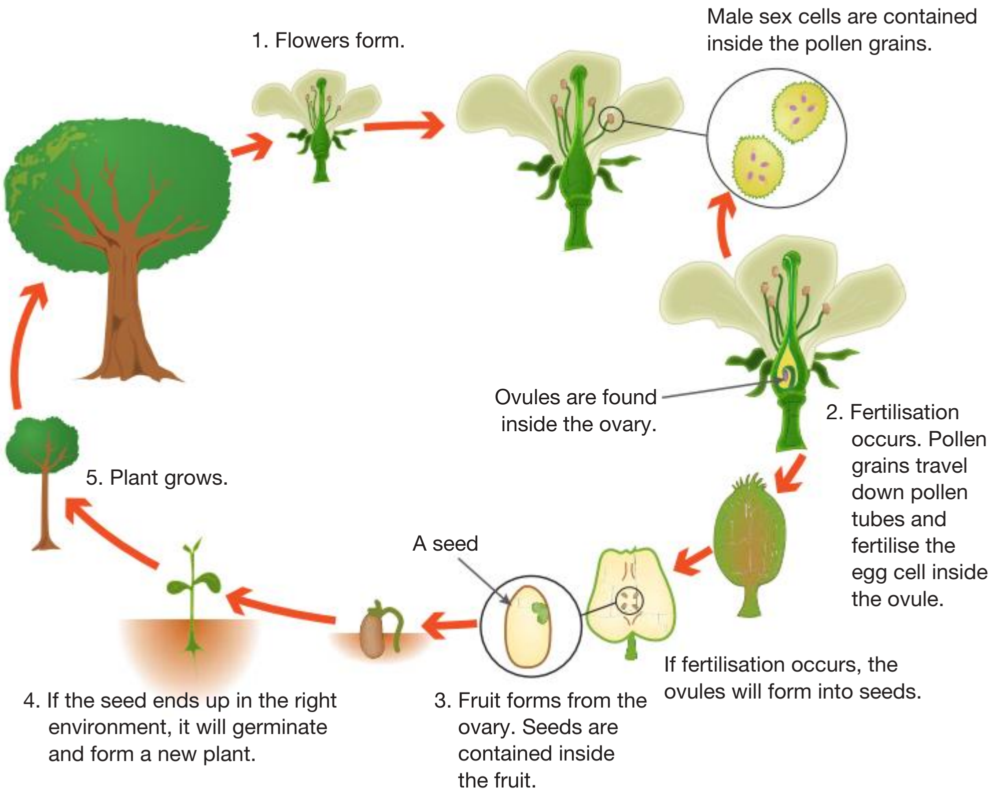
Are you aware that when you bite into an apple, cherry or orange you are actually eating the enlarged ovary of the plant? Did you know that these swollen ovaries contain the plant's 'babies' in their embryonic form? The plants are using you as a way of distributing their 'young' out into the world.

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 5.21 The life cycle of a flowering plant

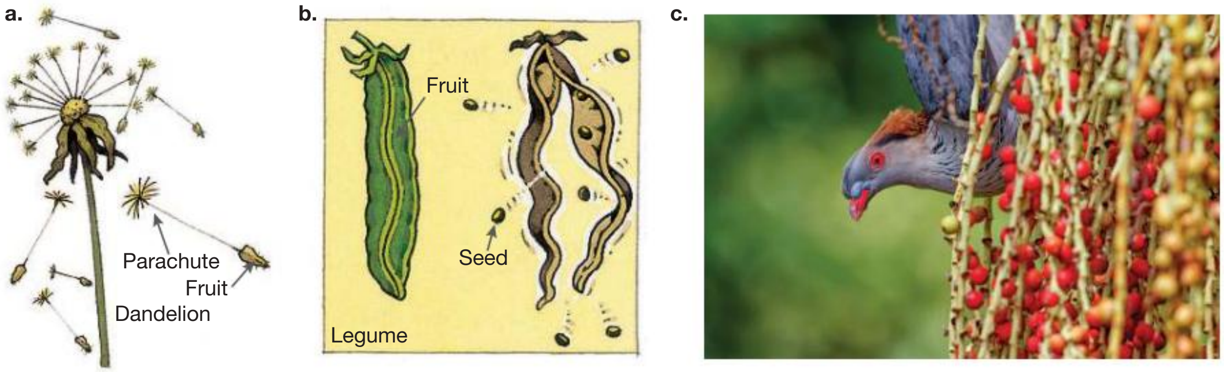


5.3.4 Seed dispersal

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 for tomatoes, grapes and apples); water (such as for coconuts); or wind (such as for 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 5.22 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.

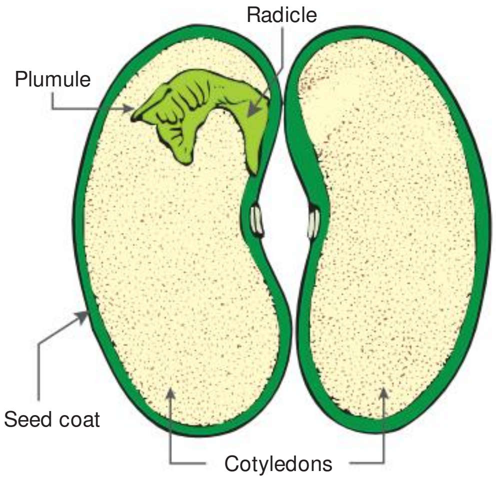
FIGURE 5.23 Emu poo effectively scatters seeds, thereby enabling plants to inhabit new areas.

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**.

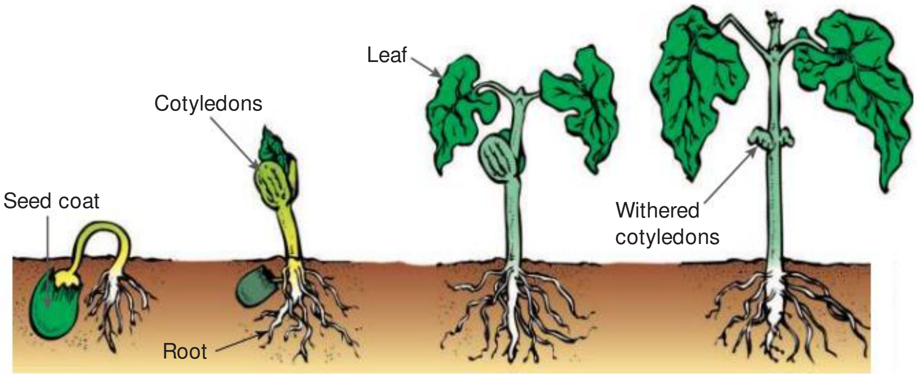
When the conditions are right, the seed bursts open and a new plant grows out. This process is called germination. When **germination** is complete, the embryo has become a young plant or **seedling**.

FIGURE 5.24 Parts of a seed



eles-2065

FIGURE 5.25 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-2309

tlvd-10801

INVESTIGATION 5.3

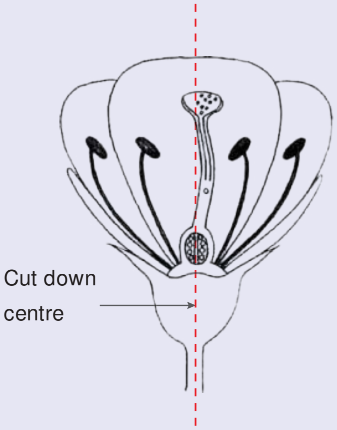
What's in a flower?

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-2311

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 a different type 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-12352)
Plant reproduction (ewbk-12354)

Video eLesson Growing plants in Australia (eles-0055)

5.3 Activities

learnon

5.3 Quick quiz on | **5.3 Exercise**

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3, 7	4, 5, 8, 10, 13	6, 9, 11, 12, 14

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

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 flow chart that shows the correct sequence for flowering plants: 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.

LESSON
5.4 Comparing reproductive strategies in animals

LEARNING INTENTION

At the end of this lesson you will be able to describe some different reproductive strategies seen in the animal kingdom.

5.4.1 Reproductive cells in animals

While some animals can reproduce asexually, most depend on sexual reproduction.

All animal cells (except mature red blood cells) have a nucleus, which contains a full set of instructions to build that animal. In sexual reproduction, the new organisms produced receive a mixture of instructions from both parents — which is why you might look a bit like your dad and a bit like your mum, but not exactly like either of them.

For this process to work, animals need specialised sex cells — or gametes. These cells have a nucleus that only contains half a set of instructions. When a male and a female gamete join, a complete set of instructions is formed and a new organism can develop and grow.

The female sex cell is called the egg, or **ovum**. Ova (the plural of ovum) are the largest cells in the human body, large enough to be just visible without the help of a microscope. They are big because they contain the food needed for the early stages of the new baby's development. Their cell membrane is coated with a jelly-like substance designed to allow only one sperm cell to get in, and they have a nucleus with only half a set of instructions.

Sperm cells are very small — about 10 000 times smaller than an ovum. They have a head section containing a nucleus with half a set of instructions and a cell membrane that contains special chemicals to allow it to get through the membrane of the ovum. They also have a middle section containing lots of **mitochondria** — the cell structures that produce energy — and a tail section that wiggles to allow the sperm to move.

When a sperm joins with an ovum it is called **fertilisation**. The fertilised ovum then divides into two identical copies of itself, these then divide into four, then eight and so on. As the number of cells increase, they specialise and form tissues, organs and systems until a complete baby is formed. The different stages of development have different names. The fertilised egg is called a zygote, the early development stage is called an **embryo** and the later development stage is called a **fetus**.

ovum female gamete or sex cell; plural = ova

fertilisation fusion of the male gamete (sperm) and the female gamete (ovum)

embryo a group of cells formed from the zygote and is developing into different body organs

fetus the unborn young of an animal that has developed a distinct head, arms and legs

ewbk-12358

FIGURE 5.26 The sperm has a tail to allow it to move to the egg. When the sperm reaches the egg the tail drops off and only the head with the nucleus enters. When the sperm nucleus joins with the egg nucleus, a full set of instructions — contained on structures called chromosomes — is created and we say that fertilisation has occurred.

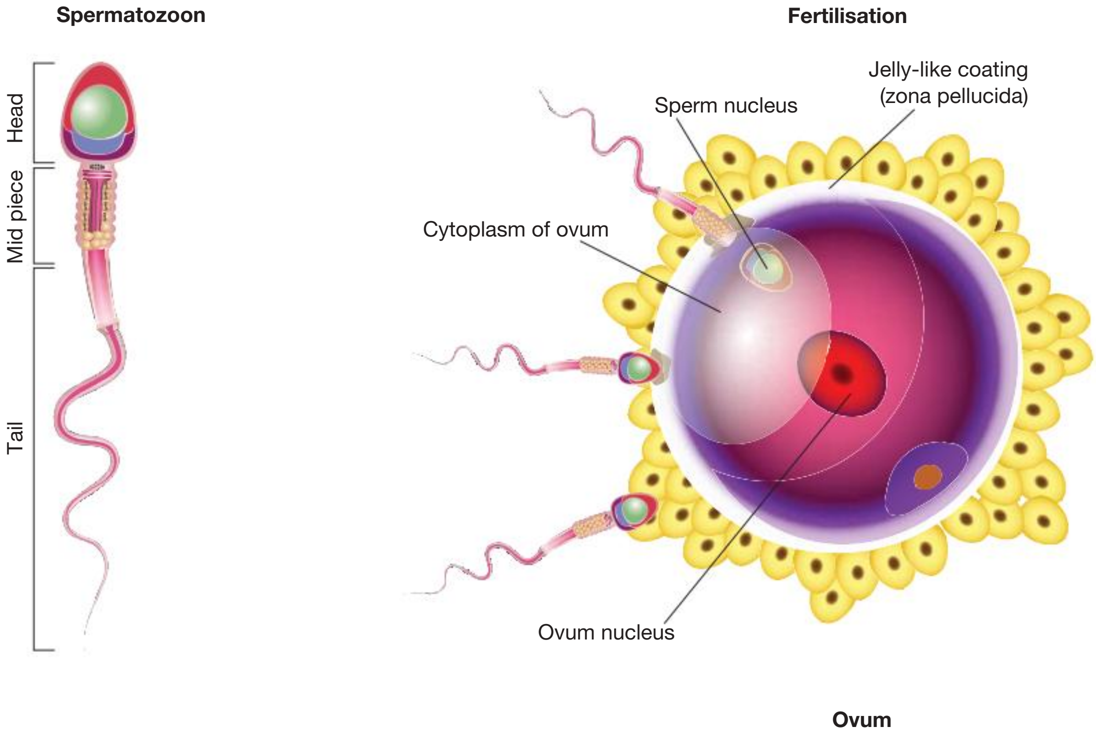


FIGURE 5.27 A hen's egg is very similar to a human egg. It is much bigger and has a shell around it because it is laid in a nest and left to develop outside the mother's body, meaning it needs protection and enough food to grow. In a human the egg develops inside the body where it is protected and fed by the mother.

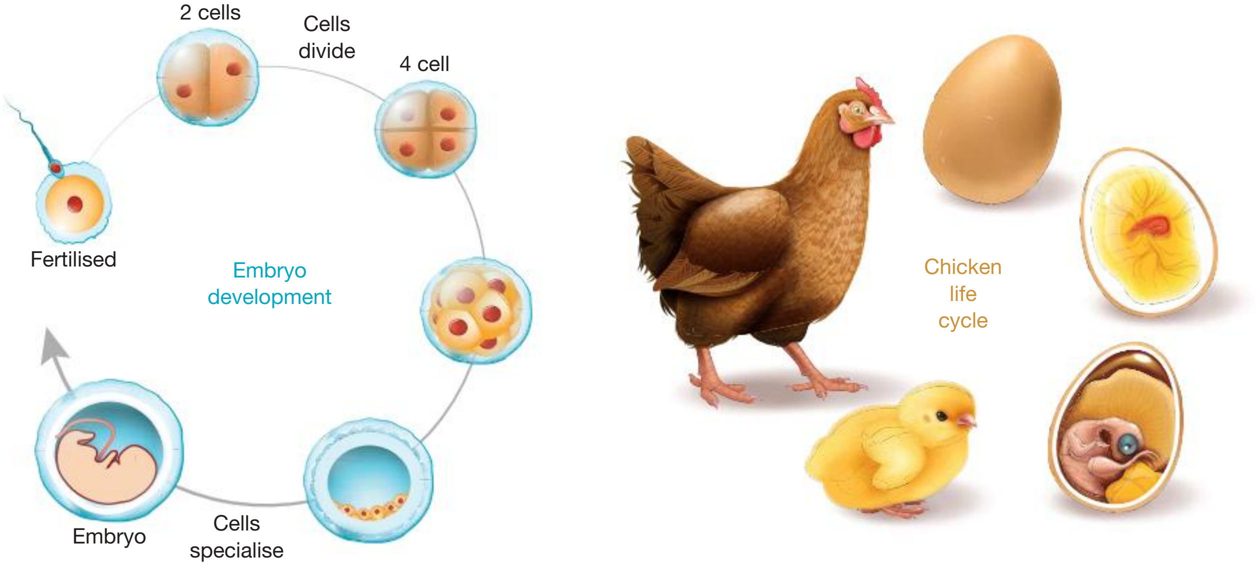
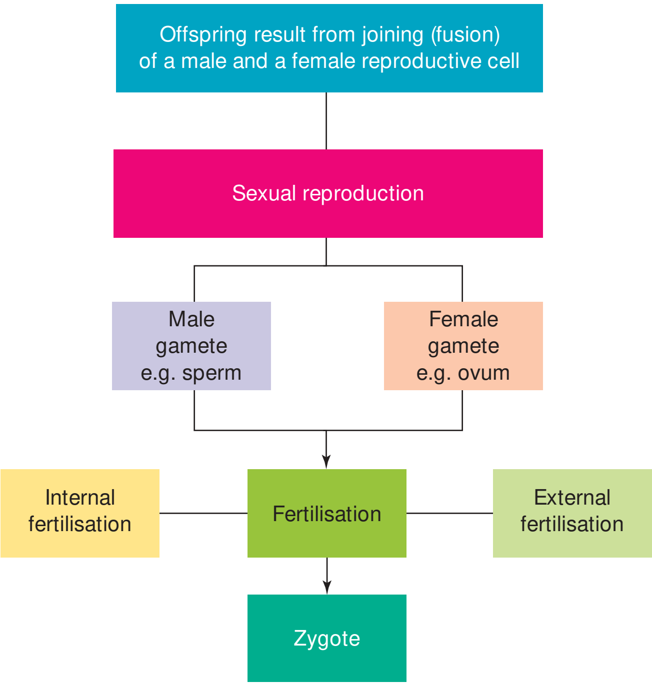


FIGURE 5.28 Sexual reproduction involves fusion of gametes.



5.4.2 Where fertilisation occurs

In some species of animal, including humans, fertilisation of eggs by sperm happens inside the body — this is called **internal fertilisation**. In other species, like clownfish, it happens outside the body, and is called **external fertilisation**.

When fish mate, the male and female swim very close to one another and release their eggs and sperm into the water. The sperm can swim through the water to reach the eggs and fertilise them.

Amphibians, such as frogs and toads, live most of their lives on land but because they mate using external fertilisation, they have to return to the water to be able to breed, as their sperm need a liquid environment to be able to swim to the eggs.

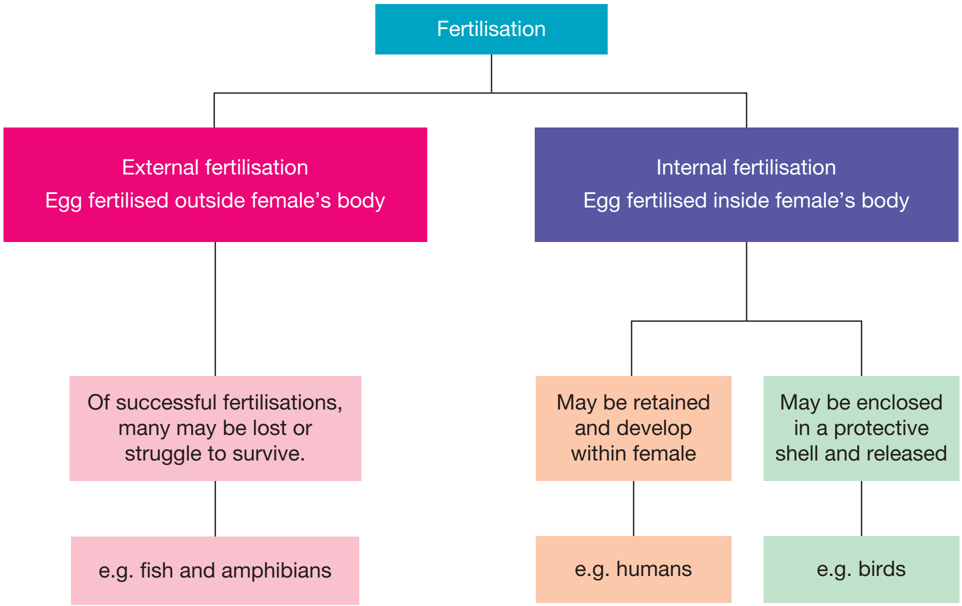
internal fertilisation	reproduction occurs when the egg remains in the female and is fertilised by sperm inserted into the female
external fertilisation	reproduction occurs when the eggs are released by the female into water and fertilised by sperm released nearby
sexual intercourse	the act of inserting sperm into the female; also called copulation or mating

Most animals that live on land have to help their sperm reach the egg. Some form of **sexual intercourse** takes place in which the male places sperm inside the female's body to fertilise the egg. The sperm are carried in a fluid that they can swim in, allowing them to move to the egg to fertilise it.

In external fertilisation the eggs are left to develop outside the mother's body. In internal fertilisation the offspring may develop inside the female's body until it is ready to be born, or the female may lay a fertilised egg outside the body, where it will develop until it hatches.

FIGURE 5.29 Frogs use external fertilisation to produce offpsring and the eggs can be found in bodies of water.

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 coral reefs 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 the lakes and rivers of Canada and Europe as well as the reefs around Australia, Indonesia, French Polynesia and the Maldives.

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 5.31 Dr Emily Fobert

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 ...

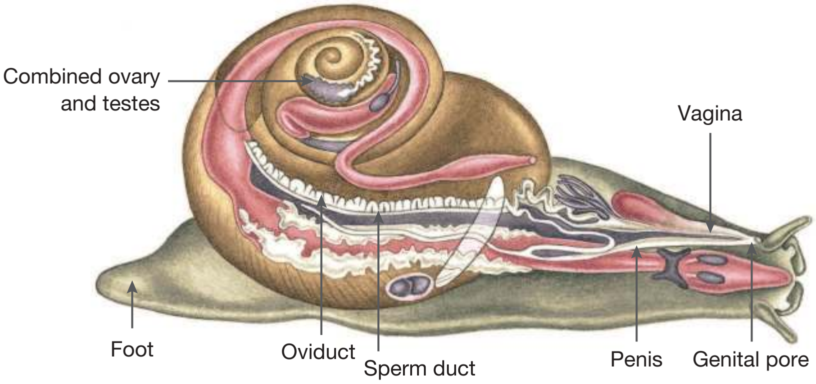
- Some reptiles and rodents actually 'cement' up the female's genitalia by using some of the semen, which sets into a hard plug, not allowing other sperm to get in.
- Male starworms are 'live-in lovers', spending their entire lives within the female's vagina. Her eggs are fertilised by these parasitic 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.



hermaphrodites organism that has both male and female reproductive organs

5.4.4 Big families, little families

Reproduction can have many risks and requires the use of a lot of energy, whether you are a bacterium dividing asexually every 20 minutes or an elephant with a pregnancy lasting nearly 2 years.

There are many reproductive strategies, but they fall broadly into two groups:

1. *r-selection:* r-selected species produce large numbers of offspring, but provide little, if any, parental care. This results in only a very small percentage of young surviving long enough to reach sexual maturity. This is a successful strategy in organisms that have a short life span and reach sexual maturity quickly, but becomes less and less effective the longer it takes to become mature as the chances of dying before reproducing increase. This approach is common among less complex organisms.
   For example, mouse pregnancies last around 3 weeks and produce around 6–8 young that are sexually mature at around 8 weeks old. While mice can live for around 4–5 years, the average life expectancy is 12 months.
   r-selected species tend to dominate temporary environments, such as lakes caused by flooding, or burnt land in the aftermath of a bushfire, as their quick reproduction produces rapid population growth.
2. *K-selection:* K-selected species produce small numbers of offspring, but invest a lot of time and effort in caring for them. This results in the production of fewer young, but greatly increases their chances of survival. This becomes a more successful strategy in complex organisms that have a long life span and take time to reach sexual maturity. For example human pregnancies last 40 weeks and usually produce only one child, who will take around 13 years to reach sexual maturity and have a life expectancy of around 80 years.
   K-selected species tend to dominate stable environments such as forests, where there is a lower likelihood of sudden environmental change reducing the survival chances of immature individuals.

In animal species it was previously thought that the time taken to reach sexual maturity, as well as the expected life span, was related to the size of the organism. However, recent research suggests that it is the complexity of the species' brain that is the determining factor. The more neurones that connect to make up the brain, the longer a species lives and the longer it takes to mature. This, in turn, is linked to producing fewer offspring but providing greater parental care.

CASE STUDY: Green turtles

Green turtles, *Chelonia mydas*, reach reproductive maturity between 30 and 50 years of age and will continue to 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!

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.

FIGURE 5.39 The male Australian redback spider is usually eaten by his sexual partner while mating with her.

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 5.41). Likewise, female moths use scented chemicals that sexually attract male moths from as far as 8 kilometres away.

pheromones chemicals that are important in communication between members of the opposite sex

Using light

Fireflies can make parts of their body glow different colours (figure 5.40). 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.

▶ eles-2542

FIGURE 5.40 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.

FIGURE 5.41 During ovulation, a female dog releases a pheromone into her urine.

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.

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.

FIGURE 5.42 The male humpback whale sings a song during the mating season to advertise his sexual availability to females.

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)

elog-2416

INVESTIGATION 5.5

Relationship between seed number and seed size

The intended outcome of reproduction is to produce enough healthy offspring to maintain the survival of the species. There are two distinct strategies adopted to achieve this:

1. **r-selected species** produce large numbers of young, but provide little parental care
2. **K-selected species** produce small numbers of young, but the parents care for and protect them.

We can investigate similar strategies in plants. Seeds contain a food store to sustain the new plant through germination until it has developed enough to start to photosynthesise its own food. Some plants produce small numbers of large seeds, increasing the chances of that individual seed surviving, while others produce large numbers of smaller seeds, increasing the chances of at least one or two of the many seeds surviving.

Aim

To investigate the relationship between seed number and seed size in a range of fruits

Materials

- chopping board
- kitchen knife
- paper towel
- variety of fresh fruits, e.g. tomato, apple, peach, watermelon, chilli pepper
- 15 cm ruler

Method

1. Cut open a fruit.
2. Remove all the seeds and wipe them clean with the paper towel.
3. Count the number of seeds and record this in a results table.
4. Measure the size of five seeds.
5. Calculate the average size of one seed by adding the 5 values from step 4, then dividing by 5.
6. Repeat for a range of fruits.
7. Plot a scattergraph of the number of seeds against the average size of one seed.

Results

1. Plot a scattergraph of the number of seeds against the average size of one seed for the different fruits.

Discussion

1. Is there a relationship between the number of seeds and seed size? Explain.
2. Discuss any difficulties experienced during this investigation and how they were overcome.

Conclusion

Summarise your findings about the relationship between seed number and seed size.

ACTIVITY: Dr Helen Mayo and the MBHA

Dr Helen Mayo was a South Australian doctor whose work on ante- and post-natal care in the early 1900s led to the formation of the Mothers and Babies Health Association, which still exists today in South Australia as the Child and Family Health Service, along with similar organisations in other states.

Create a poster or slideshow about the work of Dr Mayo, informing the reader of her life and work and how her work led to a reduction in infant mortality.

5.4 Activities

5.4 Quick quiz on

5.4 Exercise

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 3, 6, 12, 16, 17	2, 4, 7, 10, 13, 15	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. a. Identify whether each of the following statements are true or false.

Statement	True or false?
i. Many organisms produce more eggs than can survive.	
ii. In seahorses, the father can give birth to the young.	
iii. 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.	
iv. If eaten by his sexual partner, the male red-back spider has an increased chance of fertilising her eggs.	
v. Some reptiles ‘cement’ up the female’s genitalia by using semen that sets into a hard plug so that other sperm cannot get in.	
vi. Pheromones are a group of chemicals that play an important role in communication between members of the same species.	
vii. Hermaphrodites are animals that have both egg-producing and sperm-producing organs.	
viii. Fireflies make part of their body glow different colours to help find mates, but never to lure mates and then eat them.	
ix. The male humpback whale sings a song during mating season to advertise his sexual availability to females.	
x. The Tammar wallaby can only suckle one infant at a time.	

b. Justify any false responses.
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. Create a table with the following headings: Organism, Life span, Age at maturity, Number of offspring, r- or K-selected.
    Use the internet to complete the table for the following species: human, brown rat, mountain gorilla, house mouse, kangaroo.
11. 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?		

12. **SIS** Which reproductive strategy do you think is more successful in terms of ensuring the species survives? Justify your answer.

Evaluate and create

13. Using the examples from this section, identify three ways in which chemicals are important in reproduction to different animals.
14. **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.
15. **SIS** Suggest why reproduction is worth the risks that may be involved.
16. **SIS** How might we support organisms that are at risk of extinction to survive for more generations?
17. 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.

LESSON
5.5 Human reproduction

LEARNING INTENTION

At the end of this lesson 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.

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.

FIGURE 5.45 Human sperm cells surround an ovum.

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 (ova, or egg cells), 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, and 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**.

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

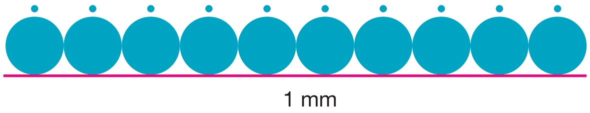
uterus the site of embryo implantation, and supports the developing fetus from implantation to birth. About the size of a pear if not pregnant

fallopian tube a tube connecting each ova to the uterus, which the egg travels through

ovulation the release of an ovum from a mature follicle in the ovary into the fallopian tube

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.

FIGURE 5.46 Human ova are approximately one tenth of a millimetre in size.



ewbk-12360

int-8239

eles-2069

FIGURE 5.47 The human female reproductive system

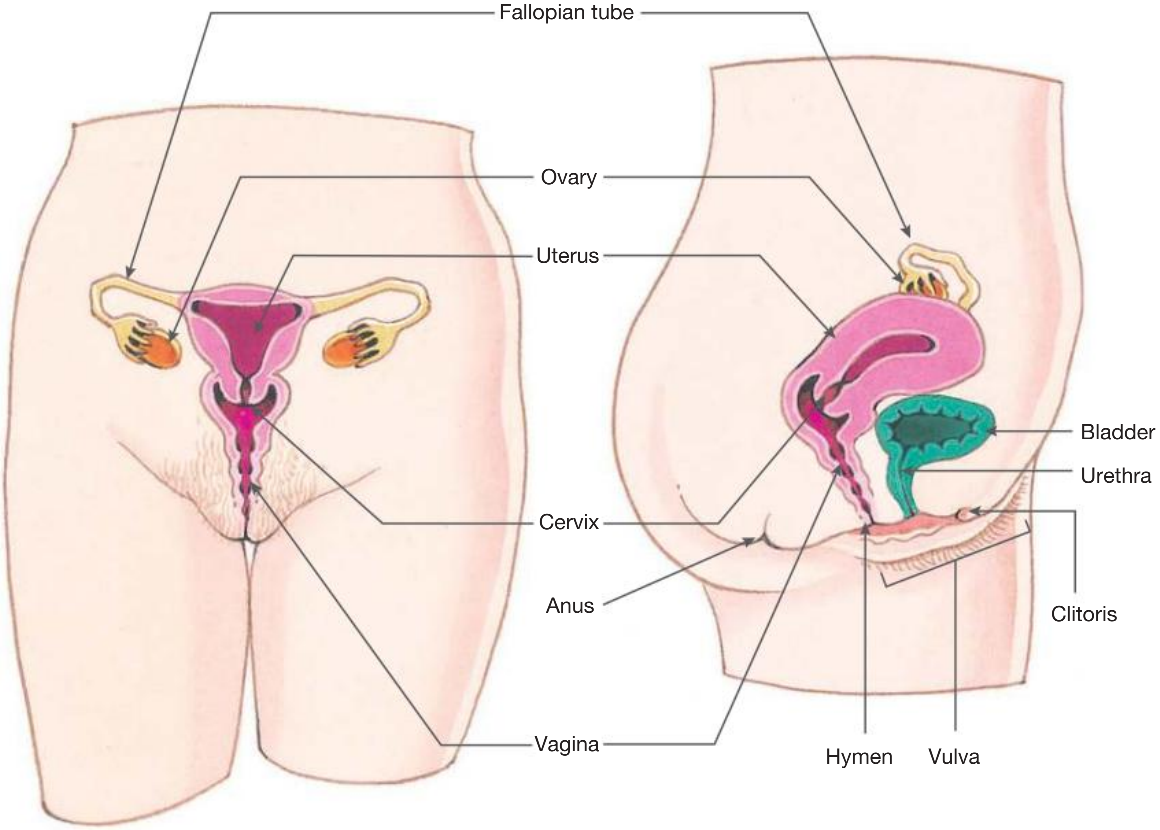
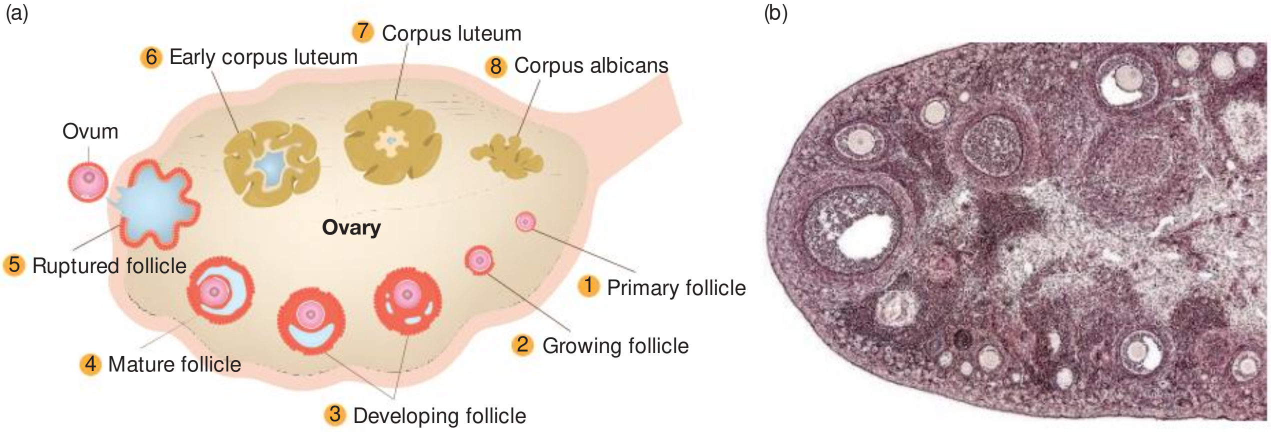


FIGURE 5.48 a. Each ovum matures inside a small sac called a follicle inside the ovary. This process is controlled by chemicals called hormones. Once an ovum is mature enough to be fertilised, the follicle bursts and the ovum is released into the fallopian tube. **b.** This process can be seen at its different stages using a powerful microscope as illustrated by the section of the cat ovary shown here.



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.

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 3 °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.

A typical ejaculation can contain 300 million sperm cells in a sticky fluid called **semen**. Sperm are about one-twentieth the size of a human ovum (figure 5.49a) 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 (figure 5.49b). 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 (figure 5.51).

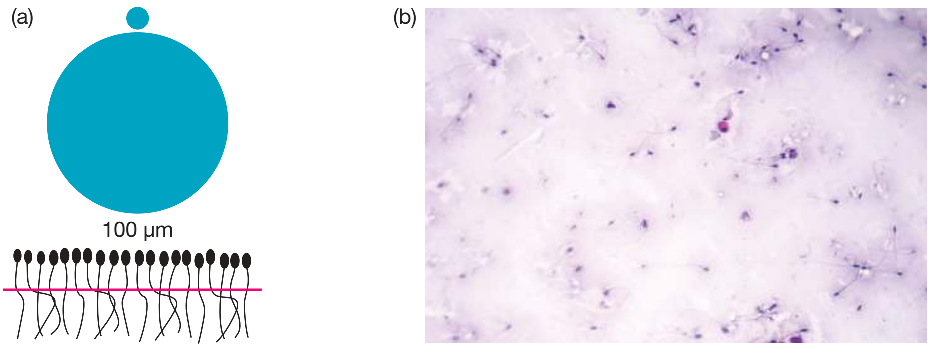
testes organs that produce sperm and sex hormones

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 5.49 a. Sperm are about 20 times smaller than ova. **b.** Photomicrograh shows their long tail for motility.



ewbk-12362

eles-2068

int-8240

FIGURE 5.50 The human male reproductive system

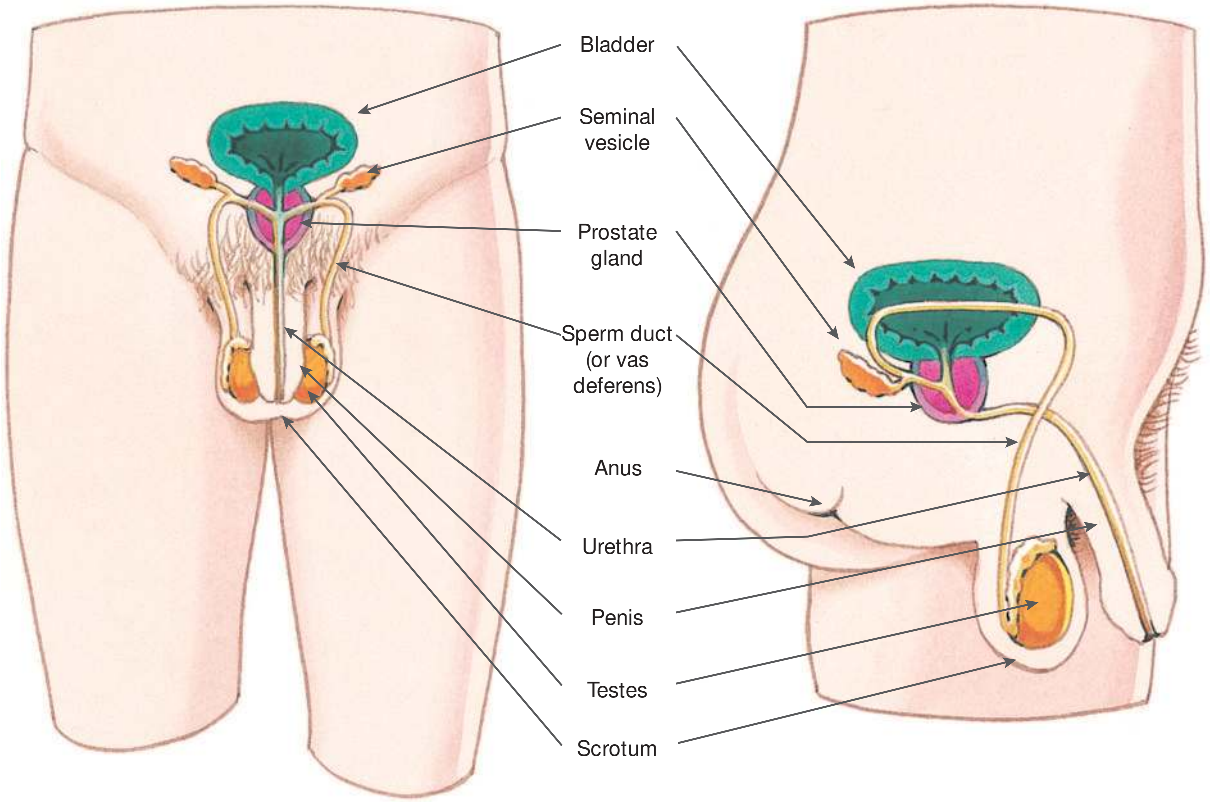
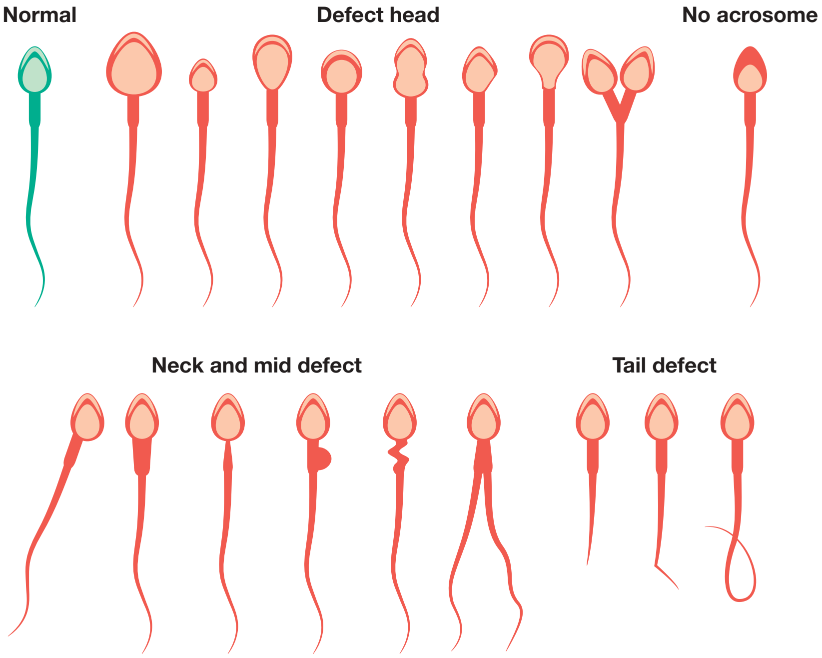


FIGURE 5.51 Sperm morphology, or shape, is very important as sperm cells without the correct head, midpiece or tail shape will not be capable of fertilising the ovum.



EXTENSION: Amazing sperm

Sperm cells are less than half a millimetre long. Viewed through a microscope lens, spermatozoa (sperm, for short) remind us 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 it is cold (keeping sperm warmer) and hangs away from the body when it is 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

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 3 °C 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.

on Resources

eWorkbooks	Human male reproductive system (ewbk-12364) Human female reproductive system (ewbk-12366)
Video eLessons	Human ovum in utero and sperm cells (eles-2539) Live human sperm (spermatozoa motion) under microscope (eles-2544)

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 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 (table 5.4). 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**.

menstrual cycle beginning of one period to the beginning of the next period

TABLE 5.4 The main changes observed during puberty

Boys	Girls
Testes grow	Breasts grow
Pubic hair develops	Pubic hair develops
Penis grows	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	

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.

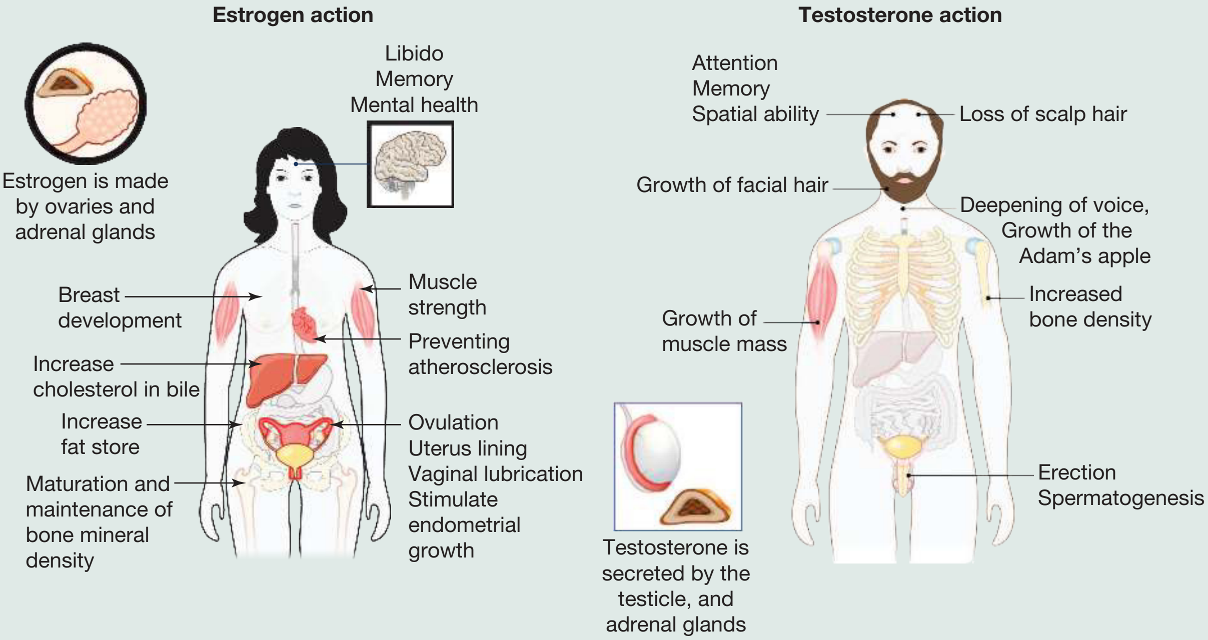
FIGURE 5.54 Other changes that occur during puberty include the growth of hair in the pubic region, under the arms and on boys' faces. Both boys and girls can experience acne as well as changes in the shape of their bodies.

EXTENSION: What are hormones?

Hormones are chemical messengers that travel around in the body 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 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 speeds up reaction times; 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 5.55 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.

target cell a specific cell in which a hormone can cause a response

menstruation the monthly bleeding, also called 'periods'. It occurs as the lining of the uterus is released.

eles-2538

FIGURE 5.56 Changes in hormone levels and the endometrium throughout the menstrual cycle

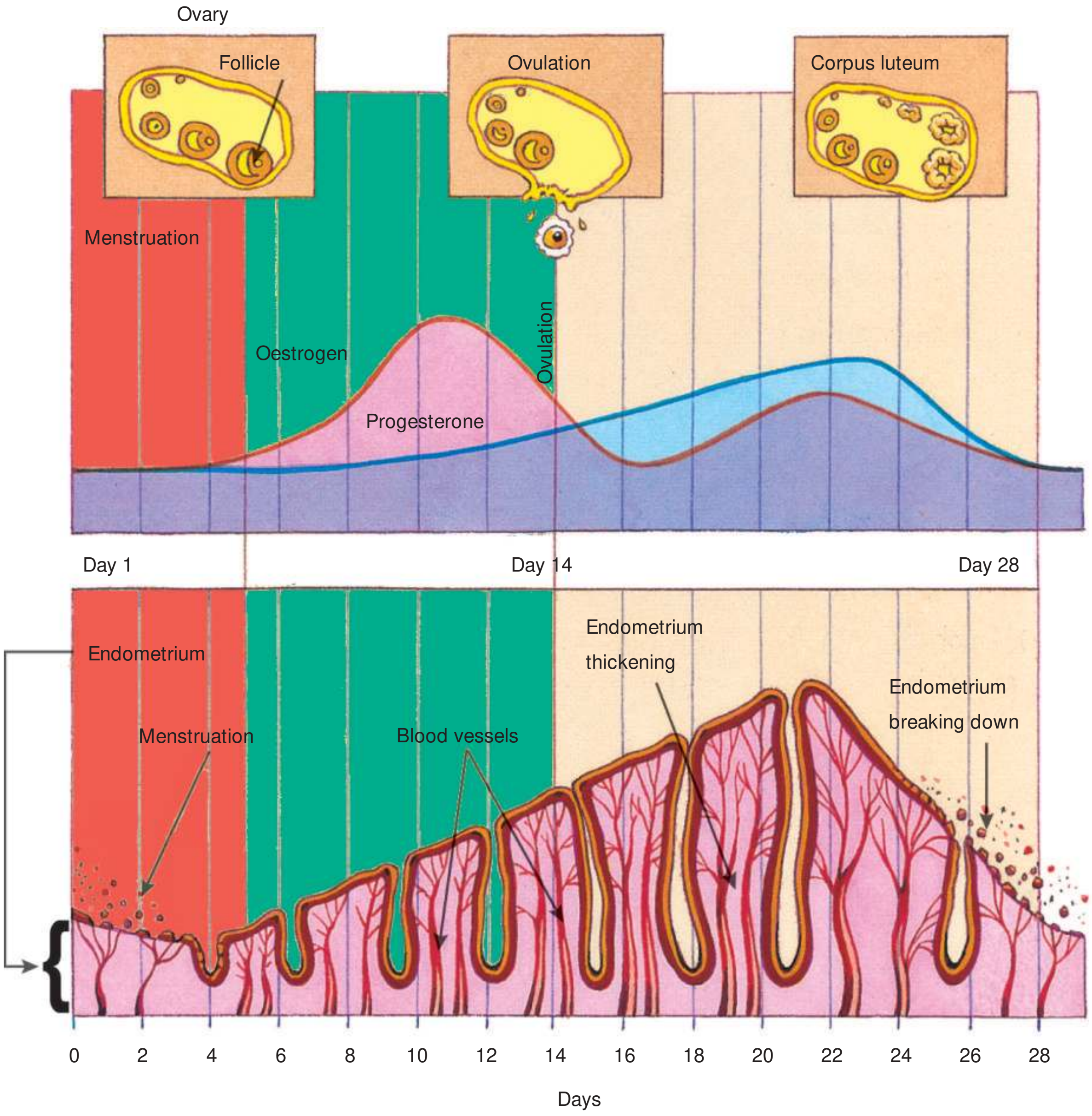
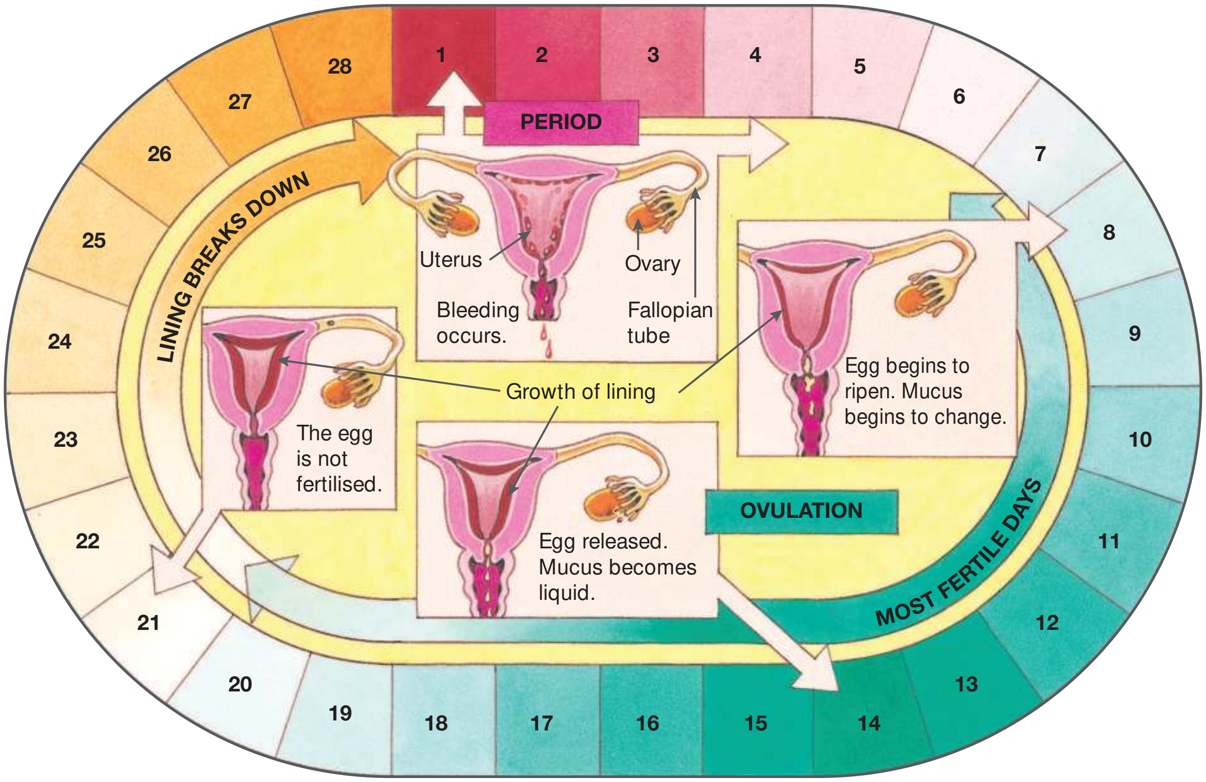


FIGURE 5.57 Menstrual cycle



on Resources

eWorkbook Menstruation (ewbk-12368)

5.5.6 Conception

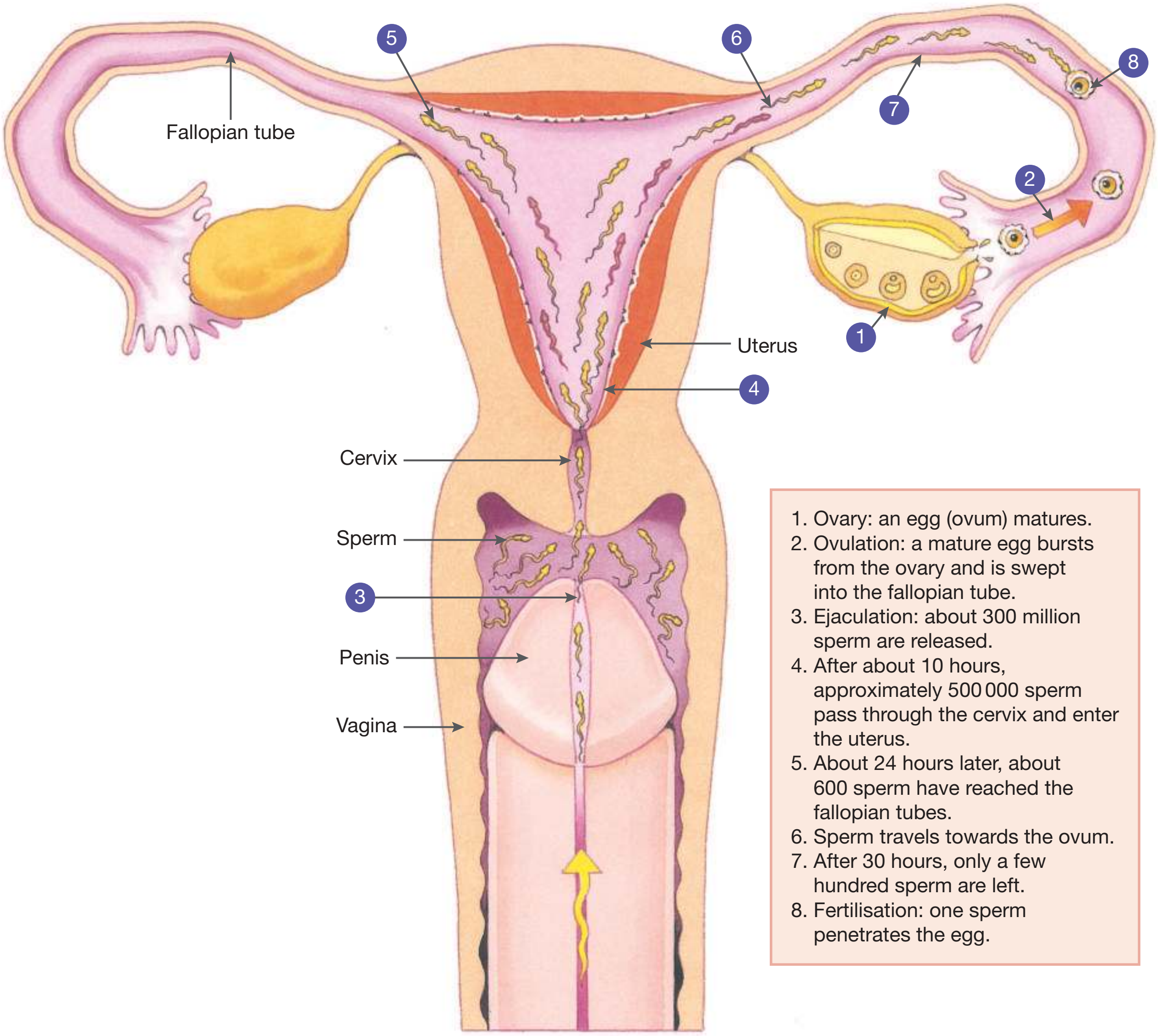
For sexual reproduction to be successful in humans, a number of things need to occur at the same time. First, there must be a mature egg in the fallopian tube, although this cannot be more than a few hours old. Second, a healthy sperm must be in exactly the same place as the ovum, release enzymes to 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.

If this happens correctly then the nucleus of the sperm, with its half set of genes, can join the nucleus of the egg, with its half set of genes, and the egg is fertilised. This is the first stage of a new life, called a zygote.

FIGURE 5.58 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

zona pellucida surrounds the ovum and embryo for the first week of development

FIGURE 5.59 Sexual intercourse — getting the sperm to the egg



1. Ovary: an egg (ovum) matures.
2. Ovulation: a mature egg bursts from the ovary and is swept into the fallopian tube.
3. Ejaculation: about 300 million sperm are released.
4. After about 10 hours, approximately 500 000 sperm pass through the cervix and enter the uterus.
5. About 24 hours later, about 600 sperm have reached the fallopian tubes.
6. Sperm travels towards the ovum.
7. After 30 hours, only a few hundred sperm are left.
8. Fertilisation: one sperm penetrates the egg.

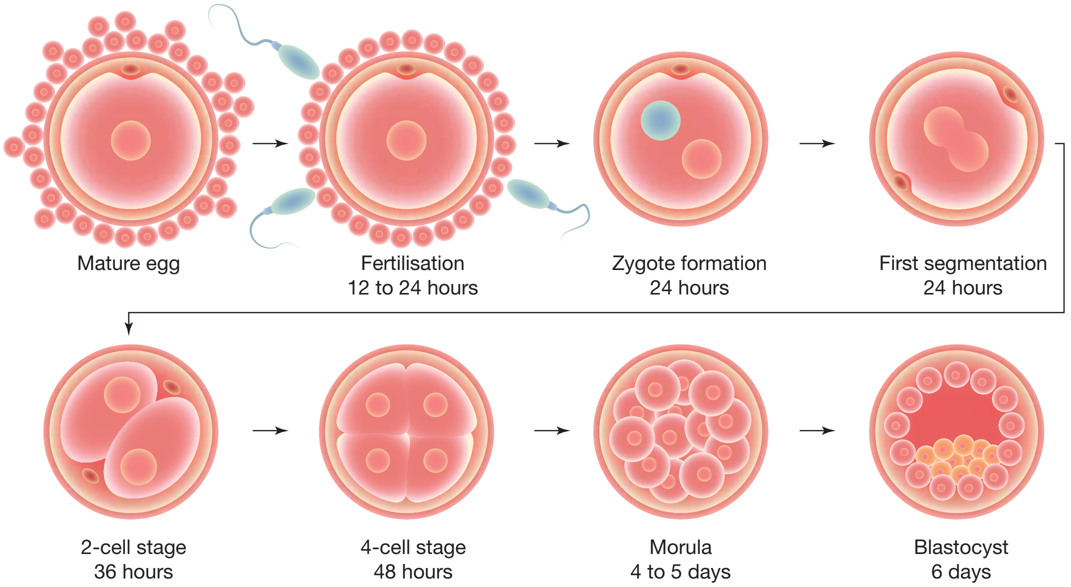
5.5.7 Developing embryo

After fertilisation the egg cell will continue to develop, continually dividing to form more and more cells, before it joins to the wall of the uterus. This stage is called implantation. Now cells start to differentiate, or specialise, to do different jobs. Some will form the new baby, while others form a structure called the placenta, which attaches the baby, now called an embryo, to its mother and allows the transport of food and oxygen to it.

Many embryos do not develop correctly and therefore fail to implant, which explains why some people have difficulty falling pregnant.

FIGURE 5.60 Image of a human blastocyst days after fertilisation with cells beginning to hatch out of the zona pellucida or shell

FIGURE 5.61 Embryo development in the first week of pregnancy



5.5.8 Pregnancy

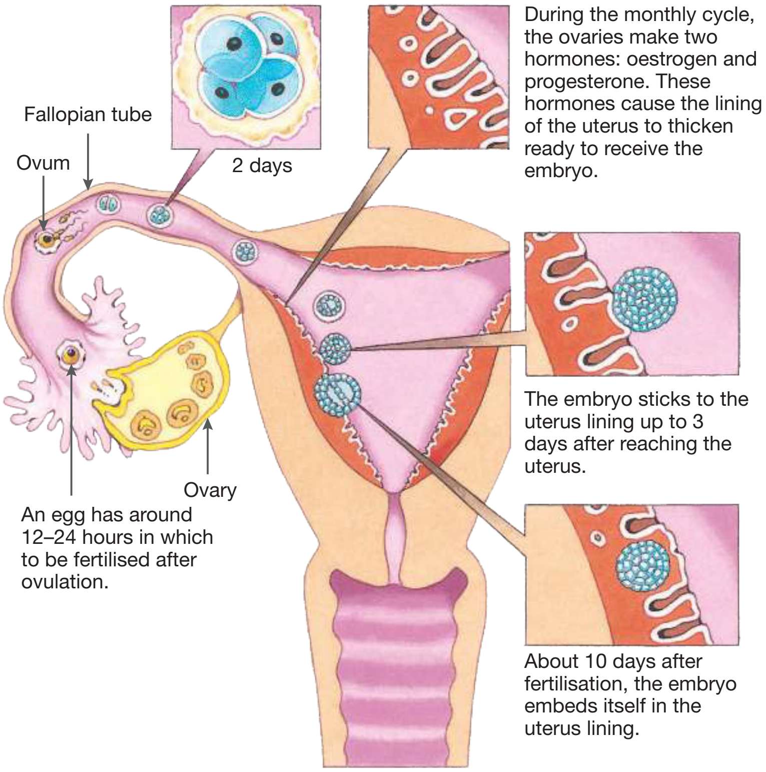
The first eight weeks

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 implants itself in the uterus lining (endometrium).

conception the successful embedding of a fertilised egg in the uterus wall

int-3408

FIGURE 5.62 The process of fertilisation through to conception



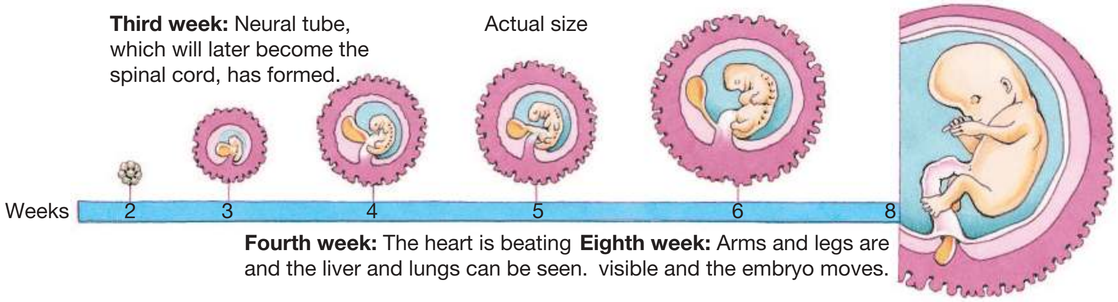
During the monthly cycle, the ovaries make two hormones: oestrogen and progesterone. These hormones cause the lining of the uterus to thicken ready to receive the embryo.

The embryo sticks to the uterus lining up to 3 days after reaching the uterus.

About 10 days after fertilisation, the embryo embeds itself in the uterus lining.

An egg has around 12–24 hours in which to be fertilised after ovulation.

FIGURE 5.63 The first eight weeks



Third week: Neural tube, which will later become the spinal cord, has formed.

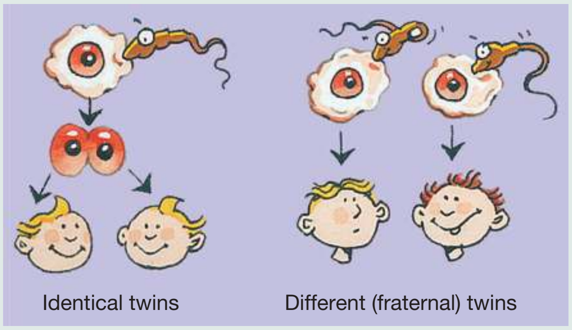
Fourth week: The heart is beating and the liver and lungs can be seen.

Eighth week: Arms and legs are visible and the embryo moves.

CASE STUDY: 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**. As both twins get identical copies of the same genes, they will be the same gender and look the same. They are natural clones.

Usually, only one ovum is released at a time. However, if several are released, two or more embryos 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** (or triplets and so on) and they are like any other brothers or sisters, they just happen to be born at the same time.



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

identical twins twins developed from the same fertilised egg

fraternal twins twins developed from different fertilised eggs

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 5.64 A human embryo at 32 days

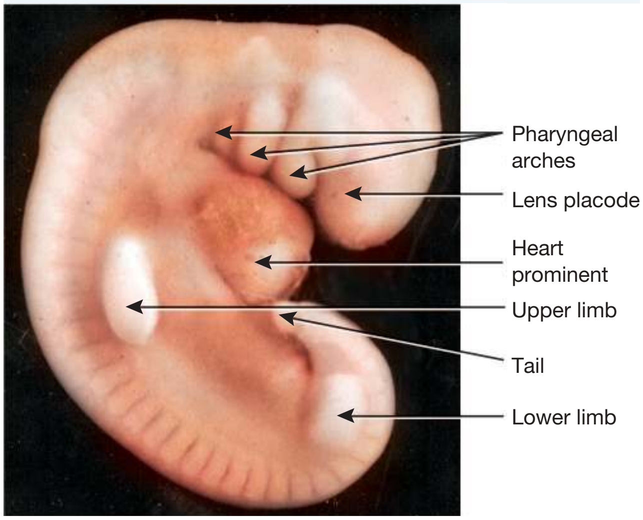
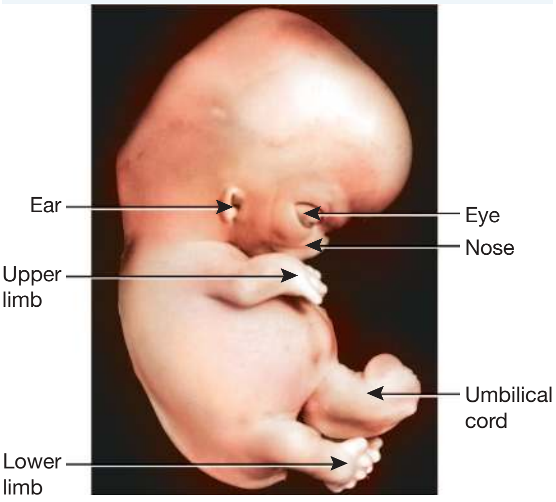


FIGURE 5.65 A human embryo at 52 days

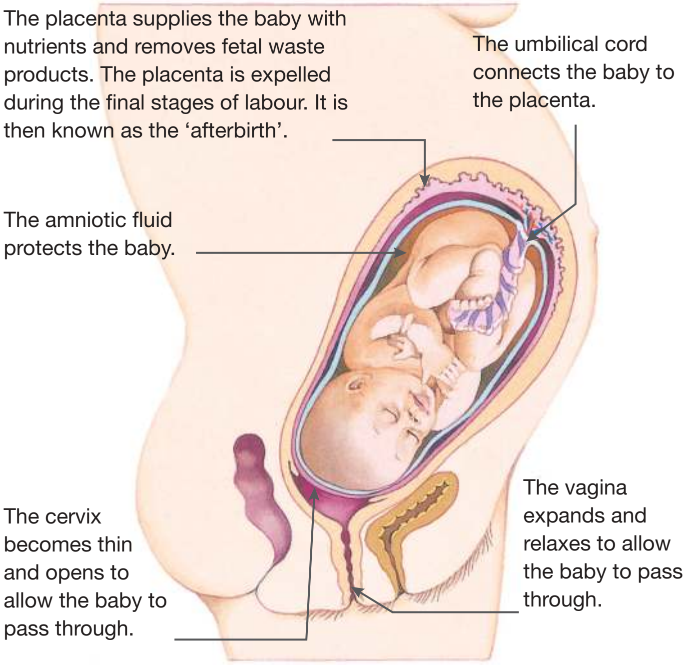


5.5.9 Giving birth

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 5.66 Ready for birth — the baby at 40 weeks' gestation

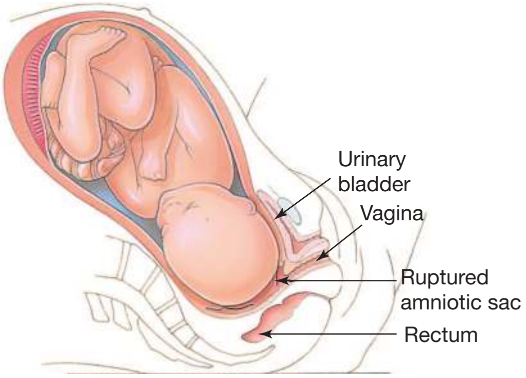
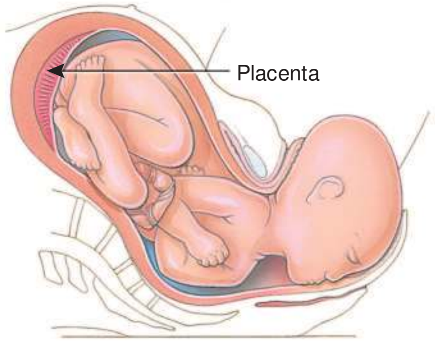
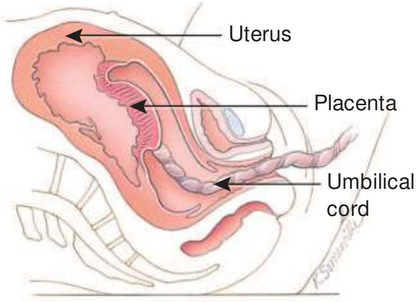


labour the process of delivering the baby, placenta and umbilical cord from the uterus

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

FIGURE 5.68 Stages of giving birth

<table>
<tr><th>First stage</th><th></th></tr>
<tr><td>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.</td><td>
</td></tr>
<tr><th>Second stage</th><th></th></tr>
<tr><td>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).</td><td>
</td></tr>
<tr><th>Third stage</th><th></th></tr>
<tr><td>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.</td><td>
</td></tr>
</table>

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.

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 5.67 Cuddling and breastfeeding can result in the release of oxytocin, which can promote feelings of trust, love and bonding.

on Resources

▶ **Video eLesson**	Giving birth (eles-2070)
eWorkbook	Inside the womb (ewbk-12370)

5.5 Activities

learnon

5.5 Quick quiz **on** | **5.5 Exercise**

Select your pathway

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

Remember and understand

1. Identify the parts of the female reproductive system:

Description	Name
a. that produces ova	
b. through which the 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:

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. **a.** Identify whether the following statements are true or false.

Statement	True or false?
i. In males, during puberty, the voice box gets smaller, which makes their voice deeper.	
ii. Sex hormones, such as testosterone, can make glands in the skin produce extra oil, which may result in pimples.	
iii. Everybody goes through puberty at the same age.	
iv. Eventually all the eggs that girls are born with will mature throughout their lifetime.	
v. The menstrual cycle is 28 days in all women.	
vi. If you are having periods, it means that you may be physically able to get pregnant and have a baby.	

b. Justify any false responses.

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 figure 5.57 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 5.56 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. Fill in 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.

10. a. Identify whether the following statements are true or false.

Statement	True or false?
i. Conception occurs when the egg cell and sperm unite to form a zygote.	
ii. The total time the unborn baby spends in the uterus is often called the gestation period.	
iii. If a human baby is born after 40 weeks, then it is called premature.	
iv. The placenta is expelled during the final stages of labour and is called the 'afterbirth'.	
v. Oxytocin is a hormone that causes the uterus to contract during childbirth.	
vi. When a baby suckles on the mother's nipple, oxytocin is released in the mother, which triggers the release of milk.	
vii. Fertilisation of the egg occurs in the uterus.	
viii. Oestrogen and progesterone cause the lining of the uterus to become thinner.	
ix. The placenta is connected to the mother's blood vessels through the uterus.	
x. A breech birth is when the baby is born bottom or feet first	

b. Justify any false responses.

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 5.47 and 5.50.
    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 a fetus from conception to birth (40 weeks).
    b. Construct a graph showing the changes in weight of a 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.

LESSON
5.6 Reproductive technologies and contraception

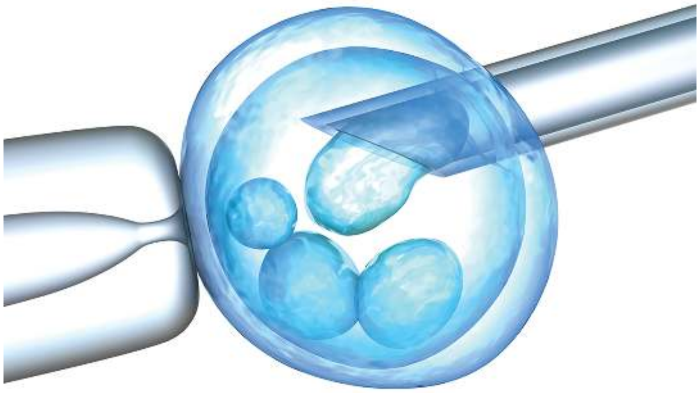
LEARNING INTENTION

At the end of this lesson 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 past 50 years with many new strategies available for couples wishing to control their fertility and avoid pregnancy.

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)**.

FIGURE 5.69 Artificial insemination



5.6.1 Preventing pregnancies

Conception involves the fertilisation of an ovum and its implantation into the wall of the uterus where it can develop into a fetus. 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.

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. The different contraceptives and their effectiveness can be seen in table 5.6.

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

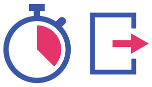
on Resources

▶ **Video eLesson** Methods of contraception (eles-0127)

TABLE 5.6 Effectiveness of different contraceptive methods

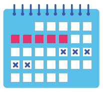
Least effective

- **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



Withdrawal
every time

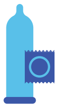
- **Spermicides**
  - Cream or jelly containing chemicals that kill sperm
  - Introduced to the vagina before intercourse
- **Rhythm method**
  - Abstaining from intercourse during the most fertile stages of the menstrual cycle (around the time of ovulation)



Fertility awareness
every time

Highly effective

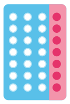
- **Condom**
  - Made of thin, strong latex
  - Male condom rolled onto erect penis just prior to intercourse
  - Female condom inserted into vagina prior to intercourse
  - Barrier to STIs
  - Most effective if used with spermicide
- **Diaphragm**
  - Thin rubber dome placed in vagina
  - Prevents sperm from reaching the cervix
  - Most effective if used with spermicide
- **Hormonal medications**
  - Hormonal control used by wome 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 of intercourse



Male condom
single use

Cervical cap
every time

Diaphragm
every time

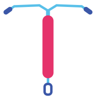


Pills
every day

Vaginal ring
every
month

Patch
every
week

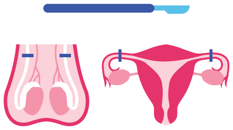
Injection
1-3 months



IUD
3–10 years

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



sterilisation for men and
women — it can be reversed
but does not guarantee
success in having
a child after

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 the University of Melbourne.

FIGURE 5.70 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.

FIGURE 5.71 Human papillomaviruses (HPV) cause warts located mainly on the hands and feet. Some strains infect the genitals and can cause cervical cancer.

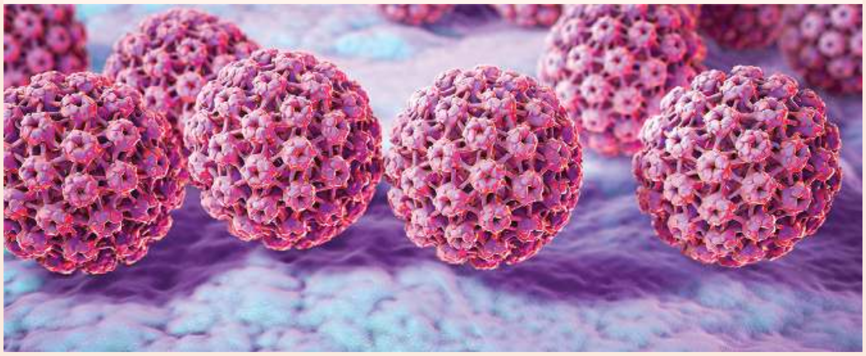


FIGURE 5.72 Professor Rachel Skinner

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:

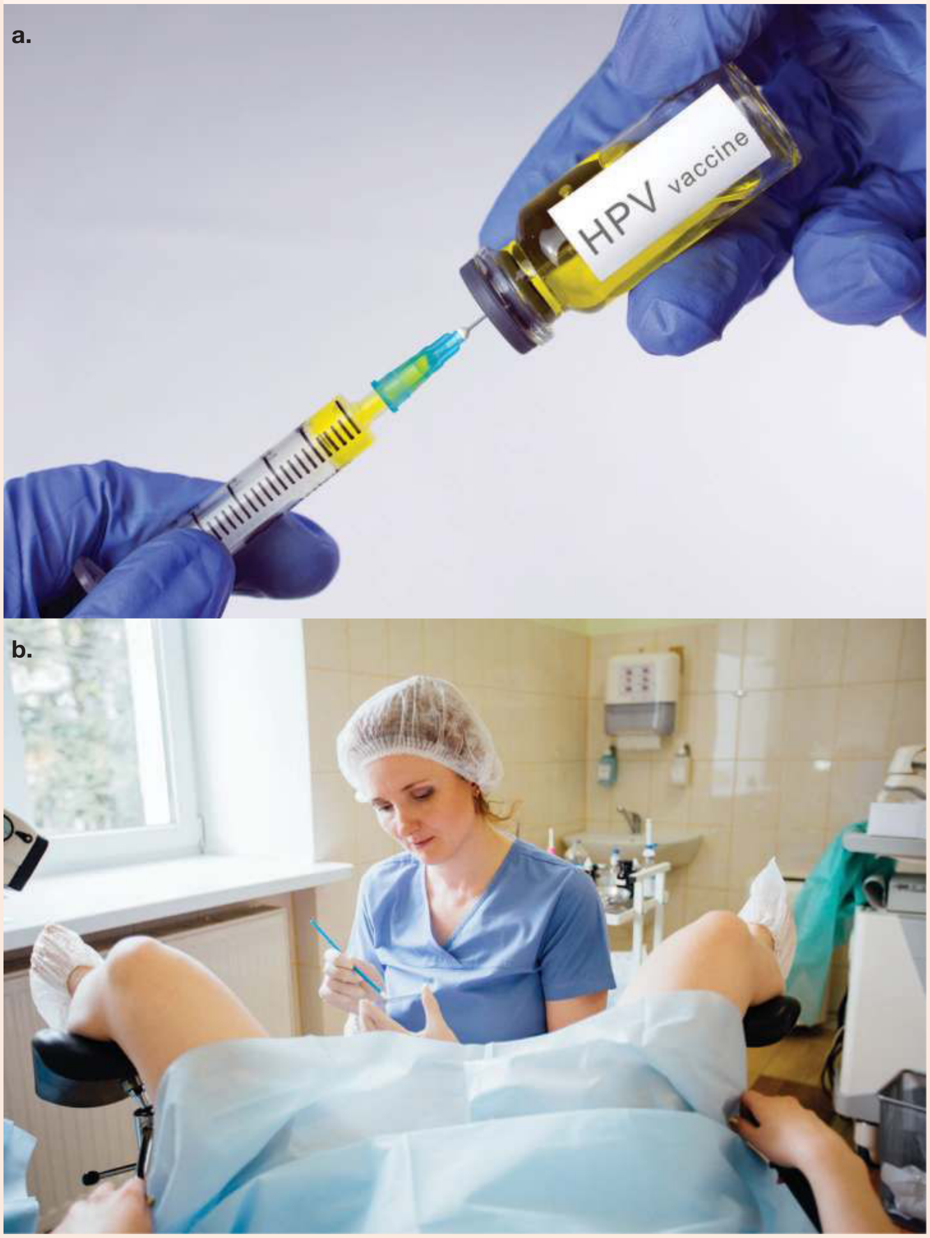
- almost all cases of genital warts and cervical cancer
- 90% of anal cancers
- 65% of vaginal cancers
- 50% of vulvar cancers
- 35% of penile cancers.

In Australia, all boys and girls are vaccinated against two of the most common types of HPV at the age of 12 or 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 of 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 5.73 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 5.74 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.

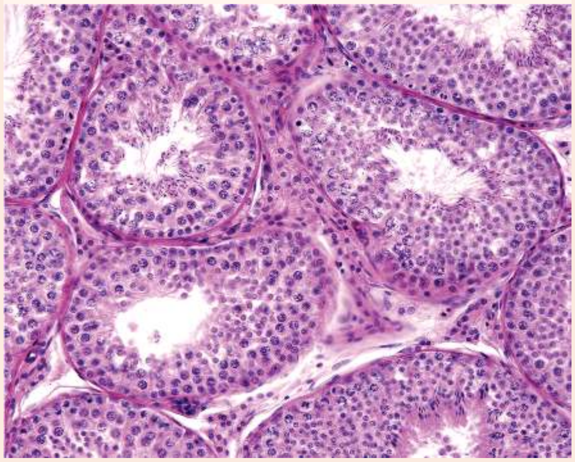
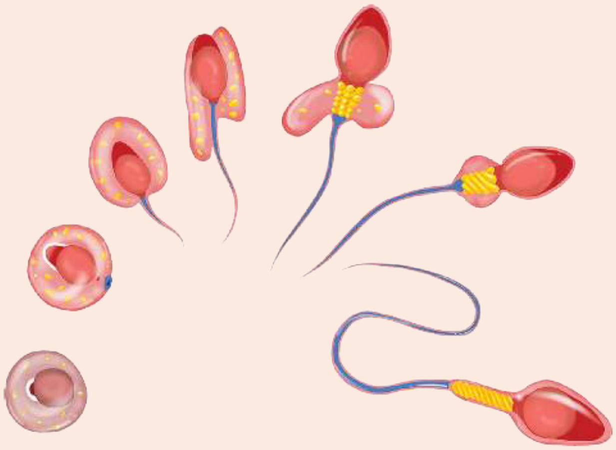


FIGURE 5.75 The process of sperm maturation from a small circular cell, spermatogonia, to a mature sperm cell with a fully formed head, midpiece and tail. Blocking this process by changing the genetic information could lead to a new male contraceptive.



This means that Cohen's group needs to explore the genetics of immature sperm cells, spermatogonia, and to 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 sperm production, quality or function, and another third of cases cannot be explained following the usual investigations.

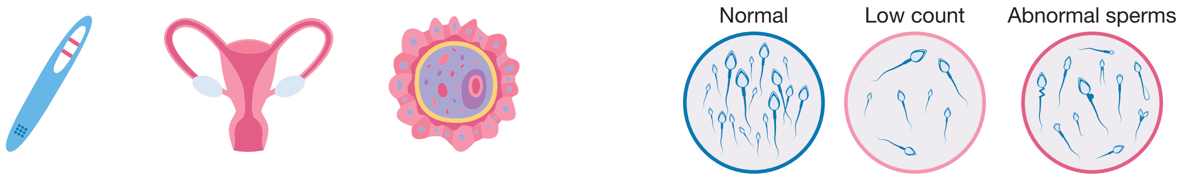
FIGURE 5.76 Infertility can sometimes result from factors in the male or in the female; however, it is common for both partners to contribute to infertility or for the exact cause to be unknown.

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 environmental factors



5.6.4 Treatment options

There are many 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 help 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 Dr 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 5.77 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.

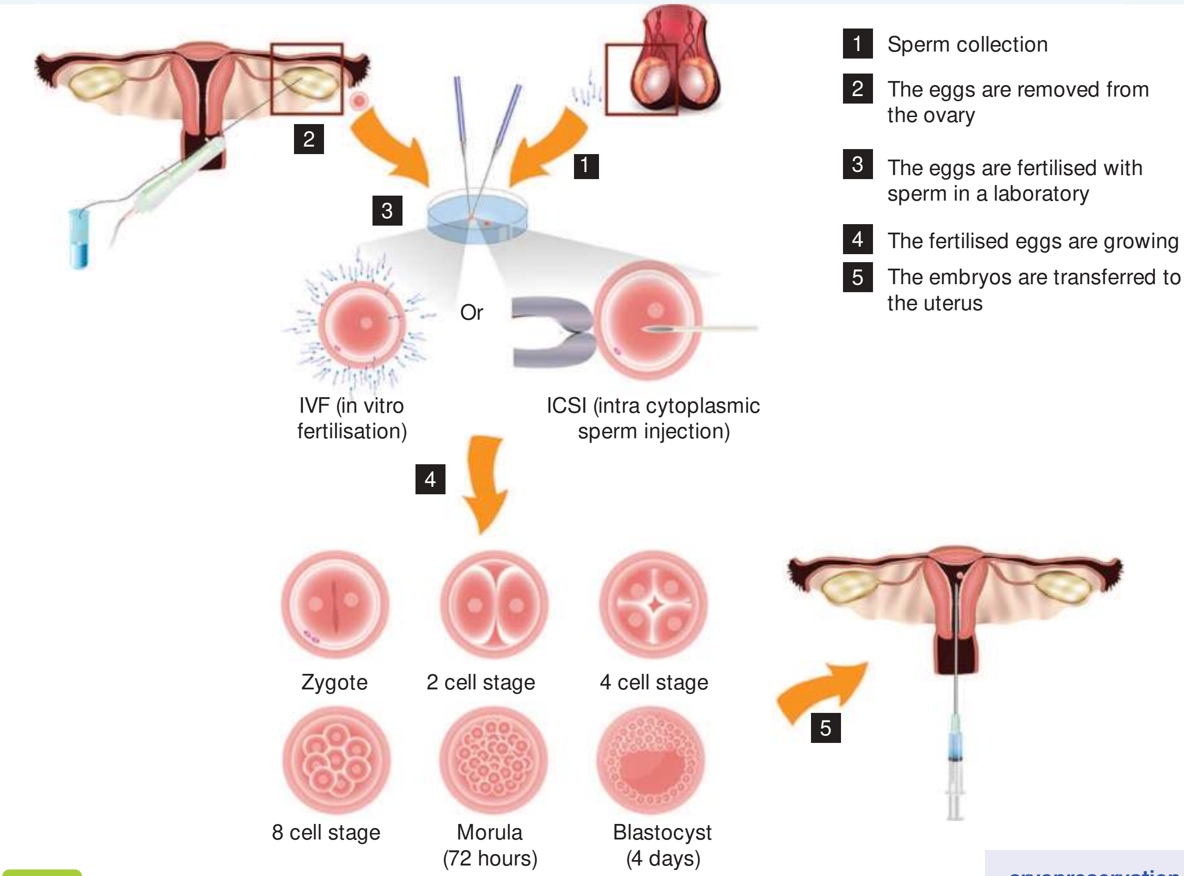
A sperm sample is collected from the male partner, checked for quality and motility, cleaned and concentrated before mixing with the ova.

FIGURE 5.78 A semen sample and prepared sperm ready for inseminating the ovum (right)

FIGURE 5.79 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 5.80 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

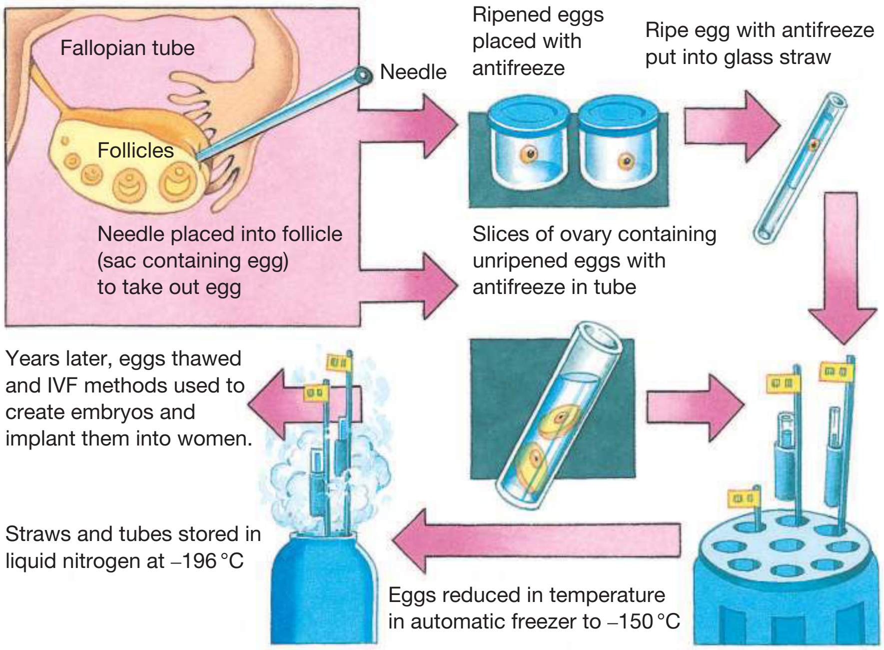
Cryopreservation

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 5.81 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 5.82 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, being **sterile**, or having poor quality gametes that 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 them. 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.

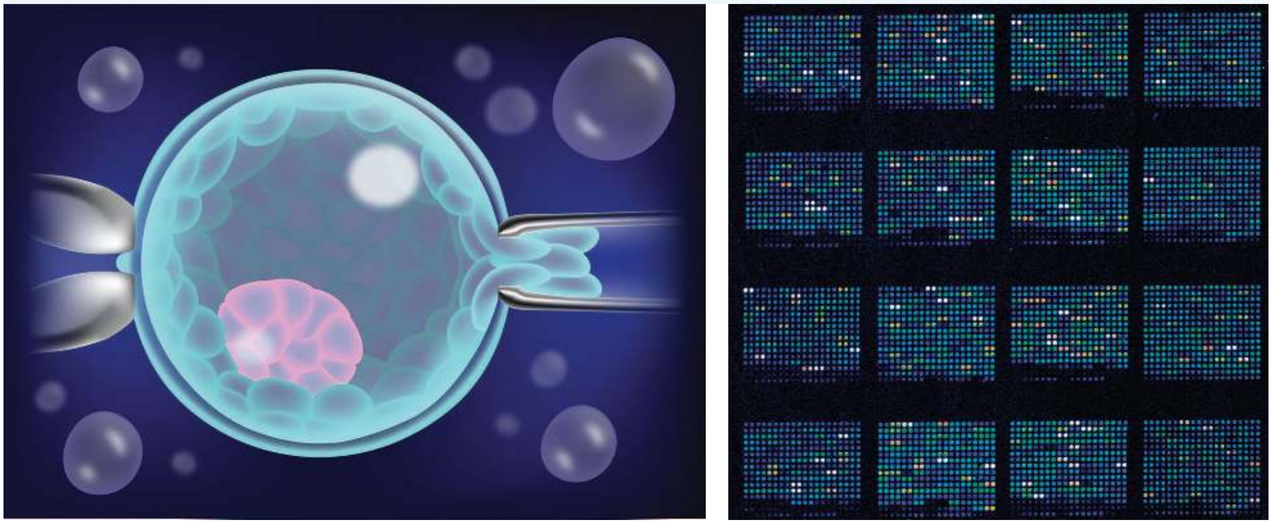
sterile a person unable to produce reproductive cells

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 5.83 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 tests available for testing the pregnancy with different levels of risk involved and different levels of accuracy. 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 5.84 In chorionic villus sampling, cells from the developing placenta are removed for testing at around 10–12 weeks of pregnancy.

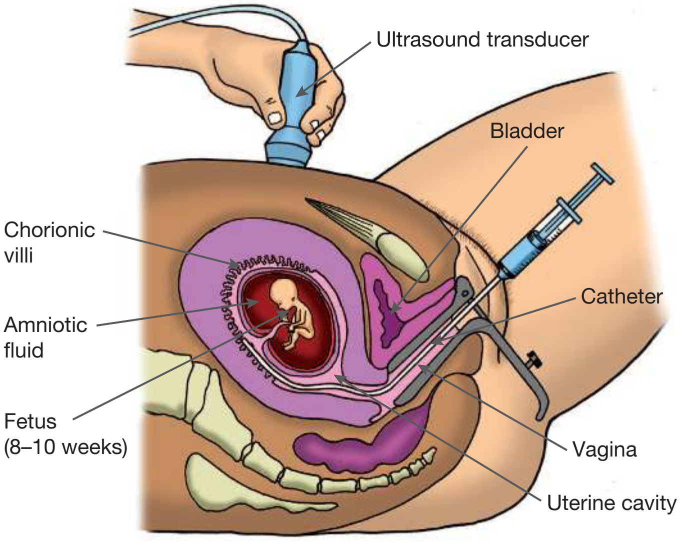
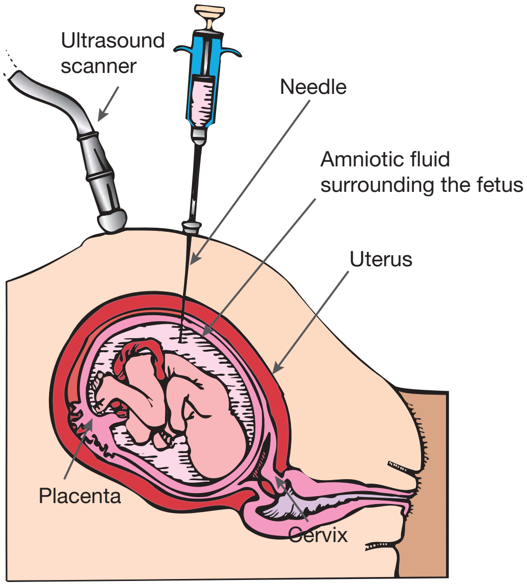


FIGURE 5.85 During amniocentesis, a fine needle is inserted into the amniotic sac of the fetus at around 14–16 weeks of the pregnancy and a small amount of fluid is drawn out to be tested.



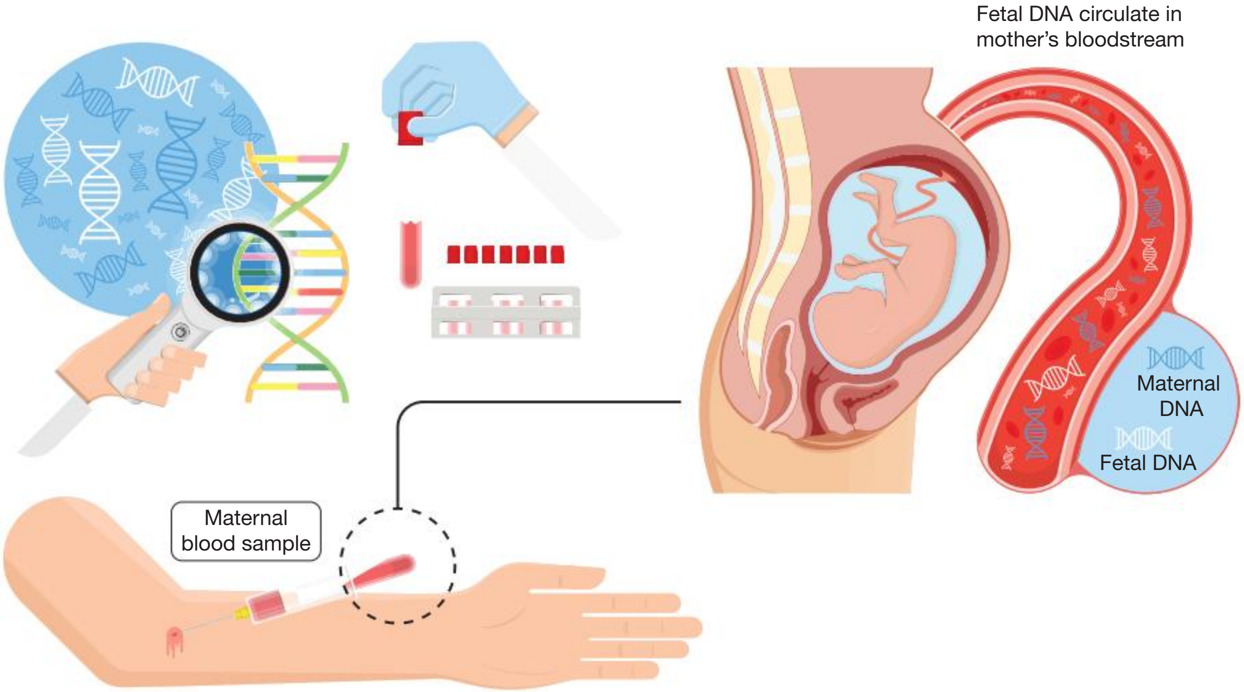
Using ultrasound imaging is non-invasive and involves observing the fetus for signs of abnormality, which is very safe but provides less information. In addition, a relatively new method of screening the unborn child for abnormalities is using maternal blood screening (**non-invasive prenatal screening**, or NIPS) which can indicate if there are genetic abnormalities in the fetus by taking a sample of the mother's blood (figure 5.88).

eles-4234

FIGURE 5.86 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

FIGURE 5.87 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.

FIGURE 5.88 Dr Petra Wale, clinical embryologist and research scientist

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.

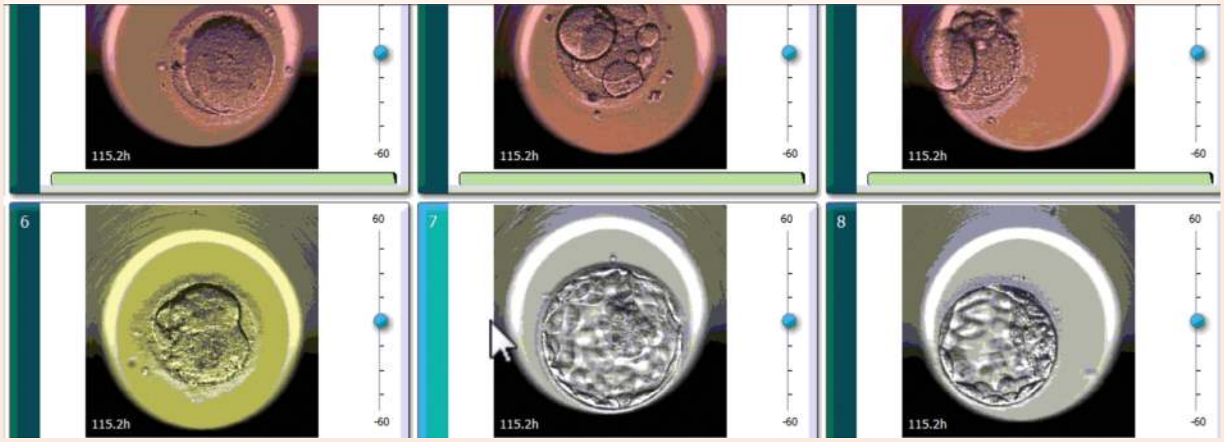
What does the future hold for IVF?

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.

In the early days of IVF, patients would have to have a number of embryos implanted, as the chances of a successful pregnancy were low. This led to a number of multiple births, with some patients having as many as eight embryos surviving implantation. This creates a significant risk to both the mother and babies and is not a desirable outcome. While the chances of success depend on a number of factors, particularly the mother's age, treatments have developed to the stage that most IVF attempts now involve the transfer of only one embryo at a time.

FIGURE 5.89 A time-lapse incubator, which can provide scientists a view of embryos as they develop without disturbing them

FIGURE 5.90 Time-lapse images of embryo 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 5.91 Inseminating (fertilising) an egg with sperm in IVF procedure

on Resources

eWorkbook IVF — discussing the issues (ewbk-12372)

5.6 Activities

learn**on**

5.6 Quick quiz on

5.6 Exercise

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 2, 5, 12	3, 4, 6, 9, 13	7, 8, 10, 11, 14

These questions are even better in jacPLUS!
- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

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 least 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. a. Identify whether the following statements are true or false.

Statement	True or false?
i. It is possible to freeze fertilised eggs so that they may be implanted at a later time.	
ii. Hormone injections can be used to increase the number of eggs released during ovulation.	
iii. Test-tube babies develop in test tubes for the first 8 weeks of their development.	
iv. A cell can be removed from the developing embryo to be tested for genetic abnormalities.	
v. 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.	
vi. The gender of a baby cannot be determined until it is born.	
vii. Ultrasound involves the use of UV waves to produce images of an unborn child inside the mother's body.	
viii. Using IVF, it is possible for 'twins' to be born years apart.	

   b. Justify any false responses.
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 lesson: Dr Petra Wale 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.

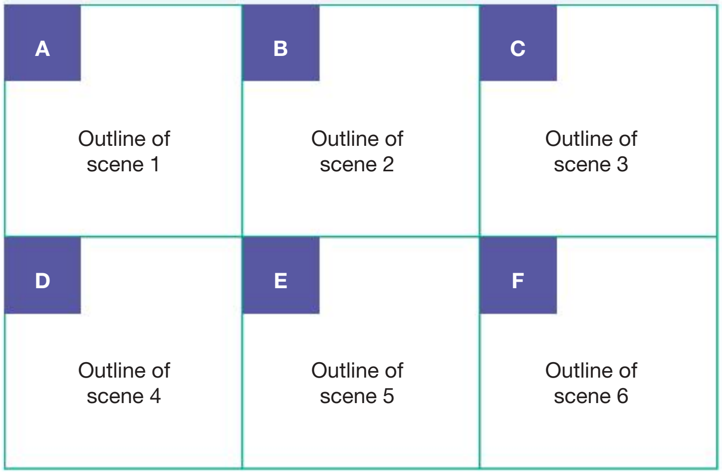
LESSON
5.7 Thinking tools — Storyboards

5.7.1 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.

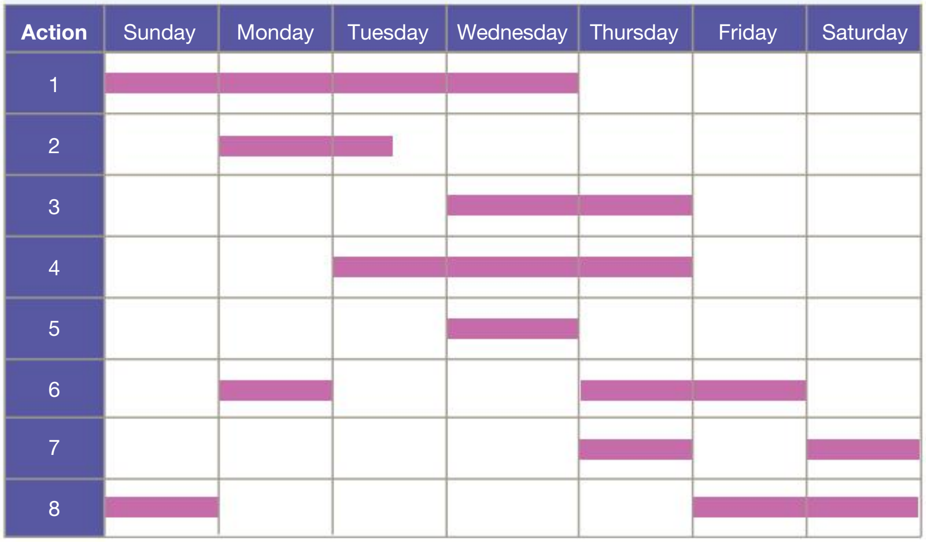
FIGURE 5.92 A storyboard



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 5.93.

FIGURE 5.93 A Gantt chart



5.7.2 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.

5.7.3 Let me do it

5.7 Activity

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-12374)

LESSON
5.8 Review

Hey students! Now that it's time to revise this topic, go online to:

Review your results **Watch teacher-led videos** **Practise questions with immediate feedback**

Find all this and MORE in jacPLUS

Access your topic review eWorkbooks

on Resources

Topic review Level 1 ewbk-12376	Topic review Level 2 ewbk-12378	Topic review Level 3 ewbk-12380

5.8.1 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 cells), 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 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.
- Genetic testing can be used to detect genetic abnormalities or increase a couple's chance of pregnancy.

5.8.2 Key terms

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

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

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

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

disperse the scattering of the seeds from plants

embryo a group of cells formed from the zygote and is developing into different body organs

endosperm the food supply for the embryo plant in a seed

external fertilisation reproduction occurs when the eggs are released by the female into water and fertilised by sperm released nearby

fallopian tube a tube connecting each ova to the uterus, which the egg travels through

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 (sperm or ova) containing half the genetic information of normal cells

generation refers to all offspring at the same stage of development

genes a coded set of instructions within DNA that determines the characteristics of an organism

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

hermaphrodites organism that has both male and female reproductive organs

identical twins twins developed from the same fertilised egg

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

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.

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

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

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

ovum female gamete or sex cell; plural = ova

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

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

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

spores reproductive cells capable of developing into a new individual without fusion with another reproductive cell

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
style the supporting part of a flower that holds the stigma
target cell a specific cell in which a hormone can cause a response
testes organs that produce sperm and sex hormones
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-40133)
eWorkbooks	Study checklist (ewbk-12382) Reflection (ewbk-12389) Literacy builder (ewbk-12383) Crossword (ewbk-12385) Word search (ewbk-12387)
Solutions	Topic 5 Solutions (sol-1138)
Practical investigation eLogbook	Topic 5 Practical investigation eLogbook (elog-2303)

5.8 Activities

learnon

5.8 Review questions

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 2, 7, 10, 13, 20, 25, 26, 31	3, 4, 5, 8, 11, 12, 17, 21, 24, 27, 28	6, 9, 14, 15, 16, 18, 19, 22, 23, 29, 30

Remember and understand

1. **a.** Identify whether the following statements are true or false.

Statement		True or false?
i.	Pollination in plants is the equivalent of fertilisation in animals.	
ii.	Gametes are reproductive sex cells.	
iii.	Binary fission in prokaryotes involves mitosis.	
iv.	Sperm production in humans is controlled by hormones.	

   b. Justify any false responses.

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

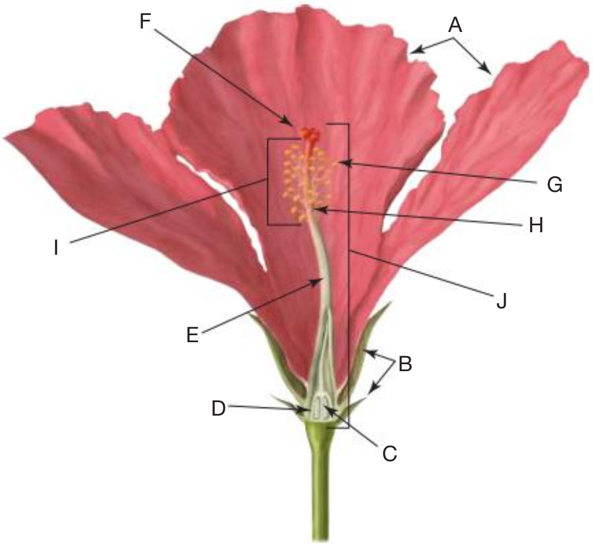
3. Match the term with the best matching description.

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

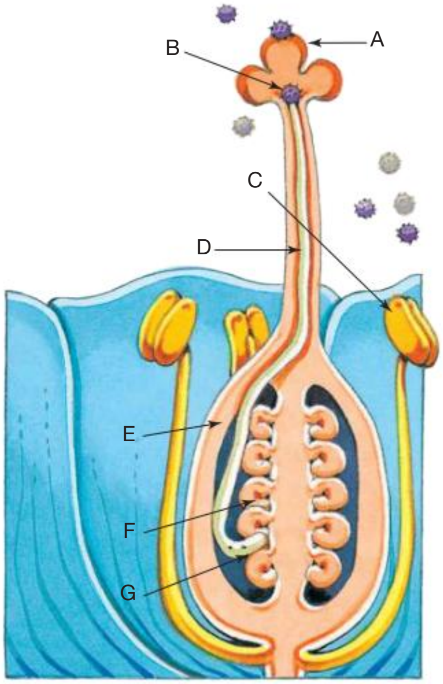
4. Match the part of the flower to its function.

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

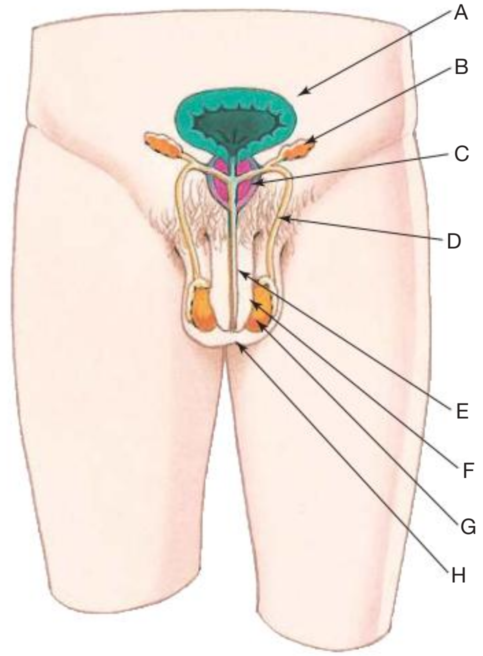
5. Write down in your workbook which letter in the following diagram corresponds to each of these terms: ovules, sepals, filament, style, stigma, ovary, anther, petals, stamen, carpel.

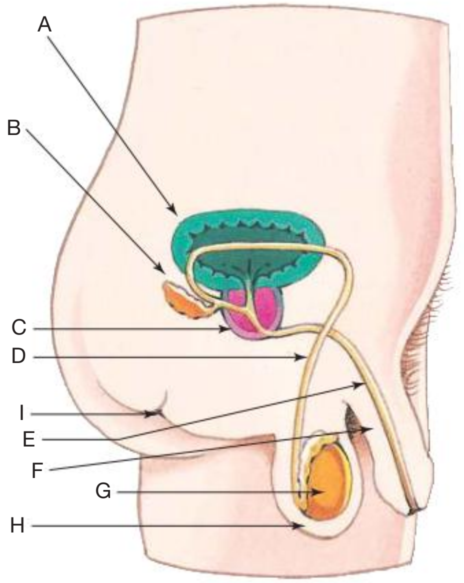


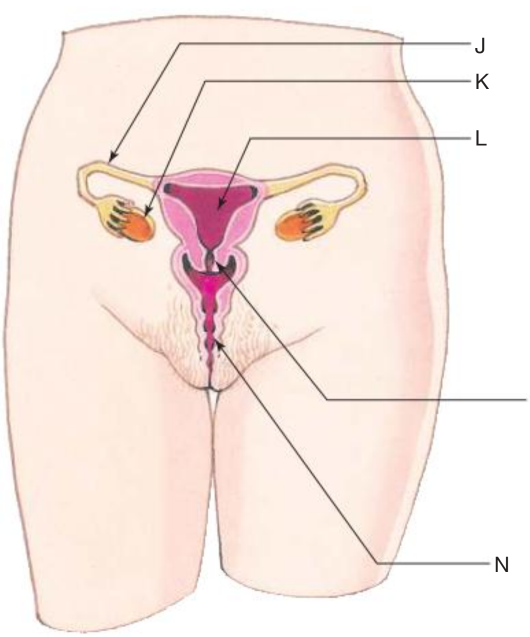
6. Label the parts of the plant in the diagram using the following terms: stigma, male gamete, pollen grain, pollen tube, stamen, ovary, ovule.

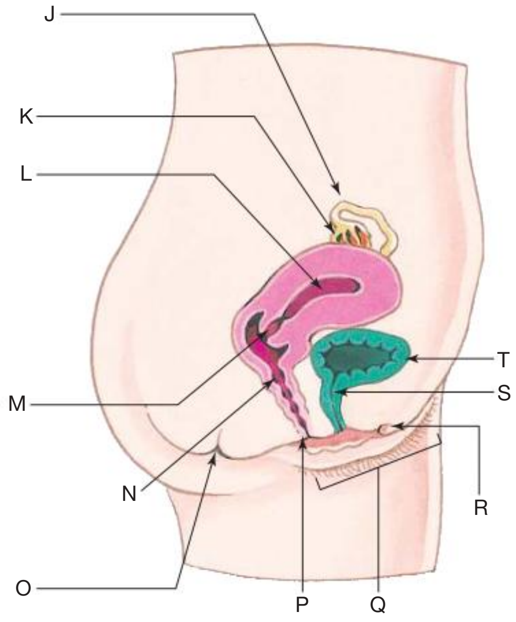


7. Identify the parts labelled A–T in the diagrams shown. Write one function of at least two parts in each diagram.







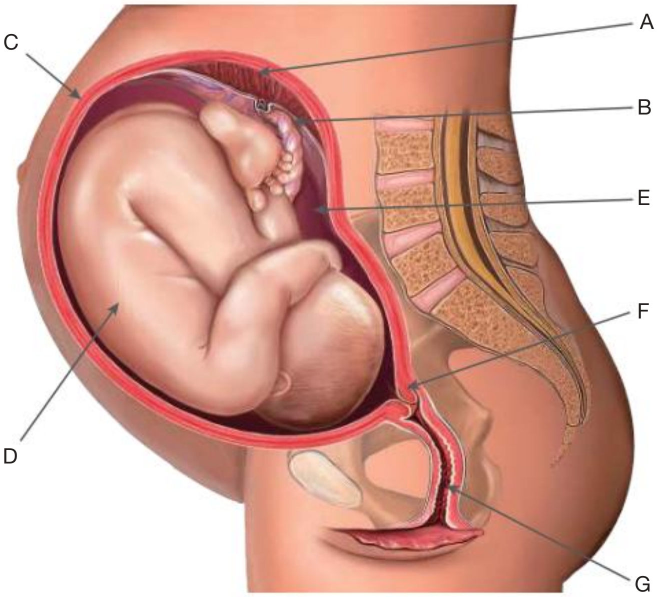


8. Summarise the disadvantages and advantages of sexual and asexual reproduction.
9. A paramecium is a single-celled organism that reproduces asexually.
   a. Make a list of the advantages and disadvantages of reproducing this way.
   b. Form a team and compare your list with that of your team. Discuss 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.

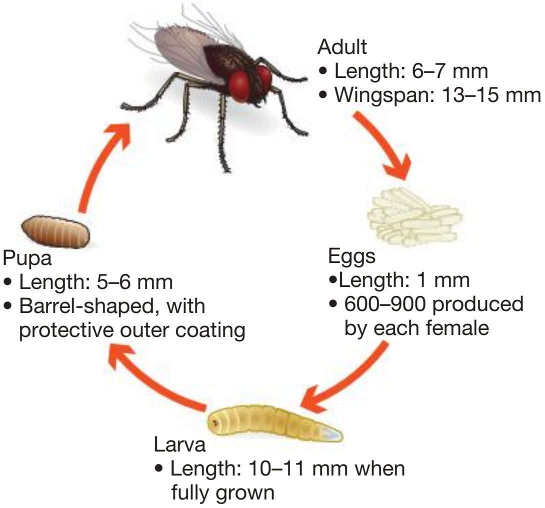
TABLE Heights (cm) of seedlings

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.

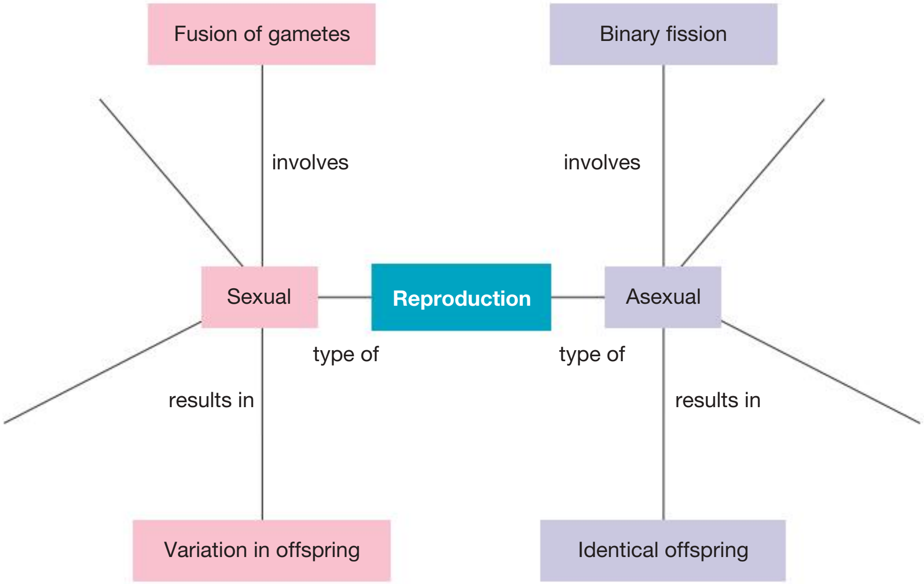
19. **SIS**
    a. Use a table to show differences between the sizes, shapes and structures of a fly during each stage of its life cycle.
    b. Construct a graph to show the differences in length during the adult, egg, larval and pupal stages of the life cycle.
    c. Suggest possible survival advantages for the differences throughout the life cycle.



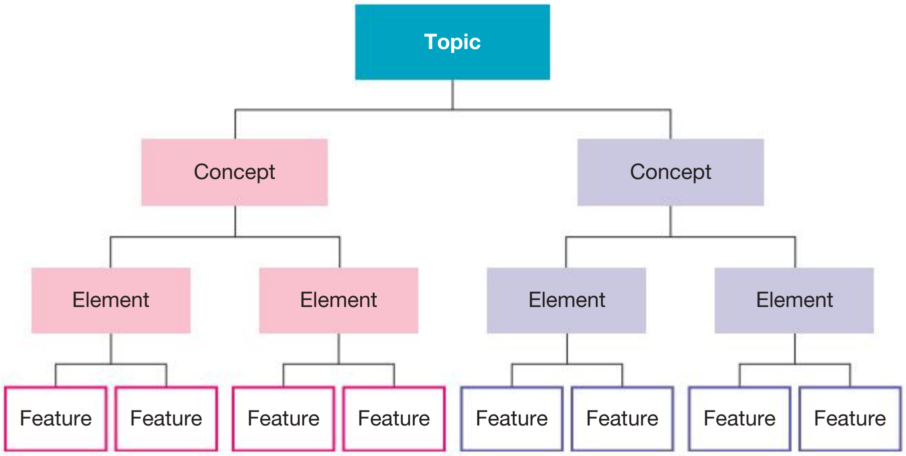
Evaluate and create

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 flow chart to show an example of a life cycle of a flowering plant. Include pollination, fertilisation, development, seed dispersal and germination.

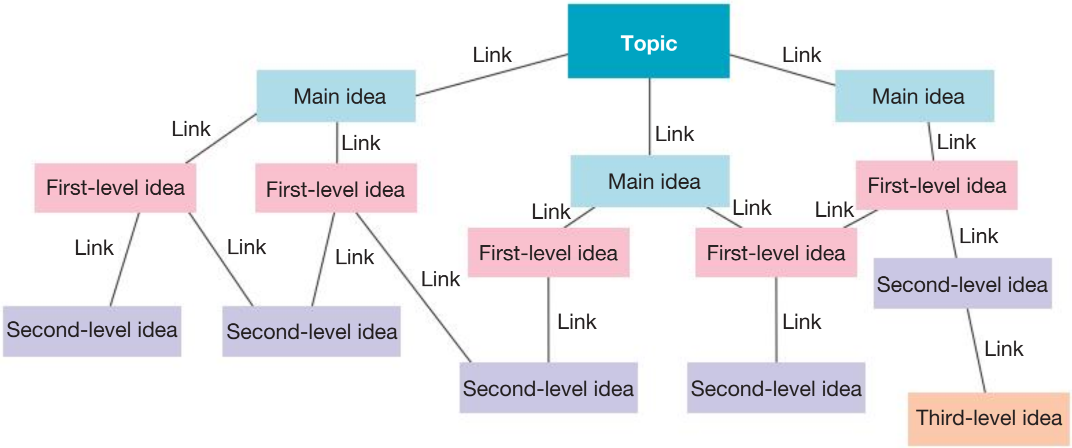
27. Use the figure shown to help you construct a summary of the differences between sexual and asexual reproduction. What other features can you add?



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.

Online Resources

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-12345)
- Student learning matrix (ewbk-12347)
- Starter activity (ewbk-12348)

Solutions
- Topic 5 Solutions (sol-1138)

Practical investigation eLogbooks
- Topic 5 Practical investigation eLogbook (elog-2303)
- Investigation 5.1: Comparing reproductive strategies (elog-2305)

Video eLesson
- Medical ultrasound of human fetus at 26 weeks gestation (eles-4234)

5.2 Asexual reproduction

eWorkbook
- Asexual reproduction (ewbk-12350)

Practical investigation eLogbook
- Investigation 5.2: Asexual reproduction (elog-2307)

Video eLesson
- Binary fission (eles-2306)

5.3 Sexual reproduction in flowering plants

eWorkbooks
- Those fabulous flowers! (ewbk-12352)
- Plant reproduction (ewbk-12354)
- Labelling parts of a flower (ewbk-12356)

Practical investigation eLogbooks
- Investigation 5.3: What's in a flower? (elog-2309)
- Investigation 5.4: Investigating features of flowers (elog-2311)

Teacher-led video
- Investigation 5.3: What's in a flower? (tlvd-10801)

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-12358)

Practical investigation eLogbooks
- Investigation 5.5: Relationship between seed number and seed size (elog-2416)

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-12360)
- Labelling the male reproductive system (ewbk-12362)
- Human male reproductive system (ewbk-12364)
- Human female reproductive system (ewbk-12366)
- Menstruation (ewbk-12368)
- Inside the womb (ewbk-12370)

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-12372)

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

5.7 Thinking tools — Storyboards

eWorkbook

- Week by week article (ewbk-12374)

5.8 Review

eWorkbooks

- Topic review Level 1 (ewbk-12376)
- Topic review Level 2 (ewbk-12378)
- Topic review Level 3 (ewbk-12380)
- Study checklist (ewbk-12382)
- Literacy builder (ewbk-12383)
- Crossword (ewbk-12385)
- Word search (ewbk-12387)
- Reflection (ewbk-3038)

Digital document

- Key terms glossary (doc-12389)

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

6 Inside the atom

CONTENT DESCRIPTION

Explain how the model of the atom changed following the discovery of electrons, protons and neutrons and describe how natural radioactive decay results in stable atoms (AC9S9U06)

Source: F–10 Australian Curriculum 9.0 (2024–2029) extracts © Australian Curriculum, Assessment and Reporting Authority; reproduced by permission.

LESSON SEQUENCE

SCIENCE INQUIRY AND INVESTIGATIONS

Science inquiry is a central component of Science curriuculum. Investigations, supported by a **Practical investigation eLogbook** and **teacher-led videos**, are included in this topic to provide opportunities to build Science inquiry skills through undertaking investigations and communicating findings.

LESSON
6.1 Overview

Hey students! Bring these pages to life online

Watch videos

Engage with interactivities

Answer questions and check results

Find all this and MORE in jacPLUS

6.1.1 Introduction

What does a cake have to do with chemistry? This model depicts an early idea for the structure of an atom. This was called the plum pudding model and was devised by English chemist J. J. Thomson. It showed negatively charged *electrons* embedded in a positively charged sphere. We now have a much better understanding of atoms and know that this model is incorrect. Atoms are the smallest component of matter and cannot be easily observed under the microscope. Over time, scientific research has resulted in the development of new scientific models of the atom in an attempt to explain what we observe, which is how scientists have come to the current accepted theory for the structure of the atom.

FIGURE 6.1 The atom was once thought to have a structure similar to this cake, which has raisins randomly mixed throughout its structure.

Models and theories are developed by scientists who research and study the prior knowledge and information of a topic, perform and observe experiments and analyse the results. They repeat experiments many times as well, with slight differences to the original experiment. By analysing all of the data obtained, scientists then fit all the data together into a model that makes sense. Models are very useful as they can be used to make predictions and to explain why something behaves the way it does. Most importantly, new discoveries can be used to improve models over time, so they are more useful and can better explain our observations.

The use of models is one example of how the scientific process keeps improving our understanding of the universe.

on Resources

Video eLesson The experiments that led to our understanding of the atom (eles-1780)

This video from the Story of Science demonstrates the fascinating experiments undertaken by scientists, which led to our evolving understanding of the atom.

6.1.2 Think about atoms and radioactivity

1. How did a plum pudding help scientists gain an understanding of atoms?
2. How did Lord Rutherford use solid gold to find out that atoms are mostly empty space?
3. What causes radioactivity?
4. Is radioactivity always dangerous?
5. How is uranium used in a nuclear reactor?
6. What's the connection between radioactivity and fossils?
7. How is radioactivity used in the treatment of cancer?

6.1.3 Science inquiry

What is all matter made of?

You probably already know quite a lot about the different types of particles that make up substances. This knowledge is the first step in your quest to find out why substances behave the way they do.

Answer the questions below to find out how much you already know about the inside story on substances.

1. The substances around you and inside you can be placed into three groups — elements, compounds and mixtures.
   - a. Which one of these groups contains substances that are made up of only one type of atom?
   - b. What is the difference between a compound and a mixture?
   - c. Arrange the substances listed below into the three groups of substances to complete the affinity diagram below.

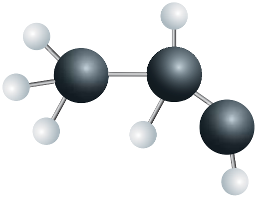
gold
blood
carbon dioxide
diamond
iron
sea water
air
chocolate thick shake
copper
table salt
soil
ammonia
concentrated hydrochloric acid
pure water
calcium
brass
sodium hydroxide
oxygen

SUBSTANCES

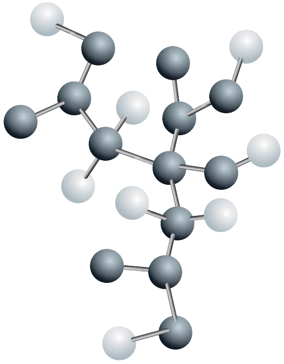
Elements	Compounds	Mixtures

2. Elements, compounds and mixtures are made up of tiny particles called atoms and molecules.
   - a. How is a molecule different from an atom?
   - b. Give an example of an element that is found as a molecule in its natural state.
   - c. List two compounds that are made up of molecules.
   - d. Name one compound that is not made up of molecules.
3. Name three different particles found inside an atom.
4. Which of the diagrams below represents:
   - a. an atom of an element
   - b. a molecule of an element
   - c. a molecule of a compound?

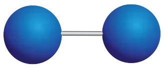
i.



ii.



iii.



iv.

on Resources

eWorkbooks	Topic 6 eWorkbook (ewbk-12419) Student learning matrix (ewbk-12421) Starter activity (ewbk-12422)
Solutions	Topic 6 Solutions (sol-1139)
Practical investigation eLogbook	Topic 6 Practical investigation eLogbook (elog-2313)

LESSON

6.2 Chemical building blocks

LEARNING INTENTION

At the end of this lesson you will be able to describe how atoms are composed of tiny subatomic particles called protons, neutrons and electrons and how the discovery of these resulted from experimental evidence. You will be able to compare protons, neutrons and electrons based on their mass, charge and location.

6.2.1 Models to explain the building blocks of matter

Most of our knowledge about the 'building blocks' of matter that we call atoms is less than 100 years old. But the idea that matter was made up of atoms was first suggested about 2500 years ago by the great philosopher and teacher Democritus. Since then, various theories and models of the atom have been accepted, rejected and modified. The timeline in figure 6.2 shows some of the important developments in our knowledge of the atom.

Atoms are tiny.

- Even the largest atoms are less than one billionth of a metre across. That's a millionth of a millimetre and about $\frac{1}{20\,000}$ of the diameter of the finest of human hairs.
- The nucleus is $\frac{1}{100\,000}$ of the diameter of an atom. If an atom were the size of the Melbourne Cricket Ground, the nucleus would be the diameter of a grain of rice.
- Atoms are mostly empty space. For example, a hydrogen atom is about 99.9999999999996 per cent empty space.

6.2.2 The structure of atoms

The current model of the atom accepted today consists of a tiny, dense **nucleus**, made up of the **subatomic** particles, **protons** and **neutrons**, which is surrounded by **electrons**. Table 6.1 and figure 6.3 summarise the properties of these particles.

Table 6.1 Subatomic particles and their properties

Subatomic particle	Charge		Relative mass	Location
Proton	Positive	+1	1	Nucleus
Neutron	Neutral	0	1	Nucleus
Electron	Negative	–1	0	Energy shells (orbits; electron cloud)

The amount of negative charge carried by each electron is equal but opposite to the amount of positive charge carried by each proton. In an atom, where the number of protons is equal to the number of electrons, there is no overall electric charge.

nucleus central part of an atom, made up of protons and neutrons; plural = nuclei

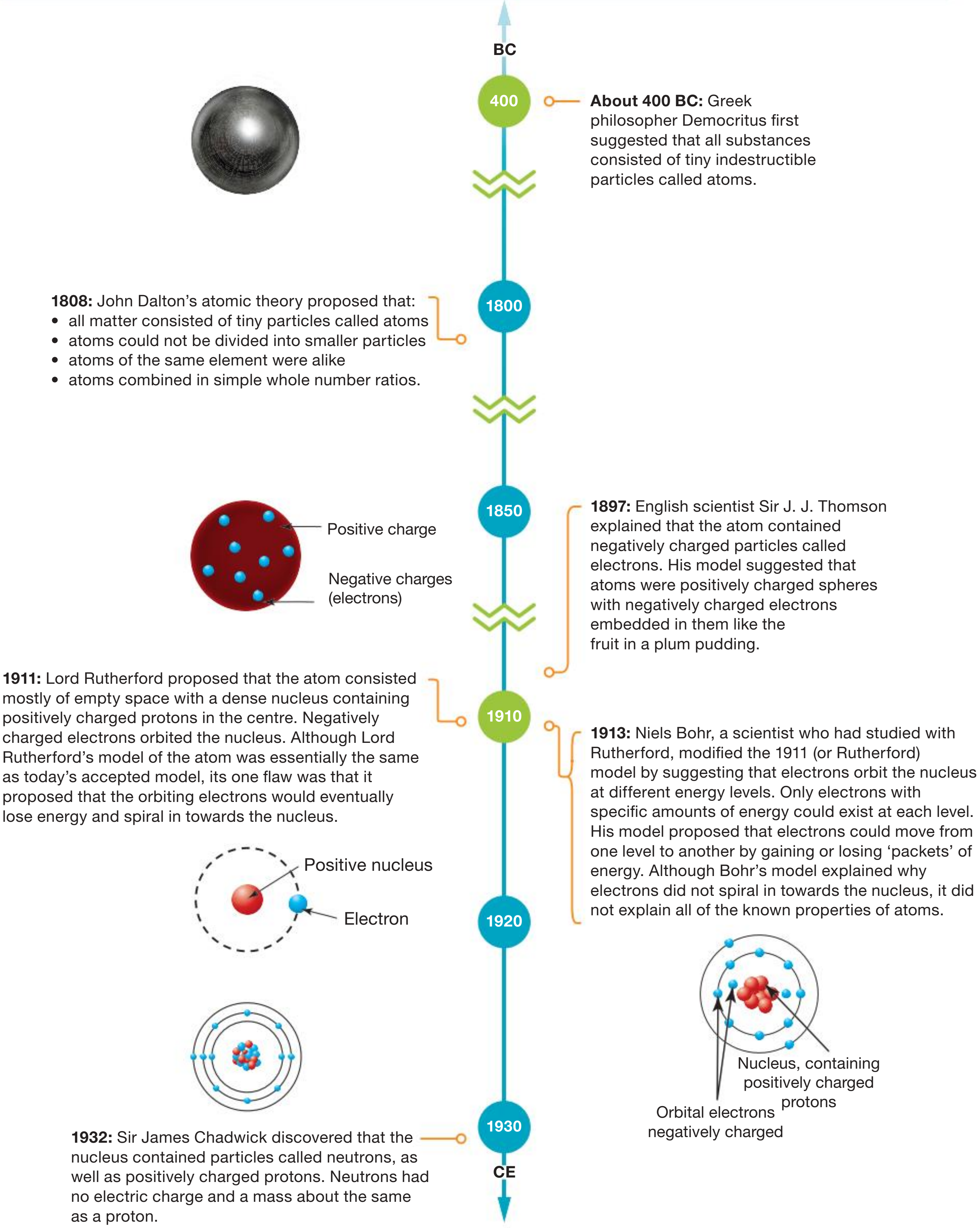
subatomic particles particles within an atom — electrons, protons and neutrons

protons tiny particles found in the nucleus of an atom. Protons have a positive electrical charge and the same mass as a neutron

neutrons tiny particles found in the nucleus of an atom. Neutrons have no electrical charge and have the same mass as a proton.

electrons extremely light (1800 times lighter than protons and neutrons) negatively charged particles inside an atom. Electrons orbit the nucleus of an atom in specific, defined regions called shells or orbitals.

FIGURE 6.2 Timeline of the development of the model of the atom



About 400 BC: Greek philosopher Democritus first suggested that all substances consisted of tiny indestructible particles called atoms.

1808: John Dalton's atomic theory proposed that:

- all matter consisted of tiny particles called atoms
- atoms could not be divided into smaller particles
- atoms of the same element were alike
- atoms combined in simple whole number ratios.

1897: English scientist Sir J. J. Thomson explained that the atom contained negatively charged particles called electrons. His model suggested that atoms were positively charged spheres with negatively charged electrons embedded in them like the fruit in a plum pudding.

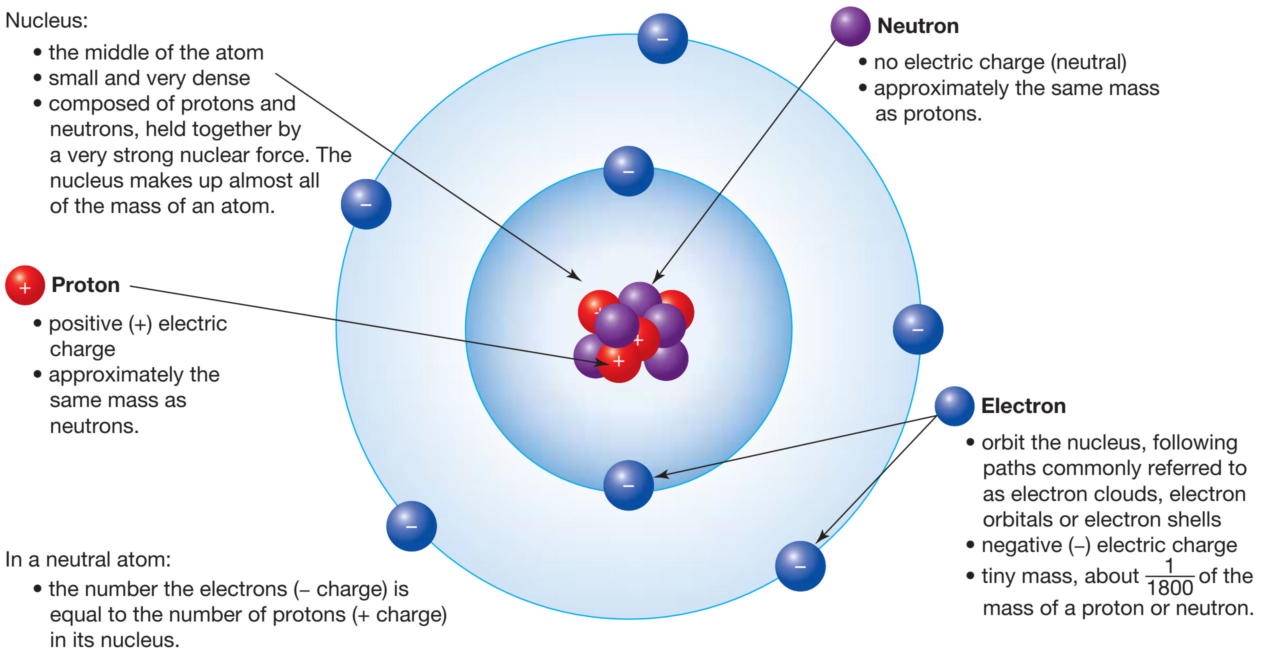
1911: Lord Rutherford proposed that the atom consisted mostly of empty space with a dense nucleus containing positively charged protons in the centre. Negatively charged electrons orbited the nucleus. Although Lord Rutherford's model of the atom was essentially the same as today's accepted model, its one flaw was that it proposed that the orbiting electrons would eventually lose energy and spiral in towards the nucleus.

1913: Niels Bohr, a scientist who had studied with Rutherford, modified the 1911 (or Rutherford) model by suggesting that electrons orbit the nucleus at different energy levels. Only electrons with specific amounts of energy could exist at each level. His model proposed that electrons could move from one level to another by gaining or losing 'packets' of energy. Although Bohr's model explained why electrons did not spiral in towards the nucleus, it did not explain all of the known properties of atoms.

1932: Sir James Chadwick discovered that the nucleus contained particles called neutrons, as well as positively charged protons. Neutrons had no electric charge and a mass about the same as a proton.

eles-2657

FIGURE 6.3 The current model of the atom



Atoms

Atoms contain the subatomic particles protons, neutrons and electrons.

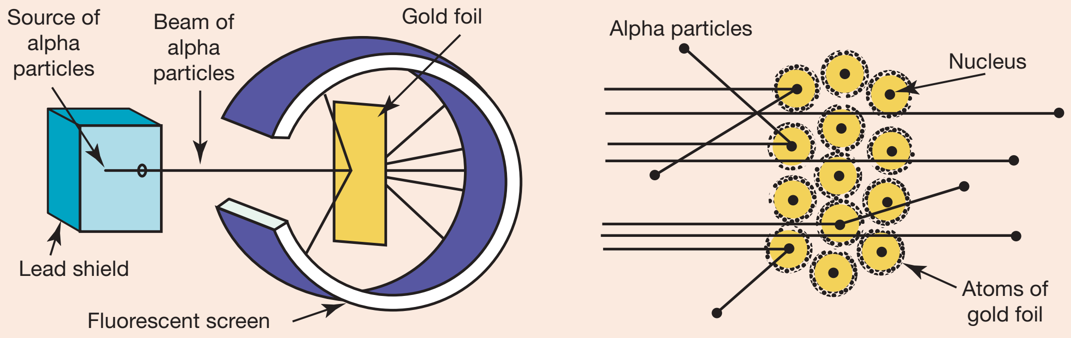
SCIENCE AS A HUMAN ENDEAVOUR: Lord Rutherford's model of the atom

Lord Rutherford's model of the atom was based on a series of experiments using very thin sheets of gold, called gold foil, and involved the following steps.

- A source of tiny, positive **alpha particles** was obtained.
- For safety, the source of alpha particles had a lead shield.
- A beam of alpha particles was fired at the gold foil.
- The pathway of the particles was detected using a fluorescent screen.
- Lord Rutherford was very clever in his design of the fluorescent screen, as it was circular shaped. This enabled him to see all pathways that the particles travelled.
- The observed results of this experiment were that many particles travelled straight through the gold foil, some were deflected at various angles and others were deflected right back to the alpha particle source.
- At the time, the bouncing back of the particles was stated as the equivalent to firing a cannon ball and having it come back to you!

alpha particles positively charged nuclei of helium atoms, consisting of two protons and two neutrons

FIGURE 6.4 An enlarged view of the gold foil experiment



Overall, Rutherford and his team observed that most of the particles went straight through the gold foil and very few were deflected back. This led them to several important conclusions:

- Rutherford explained that the few particles that were deflected back were repelled by a very small, positively charged nucleus in the atoms of the gold.
- Most of the alpha particles continued through the foil because each gold atom consists mainly of empty space.
- Lord Rutherford said later that his observations were about as credible as if you had fired a 16-inch shell at a piece of tissue paper and it had come back and hit you!

elog-2315

tlvd-10804

INVESTIGATION 6.1

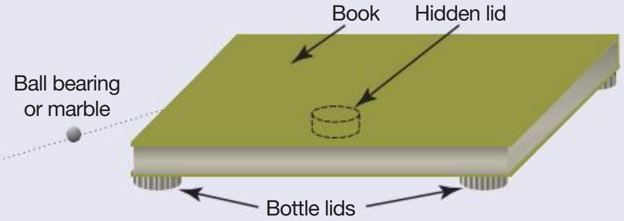
Exploring models of the atom

Aim

To explore Rutherford's experiment

Materials

- a hardcover book of at least A4 size
- 5 plastic soft drink bottle lids
- a 10 mm diameter ball bearing or 12 mm diameter marble



Method

1. Support the book on a benchtop using a bottle lid under each corner.
2. Have one member of your group lift the book, place the fifth bottle lid somewhere in the area surrounded by the other four lids and replace the book. The fifth lid represents the nucleus of the atom in this model.
3. After the other members of your group turn around, they take turns to roll the ball bearing or marble under the book to find the location of the 'nucleus'.

Results

Record the number of times the ball bearing or marble is rolled before striking the 'nucleus' for the first time.

Discussion

1. Comment on how difficult it is to locate the 'nucleus' in this model.
2. What is represented in this model of Rutherford's experiment by:
   a. the area under the book that is surrounded by the four lids
   b. the ball bearing or marble?
3. a. Recall that the plum pudding model does not contain a nucleus. Write a hypothesis for this experiment according to the plum pudding model.
   b. Based on your observations justify why this cannot be the plum pudding model of the atom.

Conclusion

Summarise the findings of the investigation in three or four sentences using correct scientific terms.

SCIENCE INQUIRY SKILLS: Repeatability

Scientists perform the same experiment multiple times and then analyse all the results. This repetition increases the accuracy of the results and allows scientists to draw conclusions with confidence.

DISCUSSION

Models of the atom have changed greatly over the past century. Do we now understand the atom completely, or could our models improve further? Learning from the past, how might such improvements be made?

6.2.3 Elements

Atoms are not all the same. To date, chemists have identified 118 different types of atoms.

Elements are substances that contain only one type of atom. For example, pure oxygen contains only oxygen atoms and pure lead contains only lead atoms. Elements are defined by the number of protons in the nucleus.

Elements

- Elements are substances that contain only one type of atom.
- An element is defined by the number of protons in the nucleus.

Representing elements

Elements are represented by an element **symbol**, and with the atomic number and the mass number.

Most symbols for elements come from the first letter or two letters of their names; for example, C for carbon and Cd for cadmium. Some atoms have symbols that have originated from a Greek or Latin name; for example, Au is the symbol for gold because gold was known in the past by its Latin name, aurum.

element a pure chemical species consisting of atoms of a single type

symbol simplified representation of an element consisting of one or two letters

symbol simplified representation of an element consisting of one or two letters

mass number the total number of protons and neutrons in the nucleus of a particular atom

Atomic number

- Each of the 118 elements known to chemists has its own **atomic number**.
- The atomic number of an element is defined as the number of protons in the nucleus of an atom of that element.
- When an atom is neutrally charged, the atomic number of the atom corresponds to the number of electrons, because the number of positive charges must be the same as the number of negative charges. For example, oxygen has an atomic number of 8 and, therefore, has eight protons and eight electrons.

Mass number

- The **mass number** is defined as the total number of protons and neutrons in an atom of an element.
- Protons have approximately the same mass as neutrons. The electron's mass is so small that it is negligible compared with protons and neutrons. Therefore, the mass of an atom depends only on the number of particles in the nucleus.

TABLE 6.2 Symbols, subatomic particles, atomic and mass numbers for the first 12 elements

Name	Symbol	Protons (atomic number)	Neutrons*	Electrons	Mass number
Hydrogen	H	1	0	1	1
Helium	He	2	2	2	4
Lithium	Li	3	4	3	7
Beryllium	Be	4	5	4	9
Boron	B	5	6	5	11
Carbon	C	6	6	6	12
Nitrogen	N	7	7	7	14
Oxygen	O	8	8	8	16
Fluorine	F	9	10	9	19
Neon	Ne	10	10	10	20
Sodium	Na	11	12	11	23
Magnesium	Mg	12	12	12	24

*The number of neutrons can vary but this is the most common number of neutrons for these elements.

on Resources

eWorkbooks Chemical building blocks (ewbk-12424)
How big is an atom? (ewbk-12426)
Top ten elements (ewbk-12428)

6.2 Activities

learnon

6.2 Quiz quiz on | **6.2 Exercise**

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 3, 5	2, 4, 7, 9	6, 8, 10

Remember and understand

1. MC Where is most of the atom's mass located?
   A. Protons
   B. Neutrons
   C. Electrons
   D. Nucleus
2. According to the plum pudding model, the atom is a ______________ with ______________ embedded in it like the fruit in a plum pudding.
3. What is the main difference between John Dalton's model of the atom and the models of Thomson, Rutherford and Bohr?
4. Complete the following table by including one example for each pair.

TABLE Comparison of subatomic particles

	Protons and electrons	Protons and neutrons	Electrons and neutrons
Similarity			
Difference			

Apply and analyse

5. Why did most of Rutherford's alpha particles go through the thin sheets of gold foil?
6. What was the main weakness of the Rutherford model of the atom?
7. SIS Why was it important for Rutherford to fire many alpha particles at the gold atoms?
8. SIS Explain why it is not surprising that the neutron was discovered quite a long time after the electron and proton.
9. Draw a diagram of the modern model of the atom and include the following labels.
   proton, neutron, electron, positive, negative, neutral, nucleus

Evaluate and create

10. SIS Is the current model of the atom proven? Explain your answer.

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

LESSON
6.3 Stability and change — inside the nucleus

LEARNING INTENTION

At the end of this lesson you will be able to explain that differences in the number of neutrons in atoms of the same element results in isotopes, some of which are unstable. You will be able to describe in simple terms how mass and energy are connected and how unstable isotopes decay. You will also be able to define half-life.

6.3.1 Neutrons and isotopes

At the centre of every atom is a tiny, solid core called the nucleus. Within the nucleus, protons and neutrons are usually held together by incredibly strong forces. However, sometimes the difference in the number of neutrons compared to the number of protons in the nucleus results in instability of the atom. Some of the mysteries of radioactivity can be unravelled by taking a closer look inside the nucleus.

All atoms of a particular element have the same number of protons. However, sometimes the number of neutrons in atoms of the same element is different. Such atoms are called isotopes. Isotopes have the same atomic number but different mass number. When defining what an isotope is, the number of electrons is irrelevant.

Atoms of the same element with different mass numbers are called **isotopes**.
- Many elements exist as two or more isotopes.
- Isotopes have the same chemical properties but different masses.

For example, hydrogen has three isotopes. Each isotope has one proton. However, the different isotopes have 0, 1 or 2 neutrons, respectively.

Naming isotopes

Nuclide notation is used to represent the isotopes of an element, and includes the atomic and mass numbers. For example, the three isotopes of hydrogen can be represented as $^{1}_{1}H$, $^{2}_{1}H$, and $^{3}_{1}H$.

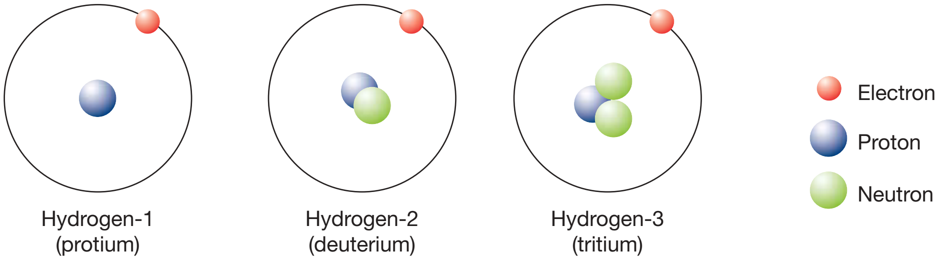
Isotopes are also named with the element name and mass number. For example, hydrogen-1, hydrogen-2 or hydrogen-3, as shown in figure 6.5.

isotopes atoms of the same element that differ in the number of neutrons in the nucleus

nuclide a type of atom characterised by the number of protons and the number of neutrons in its nucleus

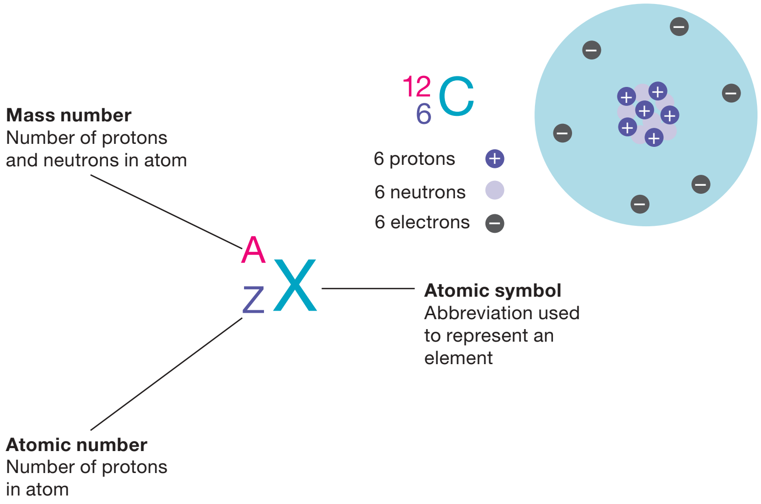
eles-2658

FIGURE 6.5 The three isotopes of hydrogen. Hydrogen-1, hydrogen-2 and hydrogen-3 are also known as protium, deuterium and tritium, respectively.



The nuclide symbol notation of carbon-12 is shown in figure 6.6.

FIGURE 6.6 Nuclide symbol notation



EXTENSION: Why are they called isotopes?

The word *isotope* is derived from the Greek words *isos*, meaning 'equal', and *topos*, meaning 'place'. It came about because even though each isotope of the same element had different numbers of neutrons and therefore different weights, they occupied the same place on the periodic table of the elements.

Stable or unstable atoms

- In **stable** atoms, the protons and neutrons found in the nucleus are held together very strongly.
- In **unstable** atoms, the neutrons and protons in the nucleus are not held together as strongly.
- Unstable isotopes **decay** to form other elements. These isotopes are said to be radioactive and are called radioactive isotopes, or **radioisotopes**.

For example, consider the three isotopes of carbon — carbon-12, carbon-13 and carbon-14 — which have identical chemical properties. However, the nucleus of carbon-14 is not stable and disintegrates naturally. Carbon-12 is a stable isotope while carbon-14 is a radioactive isotope. Generally, in small atoms, the number of neutrons is usually about the same as the number of protons. As the size of the atom increases, there tends to be more neutrons than protons in the nucleus. This difference in the number of neutrons compared to protons increases as the atom gets bigger and bigger. As a result, the element tends to become more unstable.

stable a nucleus that does not change spontaneously. The protons and neutrons in the nucleus are held together strongly.

unstable an atom in which the neutrons and protons in the nucleus are not held together strongly

decay to transform into a more stable particle

radioisotope a radioactive form of an isotope

TABLE 6.3 Examples of stable and unstable (radioactive) isotopes of carbon and uranium

Element	Symbol	Number of protons	Number of neutrons	Stable or radioactive?
Carbon-12	$^{12}_{6}C$	6	6	Stable
Carbon-13	$^{13}_{6}C$	6	7	Stable
Carbon-14	$^{14}_{6}C$	6	8	Radioactive
Uranium-235	$^{235}_{92}U$	92	143	Radioactive
Uranium-238	$^{238}_{92}U$	92	146	Radioactive

6.3.2 The relationship between mass and energy

You may remember that matter cannot be created nor destroyed, it can only be transferred or transformed into a different form. Einstein's theory of relativity states that mass and energy are the same physical entity, which is captured by the equation $E = mc^2$. In this equation, E represents energy, m represents mass and c is a constant (the speed of light). Therefore, the relationship is E α m (E varies by the same factor as m). Einstein concluded that mass and energy can (at least theoretically) be converted into each other.

Nuclear fission is another example of the relationship between mass and energy. Nuclear fission is an explosive reaction where one atom is split into one or more other atoms. A huge amount of energy is released in this process. As the number of protons in the nucleus has now been changed, new (and smaller) elements are formed. This conversion process in the atomic nuclei also results in a tiny reduction in mass. Power plants use uranium and nuclear fission to produce energy, which is then converted to electricity. You will learn more about this in section 6.4.2.

6.3.3 Radioactivity

Natural and artificial radioactivity

Natural radioactivity is radioactivity emitted from matter without energy being supplied to atoms. There are about 50 isotopes that emit radioactivity naturally. They exist in the air, in water, in living things and in the ground. Most radioactive isotopes (about 2000 in total) are made radioactive artificially by bombarding their atoms with subatomic particles like protons and neutrons.

Nuclear radiation

The energy emitted by radioactive substances is called **nuclear radiation** because it comes from the nucleus. Lord Rutherford showed that there are three types of nuclear radiation: alpha particles, **beta particles** and **gamma rays**.

nuclear radiation radiation from the nucleus of an atom, consisting of alpha or beta particles, or gamma rays

beta particles charged particles (positive or negative) with the same size and mass as electrons

gamma rays high-energy electromagnetic radiation produced from some radioactive decay; the radiation has no mass and travels at the speed of light

TABLE 6.4 The three types of nuclear radiation

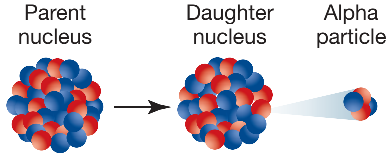
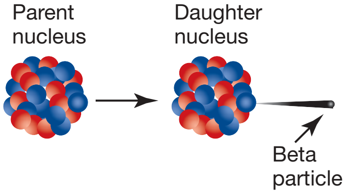
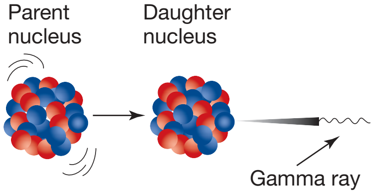
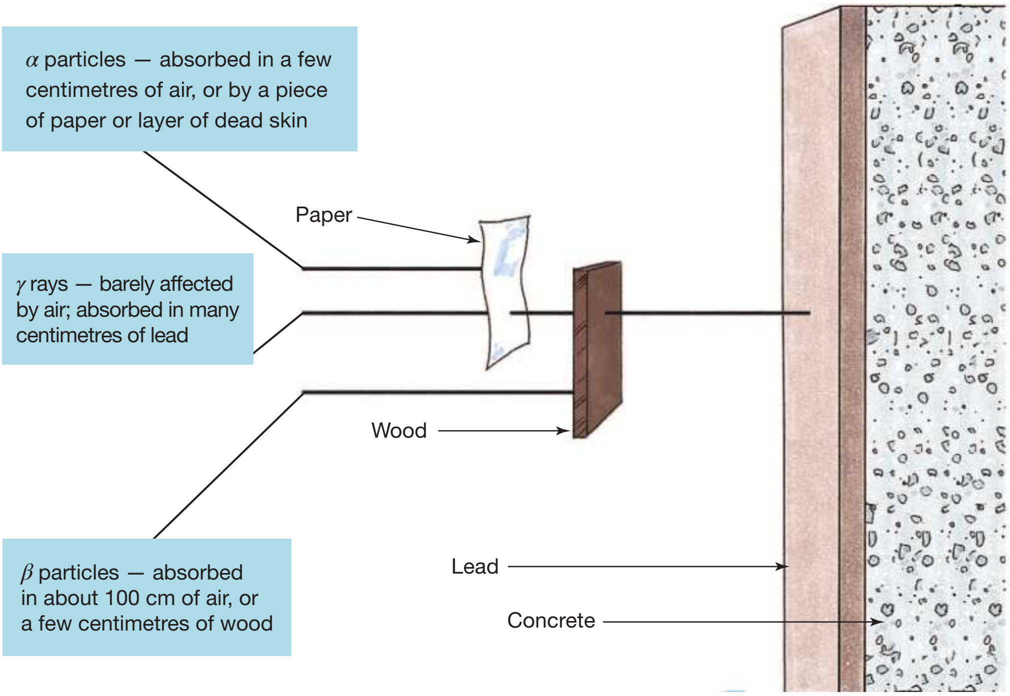
Nuclear radiation	Alpha particles	Beta particles	Gamma rays
Symbol	α	β	γ
Description	Helium nuclei that contain two protons and two neutrons, so they are positively charged	The same size and mass as electrons, can have a negative or positive electric charge and can travel at speeds as high as 99 per cent of the speed of light	Not particles, but bursts of energy released after alpha or beta particles are emitted; travel at the speed of light
Diagram of decay			
Penetration and danger to health	Cannot travel easily through materials and can be stopped by a sheet of paper or human skin. They pose little hazard to the external body but can cause serious damage if breathed in, eaten or injected.	Can penetrate human skin and damage living tissue, but they cannot penetrate thin layers of plastic, wood or aluminium.	Highly penetrating. They can cause serious and permanent damage to living tissue and can be stopped only by a thick shield of lead or concrete.

FIGURE 6.7 The different penetrating powers of alpha (α), beta (β) and gamma (γ) radiation



Resources

Video eLesson Smashing atoms in CERN (eles-1085)

6.3.4 The lives and half-lives of radioisotopes

The nuclei of different radioactive substances decay at different rates.

- The **half-life** of a radioisotope is the time taken for half of all the nuclei in a sample of a radioisotope to disintegrate or decay.
- Half-lives can vary from microseconds to billions of years.

TABLE 6.5 The half-life of an isotope and the fraction remaining after each half-life

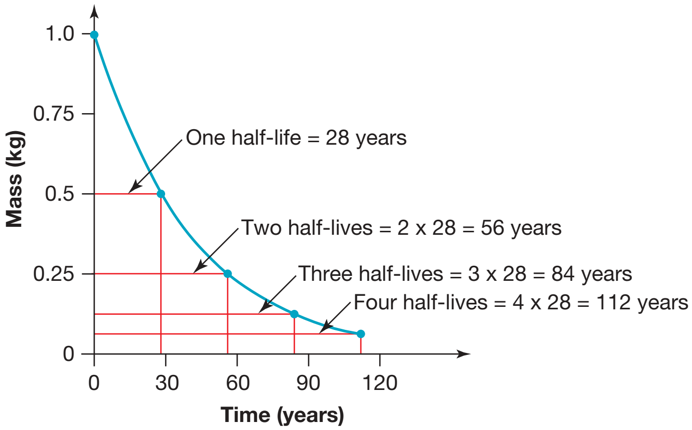
Number of half-lives	Fraction remaining
1	$\frac{1}{2}$
2	$\frac{1}{4}$
3	$\frac{1}{8}$
4	$\frac{1}{16}$

Uranium is probably the best known of the radioisotopes. There are three naturally occurring isotopes of uranium: uranium-238, uranium-235 and uranium-234.

half-life time taken for half the radioactive atoms in a sample to decay — that is, change into atoms of a different element

- Each of the isotopes spontaneously disintegrates or decays, producing alpha particles and gamma rays.
- Each isotope has its own half-life; that is, the time taken for the concentration to fall to half its initial value.
- The half-lives of each of the uranium isotopes are more than a billion years.

FIGURE 6.8 A graph showing the radioactive decay of strontium-90, which has a half-life of 28 years



on Resources

Interactivity Radioactive half-life (int-1652)

6.3.5 Background radiation

We are all exposed to background radioactivity every day. Fortunately, it is quite safe.

- Most of it comes from naturally occurring radioactive elements in the Earth's crust and atmosphere, from radon, which is produced during the breakdown of other radioisotopes; for example, uranium and thorium.
- A smaller amount comes from outer space in the form of **cosmic radiation**, mostly in the form of high energy protons emitted by stars, including the Sun. The word cosmic comes from the Greek word *kosmos*, meaning 'universe'. The Earth's atmosphere protects us from the dangers of cosmic radiation, as we will discover in topic 9.

There are even small amounts of radioisotopes in the human body, including hydrogen-3 (tritium), carbon-14 and potassium-40.

cosmic radiation naturally occurring background radiation from outer space

DISCUSSION

Most naturally occurring radioisotopes on Earth were created before the planet was formed. Given the Earth is approximately 4 billion years old, what does that tell us about the half-life of these radioisotopes?

Carbon-14 has a half-life of only 5700 years yet is 1.1% of all naturally occurring carbon. How can this observation be explained?

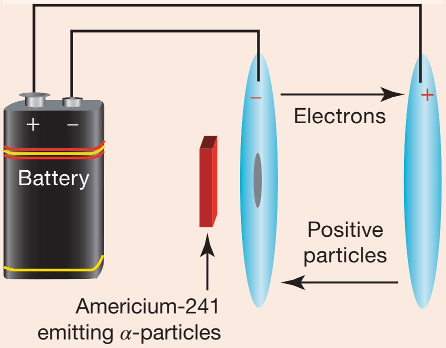
6.3.6 Smoke alarms

SCIENCE AS A HUMAN ENDEAVOUR: Using radiation to detect smoke

Smoke alarms are an example of radioisotopes used routinely in the home. They contain a tiny amount of americium-241, an alpha particle emitting radioisotope. Smoke alarms work by setting up a small electrical circuit in the detector. When that circuit is disrupted by smoke, the alarm sounds.

1. Alpha particles from americium-241 knock electrons off molecules in the air, creating positive particles and free electrons.
2. These charged particles are attracted to two oppositely charged plates, setting up a small current.
3. When the current flows there is no alarm.
4. However, when smoke particles enter the detector, they attach to the positive particles making them neutral.
5. This disrupts the current and the siren sounds.

FIGURE 6.9 What happens in the ionisation chamber?



6.3 Activities

6.3 Quick quiz on

6.3 Exercise

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 2, 5, 7, 9	3, 6, 8, 10	4, 11, 12, 13

Remember and understand

1. State what each letter represents in a nuclide symbol, $^{A}_{Z}X$.
   a. A **b.** Z **c.** X
2. Match the terms with the definitions in the following table.

Terms	Definition
a. Atomic number	**A.** Mass number – number of protons
b. Number of neutrons	**B.** Number of protons + number of neutrons
c. Mass number	**C.** Number of protons

3. Complete the following table.

TABLE Nuclide notation of different elements

Nuclide symbol	Atomic number	Mass number	Protons	Neutrons
$^{14}_{6}C$				
	19	39		
			15	17
		31		16
	92			146

4. Identify one similarity and one difference between two particles that are isotopes.
5. Alpha particles are the heaviest type of radiation. Fill in the following table with the properties of alpha particles.

TABLE Properties of alpha particles

Charge	Protons	Mass number	Nuclide symbol

6. How are we protected from cosmic radiation from outer space?

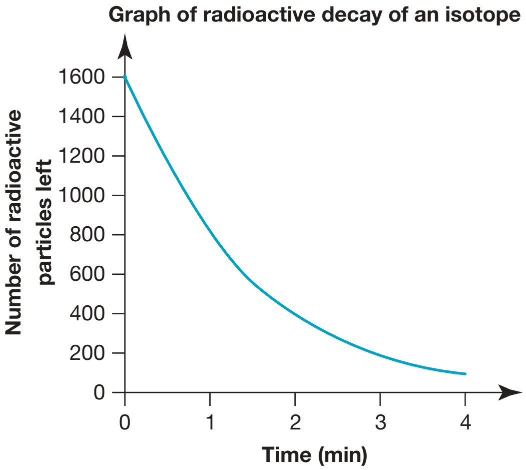
Apply and analyse

7. Are the atoms $^{230}_{93}X$ and $^{239}_{94}X$ isotopes of the same element? Explain.
8. The half-life of an isotope of tritium is 4500 days. How many days will it take an amount of tritium to fall to a quarter of its initial mass?
9. An atom of uranium-238, $^{238}_{92}U$, decays by emitting a single alpha particle. Write the nuclide symbol for the resulting atom. Explain how you got your answer.
10. Explain why the isotopes of some elements are radioactive.

11. State the type of nuclear radiation described by the following statements.
   a. A radioactive particle that has the same size and mass as an electron.
   b. A radioactive particle that is made up of two protons and two neutrons.
   c. The type of radiation that can penetrate the human body and can be stopped only by a thick shield of lead or concrete.
   d. A radioactive particle that can travel almost at the speed of light.

Evaluate and create

12. **SIS** The graph shows the decay of a radioisotope over 4 minutes.
   a. What is the half-life of this isotope?
   b. How many radioactive particles would be left after 5 minutes?
   c. When the decay takes place in a sealed container, helium gas is collected. Name one type of radiation produced in the decay.



13. **SIS** A scientist wished to determine the type of radiation emitted by a radioisotope. She had three materials (paper, plastic and lead) and an instrument called a Geiger counter, which detects nuclear radiation. She covered the radioisotope with each of the three materials and measured the radiation that passed through each material. The results of her experiment are shown in the table provided.

TABLE Results of radioactivity experiment

Material	Effect on Geiger counter readings
Paper	No effect on readings
Plastic	Readings fell by two-thirds
Lead	Readings fell by nine-tenths

   a. Identify the independent variable in this experiment.
   b. Identify the dependent variable in this experiment.
   c. Identify a controlled variable in this experiment.
   d. Complete the following table to determine whether certain variables should be controlled in this experiment.

TABLE Experiment variables

Variable	How could this variable affect the DV?	Should this variable be controlled? (Y/N)
The thickness of the material covering the radioisotope		
How far the Geiger counter is placed from the radioisotope		
The scientist wore her lab coat for only some measurements		

   e. What type of nuclear radiation does this radioisotope emit? Explain your answer, with reference to the data.

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

LESSON
6.4 Using radioactivity

LEARNING INTENTION

At the end of this lesson you will be able to describe how radiometric dating has been used to establish the age of geological formations as well as the timing of historical events. You will also be able to identify where applications of radioactivity are used in medicine and industry.

6.4.1 Radioisotopes

on Resources

Video eLesson The mystery of radium (eles-1779)

Marie Curie and her husband Pierre worked out that the element radium produced lots and lots of energy. However, it took a long time for them to determine what was actually happening — as energy cannot be created or destroyed, how was radium creating energy? During this time, radium was used in everyday consumer products from toothpaste and toys to heating pads. Radium was the new health craze, and any product that contained radium sold immediately. Marie and Pierre Curie eventually discovered that, unfortunately, radium is radioactive and is actually detrimental to our health. All the everyday consumer products containing radium that were being sold at the time were harming people rather than improving their health. Radium decays to lead (and other components), both of which are harmful to living organisms.

SCIENCE AS A HUMAN ENDEAVOUR: Using radioisotopes

In 1903, Marie Curie, her husband Pierre and Henri Becquerel were awarded the Nobel Prize in Physics for their discovery of radioactivity and their work on uranium. Little did they know that their discoveries and investigations would change the course of history.

They could not have imagined that their work would lead to the development of nuclear weapons capable of killing millions of people, of nuclear power plants that generate electricity, and of the use of radioactive isotopes to treat cancers and detect life-threatening illnesses.

Radioisotopes are used in industry, research and medicine. They can be used as radioactive ‘tracers’ to follow the movement of substances through liquids (for example, sediment movement in rivers and the movement of substances in the blood). Radioactive isotopes are also used in smoke detectors, soil analysis, pollution testing, measuring the thickness of objects, criminology and, as we will explore next, in dating samples from archaeological sites and geological formations.

6.4.2 Radiometric dating

Naturally occurring radioisotopes can be used to calculate the age of samples from archaeological sites and in determining the age of geological formations. This technique is called **radiometric dating**.

One of the most useful types of radiometric dating is **radiocarbon dating**. This uses the carbon-14 isotope, which has a half-life of 5700 years. Carbon is a very common element in living organisms, so the amount of carbon-14 left in a fossil or in an archaeological sample can be used to determine how long ago that organism died.

radiometric dating determining the ages of rocks and fossils based on the rate of decay or half-life of particular isotopes

radiocarbon dating a method of determining the age of a fossil using the remaining amount of unchanged radioactive carbon

The process, shown in figure 6.10, is as follows:

1. Carbon-14 is produced by cosmic radiation, which is radiocarbon.
2. Carbon dioxide is constantly being taken in by plants, which are eaten by animals, so all living organisms contain some radiocarbon.
3. When living things die, the decaying radiocarbon is no longer being replaced.
4. Since all fossils were once living, their age can be determined by measuring the amount of radiocarbon remaining.

After 5700 years, only half of the usual amount of radiocarbon will be left. A graph can be used to estimate the age of a sample. After about 50 000 years, the amount of radiocarbon becomes too small to measure accurately.

All rocks contain small amounts of radioactive elements such as uranium and potassium. The age of older rocks, and the fossils within them, can be determined by using radioactive elements with longer half-lives. For example, uranium–lead dating can be used to date rocks from 1 million to over 4.5 billion years old, using the decay of uranium-238 to lead-206 and uranium-235 to lead-207. This dating method has a precision of 0.1–1.0 per cent.

FIGURE 6.10 Carbon-14 generation and decay and its application in radiocarbon dating

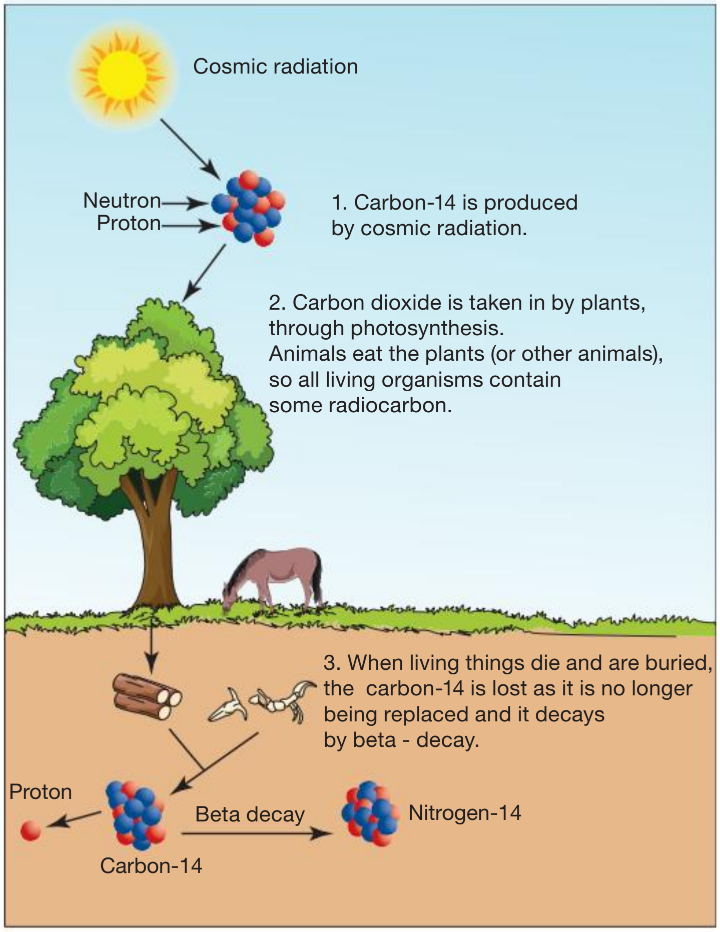
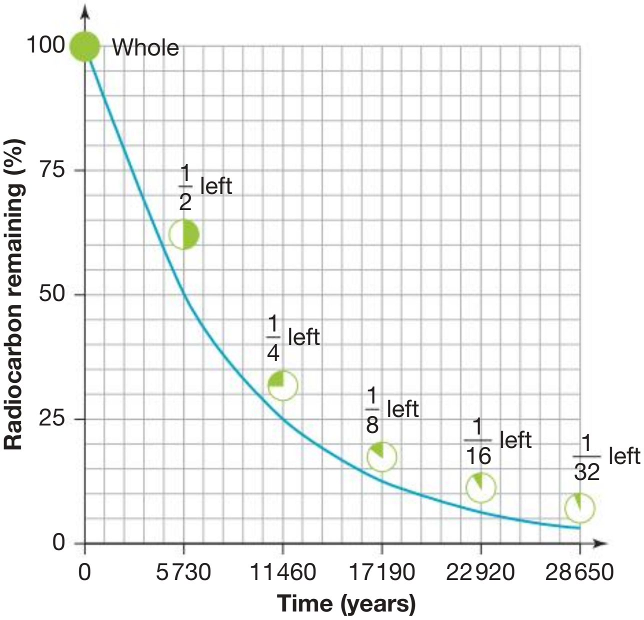


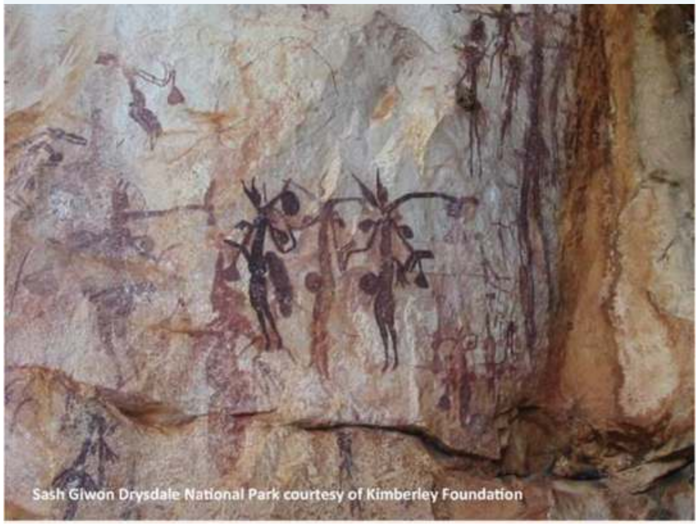
FIGURE 6.11 The decay of a sample of pure radiocarbon



Radioactivity dating and the First Peoples of Australia

Scientists have used radiocarbon and other dating methods to establish how long the First Peoples of Australia have been present on the Australian continent. This research has established that there has, in fact, been people here for over 60 000 years. Radiocarbon dating can be used to analyse a diverse range of natural materials such as sedimentary material from lakes, water, tree rings, ice cores, soil and air. It has also been used to establish the age of cultural artefacts and materials of the First Peoples of Australia. In achieving this, the story of the lives and histories of the First Peoples of Australia has been captured and recorded for historical purposes, and provides evidence that these communities were among the most advanced in terms of technology during the time of settlement.

FIGURE 6.12 Sash Gwion figures, Kimberley rock art



Sash Giwon Drysdale National Park courtesy of Kimberley Foundation

The Australian Nuclear Science and Technology Organisation (ANSTO) uses nuclear dating methods to analyse the rock art, tools, paints (ochres) and other artefacts used by the First Peoples of Australia. ANSTO were able to date some rock art sites as 16 000 years old.

EXTENSION: Consequences of working with radioactivity

Radioactivity was discovered by accident. French physicist Henri Becquerel discovered radioactivity while investigating the fluorescence of uranium salts in 1896. When he developed a photographic plate that had been left in a drawer near his benchtop, he found that it had been fogged up by radiation from the uranium salts.

This effect of radioactivity is now used in a protective device worn by people who work with radioactive materials. The ‘fogging’ of the film in this device measures the amount of radioactivity they have been exposed to.

Becquerel was the first scientist to report the effects of radioactivity on living tissue.

Our modern understanding of radiation has only been developed in about the last 130 years. Based on what you have learned so far, what do you expect were the consequences of working with radioisotopes for the early adopters in the below examples:

- scientists such as Henri Becquerel who worked closely with uranium salts
- watchmakers who painted the hands and numbers on watch faces with a luminescent, radioisotope radium-226 (workers used to form ‘points’ on their brushes by licking the bristles)?

FIGURE 6.13 This watch has been hand painted in luminescent radium paint.

6.4.3 Radioisotopes and nuclear power

The radioactive properties of uranium are used in the generation of electricity in **nuclear reactors**. Australia is one of several countries that have large, high-grade deposits of uranium, which can be used in reactors.

nuclear reactors power plants where the radioactive properties of uranium are used to generate electricity

The steps below describe the production of energy in a nuclear reactor.

1. Uranium is converted to uranium dioxide and then sealed in rods, called **fuel rods**.
2. The uranium undergoes a **fission** reaction in the reactor when neutrons are fired at the radioactive uranium at low speed (figure 6.14).
3. This causes the uranium nuclei to split and form two new elements, releasing neutrons, radiation and *heat* in the process.
4. This heat energy is used to heat water to produce steam, which is used to turn the turbines that generate the electricity (figure 6.15).

The process of steam driven turbines to produce electricity is described in detail in topic 10.

fuel rods rods that form the fuel source of a nuclear reactor; contains the fissile nuclides needed to produce a nuclear chain reaction

fission splitting of the nuclei of large atoms into two smaller atoms and several neutrons, releasing radiation and heat energy

WHAT DOES IT MEAN?

The word *fission* comes from the Latin word *fissio*, meaning ‘to split’.

eles-2659

FIGURE 6.14 An example of a nuclear fission reaction

Nuclear equation: $^{1}_{0}\text{n} + ^{235}_{92}\text{U} \longrightarrow ^{141}_{56}\text{Ba} + ^{92}_{36}\text{Kr} + 3^{1}_{0}\text{n}$

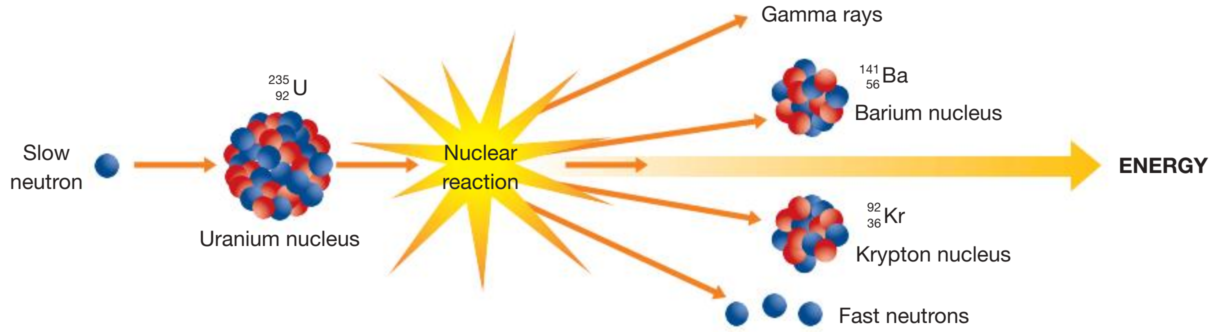
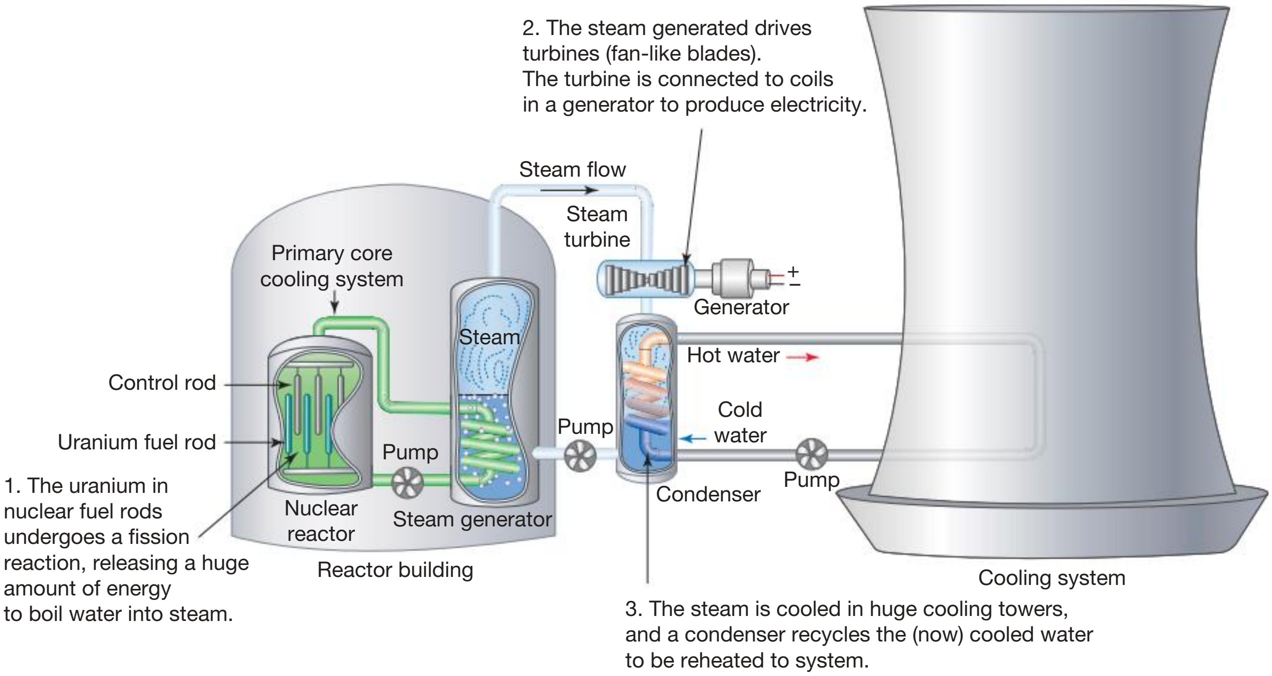


FIGURE 6.15 The heat from nuclear fission reactions boil water to produce steam, which drives a turbine to generate power.



DISCUSSION

This process of nuclear power generation is very similar to coal- and gas-fired power plants, although different sources of heat are used to boil water. What are some of the advantages of nuclear reactors over power stations that use fossil fuels? Are you aware of any disadvantages associated with nuclear reactors? Taking both the advantages and disadvantages into consideration, should we replace ageing coal-fired power stations with nuclear reactors?

Fast breeders

In some countries, fast breeder reactors use the artificial radioisotope plutonium-239 as a fuel. Plutonium-239 is made by bombarding uranium-238 with fast-moving neutrons (that's why the term 'fast breeder' is used). The plutonium-239 produced can also be used to produce nuclear weapons.

Nuclear waste

A big advantage of nuclear reactors over coal- and gas-fired power plants is that they do not generate large quantities of the greenhouse gas carbon dioxide. However, the used fuel rods in a nuclear reactor are radioactive and contain a mixture of radioisotopes.

Some of the waste radioisotopes have half-lives of only minutes, while others have half-lives of thousands of years. These waste products are currently sealed in steel containers or glass blocks and stored in power stations or buried deep at sea or underground away from groundwater. However, there is still no permanent solution to the problem of disposing of nuclear waste.

It has been suggested that nuclear waste should be sent by rocket to the Sun or into outer space. However, the risk of a rocket carrying nuclear waste exploding before leaving the Earth's atmosphere makes that solution very risky.

FIGURE 6.16 A worker inspecting output at a nuclear power plant

6.4.4 Radiotherapy in medicine

The treatment of cancer

Radiotherapy is the use of radioisotopes, or other radiation such as x-rays in medicine. Radioisotopes kill cancer cells or prevent them from multiplying. Cancer cells tend to multiply very quickly. Normal cells are also damaged by the radiation but tend not to be as badly affected. Radiation can be targeted at a small area so that surrounding tissue is not damaged. Radiotherapy is often used along with other treatments such as surgery, drugs, and harnessing the immune system (immunotherapy) to cure cancer and other diseases.

Radiation can be directed at the cancer by a machine like the one in figure 6.17. This method is known as **external radiotherapy**. The other method, known as **internal radiotherapy** or brachytherapy, involves placing radioisotopes inside the body at, or near, the site of the cancer. In some cases, both methods are used. The type of treatment depends on the type of cancer, its size and its location as well as the general health of the patient.

external radiotherapy cancer treatment where radiation is directed from an external machine to the site of the cancer

internal radiotherapy cancer treatment also known as brachytherapy. Radioisotopes are placed inside the body at, or near, the site of a cancer.

FIGURE 6.17 A patient receiving external radiotherapy treatment

The diagnosis of disease

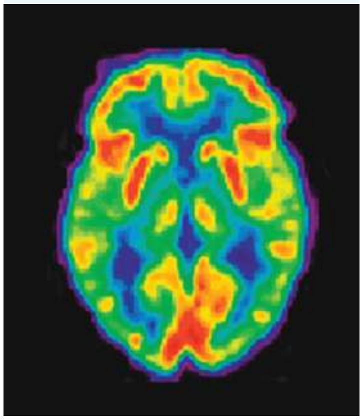
Radiography is an imaging technique that uses radiation, such as x-rays or gamma rays, to view the internal form of an object. This technique is used in both medical and industrial applications. In medical radiography, x-rays are used to produce images of the inside of the body to diagnose and monitor a wide assortment of medical conditions such as broken bones and diseased organs.

Radioactive substances can also be inserted into the body to detect or identify the cause of disease. The radiation produced by the substance while it is in the part of the body under investigation is measured to diagnose the problem (table 6.6).

TABLE 6.6 Some of the radioisotopes used in the treatment and diagnosis of disease

Radioisotope	Use	Half-life
Barium-137	Diagnosis of digestive illnesses	2.6 minutes
Iodine-123	Monitoring of thyroid and adrenal glands, and assessment of damage caused by strokes	13 hours
Thallium-201	Detection of damaged heart muscles	3 days
Iodine-131	Diagnosis and treatment of thyroid problems	8 days
Phosphorus-32	Treatment of leukaemia	14.3 days
Iron-59	Measurement of blood flow and volume	46 days
Cobalt-60	Used in radiotherapy for treating cancer	5 years

FIGURE 6.18 A PET image of the human brain



Some radioisotopes can be used to obtain images of parts of the body. The gamma rays emitted by these radioisotopes are used to produce the images. PET (positron emission tomography) scans use cameras surrounding the patient to detect gamma rays coming from radioisotopes injected into the body (figure 6.18).

radiography the process of taking an image produced by x-rays, gamma rays, or similar radiation

on Resources

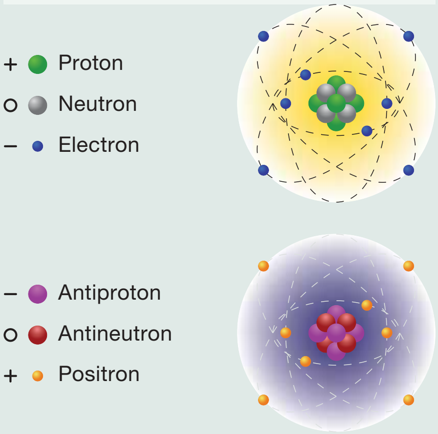
Video eLesson Nuclear medicine (eles-1084)

EXTENSION: Matter and antimatter atoms

As you know, PET detects gamma radiation emitted from radioisotopes that have been inserted into the body. However, the radioisotopes used in PET scans first emit a **positron**, which is like an electron but with a positive charge. This is antimatter, which is like the matter that makes up our universe, but the protons and electrons have the *opposite charge*; that is, positrons are positively charged electrons and antiprotons are negatively charged protons.

Antimatter is very unstable as it is annihilated when it encounters its opposite matter particle, releasing gamma radiation. It is this gamma radiation that is detected in PET, when an emitted positron encounters an electron.

FIGURE 6.19 Atoms of matter and antimatter



positron a particle emitted during PET, which is like an electron but with a positive charge

elog-2317

INVESTIGATION 6.2

Radioactive decay

Aim

To investigate the decay of a radioisotope used as a medical treatment

Materials

- graph paper or a graphing program; for example, Excel

Method

The half-life of the radioisotope iodine-131 is 8 days.

1. Calculate the mass of iodine-131 left after 8, 16, 24, 32, 40, 48, 56, 64, 72 and 80 days if 100 g is given to a patient to treat a thyroid problem.

Results

1. Present the results of your calculations in a table.
2. Choose an appropriate graph to show how the radioisotope decays. Represent time on the horizontal axis and the mass of the iodine-131 sample on the vertical axis.

Discussion

1. What fraction of the iodine-131 is left after:
   a. 8 days
   b. 16 days
   c. 24 days
   d. 80 days?
2. Why is it difficult to store radioisotopes with short half-lives?

Conclusion

Write a conclusion to this investigation as a response to the aim.

6.4.5 Industrial radiography

In industrial radiography, x-rays or gamma rays are used to inspect the structure and components for defects in materials used in aircraft and spacecraft. This method uses radiation to penetrate the material and produce an image of its internal structure. When the radiation encounters a defect, such as cracks, it undergoes changes in intensity or direction, which can then be seen as as dark areas in the image.

The image in figure 6.20, called a radiograph, allows inspectors to identify any faults or irregularities that may exist within the material. Through early fault detection, radiographic testing helps ensure the safety and reliability of aerospace structures.

FIGURE 6.20 An engineer studying an x-ray of an aircraft part. Aeroplanes undergo regular inspections to check for any defects.

6.4.6 Preserving food

If you've ever suffered from food poisoning, you will understand why it is necessary to keep food from spoiling. Food in sealed containers can be preserved by exposing it to gamma radiation. The radiation kills the micro-organisms in the food and keeps it from decomposing or becoming toxic to ingest.

ACTIVITY: Research other applications of radioactivity in our world

Topics could include:

- the use of x-rays for detection of defects in metals and composite materials (for example, in aeroplanes or other aircraft)
- the use of gamma rays to sterilise medical equipment
- the use of soft x-rays to remove static electricity
- techniques for non-destructive testing of materials (for example non-destructive testing, radiographic testing and neutron radiographic testing).

Resources

eWorkbook Putting nuclear energy to use (ewbk-12430)

6.4 Activities

6.4 Quick quiz | **6.4 Exercise**

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 4, 6	2, 3, 7	5, 8, 9

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. MC What is the name of the nuclear reaction that takes place in nuclear power stations?
   A. Radiation B. Nuclear fusion C. Nuclear fission D. Emission
2. Describe three uses of radioactive elements.
3. a. What is radiotherapy?
   b. How does it prevent the spread of cancer through the body?

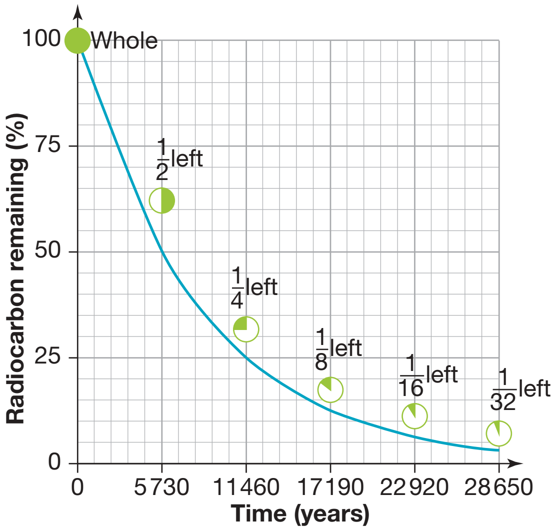
4. **MC** How do radioisotopes used in food preservation stop food from spoiling?
   A. Increases the microbial fighting properties of the food
   B. Creates a protective layer on the inside of the can
   C. Microbes that cause food spoilage are killed by radiation
   D. None of the above. Radiation is dangerous to health.

Apply and analyse

5. Explain whether carbon-14 dating can be used for fossils that are millions of years old.
   Use table 6.6 to answer questions 6–8.
6. Identify whether iodine-131 is a more stable radioisotope than barium-137. Justify your answer.

Evaluate and create

7. The use of barium-137 in the diagnosis of digestive illnesses involves the patient drinking it in a syrup. What property of barium-137 makes its use quite safe?
8. Identify an isotope best suited to use in external radiotherapy. Justify your answer.
9. **SIS** Use the graph to answer the following questions.
   a. Parts of the skeleton of a large animal are found buried in sand dunes. The amount of radioactive carbon-14 in the bones is about one-eighth of that found in the skeletons of living animals. How long ago did the animal probably die (to the nearest thousand years)?
   b. What approximate percentage of the original amount of radioactive carbon-14 would you expect to find in:
      i. a spear 11 000 years old
      ii. a skull 23 000 years old, found in a cave?



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

LESSON
6.5 The dark side of radiation

LEARNING INTENTION

At the end of this lesson you will be able to describe the health effects of radiation exposure, examples of nuclear reactor disasters (including why they occurred and the effects), and the short- and long-term impacts of nuclear weapons.

6.5.1 Advantages and disadvantages of radiation

While nuclear radiation has many uses that are beneficial to society as a whole, there is no doubt that it is very much a double-edged sword.

Disasters at nuclear power plants and the events of World War II are large-scale reminders of the dangers of radioisotopes. While the devastating power of nuclear weapons are obvious, the effects of nuclear radiation on cells can be more insidious. Nuclear radiation damages the components of cells, particularly DNA, leading to many adverse health effects.

TABLE 6.7 Advantages and disadvantages of radioisotopes

Advantages of radioisotopes	Disadvantages of radioisotopes
Radiometric dating	Nuclear weapons
Medical treatment	Nuclear disasters at power plants
Medical diagnosis	Nuclear waste from industry and medicine
Power generation	Contamination of ecosystems
Food preservation	Radiation sickness
Smoke detectors	Chronic diseases; for example, cancer
Scientific research	Mutations and birth defects

- Exposure can have immediate effects including nausea, headaches, vomiting and diarrhoea, collectively termed **radiation sickness**.
- Over longer time frames, exposure can lead to diseases such as cancer and immune system collapse later in life.
- **Mutations** in sperm and eggs can be passed from parents to children, leading to birth defects and other diseases.

radiation sickness immediate symptoms of exposure to damaging nuclear radiation

mutation damage to DNA in cells, which can be passed on to children through sperm and eggs

EXTENSION: Deaths caused by radiation

Radiation has caused the death of some remarkable people.

- Alexander Litvinenko was a former Russian secret service officer who had fled to the United Kingdom. He unexpectedly fell ill in November 2006 and died in hospital only a few weeks later. It is alleged that he was poisoned with polonium-210 placed in a pot of tea.
- It is a sad irony that Marie Curie (the woman who developed the theory of radioactivity and discovered the radioactive elements radium and polonium) died of leukaemia at the age of 67. Her illness was almost certainly caused by her constant exposure to radioactivity.

FIGURE 6.21 Marie Curie

6.5.2 When reactors go wrong

SCIENCE AS A HUMAN ENDEAVOUR: Nuclear disasters

Chernobyl, 1986

Like any other piece of complex technology, a nuclear reactor can work safely only if its many individual systems are functioning smoothly and efficiently. They must be well maintained and well managed by highly trained personnel. Unfortunately, in many cases the flaws of a nuclear reactor's design are not spotted until it is too late.

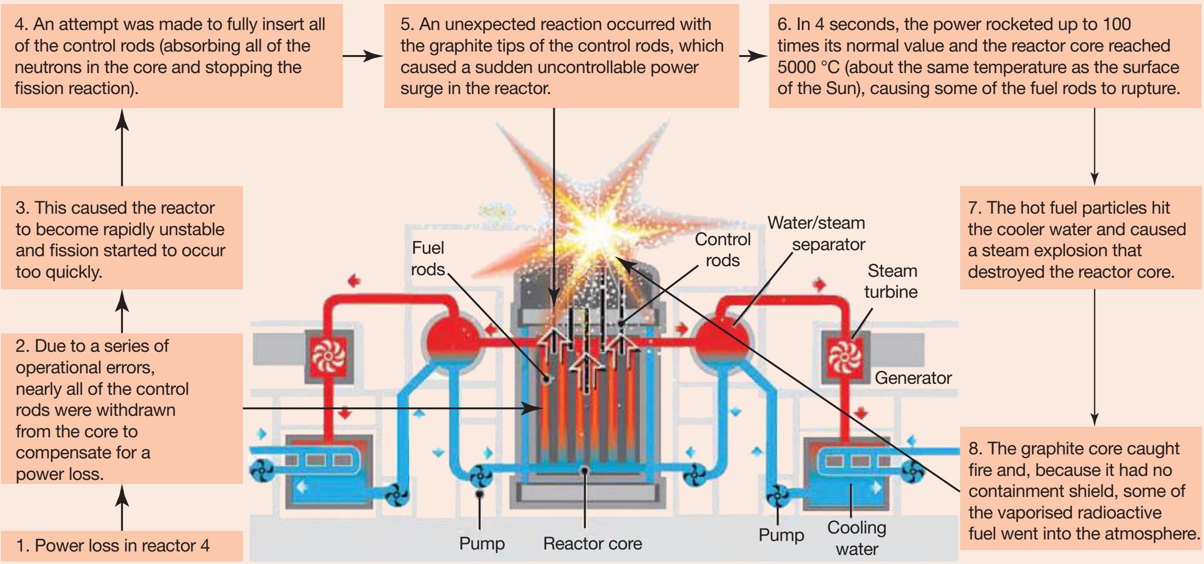
The Chernobyl Power Complex is located about 130 km from Kyiv, the capital of Ukraine. At the time of the disaster in 1986, Ukraine was part of the Soviet Union. The accident at Chernobyl was due to a combination of old technology and an operator error. Reactor 4 had three main design flaws:

- graphite control rods that can become unstable
- water coolant that can be vaporised at high temperatures
- no radiation containment shield which allowed radiation to escape from a damaged reactor.

The story began on 25 April 1986, when reactor 4 was scheduled to be shut down for routine maintenance. The events leading to the nuclear meltdown are summarised in figure 6.22.

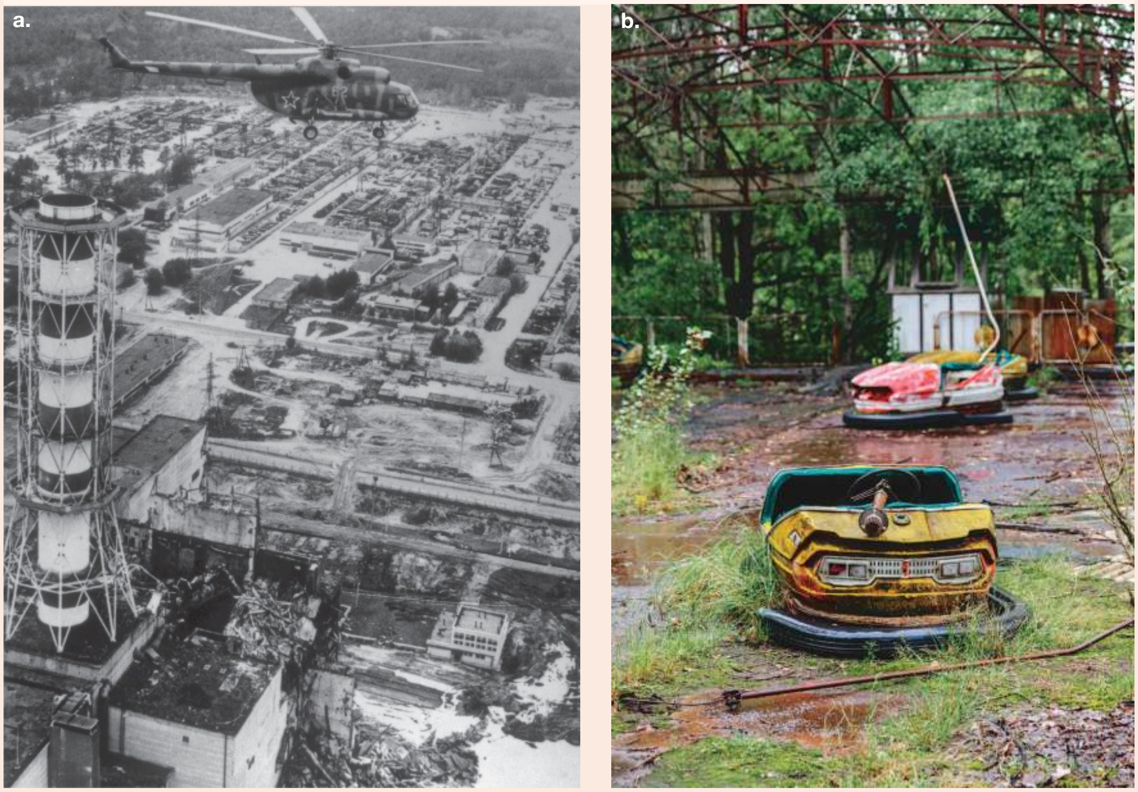
While only two people were killed in the original explosion, three others died during the night and 50 emergency workers died from acute radiation poisoning. Since the accident, the rate of thyroid cancer in children has been ten times higher in the region around Chernobyl and, of the 600 000 people contaminated by radiation, 4000 have died from long-term cancers.

FIGURE 6.22 The meltdown in reactor 4 of the Chernobyl Power Complex



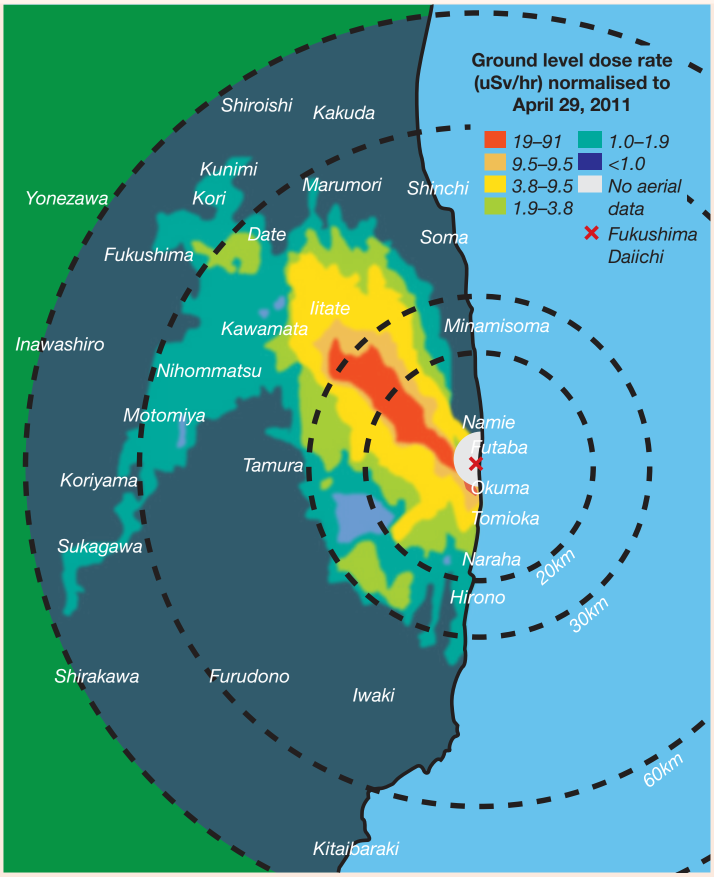
1. Power loss in reactor 4
2. Due to a series of operational errors, nearly all of the control rods were withdrawn from the core to compensate for a power loss.
3. This caused the reactor to become rapidly unstable and fission started to occur too quickly.
4. An attempt was made to fully insert all of the control rods (absorbing all of the neutrons in the core and stopping the fission reaction).
5. An unexpected reaction occurred with the graphite tips of the control rods, which caused a sudden uncontrollable power surge in the reactor.
6. In 4 seconds, the power rocketed up to 100 times its normal value and the reactor core reached 5000 °C (about the same temperature as the surface of the Sun), causing some of the fuel rods to rupture.
7. The hot fuel particles hit the cooler water and caused a steam explosion that destroyed the reactor core.
8. The graphite core caught fire and, because it had no containment shield, some of the vaporised radioactive fuel went into the atmosphere.

FIGURE 6.23 Pripyat in Ukraine was home to 50 000 people, most of whom had jobs at Chernobyl. **a.** When reactor 4 of the Chernobyl nuclear power plant exploded, the town was abandoned. **b.** Now nature is starting to reclaim it despite the remaining radiation.



Fukushima, 2011

FIGURE 6.24 Map showing the amount of radiation absorbed per hour at ground level around Fukushima, 6 weeks after the meltdown



The Fukushima Daiichi nuclear disaster was caused by a series of unfortunate events.

1. On 11 March 2011, a massive earthquake occurred off the coast of Honshu (the largest island of Japan) leaving the Fukushima nuclear reactor complex relatively unharmed but reliant on its back-up generators.
2. Unfortunately, the earthquake caused a tsunami that struck the coast of Honshu less than an hour later, killing more than 19 000 people and destroying more than 1 000 000 buildings.
3. The reactors at Fukushima Daiichi were flooded by the 15 m high tsunami, disabling twelve of the thirteen back-up generators as well as the heat exchangers that released waste heat into the sea.
4. Without power, the circulation of water coolant around the reactor cores ceased, causing them to become so hot that much of the coolant water was boiled off.
5. The heat became high enough to melt the fuel rods in reactors 1, 2 and 3 (this is referred to as a **meltdown**).
6. A reaction between the cladding of the melted fuel rods and the remaining coolant water produced hydrogen gas that exploded when mixed with the air.
7. This threw nuclear material up into the atmosphere.

More than 160 000 people had to be evacuated from the area for fear of exposure to radiation. While three employees at the Daiichi plants were killed directly by the earthquake and tsunami, there were no fatalities caused by the nuclear accident.

meltdown the melting of a nuclear-reactor core as a result of a serious nuclear accident

on Resources

Video eLesson The abandoned nuclear reactor 4 at Chernobyl (eles-2660)

6.5.3 Nuclear weapons

SCIENCE AS A HUMAN ENDEAVOUR: Effects of nuclear weapons

There are approximately 13 000 nuclear weapons in the world today, enough to destroy our planet many times over and effectively obliterate life.

The devastating effects of nuclear weapons on buildings and living organisms are due to a series of events. When nuclear weapons are detonated:

1. Enormous amounts of heat and radiation spread from the centre of the blast (known as **ground zero**) in what is called a **thermal flash**.
2. This radiation forms a fireball that generates the distinctive mushroom cloud associated with nuclear weapons. The radiation from the Hiroshima bomb formed a fireball 7 km across. At locations close to ground zero, most substances were melted or burned and organic matter (including people) was vaporised. People up to 50 km away received serious burns and those who looked directly at the flash were blinded.
3. After the initial blast, the vaporisation of particles close to the blast causes an implosion of air from further out.
4. When these inrushing air particles collide, they cause a high-pressure shock wave to spread outwards at speeds of up to 3000 km/h. This shock wave causes the destruction of buildings, blowing them outwards from the centre of the blast.
5. The blast also releases large amounts of radiation in the form of gamma rays, which can burn out electrical and electronic systems including computer networks and power grids, and even disrupt the electrical systems that control cars, planes and weaponry. This burst of energy is called an **electromagnetic pulse**.
6. The most devastating effects for survivors are due to radiation exposure. The radioactive nuclei formed during the nuclear reactions as well as tonnes of irradiated dust are blasted high into the atmosphere during detonation and the formation of the mushroom cloud.
7. In the weeks following the nuclear explosion, these come back down to Earth as **nuclear fallout**. This radioactive fallout increases the background radiation for many years where it comes down, so people in the fallout zones are exposed to higher radiation levels with damaging effects.

ground zero the centre of a nuclear weapon blast

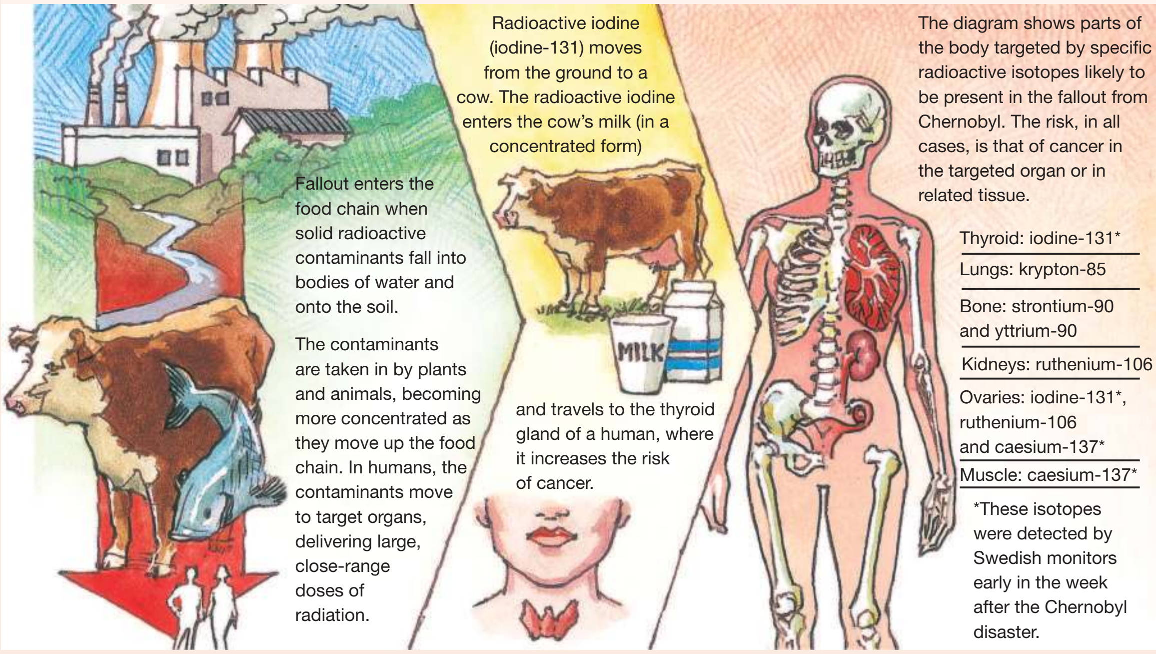
thermal flash enormous amounts of heat and radiation that spread out from the centre of a nuclear blast

electromagnetic pulse a burst of electromagnetic activity caused by the detonation of nuclear devices

nuclear fallout irradiated dust blasted high into the atmosphere during detonation and the formation of the mushroom cloud. In the weeks following the nuclear explosion, these come back down to Earth as nuclear fallout.

FIGURE 6.25 Atomic bomb destruction, Hiroshima, Japan. Around 90 per cent of the buildings were destroyed, with only a few concrete-reinforced buildings surviving. Some 70 000 people died instantly, with tens of thousands more dying in the aftermath.

FIGURE 6.26 The devastating impacts of nuclear fallout


Fallout enters the food chain when solid radioactive contaminants fall into bodies of water and onto the soil.

The contaminants are taken in by plants and animals, becoming more concentrated as they move up the food chain. In humans, the contaminants move to target organs, delivering large, close-range doses of radiation.

Radioactive iodine (iodine-131) moves from the ground to a cow. The radioactive iodine enters the cow's milk (in a concentrated form)

and travels to the thyroid gland of a human, where it increases the risk of cancer.

The diagram shows parts of the body targeted by specific radioactive isotopes likely to be present in the fallout from Chernobyl. The risk, in all cases, is that of cancer in the targeted organ or in related tissue.

*These isotopes were detected by Swedish monitors early in the week after the Chernobyl disaster.

6.5 Activities

6.5 Quick quiz on

6.5 Exercise

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 3	2, 4, 6	5, 7

These questions are even better in jacPLUS!
- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. What is radioactive fallout and why is it given this name?
2. List one effect of exposure to large doses of nuclear radiation to humans:
   a. immediately after exposure
   b. after a longer amount of time.
3. Define the following terms:
   a. meltdown
   b. thermal flash
   c. electromagnetic pulse
   d. ground zero.
4. Two natural disasters led to the meltdown in reactors 1, 2 and 3 at the power station in Fukushima.
   a. Identify the two natural disasters.
   b. Describe how each disaster affected the power plant.
   c. Identify two consequences of these events on the power plant.

Apply and analyse

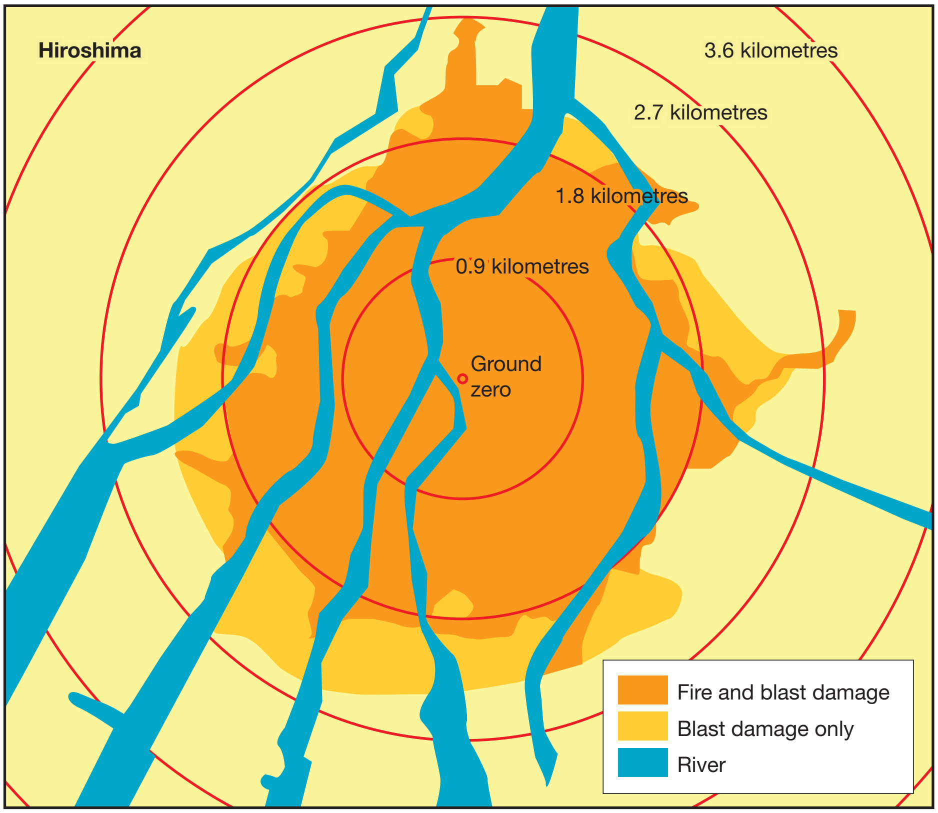
5. Identify one design flaw of reactor 4 at Chernobyl and explain how it contributed to the disaster.
6. 'The ability of nuclear radiation to kill cells is both an advantage and a disadvantage.'
   Do you agree with this statement? Justify your answer.

Evaluate and create

7. **SIS** The following table and map indicate the distribution of deaths and injuries caused by the Hiroshima bombing in 1945.

TABLE Distribution of deaths and injuries, Hiroshima bombing (1945)

Distance from ground zero (km)	Killed	Injured	Initial population
0–1.0	26 700 (86%)	3000 (10%)	31 200
1.0–2.5	39 600 (27%)	53 000 (37%)	144 800
2.5–5.0	1700 (2%)	20 000 (25%)	80 300



Atomic bomb damage of Hiroshima

a. Use this information to determine:
   i. the original population of Hiroshima (within 5 km of ground zero) before the bombing
   ii. the number of people killed who were within 1 km of ground zero
   iii. the number of people who were unharmed despite being within 1 km of ground zero.

b. As you would expect, the number of people killed gets smaller the further from ground zero that they were located. What explanations can you give that the percentage wounded doesn't follow the same pattern?

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

LESSON
6.6 Thinking tools — Concept maps and plus, minus, interesting charts

6.6.1 Tell me

What is a concept map?

A concept map is a diagram that is useful for showing what you understand about a particular topic. It helps you arrange a larger topic of complex ideas by classifying them into smaller and smaller ideas. It explains the relationships between parts or elements with statements on the links between them. A concept map is also called a knowledge map or a concept web.

What is a plus, minus, interesting chart?

A plus, minus, interesting (PMI) chart also groups a topic into ideas, but these groups are based on your perspective of the topic — that is, do you find the ideas a positive, a negative, or just an interesting aspect?

FIGURE 6.27 A concept map

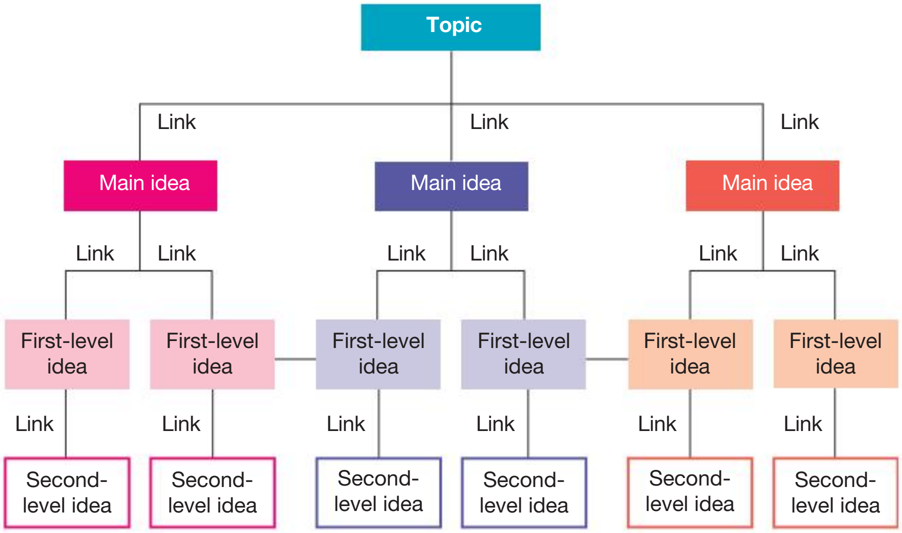
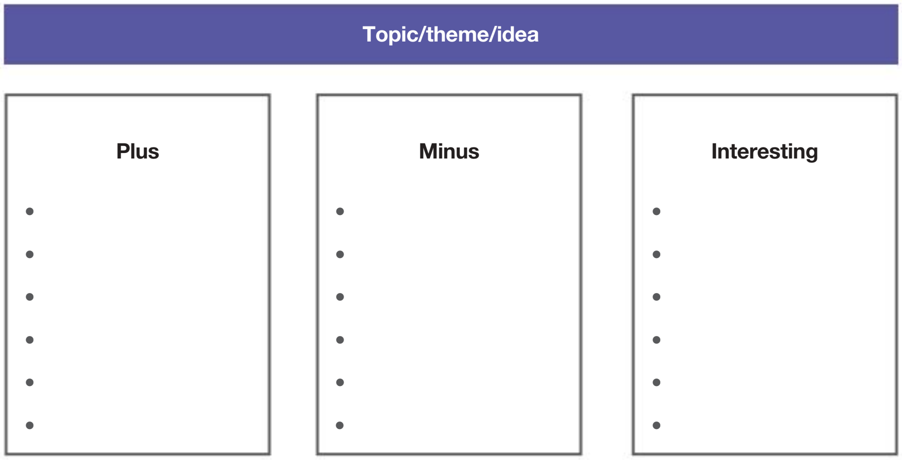


FIGURE 6.28 A PMI chart

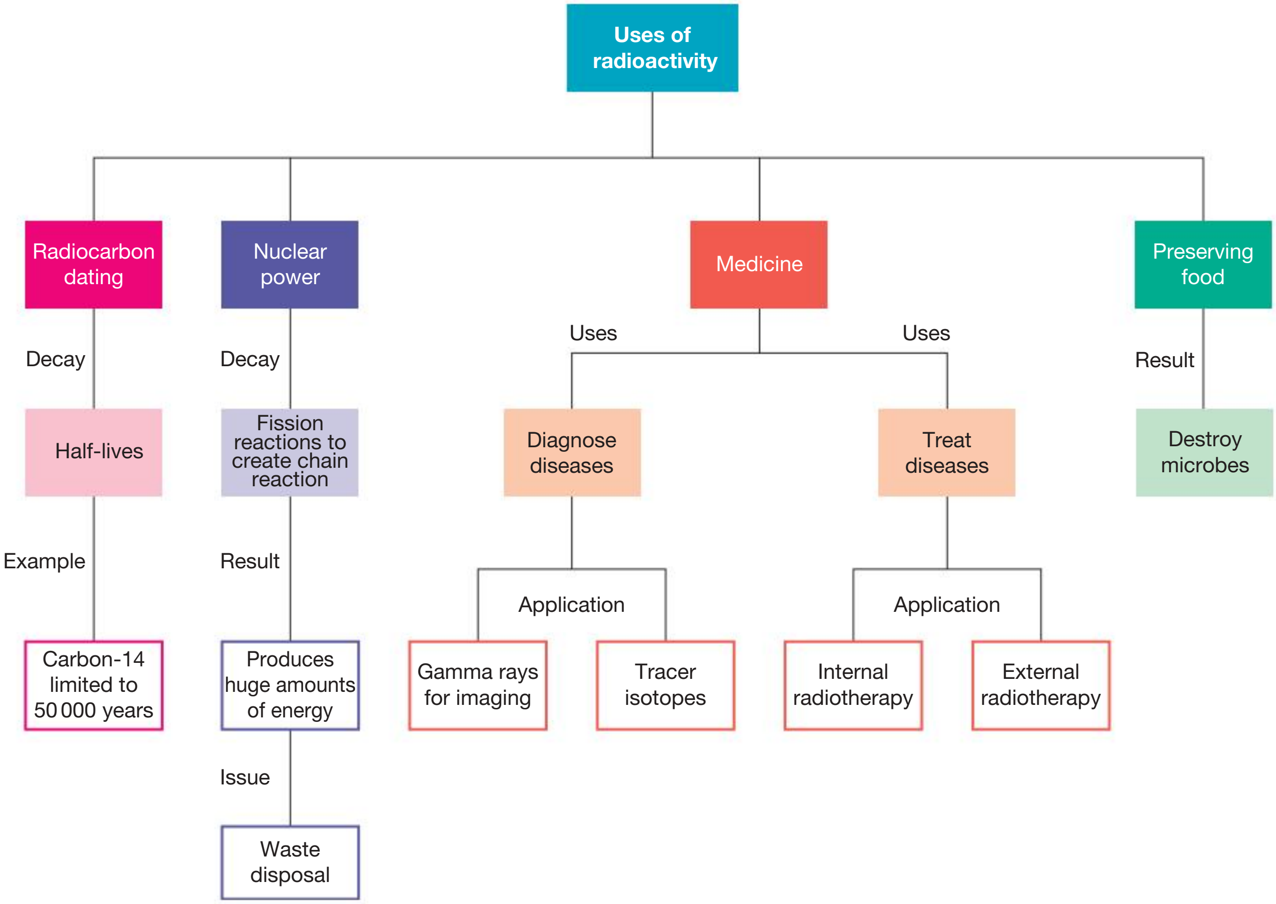


6.6.2 Show me

To create a concept map:

1. Choose a topic that has a number of different parts or ideas. Write any ideas you may have onto small pieces of paper. For example, you might choose to consider how radioactivity can be used by humans.
2. Examine your pieces of paper and put your ideas into your concept map, which looks like this:

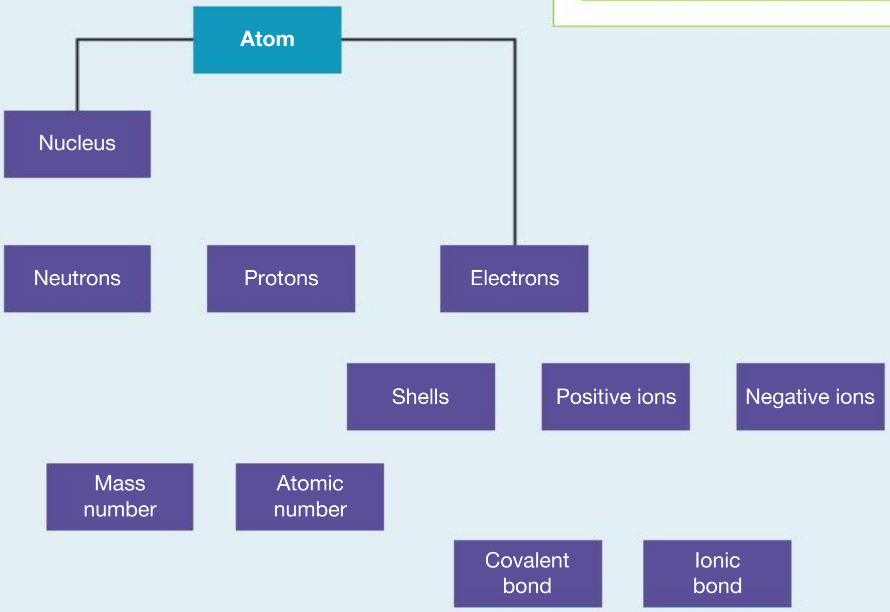
FIGURE 6.29 A concept map of the uses of radioactivity



6.6.3 Let me do it

6.6 Activity

1. A concept map can be used to illustrate some of the important ideas associated with the atom and the links between the ideas.
   a. Complete the concept map below by adding the links between the ideas.



   b. Construct your own concept map to show how ideas about what is inside substances are linked. For example, you may choose to consider what is inside a molecule of carbon dioxide, or you may choose another substance. Begin by working in a group to brainstorm the main ideas of the topic.
2. Construct a concept map of ideas associated with radioactivity.
3. Create a PMI chart on radioactivity, using the diagram below as a starting point.

Radioactivity

Plus	Minus	Interesting
• Can be used to treat cancer • • • • • •	• Radioactive isotopes can be used in nuclear weapons • • • •	• Radioactivity was discovered by accident • • • • •

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

LESSON
6.7 Review

Hey students! Now that it's time to revise this topic, go online to:

- Review your results
- Watch teacher-led videos
- Practise past VCAA exam questions

Find all this and MORE in jacPLUS

Access your topic review eWorkbooks

on Resources

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-12432	ewbk-12434	ewbk-12436

6.7.1 Summary

Chemical building blocks

- Atoms are so small we rely on scientific models to help us understand them.
- Models are based on repeated experiments and observations that help us make predictions and explain observed phenomena.
- New discoveries mean models are improved over time.
- The model of the atom has evolved from the J. J. Thomson's plum pudding model.
- The current model of the atom consists of a tiny dense nucleus, composed of positive protons and neutral neutrons, surrounded by a cloud of tiny negative electrons.
- A neutral atom has an equal number of protons (+) and electrons (–).

Stability and change — inside the nucleus

- Atoms of the same element have the same number of protons in their nucleus.
- Atoms of the same element can have different numbers of neutrons in their nucleus. This gives the atoms different masses, and these are called isotopes.
- Nuclide notation is used to represent different atoms and their isotopes.
- ${}^{A}_{Z}X$: where X is the chemical symbol of the element, A is the mass number (number of protons and neutrons in the nucleus) and Z is the atomic number (the number of protons in the nucleus).
- For different isotopes of the same element, the mass number (A) changes, as it is the number of protons and neutrons in the nucleus. Hydrogen has three isotopes: ${}^{1}_{1}H$, ${}^{2}_{1}H$, ${}^{3}_{1}H$.
- Atoms can be stable or unstable.
- In unstable atoms, the neutrons and protons in the nucleus are not held together as strongly, and decay to form other elements. These are radioisotopes.
- Natural radioactivity is emitted without any energy needing to be supplied.
- The energy emitted by radioactive substances is nuclear radiation. There are three types:
  - Alpha particles (α): a positively charged helium nuclei. They cannot travel through materials easily.
  - Beta particles (β): can be positive or negative and are the same size and mass as an electron. They travel near the speed of light and can penetrate human skin.
  - Gamma rays (γ): bursts of energy released after alpha or beta particles emitted. They travel at the speed of light and are highly penetrating.
- The half-life of a radioisotope is the time taken for half of all the nuclei in a sample of a radioisotope to disintegrate or decay.
- Background radiation comes from naturally occurring radioactive substances and a small amount from cosmic radiation.

Using radioactivity

- Radiometric dating uses the known half-lives of radioactive elements. For example, radiocarbon dating can be used to date archaeological samples. Older samples, such as very old rocks, are dated using the decay of uranium to lead.
- Uranium is used in nuclear reactors as fuel rods. The uranium is bombarded with neutrons and undergoes a fission reaction that breaks the uranium into smaller atoms and simultaneously releases a huge amount of energy. This energy is used to make steam to turn turbines and generate electricity.
- Nuclear power does not generate large amounts of greenhouse gases, but does produce radioactive waste, which is difficult to dispose of safely.
- Radioisotopes are used to treat disease through internal or external radiotherapy.
- Radioisotopes can be used to diagnose disease through the use of radioactive tracers.
- Radioisotopes can be used to preserve food by destroying the microbes in the food.

The dark side of radiation

- Disasters at nuclear power plants include Chernobyl (1986) and Fukushima (2011).
- Nuclear weapons use the energy released in nuclear reactions to generate huge blasts of energy and chemical fallout, which can kill and injure thousands of people simultaneously.
- Radiation from nuclear meltdowns and fallout causes long-term diseases and birth defects to thousands of people.

6.7.2 Key terms

alpha particles positively charged nuclei of helium atoms, consisting of two protons and two neutrons

atomic number the number of protons in the nucleus of an atom of a particular element

beta particles charged particles (positive or negative) with the same size and mass as electrons

cosmic radiation naturally occurring background radiation from outer space

decay to transform into a more stable particle

electromagnetic pulse a burst of electromagnetic activity caused by the detonation of nuclear devices

electrons extremely light (1800 times lighter than protons and neutrons) negatively charged particles inside an atom. Electrons orbit the nucleus of an atom in specific, defined regions called shells or orbitals.

element a pure chemical species consisting of atoms of a single type

external radiotherapy cancer treatment where radiation is directed from an external machine to the site of the cancer

fission splitting of the nuclei of large atoms into two smaller atoms and several neutrons, releasing radiation and heat energy

fuel rods rods that form the fuel source of a nuclear reactor; contains the fissile nuclides needed to produce a nuclear chain reaction

gamma rays high-energy electromagnetic radiation produced from some radioactive decay; the radiation has no mass and travels at the speed of light

ground zero the centre of a nuclear weapon blast

half-life time taken for half the radioactive atoms in a sample to decay — that is, change into atoms of a different element

internal radiotherapy cancer treatment also known as brachytherapy. Radioisotopes are placed inside the body at, or near, the site of a cancer.

isotopes atoms of the same element that differ in the number of neutrons in the nucleus

mass number the total number of protons and neutrons in the nucleus of a particular atom

meltdown the melting of a nuclear-reactor core as a result of a serious nuclear accident

mutation damage to DNA in cells, which can be passed on to children through sperm and eggs

neutrons tiny particles found in the nucleus of an atom. Neutrons have no electrical charge and have the same mass as a proton.

nuclear fallout irradiated dust blasted high into the atmosphere during detonation and the formation of the mushroom cloud. In the weeks following the nuclear explosion, these come back down to Earth as nuclear fallout.

nuclear radiation radiation from the nucleus of an atom, consisting of alpha or beta particles, or gamma rays

nuclear reactors power plants where the radioactive properties of uranium are used to generate electricity
nucleus central part of an atom, made up of protons and neutrons; plural = nuclei
nuclide a type of atom characterised by the number of protons and the number of neutrons in its nucleus
positron a particle emitted during PET, which is like an electron but with a positive charge
protons tiny particles found in the nucleus of an atom. Protons have a positive electrical charge and the same mass as a neutron
radiation sickness immediate symptoms of exposure to damaging nuclear radiation
radiocarbon dating a method of determining the age of a fossil using the remaining amount of unchanged radioactive carbon
radiography the process of taking an image produced by x-rays, gamma rays, or similar radiation
radioisotope a radioactive form of an isotope
radiometric dating determining the ages of rocks and fossils based on the rate of decay or half-life of particular isotopes
stable a nucleus that does not change spontaneously. The protons and neutrons in the nucleus are held together strongly.
thermal flash enormous amounts of heat and radiation that spread out from the centre of a nuclear blast
subatomic particles particles within an atom — electrons, protons and neutrons
symbol simplified representation of an element consisting of one or two letters
unstable an atom in which the neutrons and protons in the nucleus are not held together strongly

on Resources

eWorkbooks	Study checklist (ewbk-12438) Reflection (ewbk-12445) Literacy builder (ewbk-12439) Crossword (ewbk-12441) Word search (ewbk-12443)
Solutions	Topic 6 Solutions (sol-1139)
Practical investigation eLogbook	Topic 6 Practical investigation eLogbook (elog-2313)
Digital document	Topic 6 Key terms glossary (doc-40141)

6.7 Activities

learnon

6.7 Review questions

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 3, 5, 6	2, 7, 10, 11	4, 8, 9, 12

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. Which of the particles in a neutral atom has:
   a. a negative electric charge
   b. a positive electric charge
   c. no electric charge
   d. the smallest mass?
2. Describe the contributions of the following scientists to our understanding of the structure of the atom.
   a. J. J. Thomson
   b. Lord Rutherford
   c. Niels Bohr

3. Which type of nuclear radiation travels at the speed of light?
4. The hydrogen atom exists as three different isotopes.
   a. How are the atoms of each isotope different from the others?
   b. Identify two features of the hydrogen atom that are the same for each of the three isotopes.
5. Where does most of the natural background radiation that we experience every day come from?

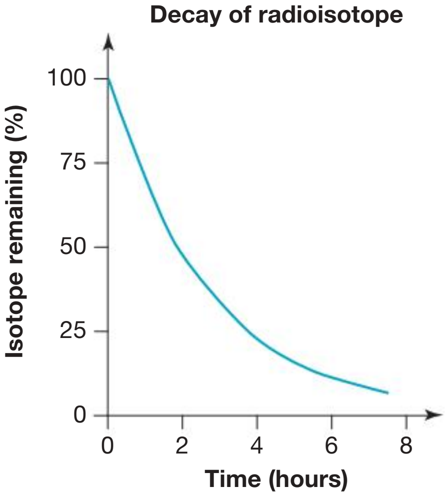
Apply and analyse

6. The diagram represents a model of a neutral atom.
   a. Which two particles make up the nucleus of the atom?
   b. Which particles are shown orbiting the nucleus in the atom?
   c. To which element does this atom belong?

7. Alpha particles are helium nuclei containing two protons and two neutrons.
   a. What is the electric charge of an alpha particle?
   b. How does the mass of an alpha particle compare with the mass of a beta particle?
   c. Suggest why alpha particles are easily stopped by human skin while beta particles are not.
   d. Which type of radiation from the nucleus is more penetrating than either alpha or beta particles?
8. Radioisotopes have many uses.
   a. What property of radioisotopes makes them useful?
   b. Describe three of the beneficial uses of radioisotopes.
   c. Some radioisotopes are considered highly dangerous even after thousands of years. Why?
9. Two isotopes of the element carbon found naturally on Earth are carbon-12 and carbon-14.
   a. How is every atom of carbon-14 different from every atom of carbon-12?
   b. What features and properties do carbon-14 and carbon-12 have in common?
   c. Which of the two carbon isotopes is stable?
10. The half-life of strontium-90 is 28 years. If a 400 gram sample of strontium-90 was left to decay, how many grams of the sample would be left after:
   a. 28 years
   b. 56 years
   c. 84 years?

Evaluate and create

11. Estimate the half-life of the isotope whose decay is shown in the graph.
12. **SIS** Explain how it is possible to use carbon-14 to estimate the age of the remains of a dead plant embedded in a rock.



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

Online Resources

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.

6.1 Overview

eWorkbooks
- Topic 6 eWorkbook (ewbk-12419)
- Student learning matrix (ewbk-12421)
- Starter activity (ewbk-12422)

Solutions
- Topic 6 Solutions (sol-1139)

Practical investigation eLogbook
- Topic 6 Practical investigation eLogbook (elog-2313)

Video eLesson
- The experiments that led to our understanding of the atom (eles-1780)

6.2 Chemical building blocks

eWorkbooks
- Chemical building blocks (ewbk-12424)
- How big is an atom? (ewbk-12426)
- Top ten elements (ewbk-12428)

Practical investigation eLogbook
- Investigation 6.1: Exploring models of the atom (elog-2315)

Teacher-led video
- Investigation 6.1: Exploring models of the atom (tlvd-10804)

Video eLessons
- A model of an oxygen atom (eles-2657)

6.3 Stability and change — inside the nucleus

Video eLessons
- Deuterium (eles-2658)
- Smashing atoms in CERN (eles-1085)

Interactivity
- Radioactive half-life (int-1652)

6.4 Using radioactivity

eWorkbook
- Putting nuclear energy to use (ewbk-12430)

Practical investigation eLogbook
- Investigation 6.2: Radioactive decay (elog-2317)

Video eLessons
- The mystery of radium (eles-1779)
- A nuclear fission chain reaction (eles-2659)
- Nuclear medicine (eles-1084)

6.5 The dark side of radiation

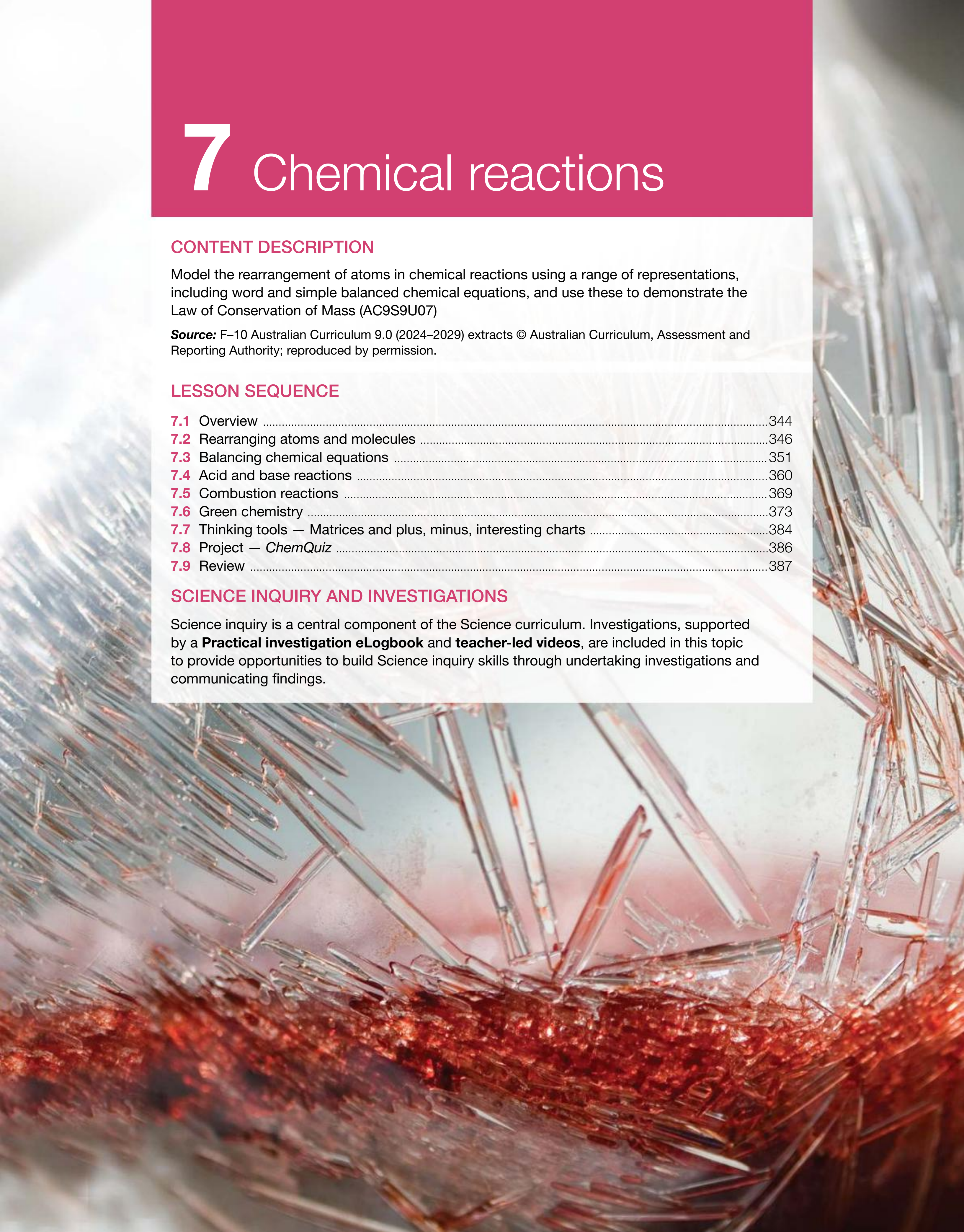
Video eLesson
- The abandoned nuclear reactor 4 at Chernobyl (eles-2660)

6.7 Review

eWorkbooks
- Topic review Level 1 (ewbk-12432)
- Topic review Level 2 (ewbk-12434)
- Topic review Level 3 (ewbk-12436)
- Study checklist (ewbk-12438)
- Literacy builder (ewbk-12439)
- Crossword (ewbk-12441)
- Word search (ewbk-12443)
- Reflection (ewbk-12445)

Digital document
- Topic 6 Key terms glossary (doc-40141)

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



7 Chemical reactions

CONTENT DESCRIPTION

Model the rearrangement of atoms in chemical reactions using a range of representations, including word and simple balanced chemical equations, and use these to demonstrate the Law of Conservation of Mass (AC9S9U07)

Source: F–10 Australian Curriculum 9.0 (2024–2029) extracts © Australian Curriculum, Assessment and Reporting Authority; reproduced by permission.

LESSON SEQUENCE

SCIENCE INQUIRY AND INVESTIGATIONS

Science inquiry is a central component of the Science curriculum. Investigations, supported by a **Practical investigation eLogbook** and **teacher-led videos**, are included in this topic to provide opportunities to build Science inquiry skills through undertaking investigations and communicating findings.

LESSON
7.1 Overview

Hey students! Bring these pages to life online

Watch videos

Engage with interactivities

Answer questions and check results

Find all this and MORE in jacPLUS

7.1.1 Introduction

Every single living thing on Earth depends on chemical reactions — from the largest mammal, the blue whale, right down to the smallest insects and microorganisms. One such reaction is the **respiration** (also called cellular respiration) that occurs in the cells of all plants and animals. It transforms oxygen and the sugars in food into carbon dioxide, water and the energy all living things need to survive. While respiration makes carbon dioxide and water, in plants chemical reactions transform carbon dioxide and water into sugars and other nutrients such as proteins and starch. This process is known as photosynthesis.

In this topic we will investigate chemical reactions. We will learn how to recognise when a chemical reaction has taken place, and how the atoms in the reactants rearrange to form the products of the reaction. We will learn the importance of the energy stored in the products and the reactants and whether a reaction will produce heat or need heat to occur.

FIGURE 7.1 Sometimes it is easy to know if a chemical reaction is taking place.

There are many types of chemical reactions, and they are used in all aspects of our lives. We will look at reactions, learning many ways to show what is happening during reactions. The periodic table has more than 100 elements but very few are found naturally, so how are these elements extracted from the compounds they are found in? While reactions can produce essential or desirable products, sometimes the by-products have side effects and damage the environment. Understanding the chemistry allows the process to be changed to reduce energy output or develop more environmentally friendly options.

respiration the process by which glucose is broken down in the presence of oxygen to produce water, carbon dioxide and energy in a form that cells can use

on Resources

Video eLesson Chemical reactions (eles-4172)

Watch this video to observe the reaction of the acid dehydration of sugar. In this reaction, concentrated sulfuric acid is poured onto icing sugar. The clip shows this highly exothermic, heat-producing reaction and the production of black carbon.

7.1.2 Think about chemical reactions

1. How do atoms behave during chemical reactions?
2. In chemical reactions, what is conserved other than energy?
3. How can you tell what has happened in a reaction?
4. Are all chemical reactions useful?
5. How do we get elements from compounds?
6. How can we reduce the damage to the environment due to chemicals?
7. Do chemical reactions only occur in the laboratory?

7.1.3 Science inquiry

Modelling chemistry

Creating models of chemical reactions helps understand what is happening in a reaction. It helps to show that matter is not created or destroyed in a reaction. The models help chemists to explain their observations. Answer the following to find out what you already know about these reactions.

1. a. What chemicals are used in your house to clean you and your clothes, and how should these be stored safely?
   b. How do the chemicals in your house react?
   c. What chemical reactions occur in your body?
2. You may have heard about green chemistry.
   a. Are all chemical reactions hazardous?
   b. Can understanding the reactions help find solutions to environmental problems?

elog-2321

INVESTIGATION 7.1

Cleaning up with baking soda and vinegar

Aim

To observe the chemical reaction between baking soda and vinegar and to investigate the cleaning properties of the reaction

Materials

- 100 mL white vinegar
- 1 tablespoon of baking soda or baking powder
- rubber gloves
- a small cleaning brush or scourer
- a dirty beaker, cup or vessel
- access to a basin or sink

Method

1. Place the dirty vessel in the sink or basin.
2. Add 100 mL of vinegar to the vessel.
3. Carefully add the baking soda or baking powder to the vinegar.
4. Use the brush or scourer to clean the vessel.
5. Rinse the vessel with water.

The cleaning products on the right can be replaced by two simple ingredients that do the same tasks.

Results

What did you observe when you added the baking soda (or powder) to the vinegar in the dirty vessel?

Discussion

1. Describe the reaction when the baking soda or powder was added to the vinegar.
2. What do you think caused this reaction?
3. Describe the cleaning effect of the reaction.

Conclusion

What can you conclude about the cleaning properties of the reaction between baking soda and vinegar?

on Resources

eWorkbooks	Topic 7 eWorkbook (ewbk-12446) Student learning matrix (ewbk-12448) Starter activity (ewbk-12449)
Solutions	Topic 7 Solutions (sol-1140)
Practical investigation eLogbook	Topic 7 Practical investigation eLogbook (elog-2319)

LESSON
7.2 Rearranging atoms and molecules

LEARNING INTENTION

At the end of this lesson you will be able to describe the difference between reactants and products, and how chemical reactions are represented.

7.2.1 Chemical reaction

A cake rising in an oven, a bath bomb fizzing in a full bathtub, and an old car getting rusty — what do they have in common? They are all evidence of chemical reactions.

Chemical reactions take place when the bonds between atoms are broken and new bonds are formed, creating a new arrangement of atoms and at least one new substance. As the new substance is formed, observable changes take place — a change in temperature or colour, the formation of a visible gas or new solid, or perhaps even just an odour.

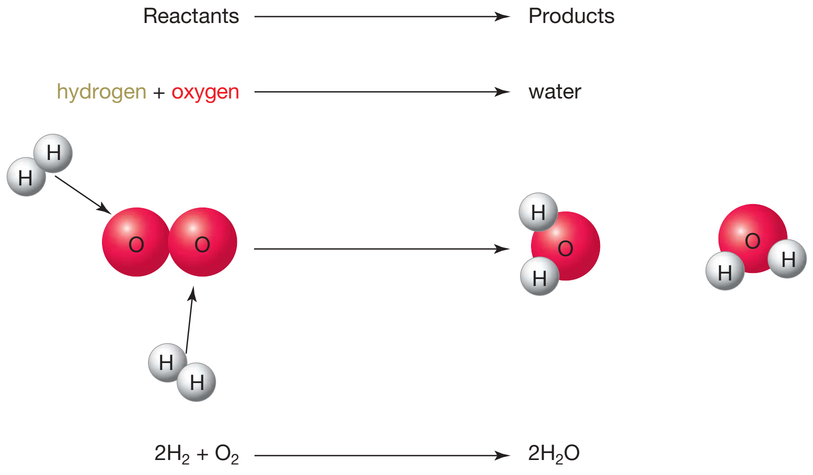
7.2.2 Reactants and products

The new substances that are formed during a chemical reaction are called the **products**. The original substances are called the **reactants**.

For example, when hydrogen gas is added to oxygen gas and ignited, the new substance water is formed. The reactants are hydrogen and oxygen. The product is water. The bonds between the hydrogen atoms and oxygen atoms are broken and new bonds are formed between oxygen and hydrogen, as shown in figure 7.2.

Notice that the hydrogen and oxygen atoms that were present in the reactants are also present in the product. There is no gain or loss of atoms. They have been rearranged to form new products. Recall that molecules can be made up of all the same atoms, as in hydrogen gas and oxygen gas or as a combination of different atoms as in water.

FIGURE 7.2 The reaction between the reactants hydrogen and oxygen to create the product water



products chemical substances that result from a chemical reaction

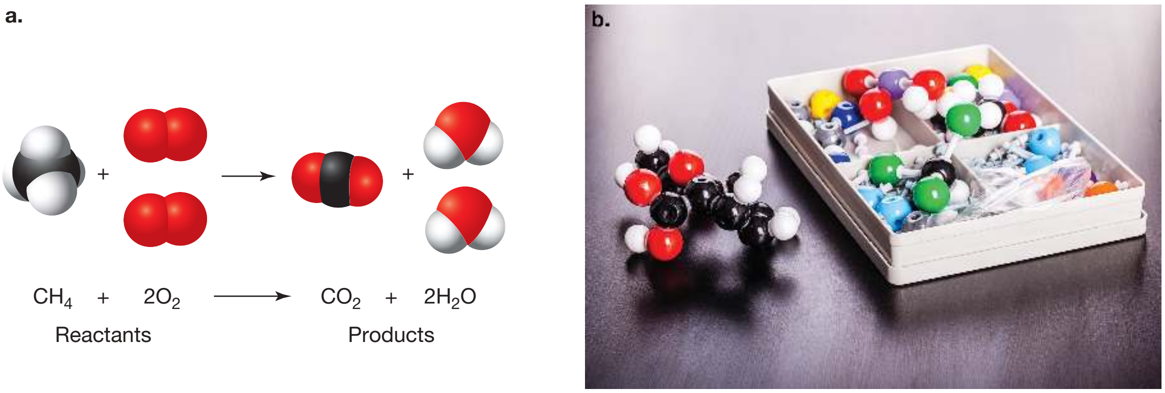
reactants the original substances present in a chemical reaction

7.2.3 Representing chemical reactions

Creating a model of a chemical reaction helps us understand what happens in the chemical reaction. There are many types of ways to represent chemical equations and models. Simple particle models use coloured spheres or circles to show the atoms of the reactants combining or rearranging to form the final product. For instance, in figure 7.3a, carbon atoms are represented as dark grey spheres, oxygen atoms as red and hydrogen atoms as white. This is a common convention, also used with molecular model sets (see figure 7.3b).

Models are helpful to understand the different types of reactions.

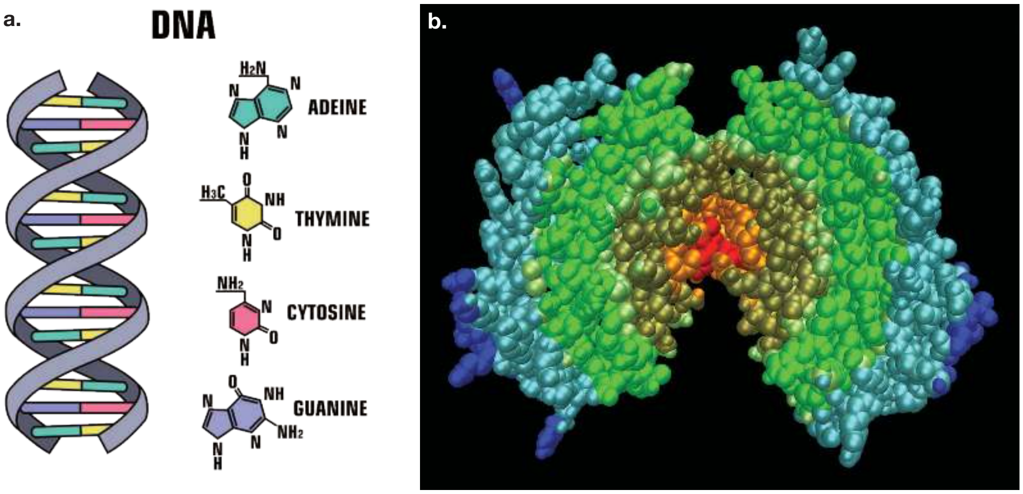
FIGURE 7.3 a. A simple representation of a chemical reaction **b.** A molecular model set



Models can help us visualise the reactions by showing that the reactants have changed, to help understand how properties have changed. These models can show the difference between ions, atoms and molecules. One of the most famous chemical models is of DNA (deoxyribonucleic acid), and the understanding of the structure (see figure 7.4a) and function of that molecule is fundamental in fields such as biology, medicine, archaeology and forensics.

Complicated chemical models, such as prions (a type of protein), viruses or drugs (see figure 7.4b) are now produced by computers.

FIGURE 7.4 a. Model of a portion of the double helix of a DNA molecule on the left, with the four building blocks that make up the molecule shown on the right **b.** A computer-generated model of human interferon beta, a drug used to treat multiple sclerosis



7.2.4 Word equations

Word equations are also used to represent a chemical reaction. The names of the substances involved are used but the chemical formulae and symbols are not used. In a chemical reaction, the reactants are the substances that react together to form or to produce the products.

$$\text{reactants} \rightarrow \text{products}$$

The reactants are on the left-hand side of the arrow, while the products are on the right-hand side of the arrow. The + sign separates each reactant or product and the arrow → means 'react to make'.

A word equation describes the reaction. For instance, the chemical reaction in which oxygen and hydrogen react together to form water is described by the following word equation:

$$\text{oxygen} + \text{hydrogen} \rightarrow \text{water}$$

ACTIVITY: Making models

Use a molecular modelling kit or some plasticine and toothpicks to make a model of the reaction between hydrogen and oxygen. If you are using a modelling kit, you will need four white atoms to model the hydrogen atoms, and to join them together in two lots of two. You will also need two red oxygen atoms joined together. Now rearrange the atoms to form two molecules of water as in figure 7.2.

7.2.5 Chemical equations

In order to communicate with each other easily about chemical reactions, scientists all over the world need to use the same language. The language used by scientists in chemistry involves chemical symbols, formulae and **equations**.

Word equations provide a simple way to describe chemical reactions by stating the reactants and products. Chemical equations that use formulae provide more information. They show how the atoms in the reactants combine to form the products.

Writing chemical equations involves some simple mathematics and a knowledge of chemical formulae. Chemical formulae are a quick way to represent the reactants and the products, that show the elements present and how many of each atom are used to make it.

Non-metal elements such as carbon (C) or hydrogen (H) or oxygen (O) can bond with other non-metals to make **molecules**. For example, methane has a formula of CH_4, which indicates that the molecule is made of one carbon atom bonded to four hydrogen atoms.

Noble gases are the only elements that exist as single, separate atoms. He, Ne and Ar are examples of these gases. All other elements that exist as gases, such as oxygen or chlorine, exist as **diatomic molecules** and therefore are shown as O_2 or Cl_2 in the chemical reactions, never just O or Cl.

Ionic substances are made of metal and non-metal atoms and form giant lattices rather than separate molecules, so their formula shows the ratio of the different types of atoms. For example, sodium chloride (known as table salt) that has a formula of NaCl, which indicates that for every one atom of Na there is one atom of Cl.

Metals also exist in a lattice and are written with only their elemental symbol (e.g. Al, Na, Mg) since they do not form molecules and there is only one type of atom present.

equation statement describing a chemical reaction, with the reactants on the left and the products on the right separated by an arrow

molecule group of atoms bonded together covalently

diatomic molecules substance containing two atoms only

Chemical equations are set out in the same way as word equations, with the reactants to the left of the arrow and products to the right. However, they are different from word equations in three ways:

- Chemical formulae are used to represent the chemicals involved
- The physical states of the chemicals are often included: (g) for gas, (l) for pure liquid, (aq) for an **aqueous solution** and (s) for solid
- Numbers are written in front of the formulae in order to balance the numbers of atoms on each side of the equation exactly.

aqueous solutions mixtures in which substances are dissolved in water

Figure 7.5 models the reaction between sodium and chlorine gas to form sodium chloride. The chemical equation shows that two atoms of solid sodium metal react with one molecule of chlorine gas to form two units of solid sodium chloride.

FIGURE 7.5 Sodium metal will react with chlorine gas to form the safer table salt. Note that the properties of each are very different.

$$2Na(s) \quad + \quad Cl_2(g) \longrightarrow 2NaCl(s)$$

Some common formulae for different compounds are listed in tables 7.1 and 7.2.

TABLE 7.1 The formulae of some common ionic compounds

Compound	Formula
Sodium hydroxide	$NaOH$
Sodium chloride	$NaCl$
Sodium sulfate	Na_2SO_4
Sodium citrate	$C_6H_5O_7Na_3$
Sodium hydrogen carbonate	$NaHCO_3$
Copper(II) hydroxide	$Cu(OH)_2$
Copper(II) sulfate	$CuSO_4$
Magnesium chloride	$MgCl_2$
Mercury(II) oxide	HgO

TABLE 7.2 The formulae of some common covalent compounds

Compound	Formula
Water	H_2O
Citric acid	$C_6H_8O_7$
Carbon dioxide	CO_2
Oxygen	O_2
Hydrochloric acid	HCl
Carbon monoxide	CO
Hydrogen	H_2
Methane	CH_4
Ammonia	NH_3

7.2 Activities

7.2 Quick quiz on | **7.2 Exercise**

Select your pathway

🟩 Level 1	🟦 Level 2	🟪 Level 3
1, 2, 7	3, 5, 8	4, 6, 9

Remember and understand

1. Fill in the blanks to complete the sentence.
   In a chemical reaction the chemicals that react in a reaction are called _____________ and the chemicals that are formed in a chemical reaction are called _____________
2. MC In what way/s are word equations different from equations in which chemical formulae are used?
   A. Word equations do not have the formulae of the chemicals involved.
   B. Word equations always include the states of the reactants and products.
   C. Numbers are used in word equations, so it is possible to know the numbers of atoms involved.
   D. All of the above.
3. MC How are the states (solid, liquid and gas) indicated in a chemical equation?
   A. The states are not indicated in a chemical equation.
   B. The symbols (s) for solid, (l) for liquid and (g) for gas are placed *after* each reactant and product.
   C. The symbols (1) for solid, (2) for liquid and (3) for gas are placed *before* each reactant and product.
   D. The symbols (s) for solid, (l) for liquid and (g) for gas are placed *before* each reactant and product.
4. MC What is an aqueous solution?
   A. A substance that has melted and formed a liquid
   B. A substance that has been dissolved in hydrochloric acid
   C. A substance that has been dissolved in water
   D. A substance in the form of gas

Apply and analyse

5. Atoms in substances are rearranged after chemical reactions. True or false? Explain.
6. Explain why it is necessary to balance chemical equations.
7. Match each metal given in the table following with its chemical symbol.

Metal	Symbols
i. Sodium	A. Cu
ii. Mercury	B. Na
iii. Magnesium	C. Mg
iv. Copper	D. Hg

Evaluate and create

8. Write a word equation for the reaction that occurs when you eat a sherbet lolly. These sweets commonly contain citric acid $C_6H_8O_7$(aq) and sodium hydrogen carbonate $NaHCO_3$(aq). In the mouth, these chemicals dissolve in your saliva and react together to form sodium citrate solution, carbon dioxide gas and water.
9. Write a word equation and show the rearrangement of atoms by drawing a simple model with spheres for the following.
   a. When carbon monoxide gas and oxygen gas react to form carbon dioxide gas
   b. When sodium hydroxide solution and hydrochloric acid solution react to form sodium chloride solution and water

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

LESSON
7.3 Balancing chemical equations

LEARNING INTENTION

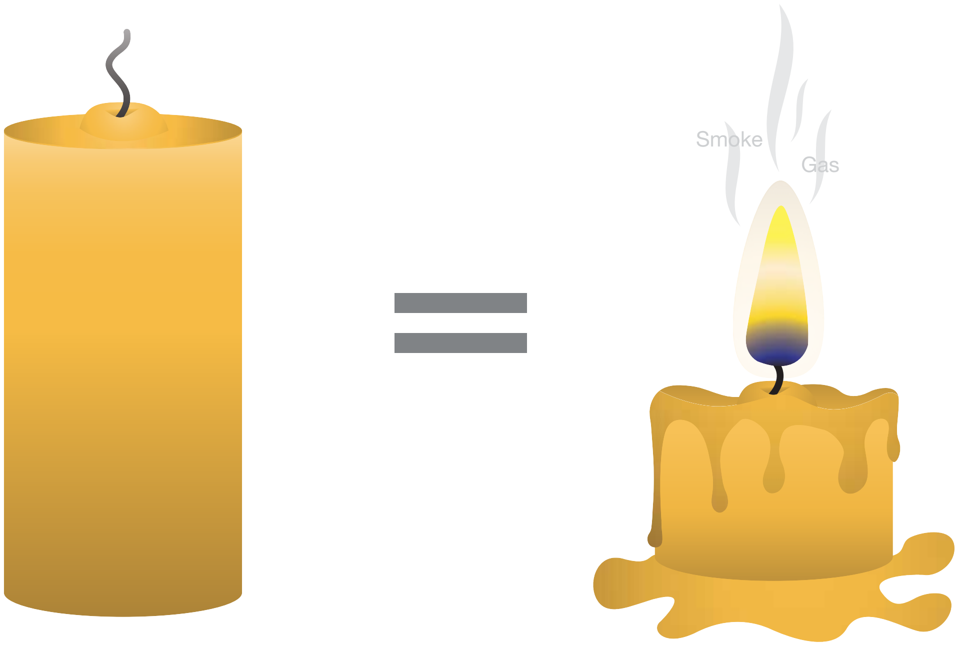
At the end of this lesson you will be able to describe the Law of Conservation of Mass and the Law of Constant Proportion, and balance simple equations.

The idea of atoms rearranging themselves may seem obvious now, but two hundred years ago it was not. It was thought, for example, that when a candle burned the wax simply vanished. In other words, it was thought that matter could disappear.

7.3.1 Conservation of mass

In the eighteenth century, French nobleman Antoine-Laurent Lavoisier showed that although a candle seems to disappear as it burns, there is as much mass present after it has completely burned as there was before. The apparent loss of mass was caused by gases moving into the atmosphere.

FIGURE 7.6 The conservation of mass

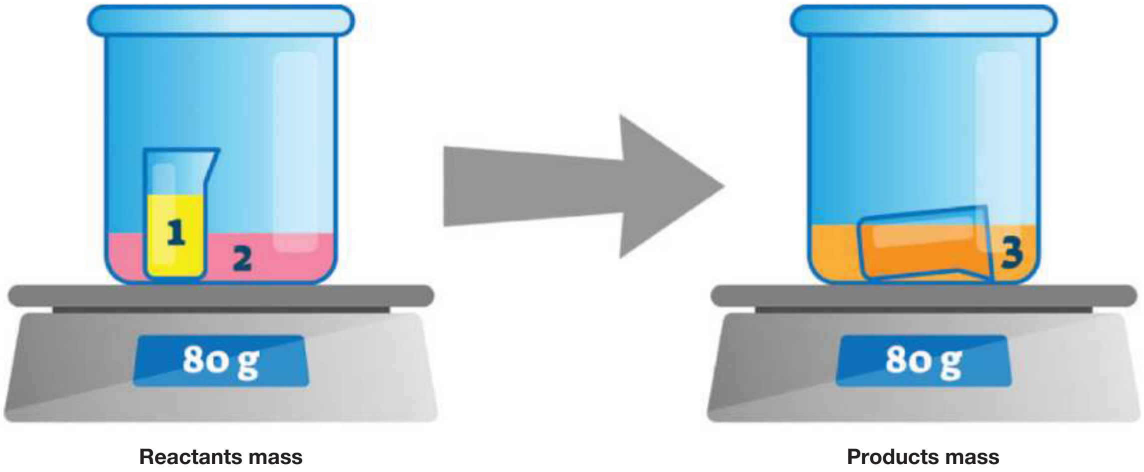


During ordinary chemical reactions or physical changes:
- the mass of the products equals the mass of the reactants
- no matter is lost or gained.

Lavoisier's ideas led to the development of the **Law of Conservation of Mass**, which states that matter can be neither created nor destroyed during a chemical reaction. Figures 7.6 and 7.7 are simple representations of the Law of Conservation of Mass.

Law of Conservation of Mass in a chemical reaction, the total mass of the reactants is the same as the total mass of the products

FIGURE 7.7 The mass of the reactants is the same as the mass of the products.



Lavoisier also provided evidence for the **Law of Constant Proportions**, which states that a compound, no matter how it is formed, always contains the same relative amounts of each element. For example, carbon dioxide (CO_2) always contains the same relative amounts of carbon and oxygen (about 27 per cent of the mass is made up of carbon). It does not matter whether the carbon dioxide forms from the reaction of sherbet in your mouth or from the reaction in the engine of a car, this proportion is fixed because every molecule of CO_2 is formed by the bonding of one carbon atom with two oxygen atoms. This law helped to shape our understanding of the way atoms bond together. In fact, after his unfortunate execution during the French Revolution, Lavoisier became known as the Father of Modern Chemistry.

7.3.2 Open and closed systems

In chemistry a *system* can be thought of as the reaction that is under study. Everything else outside this is called the surroundings or the environment. Such systems are commonly classified in one of two ways:

- A **closed system**, which does not allow the transfer of matter, to or from its surroundings.
- An **open system**, which allows matter to transfer to or from its surroundings.

Whether a system is open or closed can influence the *apparent* loss of mass in some reactions, including some that are familiar from everyday life. The evaporation of liquids is a good example of this.

Evaporation is a result of some molecules having enough kinetic energy to ‘break free’ from the liquid and escape into the gas phase above the surface. Such molecules can then move away and leave the flask as there is nothing to constrain them. This is an example of an open system, where the Law of Conservation of Mass *seems* to not hold true.

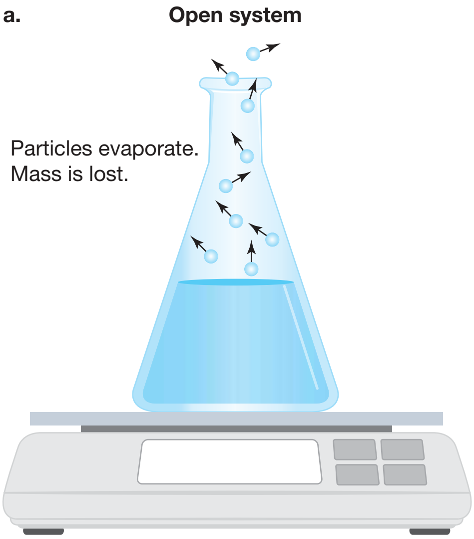
If a stopper is placed in the flask, a different result occurs. This time there is no loss in mass as the molecules, even if they rise above the surface in a gaseous state, cannot escape the flask. This is an example of a closed system, where the Law of Conservation of Mass can be observed.

Law of Constant Proportions in chemical compounds, the ratio of the elements is always the same

closed system a system in which energy, but not matter, can be transferred to and from its surroundings

open system a system in which both energy and matter can be transferred to and from its surroundings

FIGURE 7.8 The resulting mass may be affected by whether it is an **a.** open system or a **b.** closed system.



Open and closed systems

- An open system allows matter to be transferred between itself and its surroundings.
- A closed system does not allow the transfer of mass, between itself and its surroundings.

on Resources

Video eLesson Priestley and the Law of Conservation of Mass (eles-1767)

elog-2323

INVESTIGATION 7.2

Conserving mass

Aim

To compare the mass of the products of a chemical reaction with the mass of its reactants

Materials

- safety glasses
- 250 mL conical flask
- 4 Alka-Seltzer tablets
- 1 balloon
- matches
- an electronic balance
- 100 mL measuring cylinder
- water

Method

CAUTION

Wear safety glasses.

Part A:

1. Place the conical flask on the balance and pour in 100 mL of water.
2. Place two tablets alongside the conical flask and record the total mass.
3. Remove the flask from the balance and drop the tablets into the water.
4. When the reaction is complete, weigh the flask and record the mass.

Part B:

5. Rinse out the flask thoroughly and again add 100 mL of water.
6. Place two tablets inside the balloon. You may need to break the tablets into pieces to do this.
7. Stretch the neck of the balloon over the conical flask, being careful not to drop the tablets into the water. The balloon should be flopped over, resting against the side of the flask.
8. Place the conical flask and balloon onto the balance and record the total mass.
9. Lift up the top of the balloon and drop the tablets into the water in the conical flask.
10. When the reaction is complete, weigh the flask and record the mass. Do not remove the balloon.
11. After you have recorded the mass, remove the balloon. Light a match and test the gas in the conical flask. Record your observations

Results

TABLE Results of Part A, Investigation 7.2

Items weighed	Mass (g)
Mass of conical flask and 100 mL water	
Mass of conical flask, 100 mL water and two antacid tablets before reaction	
Mass of conical flask, 100 mL water and two antacid tablets after reaction	

TABLE Results of Part B, Investigation 7.2

Items weighed	Mass (g)
Mass of conical flask, 100 mL water, balloon and two antacid tablets before reaction	
Mass of conical flask, 100 mL water, balloon and two antacid tablets after reaction	

What did you observe in the gas test with the lit match?

Discussion

1. Which gas do you think filled the balloon and the conical flask?
2. Comment on your results of the total mass before and after each reaction. Explain your answer.
3. Antacid tablets can be taken to relieve indigestion. Why do we sometimes burp after taking antacid tablets?
4. Why do you think it took a long time for the Law of Conservation of Mass to be developed?
5. What improvements would you make to this experiment?

Conclusion

Write a conclusion outlining your findings when you compared the mass of the products with the mass of the reactants in the reaction.

7.3.3 Balancing the scales

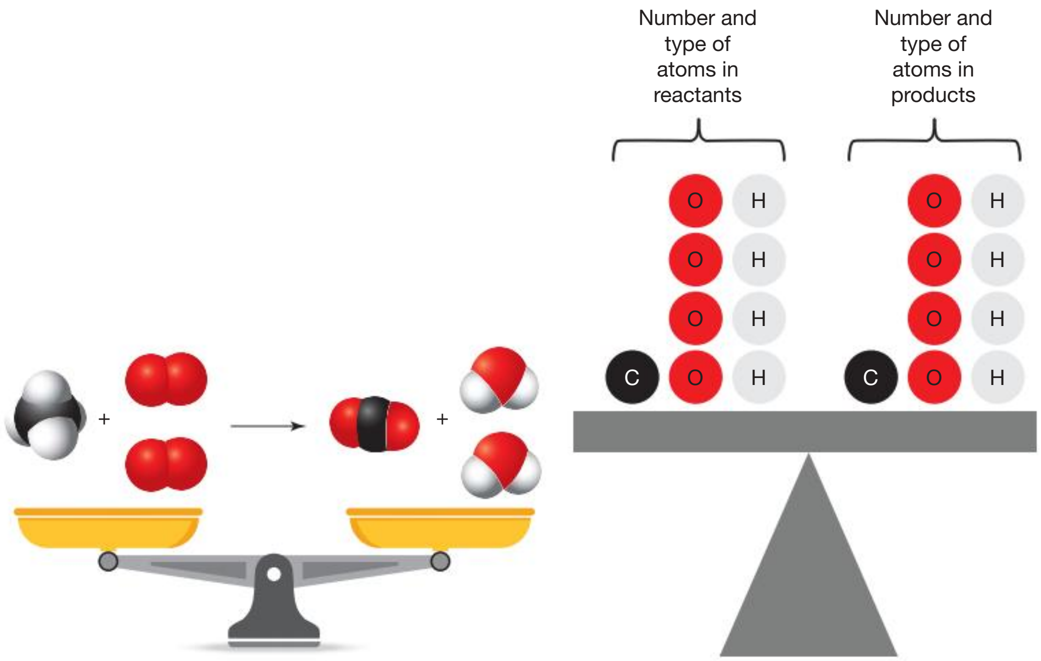
The reaction represented in figure 7.3a is the combustion of methane. This is also shown on the left of figure 7.9, in which methane reacts with oxygen to form water and carbon dioxide. Notice that one molecule of methane, CH_4, consists of one carbon atom joined to four hydrogen atoms, and oxygen is a diatomic molecule containing two atoms of oxygen. The product carbon dioxide has one carbon atom and two oxygen atoms. The other product is water, which has one oxygen atom and two hydrogen atoms.

One methane molecule will make one carbon dioxide molecule, which will use one oxygen molecule. This leaves four hydrogen atoms, which will take one additional molecule of oxygen (containing two oxygen atoms) to form two water molecules.

By counting the number of each type of atom in the reactants and in the products, you can see that nothing is created or destroyed.

Conservation of mass is shown in equations when they are balanced. Balancing the equations means ensuring that the same number of atoms for each element in the reactants is the same as the number of similar atoms present in the products, as illustrated in figure 7.9. No matter has been created or destroyed.

FIGURE 7.9 Illustration of the conservation of mass with the combustion of methane



Note that the chemical formula of a molecule shows the number of each element as subscript just after the symbol for the element, but when two or more molecules are needed to balance the scales the coefficient (number in front) of the formula is changed.

For instance, water has the formula H_2O, which means that there are two hydrogen atoms for every oxygen atom in one molecule. When the equation has a coefficient 2 in front of the H_2O there are two water molecules, which means a total of four hydrogen atoms and two oxygen atoms. You cannot just change the formula of the reactants or products; however, you can adjust how many of these are present in order to balance an equation.

In the case of the combustion of methane:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

7.3.4 Steps to balance a chemical equation

The steps used in balancing equations are described below.

Balancing equations

Step 1: Determine the reactants and products and write a word equation

The products of a reaction must be known from either observation or reliable sources (such as chemists). For example, it is well known that the product of the reaction between hydrogen gas and oxygen gas is water vapour (gas). Use the knowledge of the reactants and products to write a word equation.

$$\text{hydrogen} + \text{oxygen} \longrightarrow \text{water}$$

Step 2: Chemical formulae

You need to know the formulae of all the reactants and products. For example, the:

- formula of hydrogen gas is H_2
- formula of oxygen gas is O_2
- formula of water vapour is H_2O.

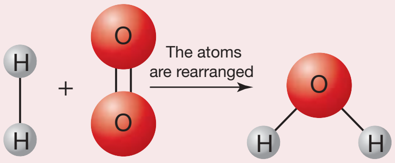
Remember! Because each substance has only one correct chemical formula, it **cannot** be changed by altering the subscript numbers.

Step 3: Write the equation

The formulae must be written according to the word equation, with reactants on the left side of the arrow and products on the right side.

$$H_2 + O_2 \longrightarrow H_2O$$

FIGURE 7.10 Reactants and products



Step 4: Balance the number of atoms

First, make a list of the elements present in the formulae under the heading 'Element', as shown in the following table. Then count up how many atoms of each element are represented by the formulae under the headings 'Reactants' and 'Products'.

Element	Reactants	Products
H	2	2
O	2	1

The law of conservation of mass states that in a chemical reaction mass is neither created nor destroyed, thus there must be the same number and type of atom on each side of the equation.

You can see that there are not enough oxygen atoms on the product side. The only way this can be adjusted is by writing numbers in front of the chemical formulae.

When we write a number **in front** of a formula, it **multiplies all the atoms** in that formula. Let's increase the number of oxygen atoms on the product side by placing a 2 in front of the formula for water.

$$H_2 + O_2 \longrightarrow 2H_2O$$

Recounting the atoms we find:

Element	Reactants	Products
H	2	4
O	2	2

The oxygen atoms are now balanced, but the hydrogen atoms are not. Let's try writing a 2 in front of hydrogen's formula on the reactant side to increase the number of hydrogen atoms.

$$2H_2 + O_2 \longrightarrow 2H_2O$$

Counting the atoms again we find:

Element	Reactants	Products
H	4	4
O	2	2

The numbers of each of the elements are the same on both sides of the equation. The equation is balanced!

Step 5: Include the states

To indicate the physical state of each chemical involved in the reaction, the following symbols are used:

- solid (s)
- liquid (l)
- aqueous (aq)
- gas (g).

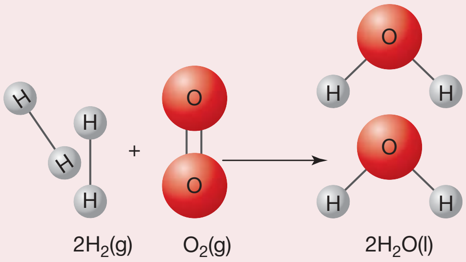
If a word equation, for a reaction in water, uses the words dissolved, dilute or solution then the symbol of state for the symbol equation is (aq).

Write the correct symbol representing the physical state of each reactant and product.

$$2H_2(g) + O_2(g) \longrightarrow 2H_2O(l)$$

The chemical equation is complete.

FIGURE 7.11 Checking reactants and products balance



CASE STUDY: Another example of balancing a chemical equation

When methane gas burns in air, carbon dioxide and water vapour are produced.

Step 1: Determine the reactants and products and write a word equation

The reactants are methane and oxygen and the products are carbon dioxide and water.

As a word equation, this is:

$$\text{methane gas} + \text{oxygen gas} \longrightarrow \text{carbon dioxide} + \text{water vapour}$$

Step 2: Chemical formulae

Determine the formulae for each reactant and product:

- methane gas = CH_4
- oxygen gas = O_2
- carbon dioxide = CO_2
- water vapour = H_2O.

Step 3: Write the equation

Replace the words in the word equation with the formulae:

$$CH_4 + O_2 \longrightarrow CO_2 + H_2O$$

Step 4: Balance the number of atoms

Count the number of atoms of each element for the reactants and products.

Element	Reactants	Products
C	1	1
H	4	2
O	2	3

If the number of atoms of each element is the same on both sides of the equation, the equation is already balanced. If not, numbers need to be placed in front of one or more of the formulae to balance the equation. These numbers are called coefficients and they multiply all of the atoms in the formula.

To balance the hydrogen atoms, put a 2 in front of H_2O:

$$CH_4 + O_2 \longrightarrow CO_2 + 2H_2O$$

The number of carbon and hydrogen atoms are now balanced, but oxygen atoms are not.

Element	Reactants	Products
C	1	1
H	4	4
O	2	4

The oxygen atoms can be balanced by putting a 2 in front of the O_2 on the left:

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

The equation is now balanced. It can be checked by counting the number of atoms of each element on both sides of the new equation.

Element	Reactants	Products
C	1	1
H	4	4
O	4	4

Step 5: Include the states

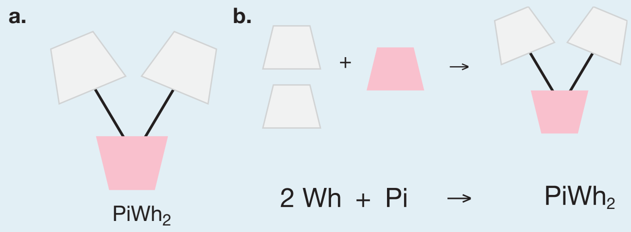
Include the states for each. Ensure that you include water as a gas, because the question specifies water vapour is produced.

$$CH_4\,(g) + 2O_2\,(g) \rightarrow CO_2\,(g) + 2H_2O\,(g)$$

ACTIVITY: Modelling equations

1. Using up to three pink (Pi) and up to three White (Wh) marshmallows as your building blocks, make as many models of different compounds as you can and write the formula for each compound you have created, such as Pi_2, Pi_3, $PiWh_2$, as illustrated in figure 7.12a.
2. Select three different compounds from part 1 and, for each, write out a reaction to produce said compound from the initial marshmallows. For example: Pi + 2Wh → $PiWh_2$, as illustrated in figure 7.12b.

FIGURE 7.12 Modelling a molecule **a.** and a reaction **b.** with marshmallows



on Resources

eWorkbooks	Chemical equations (ewbk-12451) Balancing chemical equations (ewbk-12453) A world of reactions (ewbk-12455)
Interactivity	Balancing chemical equations (int-0677)

7.3 Activities

learnon

7.3 Quick quiz on

7.3 Exercise

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 5, 7	3, 4, 8	2, 6, 9

Remember and understand

1. Fill in the blanks to complete the sentence.
Identify the second product produced by the chemical reaction.
sodium sulfate + barium chloride → barium sulfate + ____________
2. What does the Law of Conservation of Mass state?
3. Fill in the blanks to complete the sentence.
The Law of Constant Proportions states that a compound, no matter how it forms, always contains the ____________ amounts of each element; atoms in compounds always combine in whole number ratios.

Apply and analyse

4. **SIS** A piece of paper is weighed on an accurate balance and then burned, leaving a pile of ashes. The ashes are collected and weighed on the same balance.
   a. Would you expect the mass of the ashes to be the same as the mass of the paper before it was burned?
   b. Explain your answer in terms of the products produced.
5. **SIS** Explain why, when a piece of steel wool burns, the mass of the blackened material is greater than the original mass of the steel wool.
6. Write a balanced chemical equation with the states for the following.
   a. When mercury metal and oxygen gas react to form solid mercury(II) oxide
   b. When magnesium metal and hydrochloric acid solution react to form hydrogen gas and magnesium chloride solution
   c. When sodium metal and water react to form hydrogen gas and sodium hydroxide solution
   d. When copper(II) sulfate solution and sodium hydroxide solution react to form solid copper(II) hydroxide and sodium sulfate solution
   e. When iron metal reacts with oxygen gas to produce solid iron(II) oxide

Evaluate and create

7. **SIS** Read through Investigation 7.2 (you may have already conducted this investigation). Predict the results of the experiment when the balloon is left off the conical flask in Part A of the experiment.
8. Create an instructional flow chart explaining how to balance a chemical equation. Use an example that has not already been covered in this lesson to show this process.
9. Find out more about Antoine-Laurent Lavoisier, his work and why he was killed by guillotine during the French Revolution.

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

LESSON
7.4 Acid and base reactions

LEARNING INTENTION

At the end of this lesson you will be able to describe the features of acids and bases and the role they have in our everyday life.

Chemical reactions involving acids and bases play an important role in our lives. They occur in the kitchen, in the laundry, in the garden, in swimming pools and even inside the body.

7.4.1 Acids

Acids are **corrosive** substances. That means they react with solid substances, 'eating' them away. Acids have a sour taste and some acids, such as the sulfuric acid used in car batteries, are dangerously corrosive. The acids in ant stings and bee stings cause pain. Others, such as the acids in fruits and vinegar, are safe — even pleasant — to taste.

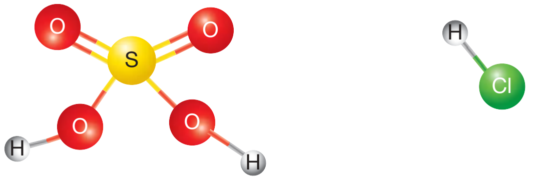
Acids can be strong or weak. Strong acids are able to react to their full extent with other substances, while weak acids do not.

- Strong acids include hydrochloric acid (HCl), sulfuric acid (H_2SO_4) and nitric acid (HNO_3).
- Weak acids include ethanoic acid (CH_3COOH), carbonic acid (H_2CO_3) and phosphoric acid (H_3PO_4).

WHAT DOES IT MEAN?

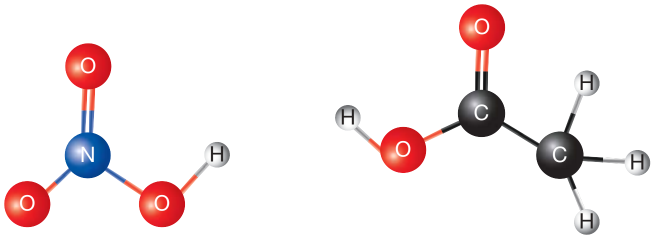
The word *acid* comes from the Latin word ***acidus***, meaning 'sour'.

FIGURE 7.13 The formula and structure of common acids. What do all the acids have in common? One of these acids is a weak acid, can you guess which?



sulfuric acid, H_2SO_4

hydrochloric acid, HCl



nitric acid, HNO_3

ethanoic acid, CH_3COOH

acids	chemicals that react with a base to produce a salt and water; edible acids taste sour
corrosive	a chemical that wears away the surface of substances, especially metals

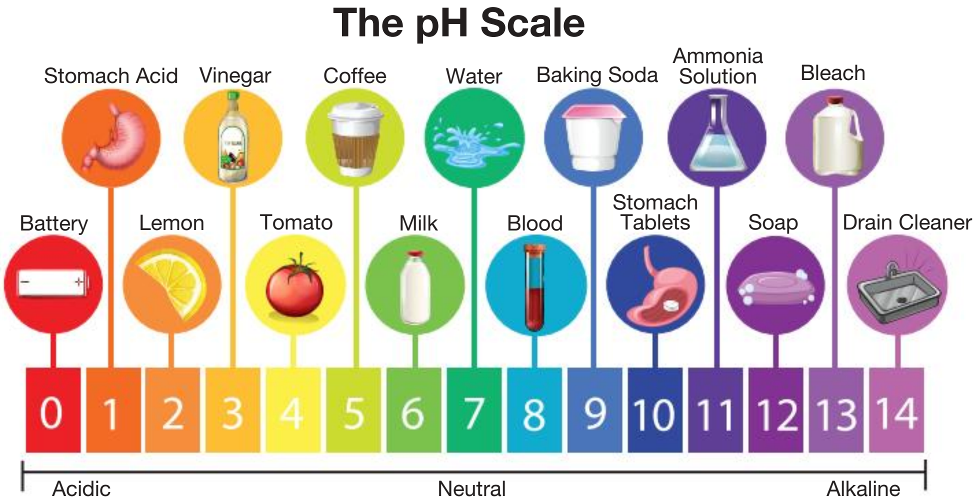
7.4.2 Bases

Bases have a bitter taste and feel slippery or soapy to touch. Some bases are very corrosive, especially caustic soda (sodium hydroxide). Caustic soda will break down fat, hair and vegetable matter and is the main ingredient in drain cleaners. Other bases are used in soap, shampoo, toothpaste, dishwashing liquid and cloudy ammonia as cleaning agents. Bases that can be dissolved in water are called **alkalis**.

Like acids, bases can be strong or weak. Strong bases also are able to react to their full extent with other substances, while weak bases do not. The strength of an acid or base is measured by the **pH scale**, which ranges from 0 to 14. A pH lower than 7 indicates the presence of an acid (the lower the pH, the stronger the acid) while a pH greater than 7 indicates the presence of a base (the greater the pH, the stronger the base). A pH of 7 is neutral.

- Strong bases include potassium hydroxide (KOH), sodium hydroxide (NaOH) and barium hydroxide ($Ba(OH)_2$).
- Weak bases include ammonia (NH_3), calcium carbonate ($CaCO_3$) and sodium carbonate (Na_2CO_3).

FIGURE 7.14 The pH scale is a measure of how acidic or basic (alkaline) a solution is.



ACTIVITY: pH at home

Look at the pH scale and find where weak acids and bases and strong acids and bases are located. Research where cleaning products, such as your shampoo, face cleaners and toothpaste, are located on this scale.

7.4.3 Neutralisation

When an acid and a base react with each other, the products include water and a salt. Such a reaction is called a **neutralisation** reaction. These reactions can be very useful. They can relieve pain caused by indigestion or the stings from wasps, bees and ants. They can be used to change the pH of soil to make it more suitable for growing particular plants. Neutralisation reactions are also used in cooking and to keep swimming pools and spas clean.

To neutralise means to stop something from having an effect. To stop the properties of acids from having an effect, a base can be added to it. Similarly, to stop a base from having an effect, an acid can be added.

bases chemical substances that will react with an acid to produce a salt and water; edible bases taste bitter

alkalis bases that dissolve in water

pH scale the scale from 1 (acidic) to 14 (basic) that measures how acidic or basic a substance is

neutralisation a reaction between an acid and a base. A salt and water (a neutral liquid) are the products of this type of reaction

A neutralisation reaction occurs when an acid and a base react.

The products are water and a salt.

acid + base → water + salt

For example:

hydrochloric acid + sodium hydroxide → water + sodium chloride

$HCl + NaOH \rightarrow H_2O + NaCl$

A neutralisation reaction, also known as a double displacement reaction, is modelled in figure 7.15.

During a neutralisation reaction, the partners from the reactants swap to form the products. AC represents the acid and BD represents the base in this case. When these two combine (swap their partners), the salt AB and water H_2O (CD in the model) are formed.

FIGURE 7.15 Model of a double displacement reaction

Neutralisation in the garden

Neutralisation reactions are used in many situations around the home. A sting from an ant or a bee is very painful as it contains an acid — formic acid (also called methanoic acid). This can be neutralised by a base such as soap or a mixture of water and baking soda. A wasp sting is painful because it contains a base and can be treated by applying an acid such as vinegar. It is important to know what has bitten you so that the correct substance can be used to neutralise the sting.

Some plants grow better in acidic soils, while other plants grow best in basic soils. If a soil is too acidic, it can be neutralised with a base such as lime. The added lime can make the soil less acidic, neutral or basic, depending on how much is added.

If the soil is too basic, ammonium sulfate can be added to the soil. This weak acid salt helps to neutralise the bases in the soil. These neutralisation reactions in your garden can help your plants to grow by providing soil with the most suitable pH.

ACTIVITY: Neutralising wee

It is claimed that the damage caused by pet urine on a garden can be neutralised by compounds such as gypsum. However, this is not exactly true. Research why this is not as simple as some sites suggest. You might like to consider these questions during your research:

- What is the expected pH of urine?
- Is pet urine more acidic or basic compared to human urine?
- What can affect the pH level?
- What is gypsum? Is it a base or an acid?
- What is the effect of gypsum on the soil?

FIGURE 7.16 Urine from pets can leave an unpleasant odour and damage plants and lawns.

TABLE 7.3 Common acids and bases and their uses

Acid	Uses
Hydrochloric acid (HCl)	To clean the surface of iron during its manufacture Food processing The manufacture of other chemicals Oil recovery
Nitric acid (HNO_3)	The manufacture of fertilisers, dyes, drugs and explosives
Sulfuric acid (H_2SO_4)	The manufacture of fertilisers, plastics, paints, drugs, detergents and paper Petroleum refining and metallurgy
Citric acid ($C_6H_8O_7$)	Present in citrus fruits such as oranges and lemons Used in the food industry and the manufacture of some pharmaceuticals
Carbonic acid (H_2CO_3)	Formed when carbon dioxide gas dissolves in water; present in fizzy drinks
Ethanoic acid (CH_3COOH)	Found in vinegar The production of other chemicals, including aspirin
Base	**Uses**
Sodium hydroxide ($NaOH$) (caustic soda)	The manufacture of soap As a cleaning agent
Ammonia (NH_3)	The manufacture of fertilisers and in cleaning agents
Sodium bicarbonate ($NaHCO_3$)	To make cakes rise when they cook

SCIENCE INQUIRY SKILLS: Spills in the laboratory

How are acid or base spills cleaned up in the science laboratory? Find out from your teacher or laboratory technician how spills are dealt with in your school.

It is important to deal with spills quickly and safely. The first thing to do is to let your teacher know if you have spilled any substance. Methods of dealing with spills may include acid or base neutralisers, absorption pads, mops or granules and inactivators. One thing you would not do is to try to neutralise a strong acid with a base as the reaction could be violent and cause further problems.

Indigestion

The hydrochloric acid in your stomach helps to break down the food you eat. It is a very strong acid, with a pH of less than 1.5. But if you eat too quickly, or eat too much of the wrong food, the contents of your stomach become even more acidic. You feel a burning sensation because of the corrosive properties of the acid; this is called indigestion.

To relieve the pain of indigestion, you can take antacid tablets. The active ingredients in antacid tablets are weak bases such as aluminium hydroxide, magnesium carbonate and magnesium hydroxide, which neutralise the acid. The cause of the relief you experience can be described by chemical equations such as:

$$\begin{array}{ccccccccc} \text{hydrochloric acid} & + & \text{aluminium hydroxide} & \rightarrow & \text{aluminium chloride} & + & \text{water} \\ 3HCl & + & Al(OH)_3 & \rightarrow & AlCl_3 & + & 3H_2O \end{array}$$

$$\begin{array}{ccccccccc} \text{hydrochloric acid} & + & \text{magnesium hydroxide} & \rightarrow & \text{magnesium chloride} & + & \text{water} \\ 2HCl & + & Mg(OH)_2 & \rightarrow & MgCl_2 & + & 2H_2O \end{array}$$

$$\begin{array}{ccccccccc}\text{hydrochloric acid} & + & \text{magnesium carbonate} & \rightarrow & \text{magnesium chloride} & + & \text{water} & + & \text{carbon dioxide} \\ 2HCl & + & MgCO_3 & \rightarrow & MgCl_2 & + & H_2O & + & CO_2\end{array}$$

One product of this last reaction is carbon dioxide gas. You burp to get the gas out of your stomach.

Acids and bases in the kitchen

Some foods, such as pickles, chutney and tomato sauce, last a long time without refrigeration because they contain acids that prevent the growth of micro-organisms that would cause them to spoil. Others, such as onions and beetroot, are preserved by storing them in vinegar, which is also known as ethanoic acid. This process of preserving food is called **pickling**.

The base sodium bicarbonate is more commonly known as baking soda. When it reacts with an acid, the products are a salt, water and carbon dioxide. Self-raising flour is a mixture of an acid and baking soda. When water or milk is added to self-raising flour, the acid and base react together. The carbon dioxide produced causes the mixture to rise when it is heated.

Two ingredients in pancakes are buttermilk (an acid) and baking soda. When the two are mixed, a salt, water and carbon dioxide are produced. The bubbles of carbon dioxide get larger as the mixture is heated, causing the mixture to rise.

The reaction between an acid and a carbonate can be described by the following equations:

$$\text{acid} + \text{base} \rightarrow \text{water} + \text{salt} + \text{carbon dioxide}$$

$$\begin{array}{ccccccccc}\text{hydrochloric acid} & + & \text{sodium bicarbonate} & \rightarrow & \text{water} & + & \text{sodium chloride} & + & \text{carbon dioxide} \\ HCl & + & NaHCO_3 & \rightarrow & H_2O & + & NaCl & + & CO_2\end{array}$$

ACTIVITY: Investigating food

Predict the outcomes of increasing the temperature of a pancake or damper mixture by adding a warm liquid to the dry ingredients. Try making pancakes yourself or research a recipe for damper to try at home. Most recipes use self-raising flour, milk or water, salt and butter.

CASE STUDY: Acid–base reactions in sherbert

The fizzy sensation that you get when you eat sherbet is due to an acid–base reaction. The sherbet consists of sodium bicarbonate and citric acid. Both of these substances are in powdered form in the sherbet and do not react with each other. When they dissolve in the saliva of your mouth a reaction takes place, producing carbon dioxide gas, hence the fizzing.

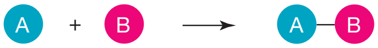
pickling preserving food by storing it in vinegar (ethanoic acid)

Synthesis and decomposition reactions

Soda water, also known as carbonated water, is water that has been infused with carbon dioxide gas under pressure. The main chemical compound responsible for the fizziness in soda water is carbonic acid, which has the chemical formula H_2CO_3. The formation of carbonic acid from carbon dioxide (CO_2) and water (H_2O) is known as a combination or **synthesis reaction**.

Synthesis reactions occur when elements or compounds combine to form a more complex product.

FIGURE 7.17 Model of a synthesis reaction: A + B → AB



A synthesis reaction occurs when carbon dioxide and water form carbonic acid:

$$\begin{array}{ccccc} \text{water} & + & \text{carbon dioxide} & \rightarrow & \text{carbonic acid} \\ H_2O & + & CO_2 & \rightarrow & H_2CO_3 \end{array}$$

The reaction of hydrogen (H_2) and oxygen (O_2) to form water (H_2O), and the reaction of iron (Fe) with oxygen (O_2) to form rust or iron oxide (Fe_2O_3) are other examples of synthesis reactions.

When carbonic acid is exposed to certain conditions, for example when you open a bottle of soda water and release the pressure, it breaks back down into water and carbon dioxide. The carbon dioxide forms the bubbles in the fizzy drink. This is known as a **decomposition reaction**.

synthesis reaction a reaction where two or more chemical species combine to form a more complex product: A + B → AB

decomposition reaction a reaction where one reactant yields two or more products: AB → A + B

Decomposition reactions are the opposite of synthesis reactions, where larger compounds break down into two or more simpler compounds or elements.

FIGURE 7.18 Model of a decomposition reaction: AB → A + B

A decomposition reaction occurs when carbonic acid breaks down into carbon dioxide and water.

$$\begin{array}{ccccc} \text{carbonic acid} & \rightarrow & \text{water} & + & \text{carbon dioxide} \\ H_2CO_3 & \rightarrow & H_2O & + & CO_2 \end{array}$$

Using electricity to split water (H_2O) into hydrogen gas, (H_2) and oxygen gas (O_2) is another example of a decomposition reaction.

Protecting your teeth from corrosive acids

Acids are corrosive. They can dissolve metals, eat away marble statues, destroy the enamel of your teeth and kill bacteria.

Because acids are corrosive, they can be very harmful. Strong acids can burn your skin and eat away clothes. If an acid is spilled on the floor, a basic powder, such as sodium bicarbonate, should be used to neutralise the acid. All spills in the science lab should be reported to your teacher.

Acid can destroy the enamel on your teeth. Teeth are protected by a 2 mm thick layer of enamel made of hydroxyapatite. After a meal, bacteria in the mouth break down some of the food to produce acids such as ethanoic acid and lactic acid. Food with a high sugar content produces the most acid. The acids produced by the bacteria can dissolve the enamel coating of the tooth. Once this protective coating is destroyed, the bacteria can get inside the tooth and cause tooth decay. The best way to prevent this chemical reaction between tooth enamel and acid from happening is to clean and floss your teeth after every meal and avoid eating sugary foods.

elog-2325

tlvd-10805

INVESTIGATION 7.3

Antacids in action

Aim

To investigate the neutralising action of an antacid

Materials

- Petri dish
- electronic balance
- spatula
- antacid powder
- 0.1 M hydrochloric acid
- 250 mL conical flask
- 100 mL measuring cylinder
- methyl orange indicator
- white tile or white paper

Method

1. Measure and record the mass of the Petri dish.
2. Add a small amount of antacid powder to the dish and record the mass of the antacid and Petri dish.
3. Add 50 mL of the dilute hydrochloric acid to the 250 mL flask.
4. Add 3 drops of methyl orange indicator.
5. Place the flask mixture on the white tile (or paper) and use the spatula to slowly add antacid from the Petri dish bit by bit. Swirl the flask to mix. Stop adding antacid when the colour changes from red to orange.
6. Measure and record the mass of the Petri dish and its contents (the unused antacid).

Results

1. What was the mass of the antacid powder?
2. What colour change occurs when the methyl orange indicator is in the acid?
3. By subtraction, calculate the mass of antacid used to neutralise 50 mL of dilute hydrochloric acid.

Discussion

1. How does your result agree with other groups in your class? Suggest reasons for the similarities or differences between your results.
2. Use your results to calculate how much antacid you would need to neutralise 500 mL of dilute hydrochloric acid.

Conclusion

Write a conclusion summarising your results. You may choose to discuss any variations in results across your class.

on Resources

eWorkbook	Acids and bases (ewbk-2325)
Video eLesson	The effects of cola soft drinks on a tooth over a year (eles-2588)
Interactive	pH rainbow (int-0101)

7.4 Activities

learn**on**

7.4 Quick quiz on

7.4 Exercise

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 2, 3, 6, 8, 9, 11, 12	4, 5, 7, 15, 16, 18	10, 13, 14, 17, 19, 20

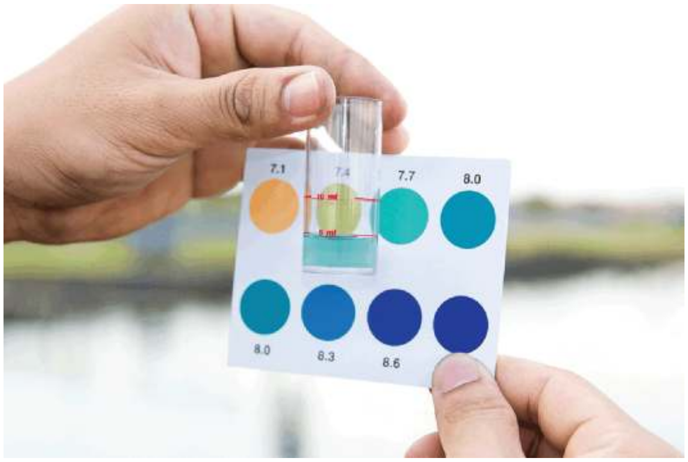
These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS ▶

Remember and understand

1. Recall what a corrosive substance is.
2. **MC** What common property do some acids and bases have when they come into contact with solid substances?
   A. High pH **B.** Low pH **C.** They produce a gas. **D.** They are corrosive.
3. **MC** Select the difference between a base and an alkali.
   A. A base cannot be dissolved in an alkali.
   B. A base can be dissolved in an alkali.
   C. Bases that are dissolved in water are called alkalis.
   D. Bases that cannot be dissolved in water are called alkalis.
4. Fill in the blanks to complete the following sentences.



   a. The substance above has a pH value of ____________ and so it is ____________ .
   b. A substance with a pH less than 7 is ____________.
   c. A substance with a pH equal to 7 is ____________.
5. Explain why the chemical reaction between an acid and a base is called neutralisation.
6. **MC** Identify the substance that is produced in all neutralisation reactions?
   A. Water **B.** Smoke **C.** An acid **D.** A base
7. How does self-raising flour help cakes rise?
8. **MC** Which acid is present in your stomach to help you digest food?
   A. Hydrochloric acid **B.** Chloric acid **C.** Citric acid **D.** Sulfuric acid
9. **MC** Why does soap relieve the pain of an ant sting?
   A. It cleans the bite area.
   B. It neutralises the acidity of the venom.
   C. It neutralises the base in the venom.
   D. It creates an alkali.
10. Explain why foods high in sugar cause so much tooth decay.
11. **MC** A salt + water + ______ gas are formed when hydrochloric acid reacts with sodium bicarbonate.
    A. oxygen **B.** carbon dioxide **C.** carbon monoxide **D.** hydrogen

▶

12. Write word equations for the reactions between:
   a. Hydrochloric acid and sodium hydroxide

hydrochloric acid + ____________ → ____________ + water

   b. Hydrochloric acid and sodium bicarbonate

hydrochloric acid + ____________ → sodium chloride + water + ____________

   c. Sulfuric acid (hydrogen sulfate) and sodium hydroxide

sulfuric acid + ____________ → ____________ + water

Apply and analyse

13. **SIS**
   a. Describe how an antacid tablet relieves the pain of indigestion.
   b. Recall or read Investigation 7.2 in lesson 7.3. Describe how you could change this investigation to model an acid stomach and antacid.
14. **SIS** A pH meter is used to measure the pH of five substances. The results are shown in the table.

TABLE pH of different substances

Substance	pH value
A	6.0
B	12.0
C	3.0
D	7.0
E	8.0

   a. Which substance is most likely to be:
      i. vinegar
      ii. milk?
   b. Which substance could be:
      i. a weak base
      ii. pure water
      iii. a strong base?
   c. Which two of the substances would you expect to be the most corrosive?
15. When you add buttermilk (an acid) to baking soda (a base) in a mixing bowl the pH increases. True or false? Explain your response.
16. Antacid tablets contain a base, which neutralises the excess acid coming from your stomach into your oesophagus and relieves the pain. When you take an antacid tablet, you would expect the pH value in your oesophagus to increase. True or false? Explain your response.

Evaluate and create

17. A stinging-nettle plant may contain an acid that is injected into your skin when you touch it. Construct a flow chart of four steps to describe how you could show that the plant does contain an acid using some of the following options.
   A. If the acid is neutralised
   B. Neutralise with a strong base
   C. The stinging feeling should be replaced by a slight burning sensation
   D. Such as a solution of bicarbonate of soda in water
   E. Such as sodium hydroxide
   F. Neutralise with an alkali.
18. Write a word equation to describe the chemical reaction between hydrochloric acid and calcium carbonate.
19. When a gardener adds lime to a soil that is too acidic, does that increase the pH? Explain.

20. **SIS** Find the websites of two antacid products such as Gaviscon®, Mylanta®, Eno® or Alka-Seltzer®.

a. Research and report on:
  - **i** the ingredients of the product or products
  - **ii** the claims made about each antacid product or products
  - **iii** advice and warnings
  - **iv** side effects.

b. Find a medical site that provides information about antacids, including side effects.

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

LESSON
7.5 Combustion reactions

LEARNING INTENTION

At the end of this lesson you will be able to describe what combustion is and how it is used to provide energy as fuels for our bodies and machines we rely on.

Some of the most spectacular chemical reactions to watch, including fireworks and the launching of spacecraft, are **combustion** reactions.

Combustion reactions are those in which a substance reacts with oxygen and heat is released. Burning is a combustion reaction that produces a flame. The substance that reacts with oxygen in a combustion reaction is called a **fuel**. Many of the fuels we use for transport and heating, such as methane, butane, octane and petrol are called **hydrocarbons**, as they are made of hydrogen and carbon.

The combustion of hydrocarbons can be summarised as:

$$\text{hydrocarbon} + \text{oxygen} \rightarrow \text{carbon dioxide} + \text{water}\,(+\,\text{energy})$$

The word *combustion* comes from the Latin word ***comburere***, meaning 'to burn'.

combustion a chemical reaction when a substance reacts with oxygen and heat is released

fuel a substance that is burned in order to release energy, usually in the form of heat

hydrocarbons compounds containing only hydrogen and carbon atoms

natural gas formed from the remains of plants and animals that died millions of years ago; it is a fossil fuel

methane the smallest hydrocarbon (CH_4), it is the main component of natural gas

7.5.1 Cooking with gas

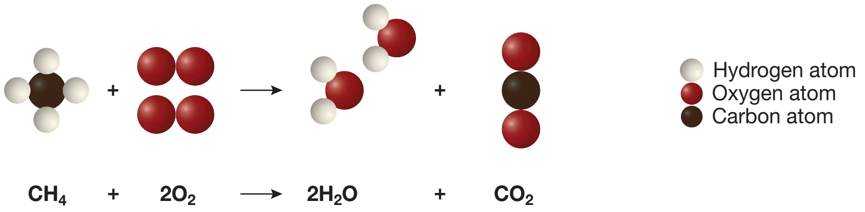
The **natural gas** used in gas stoves and ovens contains **methane**, a colourless, odourless and highly flammable gas. Natural gas formed millions of years ago from the remains of plants and animals and became trapped under rock. Its lack of colour and odour makes it very dangerous if there is a leak, so gas suppliers add chemicals that do have an odour so that the methane can be detected in the event of a leak or if the gas is accidentally left switched on. Methane reacts with oxygen, producing carbon dioxide and water, and it burns with a blue flame. The heat needed to start the reaction is provided by a match, lighter or spark.

FIGURE 7.19 Natural gas contains methane.

The equation for the combustion of methane is:

methane	+	oxygen	→	carbon dioxide	+	water
CH_4	+	$2O_2$	→	CO_2	+	$2H_2O$

FIGURE 7.20 Models showing the combustion of methane reaction



7.5.2 Essential combustion

A chemical reaction called **respiration** takes place in every cell of your body. Respiration is a slow combustion reaction. The energy required by your body is released when the fuel, glucose from your digested food, reacts with oxygen from the air that you breathe. The products of respiration are carbon dioxide, water and energy.

The chemical equation for respiration is:

glucose	+	oxygen	→	carbon dioxide	+	water	+	energy
$C_6H_{12}O_6$	+	$6O_2$	→	$6CO_2$	+	$6H_2O$	+	energy

respiration the process by which glucose is broken down in the presence of oxygen to produce water, carbon dioxide and energy in a form that cells can use; a slow combustion reaction

oxidation a chemical reaction involving the loss of electrons by a substance

7.5.3 Oxidation reactions

Combustion reactions are examples of **oxidation** reactions. However, strangely enough, not all oxidation reactions involve oxygen. Oxidation is now defined as the loss of electrons from a reactant. That is what happens to fuels when they are burned in oxygen. The reaction between copper and a silver nitrate solution is an example of an oxidation reaction that does not involve oxygen. Copper is oxidised when electrons are removed from copper atoms during the reaction that produces silver metal. This type of reaction is now known as an oxidation–reduction reaction, or for short, a redox reaction. The redox reactions you would be most familiar with are the reactions of fireworks exploding.

FIGURE 7.21 Fireworks are examples of explosive redox reactions.

on Resources

eWorkbook	Combustion (ewbk-12459)
Video eLessons	NASA Titan 3e Centaur launches with voyager probes from Cape Canaveral in the morning (eles-2592) Time lapse view of fireworks near Flinders Street Station (eles-2591)

7.5 Activities

learnon

7.5 Quick quiz on

7.5 Exercise

Select your pathway

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

Remember and understand

1. Fill in the blanks to complete the sentence.
   What characteristics do all combustion reactions have in common?
   Fuel reacts with ___________ producing _____________.
2. Fossil fuels are different from other types of fuel because they are formed from the remains of living things. True or false? Explain.
3. How is each of the following combustion reactions started?
   a. The burning of natural gas
   b. The combustion of octane in a car

4. **MC** Identify the products of all complete combustion reactions in which fossil fuels are burned.
   A. Carbon dioxide and oxygen
   B. Carbon dioxide and water
   C. Water vapour and oxygen
   D. Carbon and water
5. **MC** Identify the fuel in the combustion reaction known as respiration.
   A. Glucose
   B. Carbon dioxide
   C. Water
   D. Chlorophyll

Apply and analyse

6. Describe at least two effects on the environment of the combustion of fossil fuels.

7. **MC** Hydrogen and oxygen are cooled to extremely low temperatures so that they can be stored as liquids in the fuel tanks of rockets. Why is water, the product of the reaction, produced as a gas?
   A. The reaction between hydrogen and oxygen is highly exothermic.
   B. The reaction between hydrogen and oxygen is highly endothermic.
   C. So it can escape.
   D. So it can be captured and reused.
8. Respiration is the chemical reaction that takes place in every cell of your body. State two reasons it is classified as a combustion reaction.
9. Write an equation for an oxidation reaction that does not involve oxygen.
10. Find out how kerosene and octane are extracted from crude oil.

Evaluate and create

11. **SIS** Create a poster that shows how the burning of coal is used to generate electricity. Include the chemical equation for the combustion of coal on your poster. Also include information about where the reactants come from and what happens to the products.
12. **SIS** Different fuels produce different amounts of heat. The table shows the amount of heat produced per gram of fuel.

TABLE Heat of combustion for different fuels

Fuel	Heat of combustion (kJ per gram)
Hydrogen	141
Methane	55.6
Butane	49.7
Octane	47.9

   a. Write an equation for the combustion of butane.
   b. Create a bar graph of the information in the table.
   c. Which fuel produces the most heat per gram?

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

LESSON
7.6 Green chemistry

LEARNING INTENTION

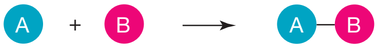
At the end of this lesson you will understand how different types of chemical reactions can be used to reduce the environmental issues involved in the production of some chemicals and understand how some elements are obtained.

Reactions are occurring all around in nature and your own home. It is useful to look for patterns to help understand what is happening. Throughout history, chemists have tried to understand and have learned to manipulate chemicals to produce a useful, wanted product and to reduce unusable and unwanted products. Chemists develop their understanding of what is happening in a reaction to solve real-world problems.

7.6.1 Synthesis of products

As mentioned in lesson 7.3, in synthesis reactions elements or compounds combine to form a more complex product.

FIGURE 7.21 Model of a synthesis reaction: A + B → AB



One very important synthesis reaction is the simple reaction of hydrogen and nitrogen to form ammonia:

$$\begin{array}{ccccc} \text{hydrogen} & + & \text{nitrogen} & \rightarrow & \text{ammonia} \\ 3H_2 & + & N_2 & \rightarrow & 2NH_3 \end{array}$$

This reaction produces the basic building block for ammonium nitrate fertiliser, the most important crop nutrient. Ammonia is produced both by soil bacteria and in industry. Over 50 per cent of the world's food production relies on the manufacturing of ammonia.

However, the industrial production of ammonia produces more carbon dioxide than any other chemical-making reaction. The reason is that the Haber process of making ammonia uses high temperatures and pressures that add up to almost 1 per cent of the world's total energy production, and create approximately 1 per cent of global annual carbon dioxide emissions.

Chemists and engineers around the world are trying to make the reaction more sustainable by using renewable energy or 'green hydrogen'. As well as exploring better ways to supply the energy or reactants for the reaction, chemists are also looking at making the reaction better. It would be a long-term project to synthesise ammonia at low temperatures and pressure. One option being explored is looking at biochemistry, using the enzyme nitrogenase, which does the same reaction but at lower temperature and pressure. The production and applications of green ammonia are represented in figure 7.22.

Another issue with the use of fertiliser is run-off into waterways. This causes blue-green algae bloom and is the main contributor to the outbreaks of crown-of-thorns starfish on the Great Barrier Reef. The juvenile starfish feed on the algae and then move out to the reef and consume the coral (see figure 7.23).

FIGURE 7.22 Green ammonia production and applications

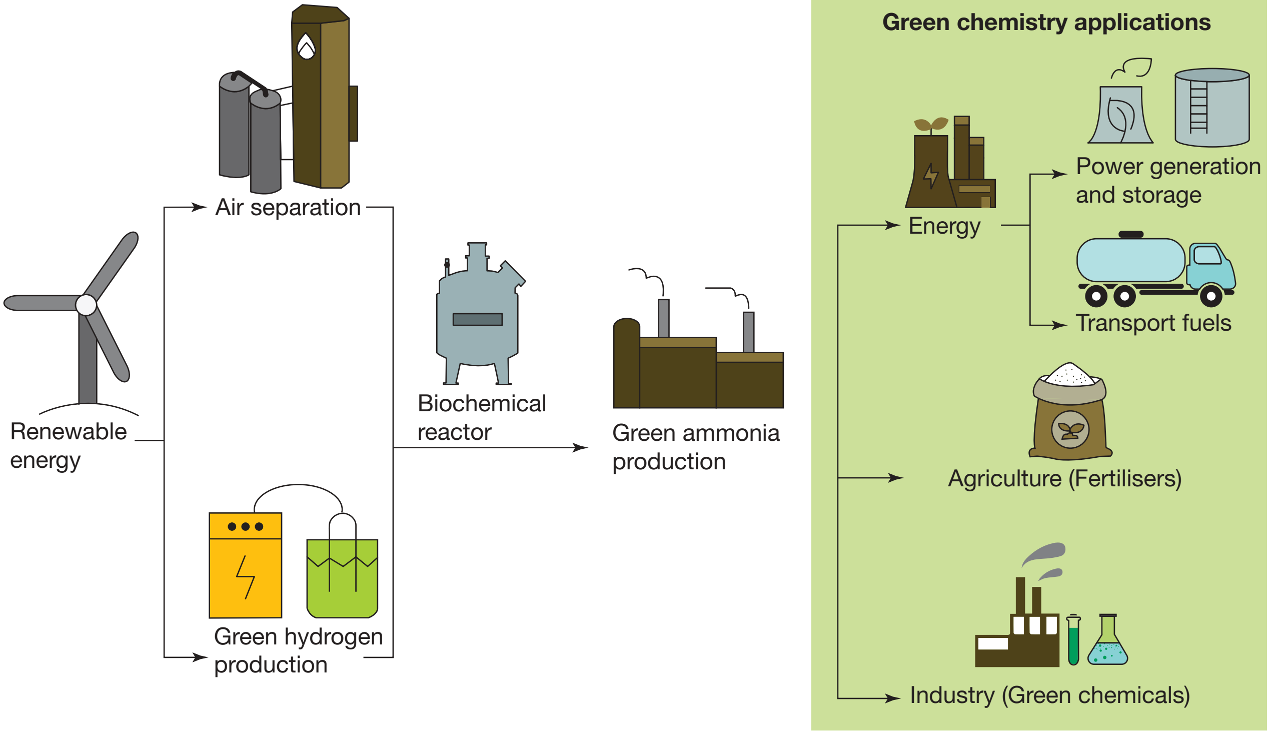
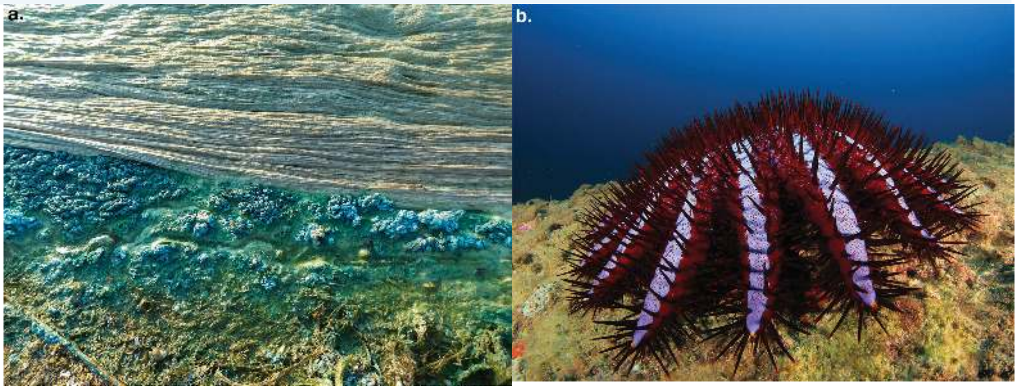


FIGURE 7.23 a. Blue-green algae bloom and **b.** crown-of-thorns starfish eating coral



Another important synthesis reaction is photosynthesis, in which carbon dioxide reacts with oxygen to form glucose and water. It is the reaction that converts light energy into glucose and fuels life on Earth. Research is underway to develop artificial photosynthesis. This may allow a cleaner way to produce hydrogen, or synthesise carbon compounds such as methanol from carbon dioxide. Methanol is a fuel that, if produced this way, would be more sustainable.

7.6.2 Extraction of elements

Elements, particularly metals, are not usually found in their pure form. They are almost always found in compounds such as oxides and chlorides. Gold is an exception because it is so unreactive that it does not react with other elements to form compounds. That’s why nuggets of almost pure gold have been discovered.

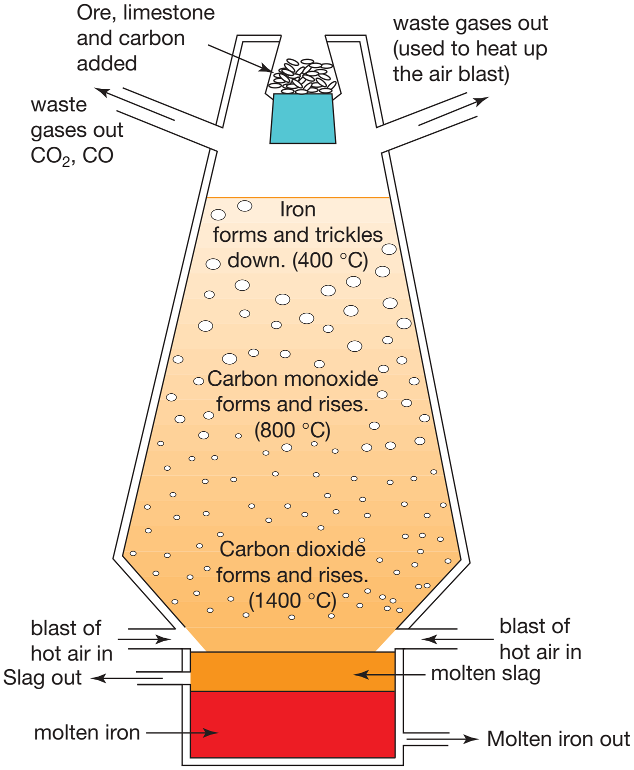
Iron

Useful metals that are not found pure in nature, such as iron and aluminium, require chemical reactions to separate the elemental metal from its ore. For example, haematite is an iron ore, containing iron oxide (Fe_2O_3). Haematite is heated with carbon in a blast furnace at around 1500 °C to separate the iron from the oxygen. Pure iron and carbon dioxide are produced in this reaction.

$$\text{iron oxide} + \text{carbon} \rightarrow \text{iron} + \text{carbon dioxide}$$
$$2Fe_2O_3(s) + 3C(s) \rightarrow 4Fe(l) + 3CO_2(g)$$

Extracting iron from its ore is useful as the iron can then be used to make steel.

FIGURE 7.24 Iron is extracted by breaking down iron oxide to form iron and carbon dioxide.



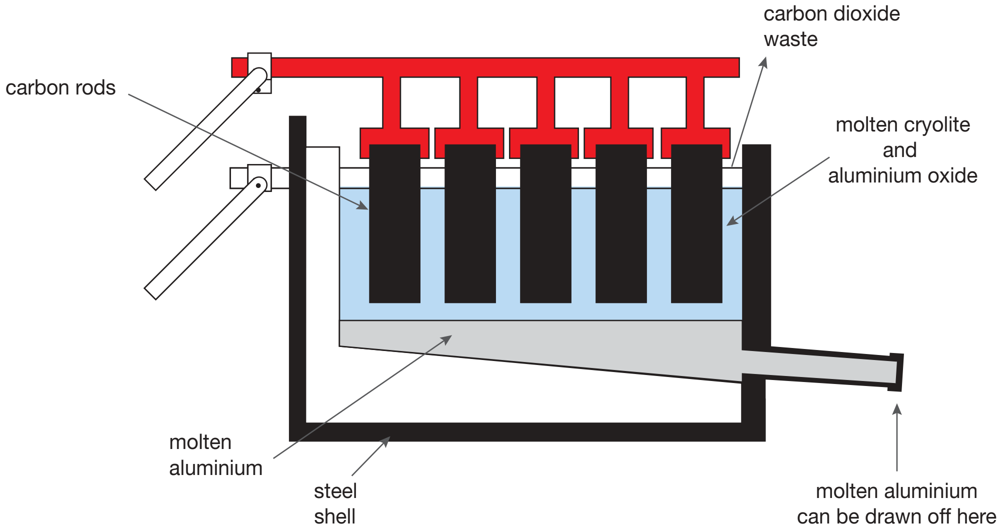
Aluminium

Aluminium is lightweight and has many uses in planes, the space industry, electronics and the canning of soft drinks. It is extracted from bauxite which is heated to around 1000 °C. To extract aluminium, electrical energy is used to force a reaction between aluminium oxide (Al_2O_3) and carbon, forming aluminium and carbon dioxide as a waste product.

$$\text{aluminium oxide} + \text{carbon} \rightarrow \text{aluminium} + \text{carbon dioxide}$$
$$Al_2O_3 + 3C \rightarrow 2Al + 3CO_2$$

This is an expensive process as the refining uses a large amount of electricity. Producing the electricity required for the reaction is also a source of carbon dioxide in the atmosphere.

FIGURE 7.25 The production of aluminum requires large amounts of energy and produces carbon dioxide.



One way to reduce the temperature of the system is to use cryolite (Na_3AlF_6), which is formed when fluoride salts are added — this reduces the temperature at which the bauxite melts to form a liquid. So two undesirable by-products are formed when aluminium is being extracted: carbon dioxide and hydrogen fluoride (HF). Hydrogen fluoride and its salts are poisonous.

The escaped hydrogen fluoride can be recycled, particularly in newer plants. Some plants neutralise the HF by forming a sodium salt, which can be filtered out.

To reduce the energy and consequential release of carbon dioxide into the atmosphere, aluminium products should be recycled as the energy required to do this is significantly less than is required to extract it from the ore. Only about 5 per cent of the energy needed to extract aluminium is used when recycling it! Recycling the aluminum you use is one way you can have a direct impact.

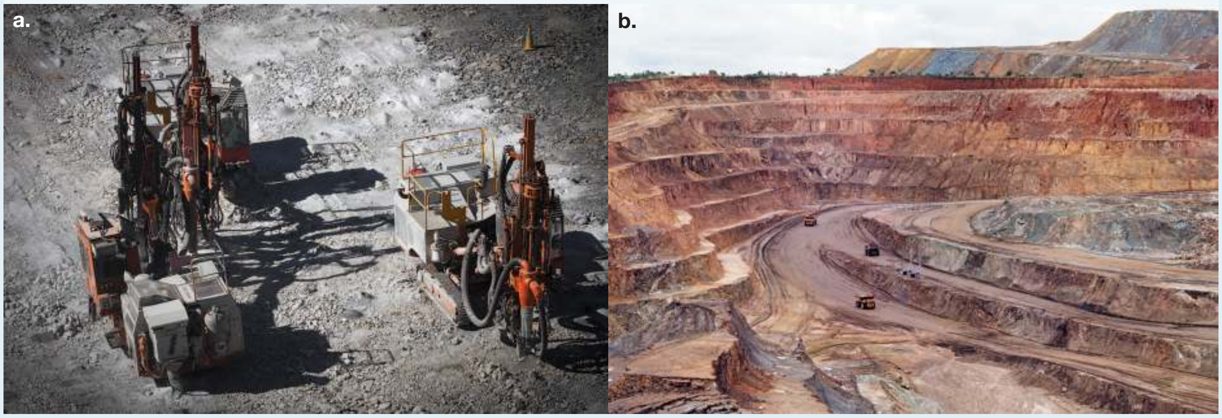
The extraction of metals from ore uses a lot of electricity and energy. And removing the ore from the earth through mining causes damage to the environment. But without the extraction of the reactive metals we would not have chemicals for use in such things as batteries. Batteries are vital to store renewable energy, such as from wind and solar, as we move away from fossil fuels.

ACTIVITY

Nickel, cobalt and lithium are key elements used in today's high performance batteries.

1. Research how these metals are extracted from ore and what the environmental concerns are in their mining and in the manufacturing of this type of battery.
2. Research the recommended ways of disposing of the batteries and whether they can be sent to landfill.
3. Write a short paragraph to summarise your findings.

FIGURE 7.26 a. A lithium mine in Western Australia. In 2021, Australia was the world leader, before Chile and China, in lithium mine production. **b.** A copper mine in the Democratic Republic of Congo (DRC). Cobalt is often a by-product of copper mining. The DRC accounts for more than 70 per cent of the world's entire cobalt production.



7.6.3 Fossil fuels

Fossil fuels such as natural gas, petrol and coal have formed from the remains of living things. They are compounds of hydrogen and carbon called **hydrocarbons**. The products of the combustion of fossil fuels always include carbon dioxide and water. Because of impurities in fossil fuels, other products of their combustion include sulfur- and nitrogen-rich gases. In some cases various dangerous gases, including carbon monoxide, are also produced. Carbon dioxide, methane and nitrous oxide are the main greenhouse gases produced by human activities and make the largest contributions to the **enhanced greenhouse effect** and climate change.

EXTENSION ACTIVITY: Incomplete combustion

If not enough oxygen is supplied to a combustion reaction, then incomplete combustion can occur. This creates different products apart from the carbon dioxide and water, including carbon monoxide and particles of carbon commonly called soot. Carbon monoxide is very dangerous as it is colourless, odourless and can cause you to become unconscious very quickly. This is why it is important to have a well-ventilated space when combustion is occurring, to allow oxygen in and carbon monoxide out.

A Bunsen burner can be used to show the results of incomplete combustion, if a heat mat or test tube is held over the flame. The least efficient flame can produce black soot. Predict which flame will produce incomplete combustion, the yellow flame or the blue flame? Test your prediction. Consider the combustion reaction for methane shown in the next section, and try to write a chemical equation showing the incomplete combustion of methane, which produced carbon monoxide (CO).

7.6.4 Acid rain

What causes acid rain?

Every year, **acid rain** causes hundreds of millions of dollars worth of damage to buildings and statues.

The photographs in figure 7.27 show the damage that has been caused to a statue over sixty years. Forests, crops and lakes are also affected by acid rain that is blown in from industrial areas.

Rain is normally slightly acidic. As clouds form and rain falls, the water reacts with carbon dioxide in the atmosphere to form very weak carbonic acid.

$$\text{water} + \text{carbon dioxide} \rightarrow \text{carbonic acid}$$

$$H_2O + CO_2 \rightarrow H_2CO_3$$

fossil fuels substances, such as coal, oil and natural gas, that have formed from the remains of ancient organisms; they can be burned to produce heat

hydrocarbons compounds containing only hydrogen and carbon atoms

enhanced greenhouse effect the additional heating of the atmosphere due to the presence of increased amounts of carbon dioxide, methane and other gases produced by human activity

acid rain rainwater, snow or fog that contains dissolved chemicals, such as sulfur dioxide, that make it acidic

FIGURE 7.27 These photographs were taken in 1908 (left) and 1969 (right). You can see the damaging effects of acid rain on this statue.

If concentrations of sulfur dioxide and nitrogen oxide are high in the atmosphere, these gases react with the water in the atmosphere to produce sulfurous acid, sulfuric acid, nitric acid and other acids.

$$\begin{array}{ccccc} \text{water} & + & \text{sulfur dioxide} & \rightarrow & \text{sulfurous acid} \\ H_2O & + & SO_2 & \rightarrow & H_2SO_3 \end{array}$$

$$\begin{array}{ccccccccc} \text{oxygen} & + & \text{sulfur dioxide} & \rightarrow & \text{sulfur trioxide} & + & \text{water} & \rightarrow & \text{sulfuric acid} \\ O_2 & + & SO_2 & \rightarrow & 2SO_3 & + & H_2O & \rightarrow & H_2SO_4 \end{array}$$

$$\begin{array}{ccccccc} \text{water} & + & \text{nitrogen dioxide} & \rightarrow & \text{nitric acid} & + & \text{nitrogen monoxide} \\ H_2O & + & 3NO_2 & \rightarrow & HNO_3 & + & NO \end{array}$$

When this rain falls, it is far more acidic than it would normally be and is known as acid rain. If the acid rain falls as snow, acid snow can build up on mountains. When this snow melts, huge amounts of acid are released in a short period.

Where do the gases come from?

Most of the gases that cause acid rain come from the burning of fossil fuels (natural gas, oil and coal) in industry, power stations, the home and cars. Fossil fuels contain sulfur in varying amounts, and when sulfur is burned in air, it forms sulfur dioxide. Nitrogen dioxide also causes acid rain and it is produced by industry and every vehicle or machine driven by an internal combustion engine. North America, China, India and Europe have a greater problem with acid rain because of the use of coal with a higher sulfur content than Australian coal, and higher population densities. The sulfur dioxide released by volcanoes also contributes to acid rain.

Damage caused by acid rain

Acid rain damages the cells on the surface of leaves and affects the flow of water through plants. It also makes plants more likely to be damaged by frosts, fungi and diseases. The acid rain collects in streams, rivers and lakes, making the waterways more acidic. A healthy lake has a pH of about 6.5 and fish, plants and insects can live in it. Acid rain causes the pH of the lake to fall. Some aquatic plants and animals cannot tolerate these acidic conditions and die. It is not only the acidic water that can kill the aquatic life. Acid rain reacts with soil, releasing minerals, which may contain elements such as aluminium. The aluminium is washed into streams, rivers and lakes and poisons the aquatic plants and animals.

When acid rain eats into buildings and statues, it is reacting with calcium carbonate in the marble or limestone, as shown in this generalised reaction.

$$\begin{array}{ccccccccc} \text{calcium carbonate} & + & \text{acid rain} & \rightarrow & \text{gypsum} & + & \text{water} & + & \text{carbon dioxide} \\ CaCO_3 & + & H_2SO_4 & \rightarrow & CaSO_4 & + & H_2O & + & CO_2 \end{array}$$

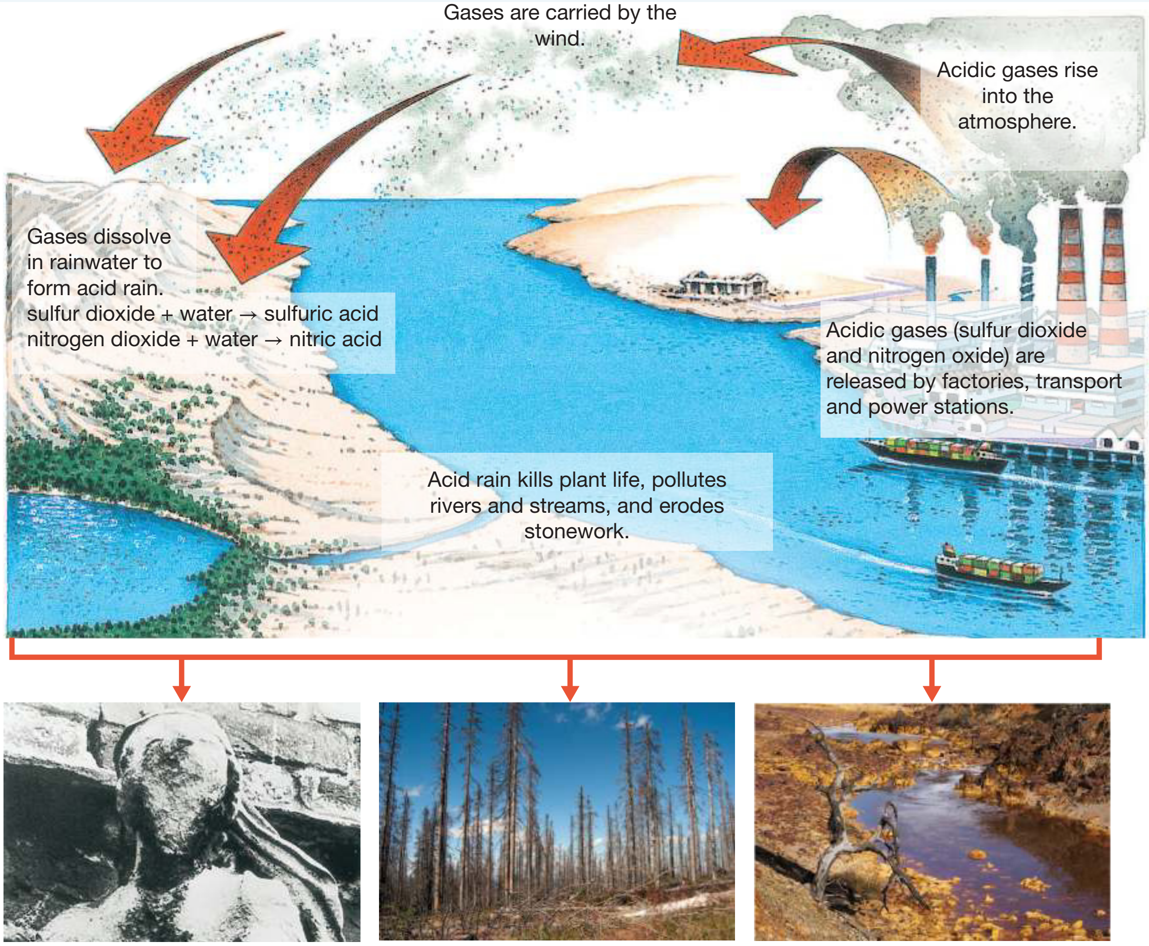
You may recognise this as an acid–base reaction, with the base (calcium carbonate) reacting with acid to produce a salt (gypsum), water and carbon dioxide.

The gypsum formed by acid rain on a statue is a powdery dust (calcium sulfate), which is washed away by the rain. As this chemical reaction continues, the statue is slowly eaten away.

on Resources

Video eLesson	The rain is burning! (eles-0065) Limestone reacting with hydrochloric acid (eles-2590)
eWorkbook	Acid rain (ewbk-12461)

FIGURE 7.28 The damage caused by acid rain



When acid rain eats into buildings and statues, it is reaching with calcium carbonate in the marble or limestone.
Calcium carbonate + acid rain → gypsum + water + carbon dioxide

Acid rain damages the cells on the surface of leaves and affects the flow of water through plants. It also makes plants more likely to be damaged by frosts, fungi and diseases. In northern Europe, entire forests have died as a result of acid rain.

Acid rain collects in streams, rivers and lakes, making the water more acidic. Acid rain causes the pH lakes to fall. Some aquatic plants and animals cannot tolerate these acidic conditions and die.

elog-2327

INVESTIGATION 7.4

Investigating acid rain

Aim

To investigate the effect of pH of acidic water on the growth of seeds

Materials

- empty milk cartons
- potting soil
- distilled water
- measuring cylinder
- vinegar (or 0.1 M hydrochloric acid solution)
- seeds (for example, lucerne, peas, cress, beans)
- universal indicator

Method

1. Cut the milk cartons so that they are about 10 cm high. These will make suitable containers for growing the seeds. Use 5 seeds per container.
2. Design an experiment to test the effect of water with different pH values on the growth of the seeds. To ensure that your tests are fair, you will need to keep everything the same in your experiment, except the one thing that you are varying. In this case you are varying the level of acidity (pH) of the water that you are putting on the plants.

Discussion

Prepare a report on your investigation. This could be a written report, a video, a wall chart or an oral presentation.

7.6.5 Reducing the environmental impact of acids

The problem of acid rain and all the damage that it causes can be solved only by reducing the release of acidic gases into the air. Some ways of doing this include:

- looking for alternative ways of producing electricity
- encouraging people to use public transport, to car pool or change to electric vehicles
- setting air quality standards.

Since the US *Clean Air Act* was amended in 1990, sulfur dioxide emissions decreased by 88 per cent between 1990 and 2017 in the US. Nitrogen dioxide emissions were down 50 per cent over the same period.

The decrease in sulfur dioxide emissions in coal burning power stations is due largely to scrubbers that are fitted to the exhaust flues. These remove the hot gases and react them with chemicals, sometimes similar to limestone (calcium carbonate) to remove the sulfur dioxide. In recent years, the move towards renewable energy and away from coal-fired power stations has made significant improvements to the levels of acid rain in Australia.

7.6.6 Reducing the environmental impact of fossil fuels

The simplest way to reduce the environmental effects of using fossil fuels is to reduce the amount of fuel used. Switching to green energy, such as solar or wind, rather than the inefficient use of coal to generate electricity is one way. Reducing the use of electrical energy by turning off appliances or selecting more energy-efficient ones is another option.

Another method is the use of biofuels. Biofuels are more sustainable as they are sourced from plants or waste oil. They too have some concerns, as crops that could be used as food are being directed to biodiesel. The concerns around the production of palm oil to make biodiesel are due to the destruction of the native habitat of orangutans and other wildlife to make way for palm trees.

Transport and electricity

The fuel used in most Australian cars is liquid **octane**. This is the major component of petrol, usually between 85 per cent and 95 per cent — other fuels make up the remainder. One of these fuels is ethanol, which is similar to octane but has fewer carbon atoms. The ethanol content of a fuel is sometimes displayed as E10, which means the fuel contains 10 per cent ethanol. Octane is obtained from **crude oil** which, like natural gas, is formed from the remains of marine plants and animals that died million of years ago. The vapour of liquid octane reacts with oxygen, producing carbon dioxide and water. The reaction is started in each cylinder of a car by a spark from a spark plug. Only 30–35 per cent of the energy released during the reaction is used to turn the wheels of the car.

octane a hydrocarbon with eight carbon atoms, it is the major component of petrol (C_8H_{18})

crude oil liquid formed from the remains of marine plants and animals that died millions of years ago—a fossil fuel. Many other fuel products are obtained from crude oil

EXTENSION: Why is ethanol added to fuel?

Ethanol belongs to the group of compounds known as alcohols. It has the chemical formula C_2H_5OH. It is an alcohol because it contains an oxygen atom and a hydrogen atom joined together in what is called a hydroxyl group (-OH). Ethanol is added to fuel as it reduces the pollution emitted and contributes fewer greenhouse gases. The presence of oxygen in the ethanol assists the complete combustion of the petrol; this reduces the emissions of poisonous carbon monoxide (CO) and other pollutants. Another environmental advantage of using ethanol is that it can be produced from waste products of sugar production.

FIGURE 7.29 Ethanol is added to most unleaded fuel in Australia and is known as E10 fuel.

The equation for the combustion of octane is:

$$\text{octane} + \text{oxygen} \rightarrow \text{carbon dioxide} + \text{water}$$

$$2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$$

The fuel used in jet aircrafts is **kerosene**, which is obtained from crude oil. Kerosene is a mixture of hydrocarbons and so does not have a single chemical formula. It contains between 12 and 15 carbon atoms. Like the octane in cars, the vapour of this fossil fuel reacts with oxygen and combusts to produce carbon dioxide and water. An electrical spark is used to start the reaction.

In 2019, about 76 per cent of Australia’s electricity was generated by the burning of fossil fuels, largely coal. The energy released during the combustion reaction is used to heat water to produce steam. The steam turns the blades of giant turbines, transforming its energy into electrical energy. Details of this process are discussed in topic 10.

Hydrogen fuel

The energy to launch spacecraft is provided by a combustion reaction. The main rocket engines are fuelled by hydrogen, which reacts with oxygen in an exothermic reaction that releases enough energy to lift more than two million kilograms off the ground towards outer space. The only product of the reaction is water. Hydrogen fuel is a very clean energy source as it produces no carbon emissions. However, it is expensive to develop and hydrogen is difficult to transport safety. Technological developments for hydrogen as a fuel are occurring rapidly, with some countries using hydrogen fuel for their mass transport, such as buses.

The chemical equation for the combustion of hydrogen is:

$$\text{hydrogen} + \text{oxygen} \rightarrow \text{water}$$

$$2H_2 + O_2 \rightarrow 2H_2O$$

kerosene fuel used in jet aircraft

CASE STUDY: Hydrogen-fuelled space travel

The US space program has used hydrogen fuel cells for all of their missions to space.

The Space Shuttle consumed nearly 3 million litres of liquefied hydrogen gas on each mission. On the International Space Station, hydrogen is created by splitting water into oxygen for breathing and hydrogen for fuel. In the future, hydrogen will be further recycled by recombining it with exhaled carbon dioxide to create water and methane. Hydrogen generation and recycling in space will reduce the need for supplies to be delivered from Earth and may bring us closer to a trip to Mars.

FIGURE 7.30 Cargo rocket delivering supplies to the ISS

ACTIVITY: Carbon dioxide in space

- Research Apollo 13 and find out what problem they had with carbon dioxide that risked the life of three astronauts.
- Research NASA to find out how they are recycling the carbon dioxide and water in the current International Space Station and find some information about their plans to go to Mars.
- Discuss how carbon dioxide levels are a problem on Earth as well as in space.

Plastics

Fossil fuels are also used to produce plastics. Plastics were originally developed to use up a waste product, ethylene, created by the fuel industry, to make better use of this chemical found in crude oil. But this has exploded to the production of many different plastics. One reason they are used so widely is that they are lightweight and take less energy to transport compared to glass or metal containers. Plastics are cheap and very versatile; for instance, they can provide stretch and breathability in clothing.

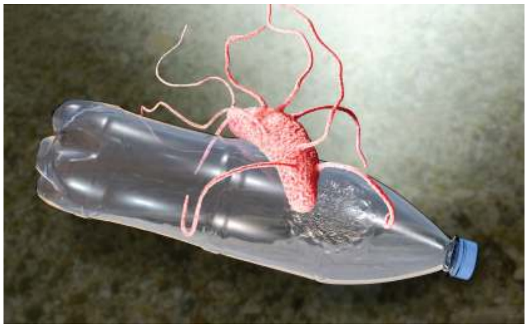
There are many issues with plastic waste due to the sheer amount of plastics being produced and thrown away. Approximately 80 per cent of plastic ends up in landfill or in the environment, such as in rivers and oceans. Chemicals added to plastics can leach into the environment. Plastics do not decompose but they can break down into small pieces called microplastics. While microplastics may not be as visible, they have been detected in marine organisms and in drinking water.

Reducing and reusing all plastics would be one way to address this. Single-use plastics such as cups or straws are one of the main sources of plastics in the environment. Thus, finding an alternative (bamboo cups, for instance) would also help.

One alternative is biodegradable plastic, which is based on natural polymers rather than fossil fuel-based ones. Over time, biodegradable plastics would be broken down into water, carbon dioxide and compost by microbes in the soil. The aim of the chemists developing these bioplastics is for them to have similarly useful properties as synthetic plastics.

Scientists are discovering that some microbes are evolving to degrade plastic. The bacterium *Ideonella sakaiensis* can consume the plastic polyethylene terephthalate (PET), which is used for bottles and clothing.

FIGURE 7.31 *Ideonella sakaiensis* is a bacterium capable of rapidly degrading polyethylene terephthalate (PET), a plastic widely used in the manufacture of packaging and containers.



7.6 Activities

learnon

7.6 Quick quiz on

7.6 Exercise

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 3, 7	2, 4, 5, 8	5, 9, 10

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. **MC** What gas is present in the air that makes rain slightly acidic even without air pollution?
   A. Carbon dioxide **B.** Nitrogen **C.** Oxygen **D.** Hydrochloric acid
2. Fill in the blanks to complete the following sentence.
   Acid rain is rain that has a ____________ than normal level of acidity. It occurs when ____________ and nitrogen oxides react with water in the atmosphere to form sulfuric, nitric and other acids. When rain forms it contains these acids, thus making acid rain.

3. Fill in the blanks to complete the following sentences.
   Acid rain harms plants by damaging the __________ on the surface of the leaves, interfering with water flow in the plant. This also makes plants more susceptible to __________. Acid rain can also make the acid level in streams very __________, and this can kill plants and animals that live in streams. As the acid rain runs off the soil it can also cause other substances, such as aluminium, to be released from __________. These substances can be __________ to plant and animal life in streams.
4. Complete this word equation:

   __________ + calcium carbonate → gypsum + water + __________

5. **MC** Which three of the substances below could be the product of an incomplete combustion reaction?
   A. Carbon **B.** Carbon dioxide **C.** Carbon monoxide
   D. Sulfur **E.** Sulfur dioxide **F.** Nitrogen

Apply and analyse

6. Motor vehicles make a large contribution to the acid rain problem. Most of them use fuel that releases acidic nitrogen oxides when it is burned. Write an account of some ways in which motor vehicle pollution could be reduced over the next thirty years.
7. **SIS** Design a wall chart that would explain how acid rain is formed and the damage that it can cause.

Evaluate and create

8. Find out some of the ways that damage caused by acid rain could be stopped or at least reduced.
9. Complete some research on the polymers LDPE and HDPE. Why are they said to be 'carbon-based'?
10. Find out what biopolymers are and compare and contrast them to common plastics.

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

LESSON
7.7 Thinking tools — Matrices and plus, minus, interesting charts

7.7.1 Tell me

What is a matrix?

A matrix is a very useful thinking tool that can assist you to identify similarities and differences between topics. They are sometime called tables, grids or a decision chart.

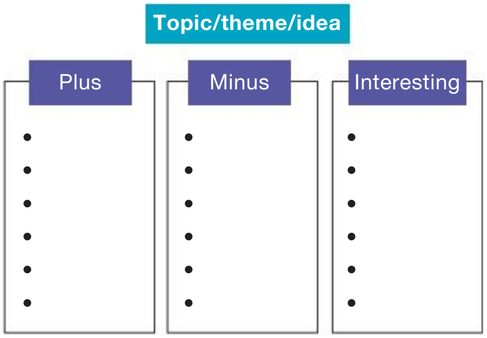
Why use a matrix instead of a PMI chart?

Similar to a matrix, a plus, minus, interesting chart (PMI) can be used to examine the key features of a topic and can help you to make a decision. However, PMI charts look at positive (plus), negative (minus) and interesting aspects of something. Matrices can have a broader application.

FIGURE 7.32 A matrix

Topic	Feature A	Feature B	Feature C	Feature D	Feature E
1	✓		✓	✓	✓
2		✓			✓
3		✓		✓	✓
4			✓	✓	✓

FIGURE 7.33 A PMI chart



7.7.2 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.

Figure 7.34 shows a matrix comparing energy of various devices.

FIGURE 7.34 Matrix comparing energy of different devices

Object or device	Light energy	Thermal energy	Electical energy
Torch	✓	✓	✓
Portable stove	✓	✓	
Instant icepack		✓	

7.7.3 Let me do it

7.7 Activities

1. Complete the matrix.

Statement	Combustion	Decomposition	Neutralisation	Synthesis
Chemical bonds are always broken.				
New chemical bonds are formed.				
The number of reactants = number of products.				
The number of atoms in the reactants = number of atoms in the product.				
A salt is always produced.				
A salt is always produced if a metal was the reactant.				
Water is always produced.				
A new substance is produced.				
One reactant is always an acid.				
One reactant is always an element.				
One product is most likely an element.				

2. Create your own PMI chart on the green chemistry topic of producing ammonia using the diagram below as a starting point.

Topic/theme/idea

Plus	Minus	Interesting
• Ammonia used as fertiliser for crops • • • • •	• Produces more carbon dioxide than the production of any other chemical • • • • •	• Fish excrete ammonia • • • •

3. Create your own PMI on the use of fossil fuels or the extraction of elements.

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

LESSON
7.8 Project — *ChemQuiz*

Scenario

Australians young and old love a good quiz show. Whether it's *Hard Quiz* or *The Chase,* programs with a quiz show format rate consistently well. While the idea of watching someone answer questions seems like an odd form of entertainment, psychologists theorise that the popularity of these programs arises from a combination of a desire to learn new information and a form of competition — after all, who hasn't watched a quiz show and yelled the answers at the screen? In recent educational studies, the use of quiz game formats as a teaching tool in the classroom is gaining support.

The Brain Mine is a company that specialises in educational resources for use in Science classrooms. On the basis of these educational studies of quiz games, they have decided that they would like to add a computer-based chemistry quiz show that teachers could purchase and run in their classrooms as a fun and effective way of improving student knowledge. As product developers at the Brain Mine, it is up to you and your team to make this happen! You are going to develop *ChemQuiz*, a chemistry-based quiz show in which the class teacher will act as the show host, groups of students will be the contestants and the questions (which pop up on a computer screen so that the contestants can see them) are based on chemistry skills.

Your task

Using PowerPoint, you will create a series of question screens for a quiz show that should run for about ten minutes. For each question screen, the host must be able to reveal the correct response after a contestant has given their answer. The question screens should be entertaining and eye-catching, and should also be easily readable by the contestants and the host (who will read the questions out as they appear).

You will need to give a demonstration of your *ChemQuiz* show with one of your group acting as the host (the role that would normally be taken by the teacher). The host will need to explain the rules of the quiz show at the start. The contestants will be your fellow students (preferably not those in your group, who will already know the answers).

on Resources

ProjectsPLUS ChemQuiz! (pro-0107)

LESSON
7.9 Review

Hey students! Now that it's time to revise this topic, go online to:

Review your results

Watch teacher-led videos

Practise questions with immediate feedback

Find all this and MORE in jacPLUS

on Resources

Access your topic review eWorkbooks

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-12463	ewbk-12465	ewbk-12467

7.9.1 Summary

Rearranging atoms and molecules

- Chemical reactions take place when the bonds between atoms are broken and new bonds are formed creating a new arrangement of atoms and at least one new substance.
- Chemical reactions can be represented by models; these help show the arrangements of the atoms in the molecule or compound.
- Chemical reactions can be representing by worded equations and simple chemical equations.
- Reactants in chemical reactions are written on the left-hand side of an equation and products are written on the right.
- To help to understand chemical reactions they are often categorised under types such as acid base reactions, neutralisation, displacement, synthesis, combustion, oxidation, decomposition, as well as exothermic or endothermic.

Balancing chemical equations

- The Law of Conservation of Mass states that matter can neither be created nor destroyed.
- The Law of Constant Proportions states that a compound, no matter how it is formed, always contains the same relative amounts of each element.
- Chemical equations use formulae to show how atoms in a reaction rearrange to form new products.
- Chemical equations should always be balanced with the same number of type of atom in the reactants and the products.
- Only coefficients may be altered to balance a chemical equation, not the chemical formulae.

Acid and base reactions

- Acids are corrosive substances and have a pH below 7.
- Bases are corrosive substances and have a pH above 7. Bases that can be dissolved in water are called alkalis.
- The pH scale ranges from 0 to 14. A pH of 7 is neutral.
- A neutralisation reaction occurs when an acid and a base react with each other; the products include water and a salt.
- Indigestion is an excess of hydrochloric acid in the stomach, which can be neutralised by an antacid.

Combustion reactions

- Combustion reactions occur when a fuel burns in oxygen gas to produce heat, water vapour and carbon dioxide.
- Fossil fuels such as octane are obtained from crude oil.
- Respiration is a type of combustion reaction involving glucose and oxygen to produce carbon dioxide and water.
- Combustion reactions are examples of oxidation reactions that involve the exchange of electrons.

Green chemistry

- Chemistry produces or synthesises a wide range of different products for use in society, usually requiring energy and often producing unwanted by-products and effects.
- Excessive sulfur dioxide and nitrogen oxide from industry react with the water in the atmosphere to produce sulfuric, nitric and other acids, which fall to the ground as acid rain.
- By understanding the reactions, it is possible to minimise energy used and waste produced, develop new processes for producing the desired products, or consider alternative solutions.

7.9.2 Key terms

acid rain rainwater, snow or fog that contains dissolved chemicals, such as sulfur dioxide, that make it acidic

acids chemicals that react with a base to produce a salt and water; edible acids taste sour

alkalis bases that dissolve in water

aqueous solutions mixtures in which substances are dissolved in water

bases chemical substances that will react with an acid to produce a salt and water; edible bases taste bitter

closed system a system in which energy, but not matter, can be transferred to and from its surroundings

combustion a chemical reaction when a substance reacts with oxygen and heat is released

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

crude oil liquid formed from the remains of marine plants and animals that died millions of years ago—a fossil fuel. Many other fuel products are obtained from crude oil

decomposition reaction a reaction where one reactant yields two or more products: $AB \rightarrow A + B$

diatomic molecules substance containing two atoms only

enhanced greenhouse effect the additional heating of the atmosphere due to the presence of increased amounts of carbon dioxide, methane and other gases produced by human activity

equation statement describing a chemical reaction, with the reactants on the left and the products on the right separated by an arrow

fossil fuels substances, such as coal, oil and natural gas, that have formed from the remains of ancient organisms; they can be burned to produce heat

fuel a substance that is burned in order to release energy, usually in the form of heat

hydrocarbons compounds containing only hydrogen and carbon atoms

kerosene fuel used in jet aircraft

Law of Conservation of Mass in a chemical reaction, the total mass of the reactants is the same as the total mass of the products

Law of Constant Proportions in chemical compounds, the ratio of the elements is always the same

methane the smallest hydrocarbon (CH_4), it is the main component of natural gas

molecule group of atoms bonded together covalently

natural gas formed from the remains of plants and animals that died millions of years ago; it is a fossil fuel

neutralisation a reaction between an acid and a base. A salt and water (a neutral liquid) are the products of this type of reaction

octane a hydrocarbon with eight carbon atoms, it is the major component of petrol (C_8H_{18})

open system a system in which both energy and matter can be transferred to and from its surroundings

oxidation a chemical reaction involving the loss of electrons by a substance

pH scale the scale from 1 (acidic) to 14 (basic) that measures how acidic or basic a substance is

pickling preserving food by storing it in vinegar (ethanoic acid)

products chemical substances that result from a chemical reaction

reactants the original substances present in a chemical reaction

respiration the process by which glucose is broken down in the presence of oxygen to produce water, carbon dioxide and energy in a form that cells can use; a slow combustion reaction

respiration the process by which glucose is broken down in the presence of oxygen to produce water, carbon dioxide and energy in a form that cells can use

synthesis reaction a reaction where two or more chemical species combine to form a more complex product: A + B → AB

on Resources

eWorkbooks	Study checklist (ewbk-12469) eWorkbook Reflection (ewbk-12476) Literacy builder (ewbk-12470) Crossword (ewbk-12472) Word search (ewbk-12474)
Solutions	Topic 7 Solutions (sol-1140)
Practical investigation eLogbook	Topic 7 Practical investigation eLogbook (elog-2319)
Digital document	Topic 7 Key terms glossary (doc-40142)

7.9 Activities

learnon

7.9 Review questions

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 2, 4, 8, 9	3, 7, 10, 12, 14	5, 6, 11, 13, 15

Remember and understand

1. A particular chemical reaction can be described by the word equation:

hydrochloric acid + magnesium carbonate → magnesium chloride + water + carbon dioxide

a. MC Select the two reactants in this chemical reaction.
A. Hydrochloric acid
B. Magnesium chloride
C. Water
D. Magnesium carbonate
E. Carbon dioxide

b. MC Select all the products of the reaction.
A. Hydrochloric acid
B. Magnesium chloride
C. Water
D. Magnesium carbonate
E. Carbon dioxide

c. MC Identify from which compound did the atoms present in the carbon dioxide come?
A. Hydrochloric acid
B. Magnesium chloride
C. Water
D. Magnesium carbonate
E. Carbon dioxide

d. This is an exothermic reaction, so the reactants have more energy stored in their chemical bonds than the products. True or false? Explain.

2. MC What observable evidence demonstrates that a chemical reaction has taken place?
A. The apparent disappearance of a substance
B. The appearance of a new substance
C. A release of energy (often heating the surroundings noticeably)
D. Absorption of energy (cooling the surroundings)
E. All of the above

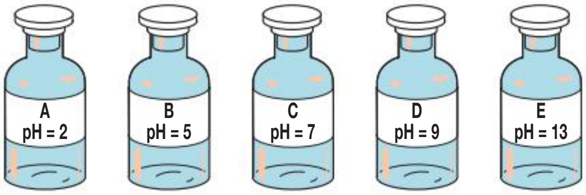
3. Use the Law of Conservation of Mass to explain why it is incorrect to say that when a candle burns it disappears.

4. Fill in the blank to complete the sentence.
The Law of Constant Proportions states that a compound always contains ____________ relative amounts of each element.

5. **MC** Nitrogen reacts with hydrogen to form ammonia.
   I. This is a synthesis reaction that over 50% of the world's food production relies upon.
   II. This process produces more carbon dioxide than any other synthesis reaction.
   III. Forming ammonia from decomposing organisms is being investigated as an alternative.
   IV. As ammonia is a natural product there are no concerns with excess production.
   Which of the following statements are correct?
   A. I only
   B. I and II
   C. II and III
   D. III and IV only.

Apply and analyse

6. The liquids in the bottles below are labelled with their pH. Which of the bottles is most likely to contain:



   a. distilled water
   b. a strong acid
   c. black coffee
   d. bathroom surface cleaner?

7. Predict the salts that would result from the neutralisation reaction between:
   a. Magnesium oxide and hydrochloric acid
   b. Copper (II) oxide and sulfuric acid
   c. Sodium hydroxide and ethanoic acid
   d. Sodium oxide and nitric acid

8. **MC** If the water in a swimming pool has a pH that is too high for hygienic and safe swimming, which type of pool chemical should be added?
   A. An acid
   B. A base
   C. Water
   D. Carbon dioxide

9. Complete the following chemical word equation:

$$\text{acid} + \text{metal} \rightarrow \_\_\_\_\_\_\_\_\_\_\_\_ + \text{hydrogen}$$

10. There are at least two reactants in every combustion reaction. One of them is called a fuel.
    a. With what substance does the fuel react?
    b. Identify one product of every combustion reaction.
    c. One product of combustion reactions is not a chemical. What is it?

11. **MC** Identify two chemical products of combustion reactions in which fossil fuels are burned.
    A. Carbon dioxide and hydrogen
    B. Carbon dioxide and water
    C. Water and hydrogen
    D. Hydrogen and energy

12. Identify the main reactant in each of the following fuels in combustion reactions.
    - a. Natural gas
    - b. Petrol
    - c. Jet aircraft fuel
13. One combustion reaction takes place in every cell of your body.
    - a. State the name of this combustion reaction.
    - b. Identify the reactants in the reaction.
    - c. Identify two chemical products of the reaction.
    - d. Write the chemical equation for this reaction.

Evaluate and create

14. Worded equations, balanced equations and modelling reactions are three different ways to represent chemical reactions.
    - a. What is the advantage of each method and why are different ones used at different times?
    - b. Which one shows the conservation of mass the best?
    - c. Demonstrate your understanding by researching a common reaction in your body or around your home and showing it in the three different ways.
15. Describe the extraction of elements such as aluminium and iron.
    - a. In what ways are they similar and how are they different?
    - b. What are the environmental effects of the extractions?
    - c. What is a simple solution you can do to reduce these effects?

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

Online Resources

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-12446)
- Student learning matrix (ewbk-12448)
- Starter activity (ewbk-12449)

Solutions
- Topic 7 Solutions (sol-1140)

Practical investigation eLogbooks
- Topic 7 Practical investigation eLogbook (elog-2319)
- Investigation 7.1: Cleaning up with baking soda and vinegar (elog-2321)

Video eLesson
- Chemical reactions (eles-4172)

7.3 Balancing chemical equations

eWorkbook
- Chemical equations (ewbk-12451)
- Balancing chemical equations (ewbk-12453)
- A world of reactions (ewbk-12455)

Practical investigation eLogbook
- Investigation 7.2: Conserving mass (elog-2323)

Video eLesson
- Priestley and the Law of Conservation of Mass (eles-1767)

Interactivity
- Balancing chemical equations (int-0677)

7.4 Acid and base reactions

eWorkbook
- Acids and bases (ewbk-12457)

Practical investigation eLogbooks
- Investigation 7.3: Antacids in action (elog-2325)

Teacher-led video
- Investigation 7.3: Antacids in action (tlvd-10805)

Video eLessons
- The effects of cola soft drinks on a tooth over a year (eles-2588)

Interactivity
- pH rainbow (int-0101)

7.5 Combustion reactions

eWorkbook
- Combustion (ewbk-12459)

Video eLessons
- NASA Titan 3e Centaur launches with voyager probes from Cape Canaveral in the morning (eles-2592)
- Time lapse view of fireworks near Flinders Street Station (eles-2591)

7.6 Green chemistry

eWorkbook
- Acid rain (ewbk-12461)

Practical investigation eLogbooks
- Investigation 7.4: Investigating acid rain (elog-2327)

Video eLessons
- The rain is burning! (eles-0065)
- Limestone reacting with hydrochloric acid (eles-2590)

7.8 Project — *ChemQuiz*

ProjectsPLUS
- ChemQuiz! (pro-0107)

7.9 Review

eWorkbooks
- Topic review Level 1 (ewbk-12463)
- Topic review Level 2 (ewbk-12465)
- Topic review Level 3 (ewbk-12467)
- Study checklist (ewbk-12469)
- Literacy builder (ewbk-12470)
- Crossword (ewbk-12472)
- Word search (ewbk-12474)
- Reflection (ewbk-12476)

Digital document
- Topic 7 Key terms glossary (doc-40142)

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

8 Global systems

CONTENT DESCRIPTION

Represent the carbon cycle and examine how key processes including combustion, photosynthesis and respiration rely on interactions between Earth's spheres (the geosphere, biosphere, hydrosphere and atmosphere) (AC9S9U03)

Source: F–10 Australian Curriculum 9.0 (2024–2029) extracts © Australian Curriculum, Assessment and Reporting Authority; reproduced by permission.

LESSON SEQUENCE

SCIENCE INQUIRY AND INVESTIGATIONS

Science inquiry is a central component of Science curriculum. Investigations, supported by a **Practical investigation eLogbook** and **teacher-led videos**, are included in this topic to provide opportunities to build Science inquiry skills through undertaking investigations and communicating findings.

LESSON
8.1 Overview

First Nations Australian readers are advised that this lesson and relevant resources may contain images of and references to people who have died.

8.1.1 Introduction

The number of predicted mobile phone users in the world in 2023 is approximately 6.8 billion people! Are mobile phones harmful to the environment or not? If you answered no to this question, you may need to consider the **carbon footprint** during the making, using and recycling of mobile phones.

carbon footprint a measure of the amount of greenhouse gases (mainly carbon dioxide) that are released into the atmosphere

FIGURE 8.1 Mobile phones are commonly used.

Electricity is required to make the handsets from rare metals, when extracting the metals from Earth's crust, when purifying the metals, when transporting components and in packaging. Electricity is required when you recharge your mobile phone. In Australia, most electricity is sourced from burning coal. When coal is burnt completely, carbon dioxide (CO_2) and water vapour (H_2O) are produced. Per year, the amount of carbon dioxide produced from manufacturing and using mobile phones is approximately 80 kilograms. For each user, about 19 kilograms of carbon dioxide is produced via text messages, phone calls and charging per year. Just imagine if you multiplied the total mass of carbon dioxide by 6.8 billion.

You can also expect the number of mobile phone users to increase in future years, because mobile phones are fast replacing telephone lines. There is an increasing need to use mobile phones to pay for things, to listen to music, to video chat with friends, to use online platforms such as Facebook, TikTok and Twitter, and for many other activities. Mobile phones are very versatile and are indispensable.

Many people are unaware that carbon dioxide is produced when using any electrical device. How can we use our scientific knowledge and understanding to reduce the amount of carbon dioxide released into the atmosphere now, rather than in 30 years' time?

on Resources

Video eLesson Climate change protests (eles-4175)

Watch this video to observe part of the Strike for Climate rally in 2019, as more individuals push for change in order to protect the environment.

8.1.2 Think about global systems

1. What are three animal species affected by climate change?
2. Why is it a problem if the global amount of carbon dioxide continues to increase?
3. Why is it becoming more difficult for tourists to visit Kakadu National Park?
4. Is the atmosphere the same as the biosphere?
5. What is a carbon footprint?
6. What is cultural burning?

8.1.3 Science inquiry

Can you fight fire with fire?

Before 2019, Australian scientists calculated net-zero carbon emissions was achievable. However, in only a short period of time during the 2019–2020 bushfire season, about 350 million tonnes of carbon dioxide were released into the atmosphere. In comparison, 530 million tonnes of carbon dioxide were released throughout the whole year in 2017. Scientists have noted that the significant increase in carbon dioxide emissions in the Australian summer of 2019–2020 was due to high temperature bushfires — since carbon dioxide gas is produced when trees burn.

FIGURE 8.2 Unburnt and burnt vegetation using cultural burning

Over many generations, First Nations Australians have used fire to manage the environment by slowly burning patches of land. This fire management approach is known as **cultural burning** or **firestick farming**. First Nations Australians often use small fires, lit in a mosaic pattern during particular seasons, so that the burns can be controlled and minimise risk to people, animals and the land. This technique of cultural burning reduces the amount of bushfires during summer and helps to lower the amount of carbon dioxide emissions. View the **Cultural burning** fact sheet in the weblinks before answering the following questions.

Questioning and understanding

1. a. What are the main differences between bushfires and cultural burning?
   b. Identify the evidence that supports why scientists are concerned about bushfires.
   c. How does cultural burning reduce carbon dioxide emissions?
   d. Identify the effects of bushfires on **biodiversity**.
   e. Watch the video in the weblink, **Fighting fire with fire**. What are the conditions for a cool or cultural burn?

cultural burning a fire management technique used by First Nations Australians to burn patches of low-lying vegetation or grass, leaving some parts unburnt and some parts burnt

firestick farming another term for cultural burning or cool burning

biodiversity total variety of living things on Earth

Planning and conducting

2. a. Describe the fieldwork and laboratory work that a scientist would need to conduct to measure the amount of smoke and carbon dioxide emitted from a plot of grass or vegetation. Explain why it is essential for the scientist to conduct their work during different times of the year.
   b. To reduce future carbon dioxide emissions, scientists need to work with First Nations Australians. What information needs to be shared between both groups to ensure successful cultural burning practices?

Analysing and evaluating

3. a. Identify the evidence that suggests that First Nations Australians have been using cultural burning for thousands of years.
   b. Construct a table regarding the benefits and issues regarding bushfires and cultural burning.

Communicating

4. a. Watch the videos in the weblinks, **Three things I know about fire management** and **How to conduct a cool burn**. Create a set of educational cards to describe and share the importance of cool burning. You may like to draw related pictures on the back of your cards.
   b. Share your educational cards with the rest of the class.

on Resources

Solutions	Topic 8 Solutions (sol-1142)
eWorkbooks	Topic 8 eWorkbook (ewbk-12534) Starter activity (ewbk-12536) Student learning matrix (ewbk-12538)
Video eLesson	Climate change protests (eles-4175)
Practical investigation eLogbook	Topic 8 Practical investigation eLogbook (elog-2343)
Weblinks	Cultural burning Fighting fire with fire Three things I know about fire management How to conduct a cool burn

LESSON
8.2 Global systems

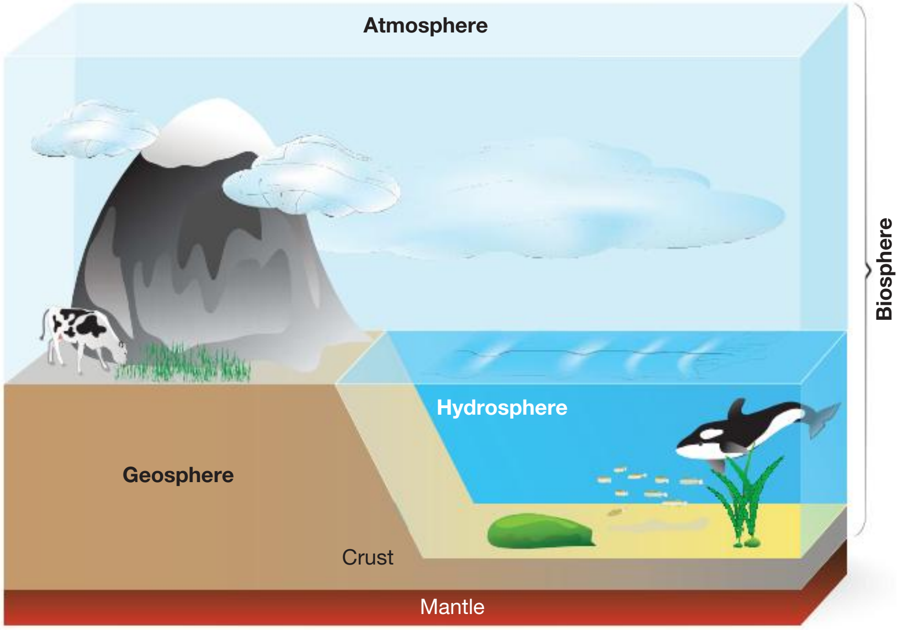
LEARNING INTENTION

At the end of this lesson you will be able to describe how the biosphere supports all life on Earth, and describe the processes that causes carbon to be cycled to and from the atmosphere

8.2.1 Introducing Earth's global systems

Earth is made up of a number of interconnected systems. Four of these are considered to be global systems. These are the **biosphere**, the **atmosphere**, the **hydrosphere** and the **geosphere** (also called the **lithosphere**). Interactions occur between all of these spheres with each other and the radiant energy of the Sun.

FIGURE 8.3 Diagram showing the relationship between the biosphere, atmosphere, lithosphere and hydrosphere



biosphere the layer in which all living organisms (biota) exist, containing the atmosphere, geosphere and hydrosphere

atmosphere the layer of gases (such as nitrogen, oxygen, methane and carbon dioxide) around Earth

hydrosphere includes all the water above, on, and under Earth's surface such as the oceans, seas, lakes and rivers

geosphere comprises of Earth's outer crust and upper most part of the mantle and includes soil and rocks; also lithosphere

The atmosphere is the layer of gases (such as nitrogen, oxygen, methane and carbon dioxide) around Earth. The hydrosphere includes the water above, on, and under Earth's surface such as the oceans, seas, lakes and rivers. The geosphere or lithosphere comprises of Earth's outer crust and upper most part of the mantle and includes soil and rocks. The biosphere includes all living things (**biota**) and all of the ecosystems on Earth. The biosphere extends down to the deepest oceans and beyond, where roots and microoganisms survive, and includes all the airspace where life exists too; thus, the biosphere overlaps the atmosphere, hydrosphere and geosphere.

Within these ecosystems, nutrients and materials are cycled continuously including carbon, nitrogen, phosphorus and water. This topic focuses on the carbon cycle and the role carbon dioxide plays in the **greenhouse effect** and its direct link to **global warming**.

EXTENSION: Where did these words come from?

The names for the different spheres within the biospherehave a Greek root. Theycome from the words *atmos* ('vapour'), *hydro* ('water'), *lithos* ('stone') and *sphaîra* ('globe' or 'ball'). These combine to make:

- atmosphere — vapour globe
- hydrosphere — water globe
- lithosphere — stone globe.

biota the living things within a region or geological period

greenhouse effect a natural effect of Earth's atmosphere trapping heat from the Sun, mainly by carbon dioxide, resulting in warmer temperatures

global warming increase in the surface temperature above Earth

photosynthesis the process by which phototrophic organisms (such as plants) use light energy, carbon dioxide and water to make glucose and oxygen

respiration the process where glucose is broken down in the presence of oxygen to produce carbon dioxide, water and a form of energy that cells can use; also cellular respiration

combustion a chemical reaction where a fuel reacts rapidly with oxygen to produce heat energy, carbon dioxide and water

phototrophic an organism that obtains energy from sunlight via photosynthesis

8.2.2 The carbon cycle and interactions between Earth's spheres

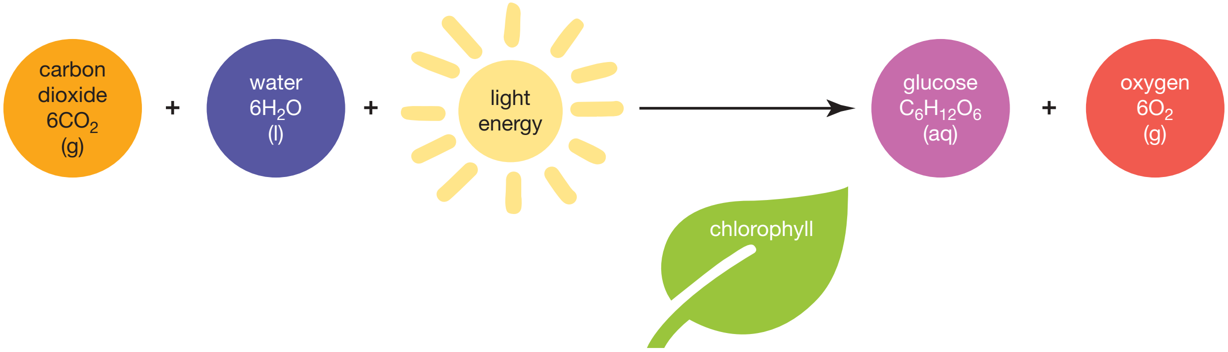
Carbon is everywhere

Carbon is present in various forms on Earth. To understand how carbon is constantly cycled, it is essential to understand where it is located on Earth and how it is removed and returned into the atmosphere. It can be found in the hydrosphere as dissolved carbon dioxide; in the geosphere as coal or oil deposits and rocks such as limestone; in the atmosphere as methane or carbon dioxide; and in living things (biota) as proteins, carbohydrates, fats and DNA. Carbon cycles through Earth's spheres via processes such as **photosynthesis**, **respiration** and **combustion**, which absorb and release carbon dioxide (CO_2).

Photosynthesis

Photosynthesis is the process by which plants (and other **phototrophic** organisms such as algae) take in carbon dioxide (CO_2) and water and use light energy to make glucose ($C_6H_{12}O_6$) and oxygen (O_2).

FIGURE 8.4 The process of photosynthesis



Respiration

Respiration (also cellular respiration) is the process by which stored glucose is converted into a form of energy that cells can use. In this reaction, glucose ($C_6H_{12}O_6$) is broken down in the presence of oxygen (O_2) and both carbon dioxide (CO_2) and water (H_2O) are produced.

FIGURE 8.5 The process of cellular respiration

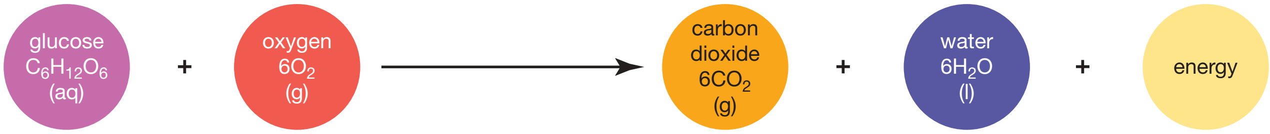
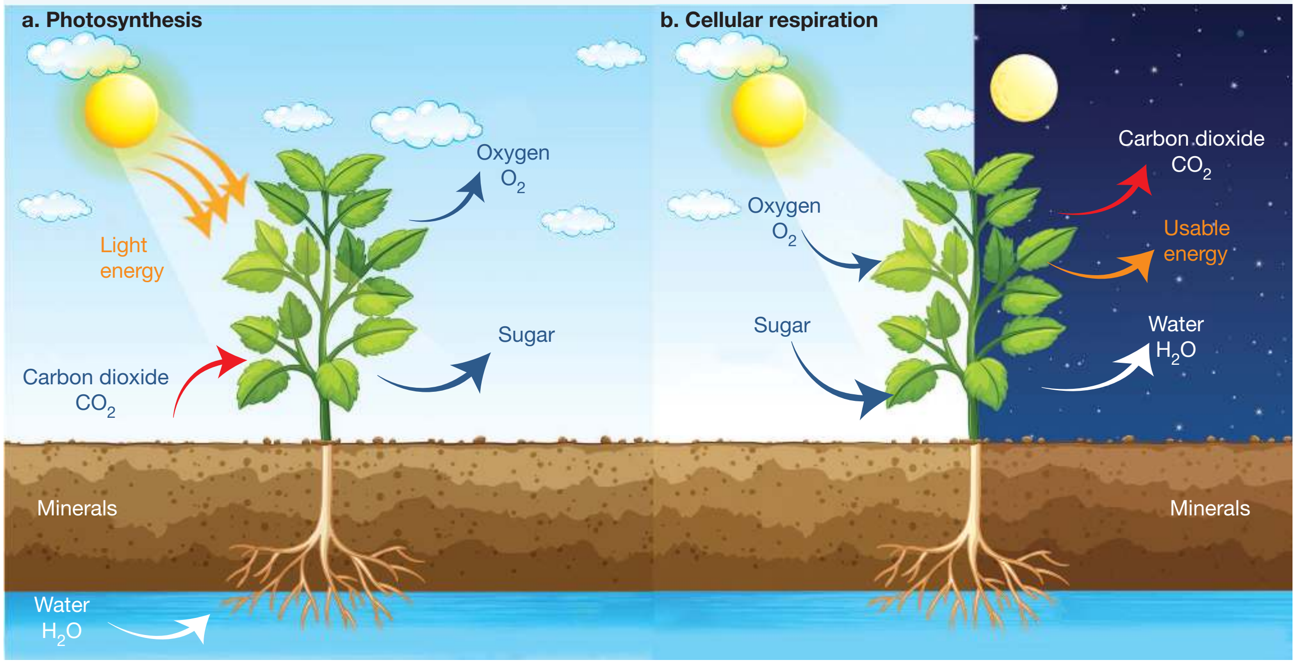


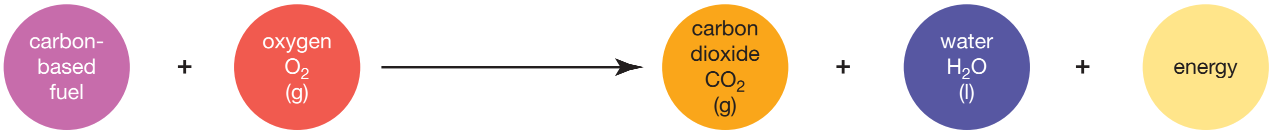
FIGURE 8.6 a. Photosynthesis that occurs during the day and **b.** cellular respiration that occurs during both the day and night



Combustion

Combustion is a chemical reaction where a fuel reacts rapidly with oxygen (O_2) to produce heat energy, carbon dioxide (CO_2) and water (H_2O). Wood and grass burning in a bushfire is an example of combustion in nature.

FIGURE 8.7 A combustion reaction



The carbon cycle

Carbon travels from the atmosphere to living things when carbon dioxide is absorbed by plants and other phototrophic organisms during photosynthesis. Carbon dioxide is then released by living things back into the atmosphere as a result of the process of respiration. The combustion or burning of fossil fuel (such as coal from the geosphere) will also result in carbon dioxide being released into the atmosphere. The carbon dioxide in the atmosphere is then available for use in photosynthesis again — and the cycle continues.

The carbon cycle models how carbon moves through the spheres in a circular loop, as shown in figures 8.8 and 8.9.

int-9188

ewbk-12539

FIGURE 8.8 A simplified image of the carbon cycle

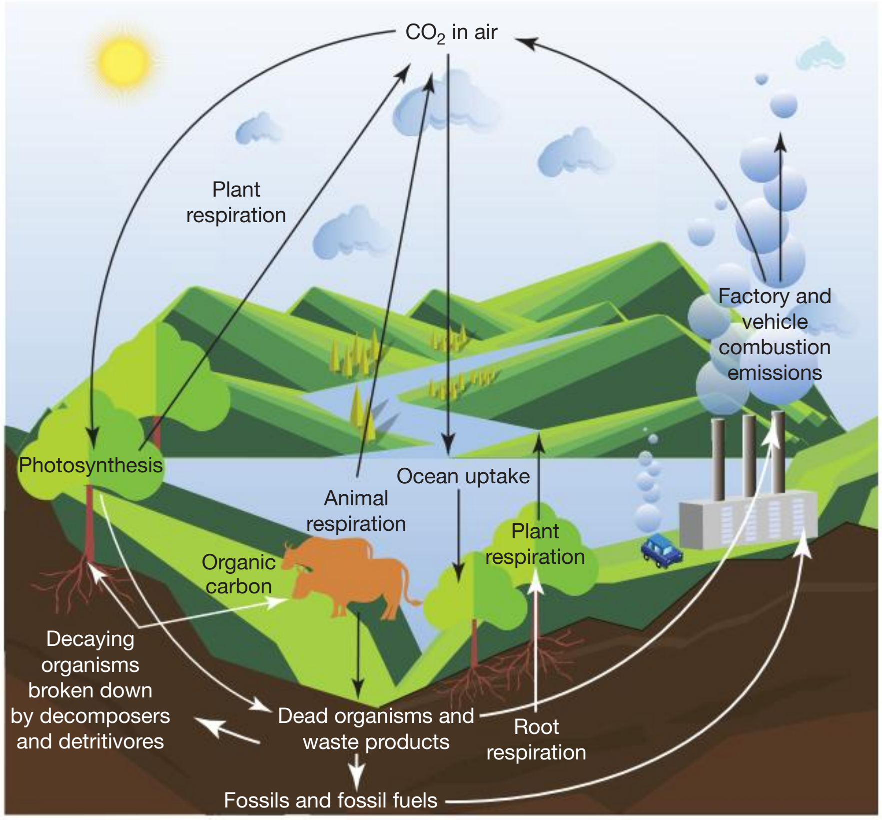
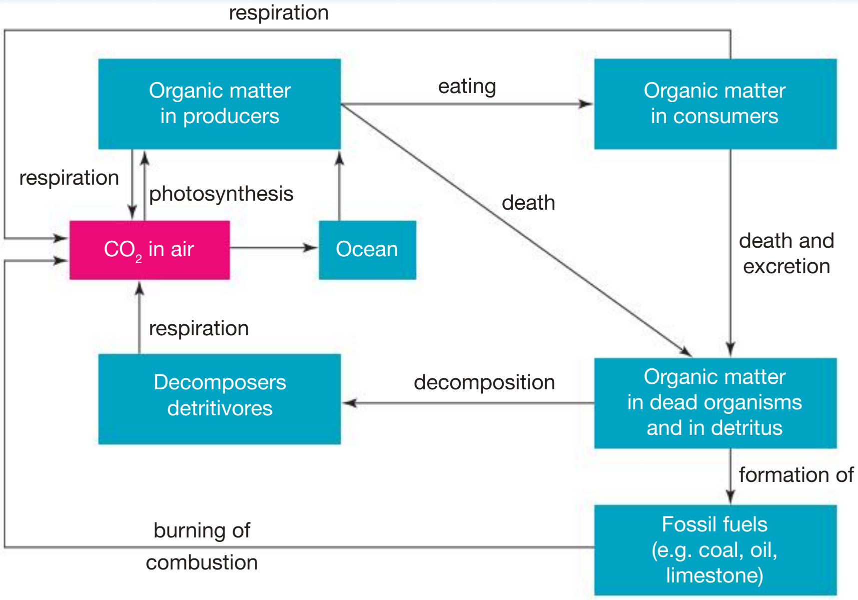


FIGURE 8.9 A simplified illustration of how carbon is cycled within an ecosystem



The atmosphere

In the atmosphere, most of the carbon exists as carbon dioxide gas, $CO_2(g)$. Figure 8.10 shows some sources of atmospheric carbon dioxide. Globally, the concentration of carbon dioxide has increased by about 12 per cent since the year 2000. In May 2023, the concentration of carbon dioxide was 421 parts per million (ppm) compared to 370 ppm in 2000.

FIGURE 8.10 Sources of atmospheric carbon dioxide: **a.** farming cattle **b.** factory emissions **c.** crops

The hydrosphere

The waters of our planet make up the hydrosphere and come from the surface of the planet, underground and from the air (approximately 4 per cent). The water cycle demonstrates how water continually moves around in different states (ice, liquid and gas).

Why is water so important? All organisms on Earth require water to survive. For example, plants need water for photosynthesis and if they do not have water, they will die. Consequently, consumers of these plants will also perish and so on. The evaporation of water from the sea surface is also important for the movement of heat as part of the climate system. This evaporation helps cool the surface of the ocean and helps to reduce the greenhouse effect.

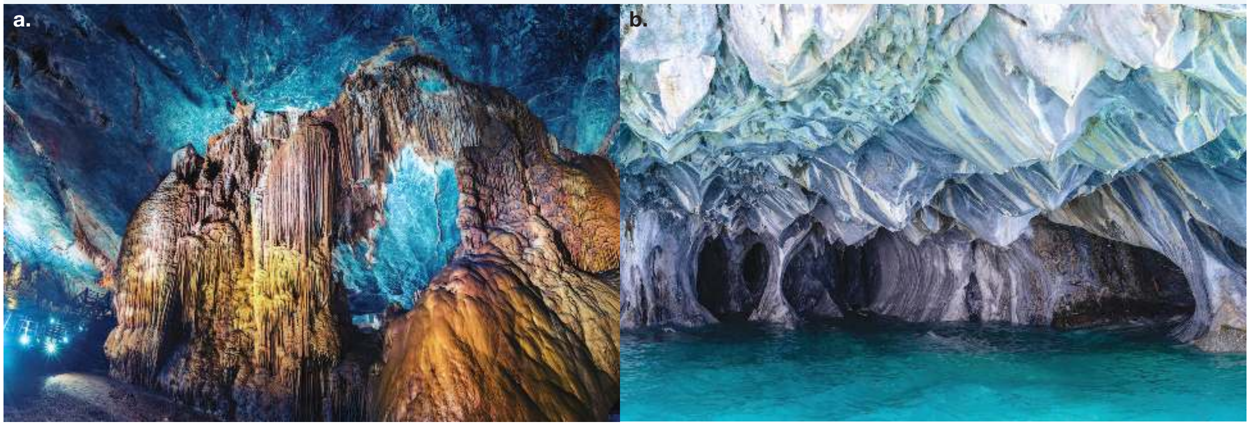
Within oceans, lakes and seas, carbon can be stored as dissolved CO_2, in shells, or deep in the ocean bed as calcium carbonate due to the decay of dead sea plants and animals over thousands of years.

FIGURE 8.11 The hydrosphere includes all water bodies, and is essential to our climate and all life on Earth. Carbon is found dissolved in oceans and in the ocean bed.

The geosphere

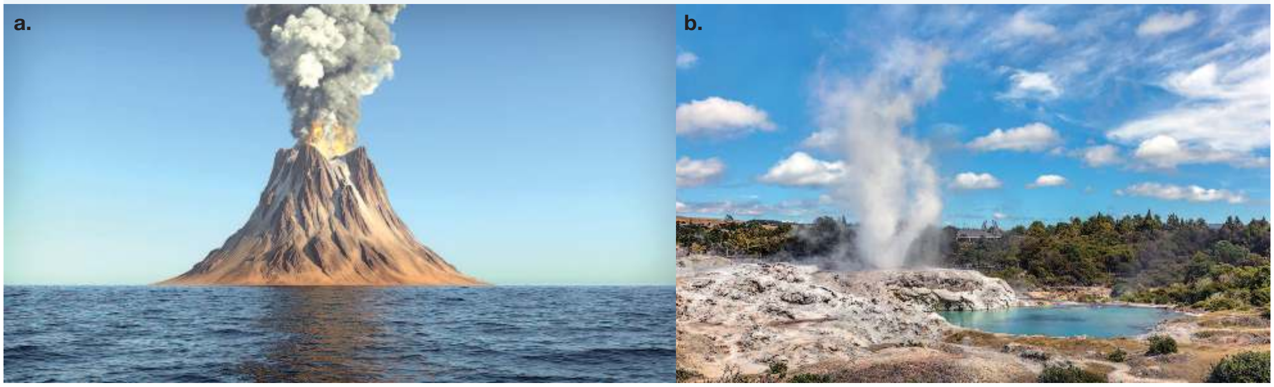
Earth's rocky crust (consisting of igneous, sedimentary and metamorphic rocks) and soil make up the geosphere (lithosphere). Carbon can be found in the sedimentary rocks as calcium carbonate, a form of **limestone** or **marble**. Figure 8.12 shows examples of caves containing calcium carbonate. The deeper parts of the earth may contain diamond and graphite, which are **allotropes** of carbon.

FIGURE 8.12 Caves containing calcium carbonate: **a.** limestone cave **b.** marble cave



Carbon dioxide can react with rain to form weakly acidic water, which can dissolve minerals on Earth's surface. These minerals may be washed away and can eventually reach the ocean to form limestone. Violent volcanic eruptions or hot spring vents can return carbon dioxide back into the atmosphere.

FIGURE 8.13 **a.** Volcanic eruptions and **b.** Hot springs release carbon dioxide gas into the atmosphere.



The decomposition of organisms or parts of organisms (such as the leaves, roots and branches of plants) in the soil is another source of carbon. Decomposition involves the breaking up a substance into smaller parts. Microorganisms, fungi and other **decomposers** that live on or in the soil assist in the breaking down of dead and decaying matter. Other organisms, called **detritivores**, also feed on decomposing organic matter and undergo cellular respiration.

on Resources

Weblink Working Together — Earth's Systems and Interactions

limestone a sedimentary rock formed from the remains of sea organisms; it consists mainly of calcium carbonate (calcite)

marble a metamorphic rock formed as a result of great heat or pressure on limestone

allotropes different forms of the same element; diamond and graphite are allotropes, which contain carbon

decomposers small organisms that break down dead and decaying matter

detritivores organisms that feed on decomposing organic matter

8.2.3 Human impact on Earth's cycles

With a greater focus on Earth's climate and human activities that have a detrimental effect on ecosystems and cycles, people are now finally understanding that changes need to be made before it's too late.

So what are the main factors that have a detrimental effect on our planet and the carbon cycle?

Deforestation

Deforestation can occur when humans clear forests to build houses or produce food. This may have an impact on the carbon cycle, in which carbon dioxide is removed from the atmosphere during photosynthesis and released back into it as a result of cellular respiration. If phototrophic producers are reduced in number or removed from ecosystems, less carbon dioxide will be removed from the atmosphere and an overall increase in atmospheric carbon dioxide may result.

deforestation the process of clearing trees to convert the land for other uses

desertification the process in which fertile regions become drier and more arid

The repurposing of the land after deforestation may also result in further imbalances. An increase in cattle, for example, can also result in increased release of carbon dioxide and methane gas into the atmosphere. Alternately, replacing the original forest trees with crops with lower photosynthesis rates may not only result in increased carbon dioxide, but also a reduction in the amount of carbon stored in ecosystems. In some areas, deforestation may also increase the chance of **desertification** and the region becoming dry and arid.

Mining

Mining for precious metals used in items such as mobile phones or for non-renewable energy sources such as coal requires land to be cleared (deforestation). Mining also destroys rocks, which releases stored carbon. Consequently, this results in more carbon in the atmosphere.

Since mining relies heavily on using fossil fuels for energy in extraction, production and recycling, then large amounts of carbon dioxide are released into the atmosphere. Mining reduces biodiversity by destroying natural habitats.

FIGURE 8.14 Birds eye view of an opencast mining quarry

Burning fossil fuels and combustion

Non-renewable fuels such as crude oil products (for example, petrol, diesel, coal and natural gas) are very useful to us. Burning of these fuels in air with oxygen can result in the release of heat energy. This is an example of a type of chemical reaction called combustion.

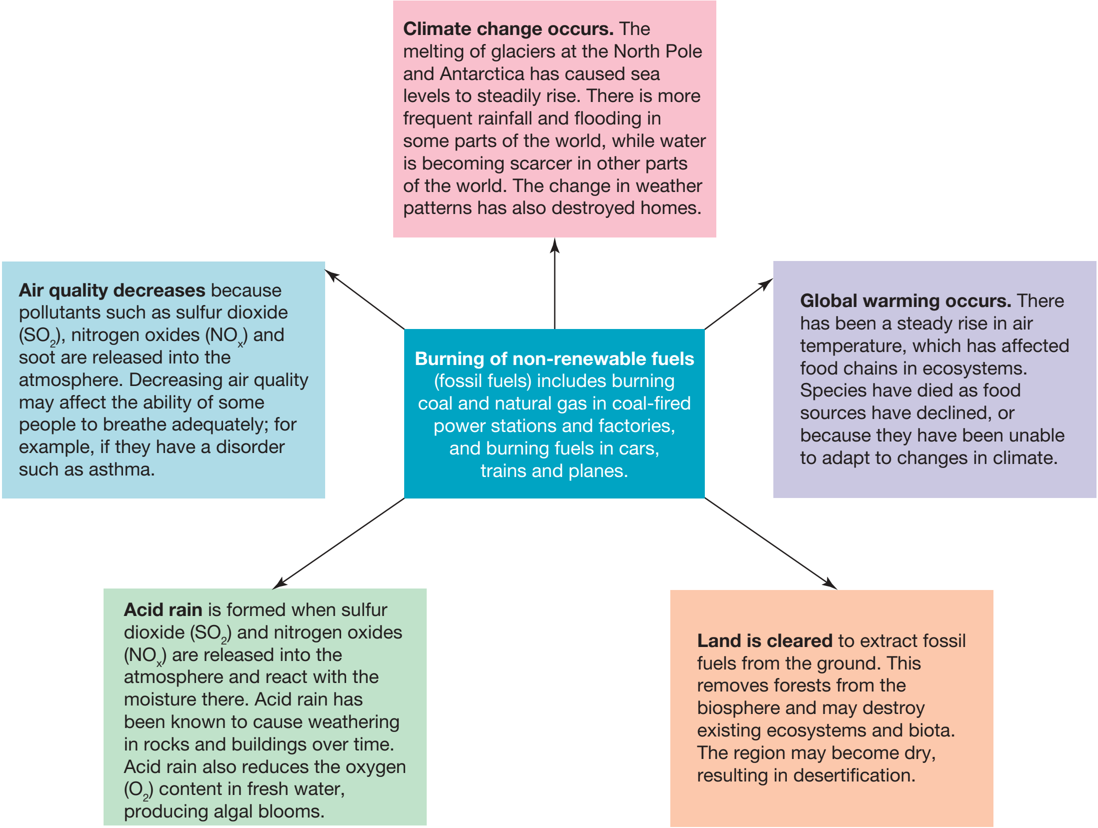
When **fossil fuels** are burnt, carbon dioxide and water vapour are also released into the atmosphere. These are both known as greenhouse gases, which can be responsible for a gradual rise in air temperature. Other pollutants such as soot, nitrogen oxides and sulfur oxides (such as sulfur dioxide and sulfur trioxide) may also be released.

An example of this is the combustion of methane with oxygen gas, to produce carbon dioxde and water.

$$\begin{array}{ccccccccc} \text{methane} & + & \text{oxygen} & \rightarrow & \text{carbon dioxide} & + & \text{water} \\ CH_4 & + & 2O_2 & \rightarrow & CO_2 & + & 2H_2O \end{array}$$

The burning of non-renewable fossil fuels has had an impact on our biosphere in several ways, as shown in figure 8.15.

FIGURE 8.15 A summary of the effects caused by burning non-renewable fuels



Burning of non-renewable fuels (fossil fuels) includes burning coal and natural gas in coal-fired power stations and factories, and burning fuels in cars, trains and planes.

Climate change occurs. The melting of glaciers at the North Pole and Antarctica has caused sea levels to steadily rise. There is more frequent rainfall and flooding in some parts of the world, while water is becoming scarcer in other parts of the world. The change in weather patterns has also destroyed homes.

Air quality decreases because pollutants such as sulfur dioxide (SO_2), nitrogen oxides (NO_x) and soot are released into the atmosphere. Decreasing air quality may affect the ability of some people to breathe adequately; for example, if they have a disorder such as asthma.

Global warming occurs. There has been a steady rise in air temperature, which has affected food chains in ecosystems. Species have died as food sources have declined, or because they have been unable to adapt to changes in climate.

Acid rain is formed when sulfur dioxide (SO_2) and nitrogen oxides (NO_x) are released into the atmosphere and react with the moisture there. Acid rain has been known to cause weathering in rocks and buildings over time. Acid rain also reduces the oxygen (O_2) content in fresh water, producing algal blooms.

Land is cleared to extract fossil fuels from the ground. This removes forests from the biosphere and may destroy existing ecosystems and biota. The region may become dry, resulting in desertification.

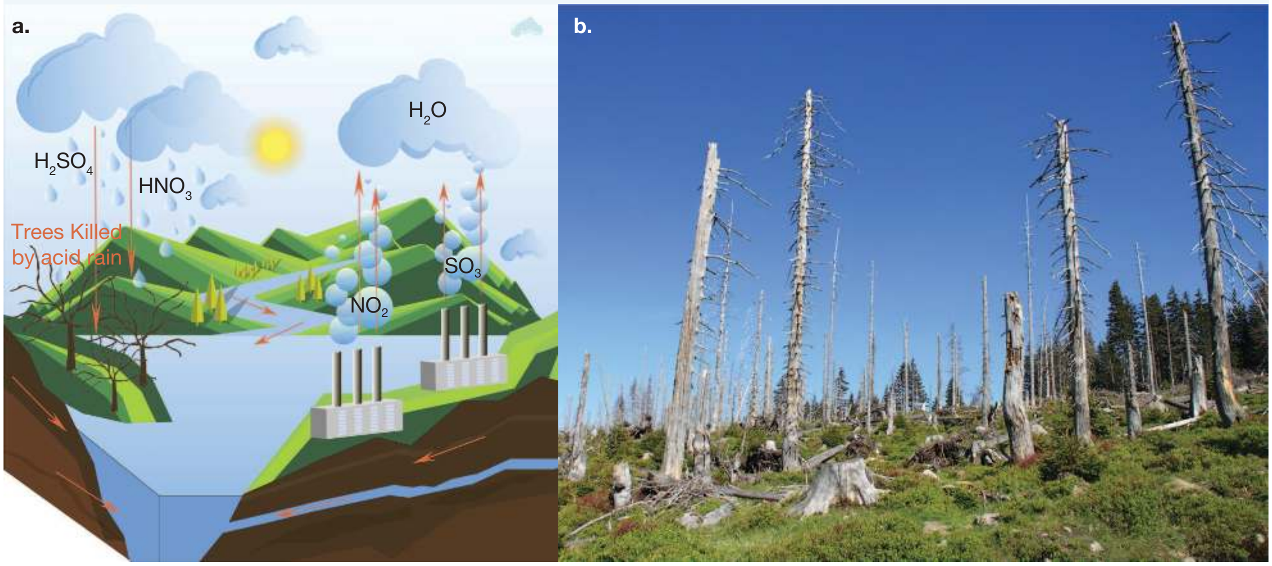
Industrial wastes

Industrial wastes that contain nitrogen oxides are also released into the atmosphere. Nitrogen oxide (NO_2 known as nitrogen monoxide) and sulfur dioxide (SO_2) can react with water vapour to form nitric acid (HNO_3) and sulfuric acid (H_2SO_4), respectively, and then leave the atmosphere via the water cycle as **acid rain**. This process is shown in figure 8.16a. This can change the acidity of water systems, resulting in the death of organisms shown in figure 8.16b.

fossil fuel a fuel that is non-renewable and unsustainable (e.g. coal and natural gas)

acid rain rainwater, snow or fog that contains dissolved chemicals that make it acidic

FIGURE 8.16 a. How acid rain is produced **b.** The effects of acid rain on trees



Travel

Humans also need to get around, whether internationally or locally, and this often involves the use of aeroplanes and cars. As these transport options burn petrol (a carbon-based product), carbon dioxide is released into the atmosphere.

Increased levels of carbon dioxide have led to increased global temperatures, which evidence suggests is resulting in melting ice caps, rising sea levels and unusual weather patterns. These events may threaten the different cycles in the atmosphere and the survival of organisms in many ecosystems.

FIGURE 8.17 a. Cars release carbon dioxide when they burn petrol and diesel. **b.** Increased greenhouse gases may result in melting ice caps

Increasing human population

A greater population increases the magnitude of the impact by humans. For example, an increase in human population creates demand for more food, which results in the need for more livestock, which in turn leads to increased deforestation and a reduction of nutrients in the soil.

With the growing populations, there is a higher demand for electricity, heating and cooling, and transport. More carbon dioxide is released into the atmosphere because these daily processes are dependent on using fossil fuels.

Science inquiry: Plastic panic!

The global issue of plastic waste started as early as the 1950s. Plastic packages, wrappers, and bottles have been dumped in the oceans, killing pelicans and turtles and destroying populations of smaller animals and plants. Figure 8.18 shows the plastic waste found in some of our oceans. Over the years, plastic waste has degraded into very tiny plastic particles called **nano plastics**. Since one nano plastic particle is similar in size to a red blood cell, many of the plastic particles are dispersed by wind and eventually end up in people.

FIGURE 8.18 Plastic waste found in the sea

In 2019, the production and burning of plastics have added an additional 850 million **metric tonnes** of greenhouse gases, mainly in the form of carbon dioxide. Scientists predict that these figures will rise to 34 **gigatonnes** in 2030 and 156 gigatons by 2050. If society continues to use plastics, then the world will not be able to meet the 2050 target of zero carbon emissions. Global temperatures will increase by 1.5 °C.

Questioning and predicting

1. **a.** What are the benefits of using plastics to society?
   b. Use your understanding of the biosphere to explain how nano plastics have ended up in humans.
   c. What is the ratio of carbon dioxide emissions due to plastic production and burning between 2019 and 2050?
   d. Why is society concerned with the increasing carbon dioxide emissions?

Planning and conducting

2. Describe how scientists make predictions on the amount of carbon dioxide emissions released from the production and burning of plastics.

Analysing and evaluating

3. Do you agree or disagree that increasing or reducing plastic use is beneficial or harmful? Justify your response by considering the pros and cons.

Communicating

4. **Unplastify** is a global team who provide students with achievable conservation strategies, which reduce world-wide plastic pollution and carbon dioxide emissions.
   a. Click on the **Ocean purpose project** weblink. Design a poster, PowerPoint or documentary video.
   b. Present your work in a 5-to-10-minute talk to the rest of the class.

nano plastics tiny plastic particles formed from the degradation of plastic products over many years

metric tonne one metric tonne is equal to 1000 kg

gigatonne 10^9 tonnes or 10^{12} kg

unplastify a world organisation who educate students and provide projects to reduce plastic waste and carbon dioxide emissions

on Resources

Weblink Ocean purpose project

elog-2345

INVESTIGATION 8.1

Testing for photosynthesis

Introduction

Fresh soda water contains carbon dioxide gas (CO_2). When CO_2 is dissolved in water, carbonic acid (H_2CO_3) is formed and the solution becomes slightly acidic. The equation that represents CO_2 in water is:

carbon dioxide gas and water produces carbonic acid

or

$$CO_2(g) + H_2O(l) \rightarrow H_2CO_3(aq)$$

Bromothymol blue is an indicator that is used to determine the presence of CO_2 and acidity in water. If CO_2 is dissolved in water, then the solution is acidic and the colour of the solution is yellow. If CO_2 is absent, then the solution is neutral (less acidic) and the colour of the solution is blue.

Aim

To investigate the effect of light on photosynthesis

Materials

- 4 test tubes
- 2 test tube racks
- 1 x 10 mL measuring cylinder
- 4 rubber stoppers
- unopened bottle of soda water
- spinach or elodea plant
- bromothymol indicator

Method

1. Label the test tubes A, B, C and D.
2. Mark test tubes A and B ‘light’ and test tubes C and D ‘dark’.
3. Measure 10 mL of fresh soda water and pour it into test tube A. Add four drops of bromothymol blue and shake the contents of the test tube.
4. Repeat step 2, with test tubes B, C and D.
5. Place the spinach or elodea plant into test tubes B and D.
6. Place rubber stoppers in the test tubes.
7. Place test tubes A and B in a test tube rack on a window ledge or underneath a lamp.
8. Place test tubes C and D in a test tube rack in a cupboard.

Results

Construct a table and note your observations each day for approximately two weeks.

Discussion

1. Write a hypothesis about the effect of light on photosynthesis.
2. Identify the dependent and independent variables in this investigation.
3. Identify two controlled variables in this investigation.
4. State the chemical and worded equation for photosynthesis.
5. How is photosynthesis linked to the carbon cycle?
6. Describe a modification to the method, which investigates how the intensity of light affects the rate of photosynthesis.

Conclusion

Summarise the findings for this investigation.

elog-2347

INVESTIGATION 8.2

Rate of melting ice on land and in the sea

Introduction

Most of Earth's land ice appears as sheets of ice in Antarctica and Greenland, or glaciers and icebergs. Sea ice is frozen ocean water, which forms, grows, and melts in the ocean. Sea ice floats on the ocean surface and is moved by climatic changes, such as direction of winds and ocean current. Both melting ice in the sea and land increase ocean levels.

Aim

To investigate the rate of melting ice on land and in the sea

Materials (per group)

- 2 × identical clear plastic containers (at least 15 cm × 15 cm)
- plasticine or rock (enough to fill half of each container)
- tray of ice cubes
- timer or stopwatch
- cold water
- salt water
- 1 × 100 mL measuring cylinder
- ruler

Method

1. Label the two plastic containers, 'land' and 'sea water'.
2. Half fill each container with plasticine. If plasticine is not available, half fill each container with rocks or stones.
3. Using the measuring cylinder, add cold water into the 'land' container until the water level is about two-thirds the height of the plasticine or rocks in the container. Note the volume of cold water added to the 'land' container.
4. Add the same volume of salt water (noted in Step 3) to the 'sea water' container.
5. Add ice cubes to the plasticine of the 'land' container.
6. Add the same number of ice cubes to the salt water in the 'sea water' container.
7. Use a permanent marker to mark the height of water in each container. Start a timer or stopwatch.
8. Measure the height of the water in each container in equal time intervals, e.g. every 2 minutes.

Results

Record results in the table that follows and write an appropriate title.

Time* (minutes)	Water depth (land ice), mm	Water depth (sea ice), mm
0		
2		
4		
6		
8		
10		
12		
14		
16		
18		
20		

**Additional time may be required to see the effect of melting ice on land compared to melting ice in the sea.*

Discussion

1. Identify the dependent and independent variables in this investigation.
2. Identify two controlled variables in this investigation.
3. Which melts faster? Land ice or sea ice? Give a reason for your choice.
4. How is melting ice linked to the carbon cycle?
5. Describe a modification to the method, which investigates the rate of melting ice in freshwater and seawater.

Conclusion

Summarise the findings for this investigation.

EXTENSION: Will planting more trees solve our problems?

Visit the **Australian State of the Environment: Land** weblink and read through the information about land clearing (or research your own information about land clearing and deforestation in Australia) and answer the following questions.

1. Carefully examine the graph (figure 34) showing annual areas of primary clearing, provided in the weblink.
   a. How has land clearing in Australia changed over the year? Describe any patterns observed.
   b. Determine the period that had the smallest amount of land clearing. Explain why.
2. Research what desertification is and determine if it is possible that parts of Australia are experiencing desertification. What other information would you need in order to confirm if it is happening or not?
3. Would planting more trees solve the issue of deforestation? Justify your reasoning.

on Resources

eWorkbook	Recycling carbon (ewbk-12541)
Video eLesson	Excessive clearing and deforestation (eles-2905)
Interactivity	Lake Urmia in 1998 and in 2011 (int-5605)
Weblinks	Australian State of the Environment: Land Our world in data

8.2 Activities

learnon

8.2 Quick quiz on

8.2 Exercise

Select your pathway

🟩 LEVEL 1:	🟦 LEVEL 2:	🟪 LEVEL 3:
1, 3, 5, 7, 9, 11, 12	2, 4, 6, 9, 13, 16	8, 10, 14, 15, 17

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. What is the name of the life-support system of our planet?
2. Identify the missing terms to complete the sentence.
   The ________ consists of the atmosphere, lithosphere, hydrosphere and biota (living things), the _________ between them, and the ________ energy of the Sun, and is considered to be the ___________ system of our planet.
3. Match the part of the biosphere with its description.

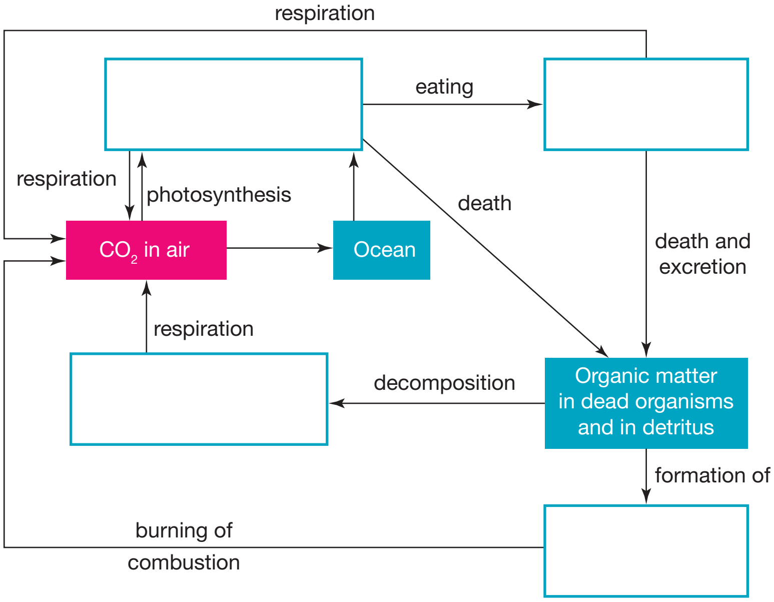
Term	Description
a. Atmosphere	**A.** Includes soil, rocks (e.g. limestone), coal and oil
b. Lithosphere	**B.** Includes living organisms within a region
c. Biota	**C.** Includes water and dissolved carbon dioxide
d. Hydrosphere	**D.** Includes oxygen, methane, carbon dioxide and ozone

4. Explain the importance of the lithosphere.
5. Describe how acid rain forms and the effects it may have.

6. Name four gases that you would find in the atmosphere from the burning of fossil fuels.
7. Explain how the carbon cycle is linked to the biosphere.

Apply and analyse

8. Clearly outline how excessive clearing and deforestation impacts the carbon cycle.
9. Identify where and how the non-living parts of the biosphere (atmosphere, lithosphere and hydrosphere) and the living parts (biota) interact in the carbon cycle.
10. Explain why an increase in the use of non-renewable fuels is of concern for the atmosphere. What recommendations would you suggest for the use of non-renewable fuels?
11. a. Suggest how photosynthesis and cellular respiration link to the carbon cycle.
    b. With respect to these processes, explain how an increasing population would affect these cycles.
12. a. Label the following figure of a simplified view of the carbon cycle using the following terms: Decomposers and detritivores, Fossil fuels, Organic matter in consumers, Organic matter in producers.



    b. Describe the effect on the carbon cycle if decomposers and detritivores were removed from the ecosystem.
13. Explain why a small part of the hydrosphere contains water that is suitable for drinking.
14. **SIS** Write the chemical equations to represent the reactions involved in the formation of acid rain.

Evaluate and create

15. Research and produce a report on the effects of human activity on the following.
    a. Atmosphere
    b. Lithosphere
    c. Hydrosphere
    d. Carbon cycle
16. **SIS** Follow the weblink **Our world in data** in the Resources panel to see the trends in global CO_2 emissions due to fossil fuels and industry.
    a. Describe the trend observed in the graph ‘Annual CO_2 emissions’.
    b. By how much did global annual CO_2 emissions increase between 1990 and 2021?
    c. Using the graph ‘Per capital CO_2 emissions’, compare Australia with two other countries and discuss reasons why there are differences between the per capital CO_2 emissions.
17. **SIS** Dams may provide a solution to reducing desertification. Research and describe the advantages and disadvantages of damming a river.

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

LESSON
8.3 The greenhouse effect

LEARNING INTENTION

At the end of this lesson you will be able to explain how carbon dioxide emissions cause an enhanced greenhouse effect and global warming, as well as describe evidence of global warming.

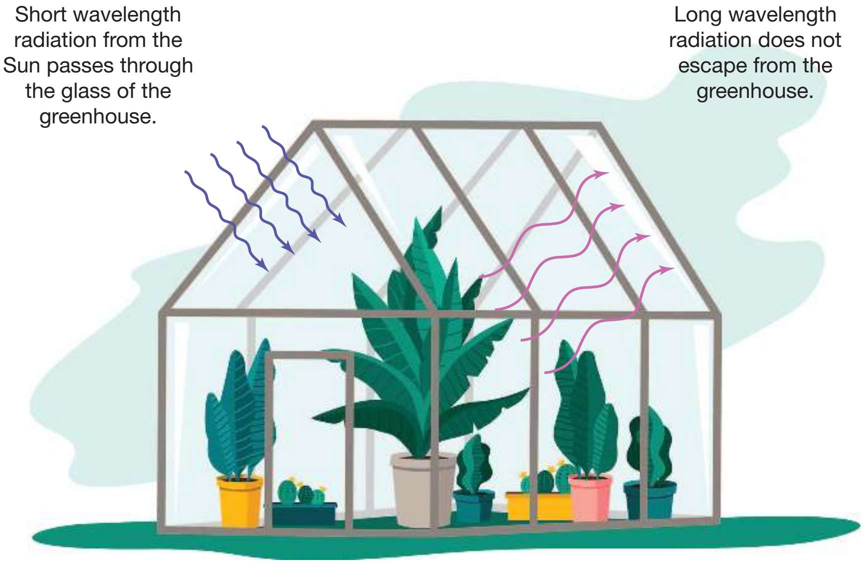
8.3.1 Global warming and the enhanced greenhouse effect

Life exists on Earth because its atmosphere contains oxygen gas and protects living organisms from the harmful **ultraviolet (UV)** radiation from the Sun's rays. The temperature on Earth is kept within a specific range of temperatures to allow all animals and plants to live.

Greenhouse

A **greenhouse** is made of glass and often contains flowers and vegetables. A greenhouse is commonly used to grow plants during the winter months, as the temperatures are too cold for growth.

FIGURE 8.19 A greenhouse



Sunlight or short-wave **radiation** passes through the greenhouse during the day, heating the plants and soil inside. The glass of the greenhouse prevents the longer wavelength radiation, such as **infrared**, from escaping. Since radiation cannot leave the greenhouse, the greenhouse heats up considerably during the day.

ultraviolet (UV) a form of short-wave radiation, where energy comes from the Sun

greenhouse a building containing glass walls and a glass ceiling

radiation a method of heat transfer that does not require particles to transfer heat from one place to another

infrared a type of energy wave that is part of the electromagnetic spectrum

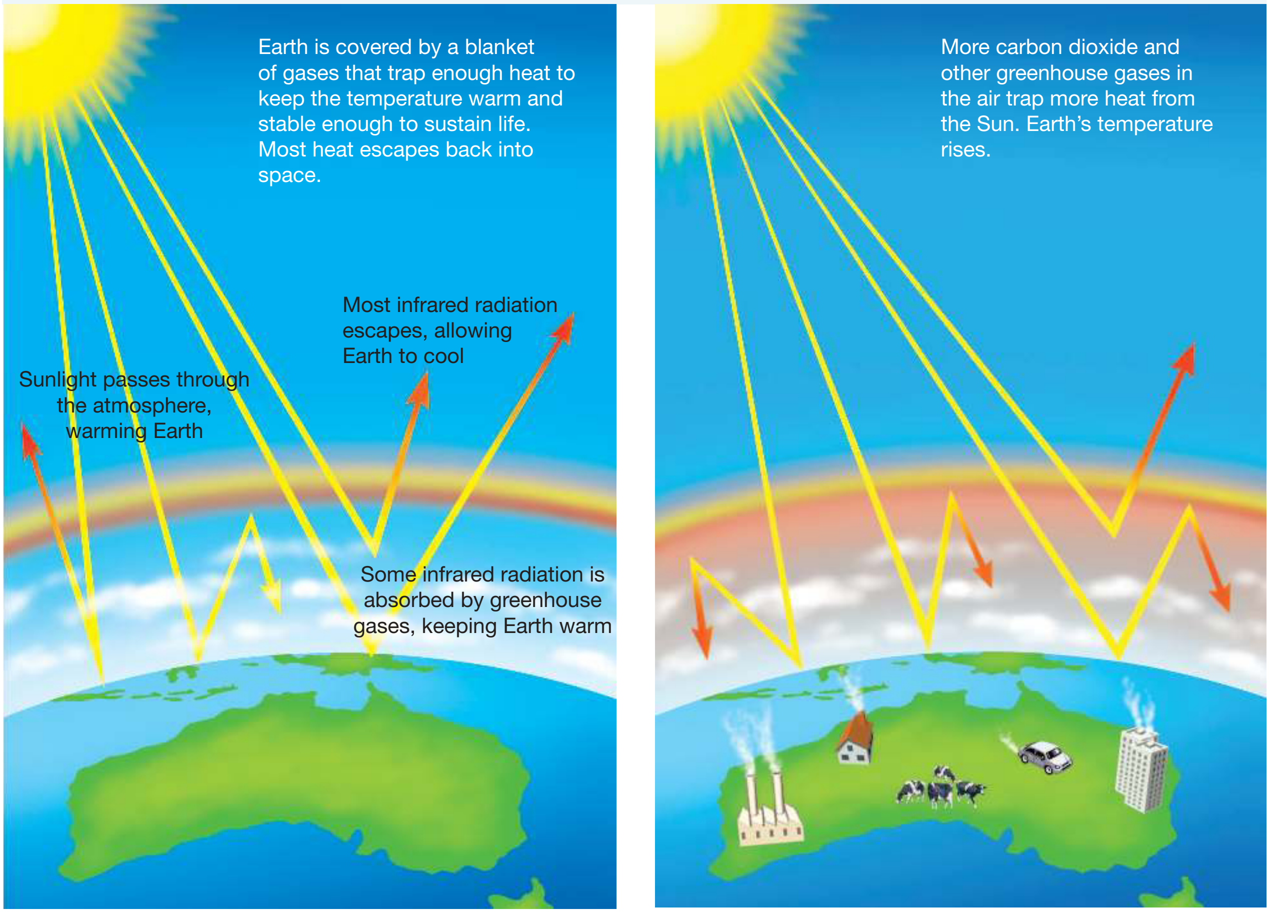
Earth's atmosphere behaves like a greenhouse. The Sun's radiation passes through each layer of the atmosphere and is absorbed by the soil and oceans, increasing their temperatures. **Greenhouse gases** such as carbon dioxide, water vapour and methane are able to prevent most of the infrared radiation from escaping. These gases scatter the infrared radiation back to Earth. Since infrared radiation cannot enter space, Earth's oceans and land become warmer. This process is known as the greenhouse effect.

greenhouse gases gases found in the atmosphere that contribute to the greenhouse effect, trapping the Sun's heat

enhanced greenhouse effect an intensification of the greenhouse effect caused by an increase in greenhouse gases in the atmosphere

Carbon dioxide gas is the main contributing gas to the greenhouse effect. Nitrous oxide, methane gas and water vapour also contribute to the greenhouse effect. Between the early 1800s and the 2020s, the amount of CO_2 released into the atmosphere increased from 280 parts per million (ppm) to about 420 ppm. The global temperature of Earth has risen, and this phenomenon is known as global warming or the **enhanced greenhouse effect**. Figure 8.20 shows how infrared radiation is trapped in the enhanced greenhouse effect.

FIGURE 8.20 Greenhouse gases and the enhanced greenhouse effect



on Resources

Interactivity Sources of greenhouse gases (int-5884)

Weblink Climate science investigations

elog-2418

tlvd-10807

INVESTIGATION 8.3

Modelling the greenhouse effect

Aim

To understand how the greenhouse effect warms the Earth's atmosphere

Materials

- 2 × retort stands
- 2 × boss heads
- 2 × clamps
- 3 × 500 mL conical flasks
- 2 × lamps fitted with heat globes
- permanent marker
- 2 × thermometers
- stopwatch
- 2 × conical flask stoppers
- 2 × pieces of black card
- sticky tape
- 25 mL measuring cylinder
- delivery tube with stopper
- 25 g bicarbonate of soda
- 120 mL vinegar

Method

1. Set up the two retort stands with the boss heads and clamps.
2. Label two of the conical flasks 'AIR' and 'CO_2' with the permanent marker.
3. Attach the black card to one side of the 'AIR' flask using sticky tape and put the conical flask stopper in the neck of the flask.
4. Secure the 'AIR' flask in one of the set-up clamps, with the black card facing away from the lamp.
5. Make sure the clamp is not too tight as there will be some expansion. Ensure the plugs are in place in the top of the conical flask stopper.
6. Tip all of the bicarbonate of soda into the *unlabelled* flask.
7. Measure out approximately 15 mL of vinegar into the measuring cylinder and tip this into the unlabelled flask. Immediately stopper the flask with the delivery tube leading into the 'CO_2' flask. The end of the tube should be at the bottom of the 'CO_2' flask.
8. Hold your hand over the neck of the 'CO_2' flask to keep the CO_2 inside.
9. When the reaction is complete, add another 20 mL of vinegar. Continue until the vinegar has all been used.
10. Make sure the plugs are in place in the top of the conical flask stopper and place this in the 'CO_2' flask when the reaction is complete following the last addition of vinegar.
11. Attach the black card to one side of the 'CO_2' flask using sticky tape and secure this flask in the other clamp as in step 4.
12. Ensure the lamp is facing the flask, and that it is so close that it is almost touching, with the gap between them the same for each lamp and flask.
13. Put the thermometer in one of the openings of the conical flask stopper for both flasks. They must be pushed in *gently* until they are secure.
14. Record the initial temperature when the lamp is off.
15. Turn on the lamps and start the stopwatch at the same time.
16. Record the temperature of each flask every minute for 15 minutes.
17. After 15 minutes, turn the lamps off and continue to record the temperature of each flask for 5 minutes.
18. When you are finished, clear away equipment as directed by your teacher.

Results

Present your results in a table similar to the following with rows for 0–20 minutes.

TABLE Temperature of flasks filled with air or carbon dioxide while heating and cooling over a period of 20 minutes

Time (minutes)	Temperature in °C	
	Air flask	CO_2 flask

Discussion questions

1. What were the independent, dependent and controlled variables?
2. What was the heat globe representing?
3. What was the general trend in the data in the two flasks while the heat lamp was turned on?
4. What was the general trend in the data in the two flasks after the heat lamp was turned off?

Conclusion

Summarise the findings of this investigation.

8.3.2 Evidence of global warming

In Australia, global warming has increased average temperatures and sea levels over the past 60 years. There are fewer cold days and more floods. Similar events have occurred across the world.

The Great Barrier Reef

The Great Barrier Reef is a large coral reef, about 2000 kilometres long, in Queensland (figure 8.21). The coral is the home of many ocean ecosystems as it contains thousands of fish and other small animals and plants. It has taken many millions of years for the coral to slowly grow using the carbon carbonate deposits in skeletons and the remains of dead marine organisms.

FIGURE 8.21 The Great Barrier Reef

The increased absorption of CO_2 by the ocean over recent decades has increased its acidity. Not only has the ocean acidity increased, but so too has the temperature of the ocean. This event has decreased the number of organisms populating the coral reef. The change in pH has dissolved the coral reef, making it more susceptible to destruction in stormy weather and providing even less protection to the living inhabitants. The existence of many species is under threat (figure 8.22).

on Resources

Weblink Coral reef bleaching

FIGURE 8.22 Increased acidity has caused the Great Barrier Reef to bleach.

elog-2349

INVESTIGATION 8.4

Effect of carbon dioxide on ocean acidity

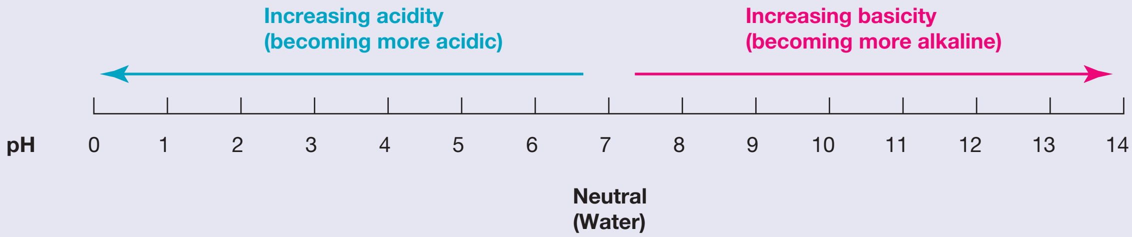
Introduction

Carbon dioxide from the atmosphere is dissolved into oceans and lakes, producing carbonic acid (H_2CO_3).

Fresh soda water contains carbon dioxide gas (CO_2) dissolved in it.

Scientists use a pH scale to measure the acidity of solutions. The scale is based on a logarithmic scale.

FIGURE 8.23 The pH scale



A pH of 6 means that the solution contains more carbon dioxide gas dissolved in it and it is more acidic than a solution which has a pH of 7. Water is regarded as neutral, as it is not acidic or alkaline.

Aim

To investigate the effect of carbon dioxide on ocean acidity

Materials

- 5 × 250 mL beakers
- 250 mL fresh soda water
- glass rod
- 2 × 100 mL measuring cylinders
- universal indicator or pH probe
- 250 mL sea water or salty* water (30 per cent)

*The concentration of sea water is approximately 30 per cent m/v. If sea water is unavailable, salty water can be prepared by dissolving 30 g of salt in 100 mL of deionised water.

Method

1. Label the 5 beakers A, B, C, D and E.
2. Refer to the table below and add the volumes of soda water and sea water respectively to each beaker.

TABLE Volumes of soda water and sea/salty water in each solution

Beaker	Volume of soda water (mL)	Volume of sea/salty water (mL)
A	100	0
B	75	25
C	50	50
D	25	75
E	0	100

3. Use a clean stirring rod to mix the contents of each beaker.
4. Keep the temperature of the beakers constant.
5. Measure the pH of the solution in each beaker using a pH probe. Alternatively add 10 drops of universal indicator to each beaker and use a universal indicator chart to determine the pH of the solution.

Results

Construct a table and note your pH measurements.

Discussion

1. Write a hypothesis about the effect of carbon dioxide on ocean acidity.
2. Identify the dependent and independent variables in this investigation.
3. Explain why beaker E had no soda water.
4. Why is the temperature kept constant in this investigation?
5. Suggest a modification to the experimental design, which would improve the reproducibility of the results.
6. Explain why ocean acidification is a global concern.

Conclusion

Summarise the findings of this investigation.

Uluru

Uluru (figure 8.24) sits upon the lands of the Anangu people in the Northern Territory. It is one of the largest rocks in the world and is known for its vivid orange-red colour at sunset. Uluru is a special landmark for First Nations Australians as it signifies the beginning of time. It is believed that this rock started forming about 550 million years ago. Many people have travelled from all parts of Australia and the world to visit Uluru.

Due to increasing global temperatures, scientists predict that there will be 100 days each year of temperatures 35 °C or more around 2030, and 160 days each year by 2090, making it likely that the number of tourists visiting Uluru will decrease.

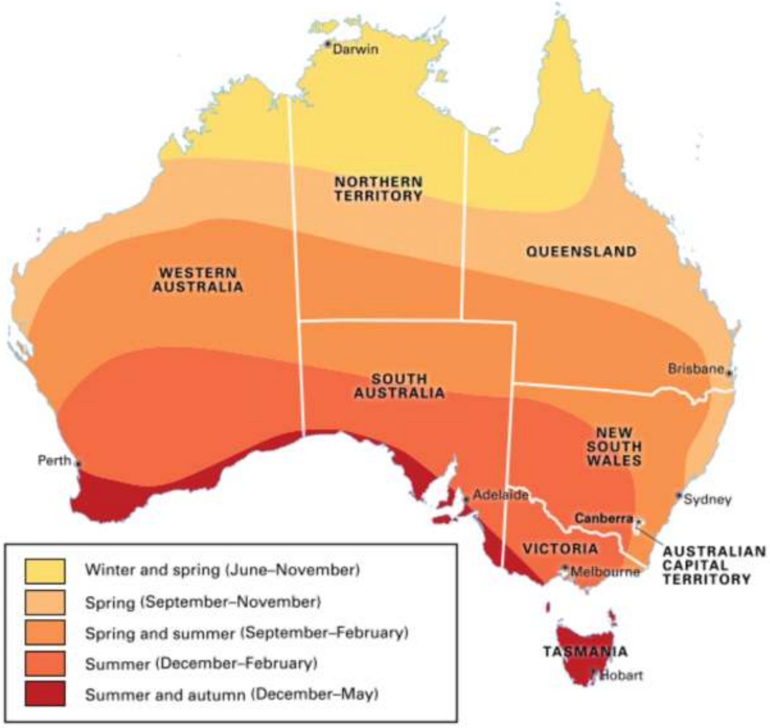
FIGURE 8.24 Uluru

Bushfires

Bushfires are high temperature fires that burn uncontrollably. Since 2019, the frequency and intensity of bushfires has increased. The rise in global temperatures has dried forests and plants earlier in the summer, rather than towards the end of the season. Many outback properties and animal habitats have been destroyed due to rapid burning of grasslands, which spreads uncontrollably in seconds.

FIGURE 8.25 A high temperature bushfire

FIGURE 8.26 Bushfire seasons in Australia



Ice melting

Antarctica consists of a large block of land ice. Many scientists have indicated that in 2022, Antarctica is melting at its fastest rate for over 5500 years, due to increasing global CO_2 emissions. Scientists suggest that the sea levels will rise by 70 metres and that some of the cities will be underwater if Antarctica completely melts. New infrastructure would need to be developed if people are to live under water.

FIGURE 8.27 An artist's drawing of what an underwater city might look like in the future

SCIENCE AS A HUMAN ENDEAVOUR: Greta Thunberg

In 2018, at the age of 15, Greta Thunberg spent time outside the Swedish Parliament voicing her concerns about global warming and calling for stronger action on climate change. This garnered worldwide media attention and saw a spotlight put on the issue. Since then, students around the world have marched in their respective cities to force their governments to take action on climate change now. As Thunberg said, 'I have learned you are never too small to make a difference.'

FIGURE 8.28 Greta Thunberg

elog-2351

INVESTIGATION 8.5

Carbon footprint activity

Introduction

A carbon footprint is a measure of the amount of greenhouse gases (mainly carbon dioxide and methane) that are released into the atmosphere due to a person's use of products and their activities, hobbies and interests, community events, travel and transport.

Just about anything you do determines the value of your carbon footprint. For example, the clothes you wear, what electrical devices you use — even playing soccer or basketball will affect your own personal carbon footprint.

The units used for carbon footprint are CO_2 equivalent emissions or CO_2e. The average worldwide CO_2 footprint is about 4.8 tonnes per year, while the average footprint in Australia is about three times that at 15.48 tonnes per person per year.

Aim

To determine the factors that affect a person's carbon footprint

Materials

Use the **WWF footprint calculator** weblink in the Resources panel to complete the following questions.

Discussion

1. Is the carbon footprint calculator website reliable or not? Explain your answer.
2. Hypothesise how many Earths would be required to sustain your current lifestyle.
3. Answer each question in the calculator to the best of your ability, adding details to improve the accuracy of your footprint. Explain the outcome of your footprint after entering your data. Do you think this is an accurate representation of your footprint?
4. Identify ways you could reduce your footprint so that fewer Earths would be required.
5. Is it possible for the answers in question 4 to be implemented by the rest of society? Justify your reasoning.
6. Scientists like to formulate questions to investigate scientifically in the hope of discovering new ways to reduce carbon and greenhouse emissions. Formulate two questions you would want to investigate as a scientist and identify how you would collect the information required and what you would need to find out to help answer the question.

Conclusion

Summarise the findings of this investigation.

DISCUSSION

1. Which of the following actions would you be prepared to take so that you can contribute to the fight against global warming?
   - Walk, cycle or use public transport rather than relying on someone to drive you to school, work or leisure activities.
   - Change your diet so that you eat less meat and more fruit and vegetables.
   - Recycle paper, aluminium and steel cans, glass and plastics.
   - Stop using electric clothes dryers, and instead use outdoor clothes lines in dry weather and indoor folding clothes airers in wet weather.
   - Buy fewer clothes or buy clothes second-hand.
2. Select one of the actions in question 1 that the government could enforce by passing new laws, and explain how it could be done.

on Resources

eWorkbook Global warming and the greenhouse effect (ewbk-12543)

Video eLessons Global warming in Australia (eles-0057)

Weblinks
2010 Sustainable Cities Index
2022 Sustainable Cities Index
WWF footprint calculator
Sea rise satellite data

8.3 Activities

learnon

8.3 Quick quiz on

8.3 Exercise

Select your pathway

🟩 LEVEL 1:	🟦 LEVEL 2:	🟪 LEVEL 3:
1, 3, 4, 5, 7, 8	2, 6, 9, 11, 12	10, 13, 14, 15, 16

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. Consider the statements about the greenhouse effect in the table below. Beside each statement, write the numbers 1–6 in the correct order, starting at the Sun.

Number	Statement
	When solar energy waves hit Earth's surface, they slow down and form longer heat (thermal) energy waves.
	Some solar energy waves reflect off from the clouds, and greenhouse gases such as carbon dioxide gas is returned to space.
	These longer heat energy waves have trouble getting back out into space through carbon dioxide gases.
	Heat trapped in the atmosphere warms the planet.
	Other solar energy waves make it to Earth's surface.
	Short-wave solar (radiant) energy waves enter the atmosphere from the Sun.

2. a. Identify whether each of the following statements is true or false.
    i. Carbon dioxide is the only greenhouse gas.
    ii. Carbon dioxide emissions cause a rise in global temperatures.
    iii. The emission of carbon dioxide gases has only changed the acidity of the oceans.
    iv. There are net carbon dioxide emissions in the world.
   b. Rewrite any false responses to be true.
3. Identify three pieces of evidence that rising atmospheric temperatures is occurring in Australia.
4. Define the greenhouse effect and state how this differs to the enhanced greenhouse effect.
5. Why are plants regarded as a fuel?
6. What factors create a favourable environment for bushfires to occur?
7. Identify five different ways you could reduce your carbon footprint.

Apply and analyse

8. a. What causes coral bleaching?
   b. What triggers coral bleaching?
   c. How does coral bleaching affect the biodiversity of organisms living in coral?
9. Describe three pieces of evidence that global warming is occurring worldwide.
10. How do scientists predict future bushfires? Explain your response.
11. Describe two factors related directly to a rise in sea levels.

Evaluate and create

12. The temperature on Venus is above the boiling point of water. What would happen to the amount of CO_2 and Venus' temperature if all the oceans evaporated?
13. **SIS** Navigate to the weblink **Sea rise satellite data** to answer the following.
    a. Explore the trendline and collect sea rise data from 2010 to present. Graph the data on an Excel spreadsheet.
    b. Describe the trendline from 2010.
14. **SIS** How is technology used to save the world's coral reefs?
15. Is the Sun to blame for rising global temperatures? Justify your response.
16. Design an investigation that determines the effect of ocean acid on the strength of seashells. You are provided with the following materials:
    - 10 mL measuring cylinder
    - 0.10 M hydrochloric acid
    - seashells
    - electronic scales
    - 5 × 250 mL beakers
    - pH probe or universal indicator
    - universal indicator chart
    - sea water (30 per cent m/v)

    The hydrochloric acid will acidify the sea water. This action will be like acidifying ocean water with dissolved carbon dioxide gas.
    a. Identify the dependent and independent variables.
    b. Write an aim and hypothesis for the investigation.
    c. Write a method that determines the effect of ocean acid on the strength of seashells.

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

LESSON
8.4 Reducing carbon dioxide globally

LEARNING INTENTION

At the end of this lesson you will be able to discuss how carbon dioxide emissions can be reduced on a global scale.

8.4.1 Future global net carbon dioxide emissions

Hundreds of thousands of years ago, the amount of carbon dioxide in the atmosphere worldwide was between 170 and 300 ppm. carbon dioxide levels have increased to just over 420 ppm, causing global warming around the world. A major treaty was signed by world leaders in 2015 in Paris, promising to reduce carbon dioxide emissions to 0 ppm by the year 2050. According to international climate agreements, Australia will reduce greenhouse emissions to 30 per cent below current levels by 2030.

Over 200 scientific organisations have reached the consensus that global temperatures are rising because of increasing atmospheric emissions of carbon dioxide gas and other greenhouse gases directly produced from the burning of fossil fuels, which are required for transport, factories, and homes. The following agreements have been integral in addressing this current issue.

UN Framework Convention on Climate Change (UNFCCC), 1992

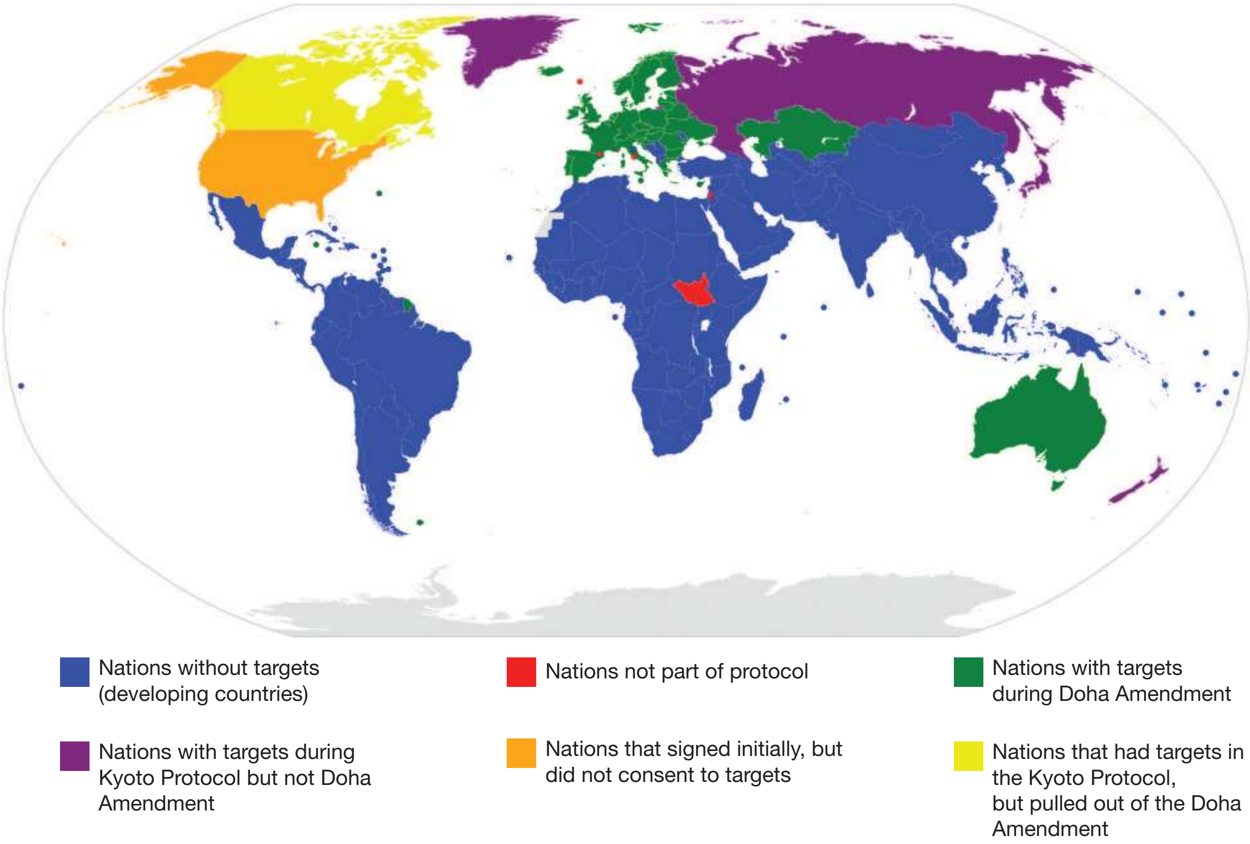
The UNFCCC agreement was supported by 197 countries. It was the first treaty that focussed on reducing carbon dioxide and other greenhouse gases in the atmosphere.

Kyoto Protocol, 2005

The protocol was created in 1997 and enforced in 2005, supported by 152 countries. The goal was to reduce emissions by an average of 5% below 1990 levels. China and India did not participate in the Kyoto Protocol. Although the United States initially agreed with the terms, they decided a few years later to withdraw.

In December 2012, the Kyoto Protocol was extended and became the Doha Amendment. This amendment added new emission reduction targets for the period 2012 to 2020 and was adopted by most of the parties of the Kyoto Protocol.

FIGURE 8.29 Different involvements around the world in the Kyoto Protocol and Doha Amendment



Paris Agreement, 2015

The main difference between the Kyoto Protocol and Paris Agreement, is that the latter requires all countries to reduce the global average temperatures from rising by 1.5 °C by 2050 and to achieve net-zero carbon emissions after 2050. As shown in figure 8.30, 146 countries have accepted or ratified the agreement, 48 countries have signed the agreement and 3 countries have not accepted the agreement.

The global temperature rise of 1.5 °C is critical. Based on research data collected from satellites and field work, scientists have predicted the following events will occur (as shown in figure 8.31).

- Frequency and longevity of heat waves will make temperatures more unbearable for people.
- More droughts and floods may lower the amount of food grown in crops and reduce the populations of land animals and plants.
- Arctic ice will melt causing sea levels to rise and may be responsible for some coastal cities, towns, and villages to be submerged eventually.
- Ocean acidity will destroy coral reefs, which will reduce the species of animals living in the ocean. A food shortage will be caused by decreasing fish populations.

FIGURE 8.30 Status of acceptance in the Paris Agreement

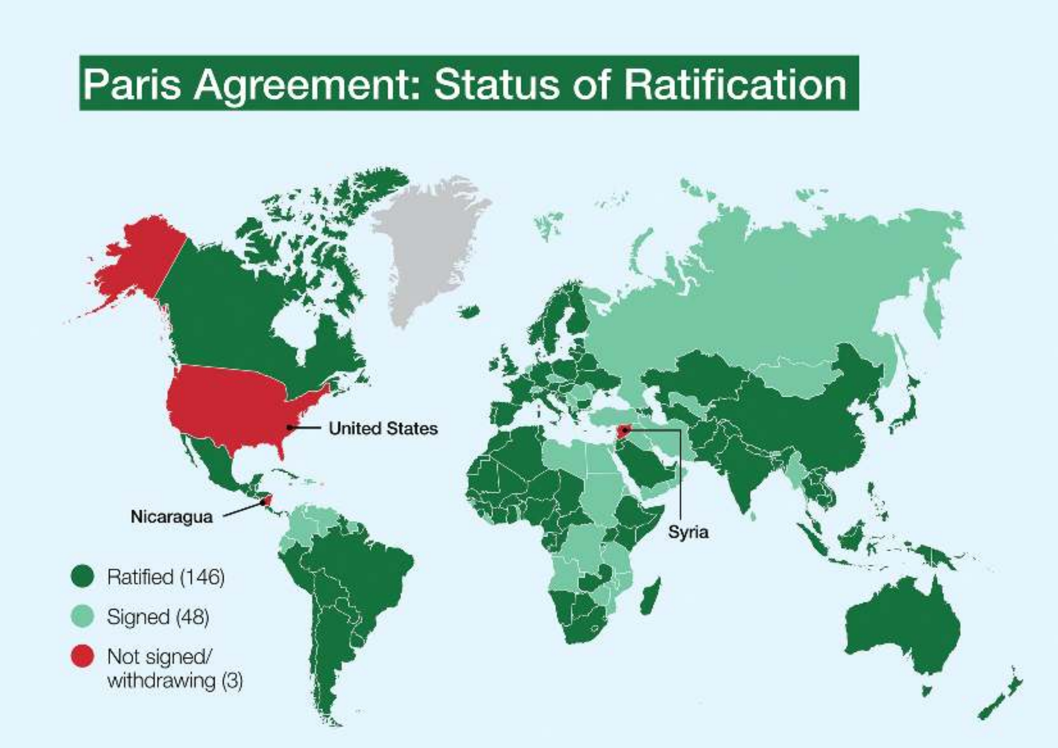


FIGURE 8.31 Consequences of not achieving a global rise of 1.5 °C: **a.** drought **b.** floods **c.** sea rising **d.** endangered species

The strategies that reduce carbon dioxide gas emissions globally (and reduce global temperature rise) are discussed in the lessons that follow.

8.4.2 Using green energy sources

A green energy source is a sustainable energy source that does not produce any CO_2 emissions when used and does not produce pollutants that may harm the environment. Examples include solar energy, wind energy, **hydroelectricity** and **geothermal energy**.

Solar energy

Solar energy is a good alternative to burning coal for electricity. When solar or photovoltaic cells absorb sunlight, the photons or light particles remove electrons from atoms, converting the solar energy into electricity. Solar panels provide electricity to individual homes, whereas solar farms provide enough electricity to power thousands of homes. The disadvantage of using solar energy is that electricity cannot be produced at night — solar energy is converted into electrical energy only during the daytime.

FIGURE 8.32 Solar cells convert sunlight to electricity.

Wind energy

Wind turbines are used to produce electricity. The blades are attached to a shaft that produces electricity when the blades are turned by wind currents. In terms of size, the wind turbines are as high as a building, about 70 metres. The wind turbine blades are about 50 m long. Wind farms vary in the number of wind turbines they have, from 5 to 150. An average turbine can provide electricity to 900 homes.

FIGURE 8.33 Wind turbine farm generating electricity using wind power

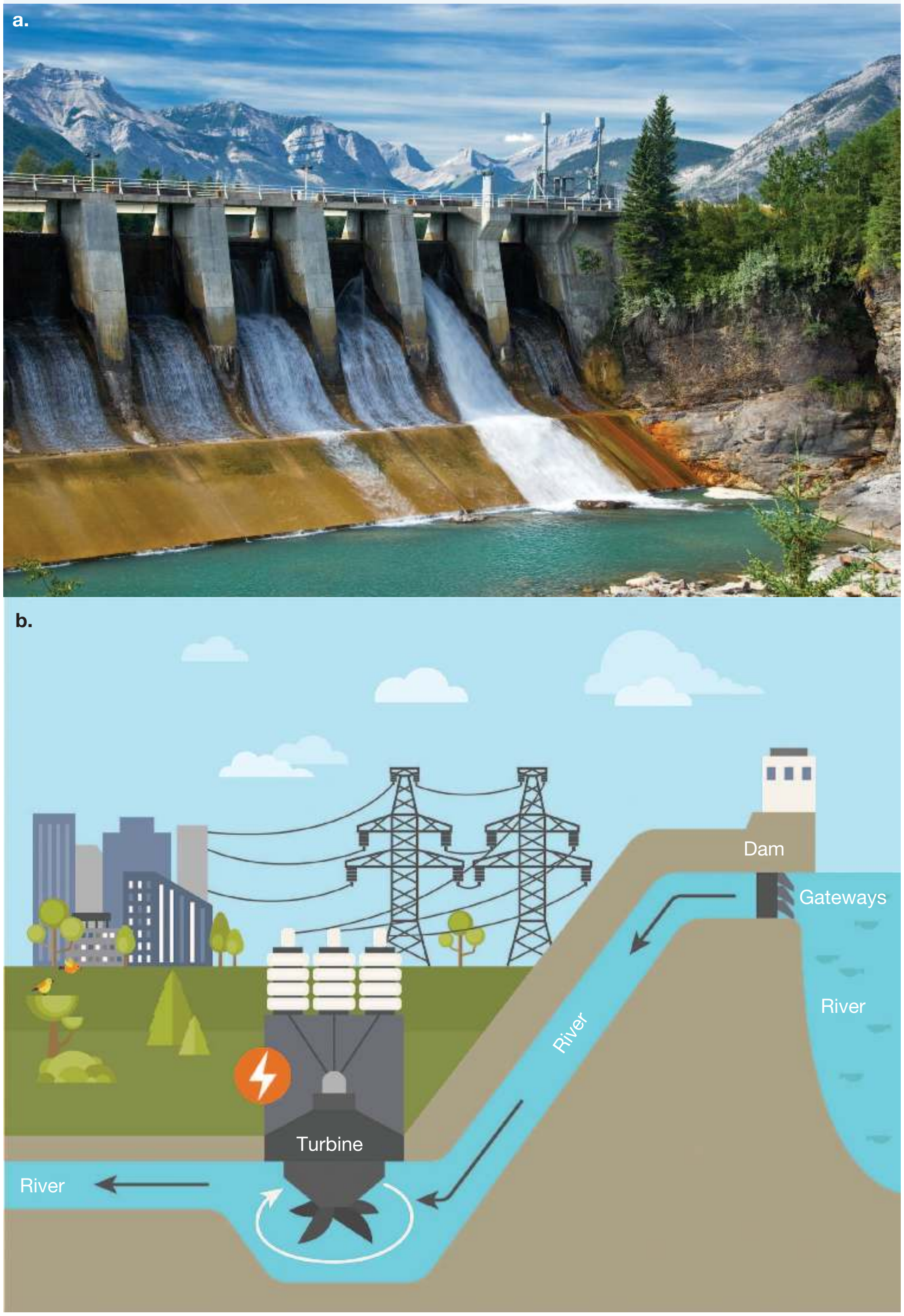
hydroelectricity a type of renewable energy that uses water overflowing from a dam to generate electricity

geothermal energy a renewable energy source that uses heat from within Earth to produce steam, which drives turbines to form electricity

Hydroelectricity

When water flows rapidly from a dam or reservoir, it spins the turbine blades of a generator to produce electricity. As the water flows from a high point of the dam or reservoir, it gains potential energy and is converted to kinetic energy. The kinetic energy is used to spin the turbine blades and electricity is formed in a generator. The rate of flow of water is controlled.

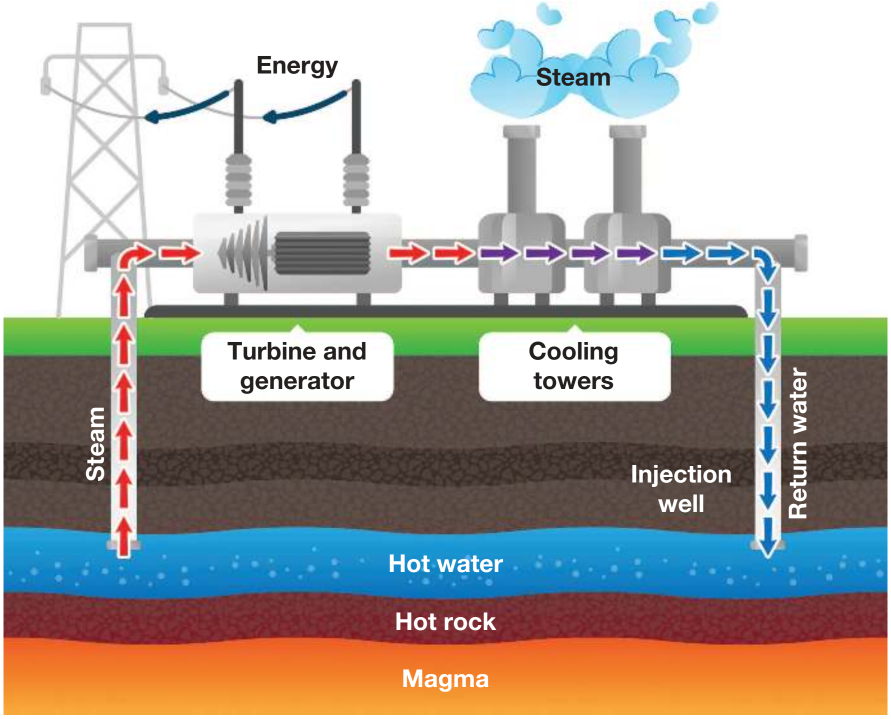
FIGURE 8.34 a. Dam **b.** Hydroelectric power generator



Geothermal energy

The temperature beneath Earth's crust increases as the depth increases because a slow breakdown of radioactive particles occurs in rocks. Geothermal energy is obtained by drilling into reservoirs of hot water several kilometres below Earth's surface. Hot water or steam is pumped back to the surface and spins the turbines producing electricity.

FIGURE 8.35 Steam or hot water is used to spin the turbines in a geothermal plant.



8.4.3 Renewable fuels

The fuels bioethanol and biodiesel are both biodegradable. If their wastes are introduced into waterways or soil, they will not harm the environment when they are decomposed by bacteria. Some carbon dioxide emissions are produced to make bioethanol and biodiesel, when farm machinery is used for cropping, transporting resources or during manufacturing (though these emissions are less than those from petrol or other non-renewable fuels). Bioethanol and biodiesel are therefore considered to be renewable fuels rather than green fuels.

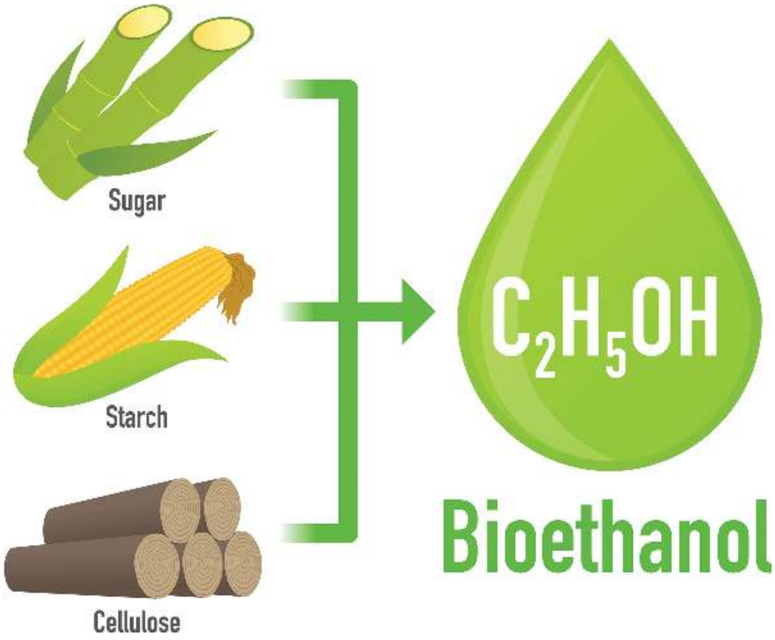
Bioethanol

To reduce the amount of carbon dioxide emissions into the atmosphere, one alternative is to add bioethanol to petrol for use in motor vehicles. Bioethanol is a suitable alternative to petrol since it is produced from plant crops such as sugar cane and corn, and it can be produced relatively quickly compared to fossil fuels. Bioethanol emits considerably less carbon dioxide than petrol, which is a non-renewable energy source.

A bioethanol blend of E5 means that there is 5 per cent bioethanol and 95 per cent petrol. E10, E25, E85 and E100 are also available globally. Currently, the E10 blend fuel has been approved by Australian regulators, since its use does not require any modifications to the petrol engines of most cars. However, engines will need to be modified if higher concentrations of bioethanol are used.

One disadvantage of using bioethanol is that it produces less energy than petrol; about 60 per cent of petrol for the same amount of fuel.

FIGURE 8.36 Sources of bioethanol

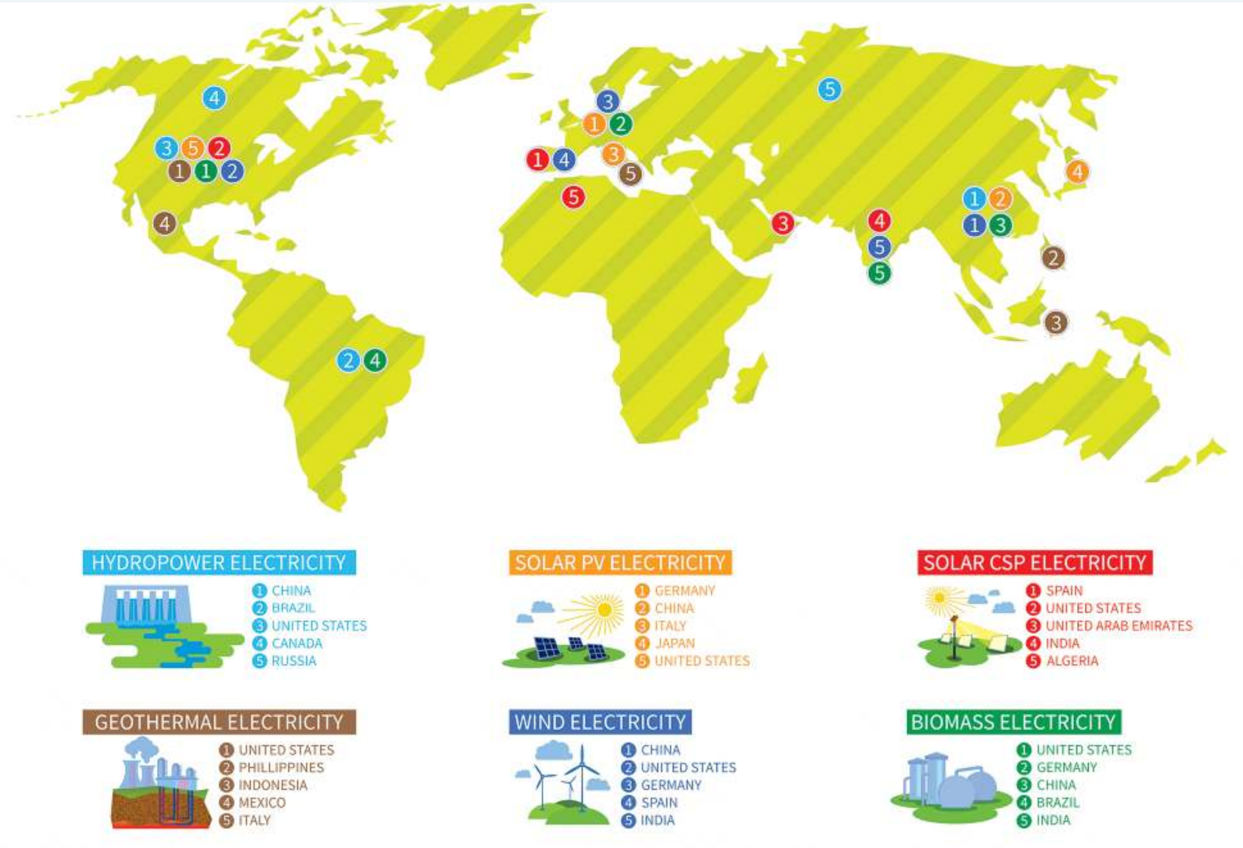


Biodiesel

Biodiesel is made from animal and plant waste (examples include algae, sewage, food waste and plant oils) and is regarded as a renewable fuel. Biodiesel is used as fuel for vehicles and to generate electricity.

FIGURE 8.37 Many different types of materials can be used to make biodiesel including coconut oil, sugarcane, wood chips and food waste.

FIGURE 8.38 Countries that are currently using green and renewable energy sources for electricity. The top five countries for each renewable energy source are also listed



8.4.4 Carbon capture and storage

Carbon capture and storage (CCS) is a technique used to prevent or reduce carbon dioxide emissions into the atmosphere, by storing this gas underground. This technique allows industries to continue to use electricity (from non-renewable fuels) to make products. CCS involves three steps: capturing of CO_2, transportation and storage.

CO_2 capture

Carbon dioxide is separated from the exhaust of power stations, factories and plants. The fuel is burned in an oxygen-rich (O_2) environment, instead of air (which contains only 21 per cent O_2). More concentrated amounts of carbon dioxide emissions are obtained using an oxygen rich environment. This makes it easier and cheaper to capture.

Transportation and geosequestration

The captured carbon dioxide is compressed and chilled to a liquid. Using pipelines or ships, the chilled carbon dioxide liquid is transported to a storage site.

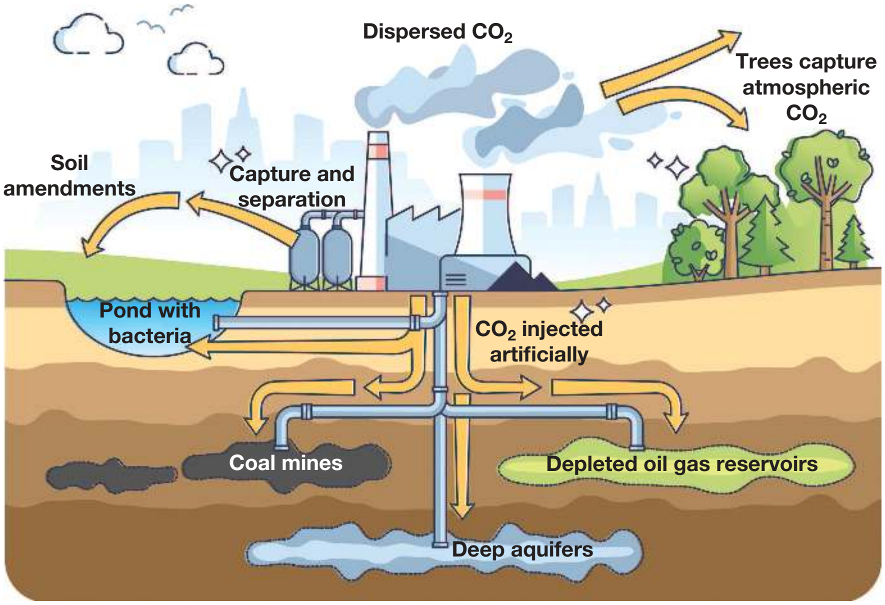
Carbon dioxide is stored at a depth of 800 metres or more below the ground. At this depth, CO_2 is a **supercritical** liquid. Storing carbon dioxide underground is also known as **geosequestration**.

carbon capture a method used to collect carbon dioxide and store it

supercritical a highly compressed liquid

geosequestration storage of liquid carbon dioxide well below Earth's surface

FIGURE 8.39 Outline of carbon capture and geosequestration

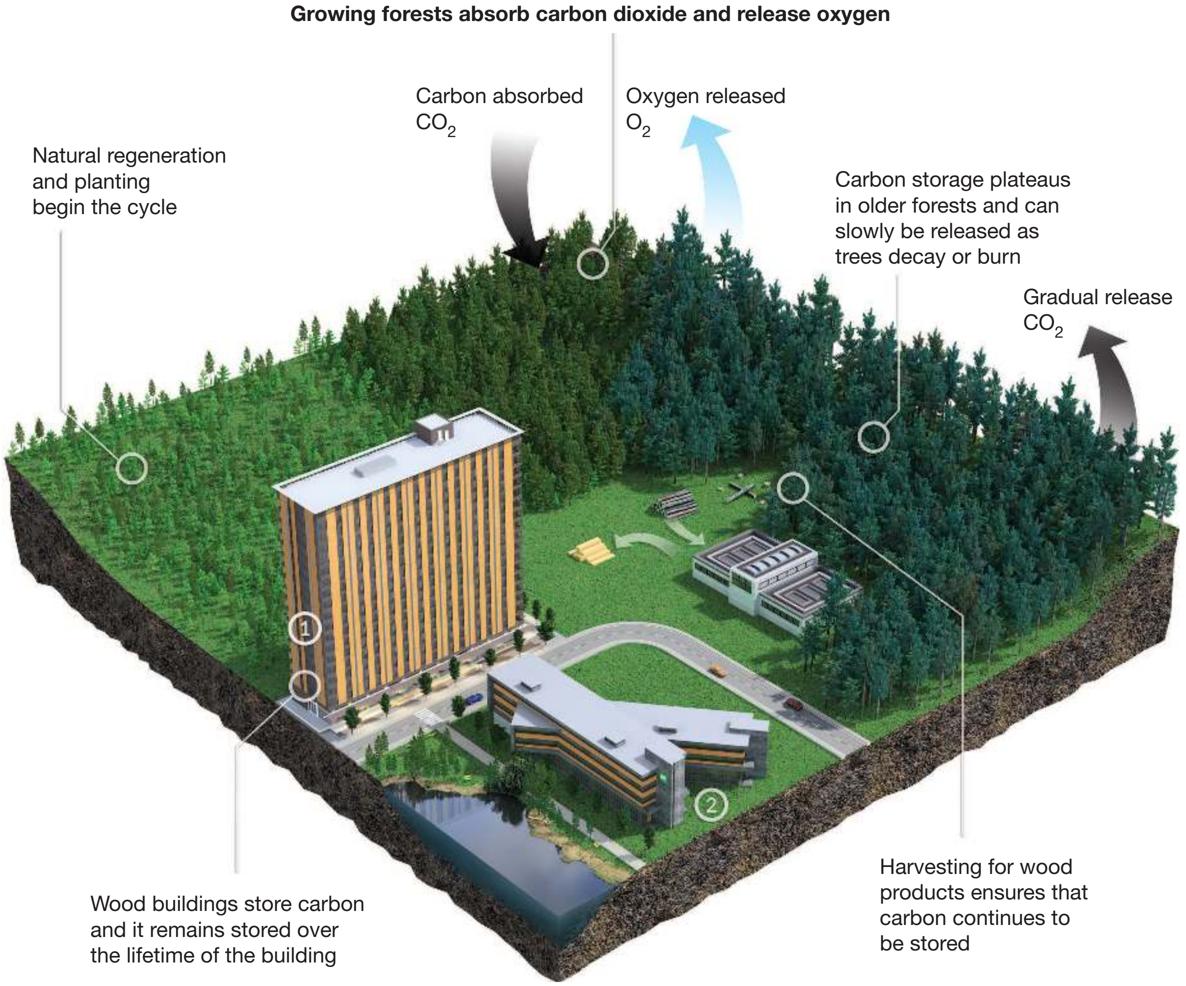


8.4.5 Sustainable forests

Trees use the carbon dioxide from the atmosphere when they undergo photosynthesis. It is recognised that 50 per cent of each growing tree contains carbon stored in the branches, leaves, trunk and roots. Trees improve the soil content and provide shelter for organisms. They may also improve the variety of plants and animals living in a specific habitat. Wood products from trees contains stored carbon. These products are used to build the timber frames of houses and buildings, and in furniture and floorboards. Since 4 million tonnes of carbon are stored in Australia's national forests per year, it makes sense to continue maintaining the forests (such as replacing older or dying trees) to tackle climate change.

FIGURE 8.40 Eucalyptus trees store carbon for many decades.

FIGURE 8.41 How carbon stored in wood can be locked away, rather than being released into the atmosphere. Would burning wood be another way to store carbon?



8.4.6 Electric vehicles

An electric vehicle (EV) has many environmental benefits compared to petrol-fuelled cars. EVs do not produce carbon dioxide when driven. However, it is not entirely true to say that an EV has zero emissions because electricity is used and CO_2 is released to make the car panels and put them together during the manufacturing process. EVs are also a better solution than petrol-fuelled cars because of the rising cost of fuel.

By 2025, it is estimated that 20 per cent of car sales will be electric. A further increase to 40 per cent is expected by 2030. The time it takes to recharge an EV varies from 30 minutes to 12 hours. This may be considered to be a small disadvantage.

FIGURE 8.42 Charging an electric vehicle

elog-2353

INVESTIGATION 8.6

Measuring carbon storage in trees (field trip)

Introduction

Trees take in carbon dioxide (CO_2) and use water to produce glucose during photosynthesis. While some CO_2 is released into the atmosphere during respiration, about half the amount of glucose produced during photosynthesis is stored as biomass in trees. This form of carbon capture is known as forest or carbon sequestration. Forest sequestration is a useful strategy in reducing the amount of CO_2 in the atmosphere. The diameter or height of trees can be used to determine how much carbon is stored in a tree or shrub.

Aim

To measure the carbon storage in a local area

Materials

- measuring tape

Method

1. Divide the area of investigation (for example, a forest or park) into sections or quadrants of 5 square metres. Your teacher may decide to change this number.
2. Record the type of tree (native hardwood, such as gum tree; softwood, such as pine; or other) and measure the circumference in centimetres.
3. Measure and record the height of any shrubs in the section.

Results

1. Use the **Measuring carbon storage** weblink in the Resources panel to determine the amount of carbon stored in the trees and shrubs.
2. Represent the class results in a table.

Discussion

1. What is the process by which carbon is produced in trees and plants?
2. How does carbon storage in trees link to the amount of CO_2 released into the atmosphere?
3. Use the results to identify any trends in the results table.

Conclusion

Summarise the findings of this investigation.

on Resources

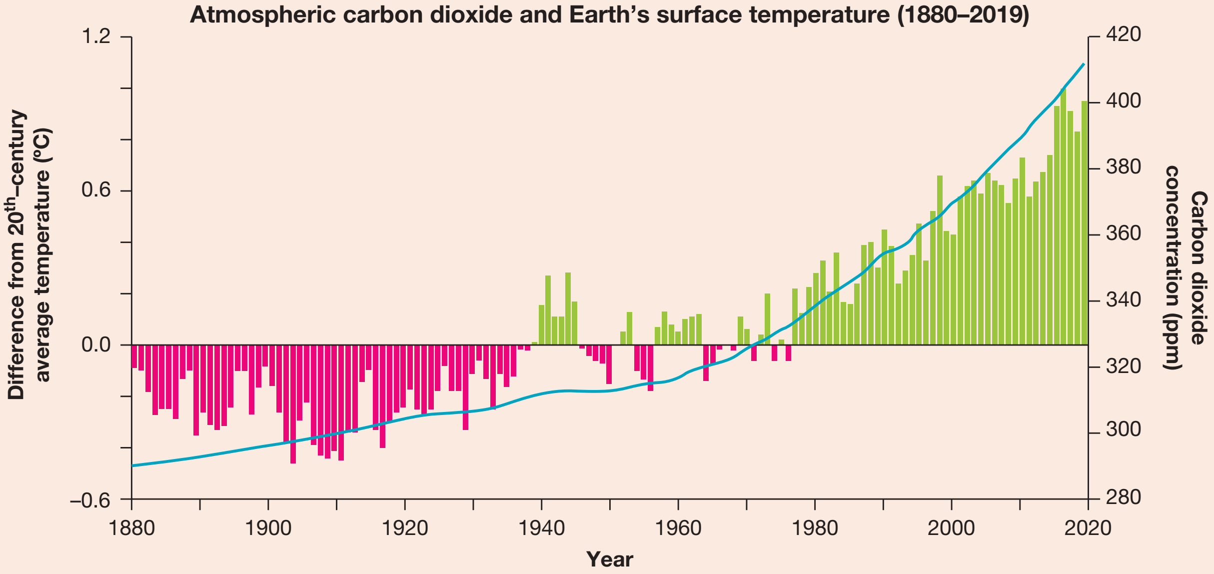
Interactivity The survival game (int-0217)

Weblinks Measuring carbon storage
Forest sequestration

SCIENCE AS A HUMAN ENDEAVOUR: Global coral reef restoration

In 2021, the average global temperature rise was 1.13 °C. Since 2015, this is the seventh consecutive year in which the average global temperatures were found to be above 1 °C. It is imperative that everyone works together and thinks together to reduce the global carbon dioxide emissions by 2050 to zero, so that the temperature increase is below 1.5 °C.

FIGURE 8.43 Relationship between carbon dioxide emissions and global temperatures



Marine biologists recognise the importance of conserving the biodiversity in the ocean, by growing new coral and establishing more habitats for the organisms to survive and thrive. In 2 to 5 years, the tourism industry can benefit from the projects with the aesthetic beauty of the new coral growth. The fisheries sector can benefit as fish populations flourish around the new habitats. To promote the growth of coral, reef restoration projects have been implemented all over the world. This involves adding steel bars (hexagonal stars or cages) to the ocean floor and tying resilient, fast growing coral pieces to the steel.

The Mars Assisted Reef Restoration System (MARRS) has contributed significantly to coral reef restoration. The have installed over 280 000 reef fragments in many areas, such as Australia's Great Barrier Reef, Mexico's Mesoamerican Reef, and several other countries in the Pacific, Indian and Atlantic Ocean. In two years, MARRS has achieved amazing results with the amount of coral increasing from 10% to 60%.

FIGURE 8.44 A deep sea diver working with the steel cages

8.4 Activities

learnon

8.4 Quick quiz on	8.4 Exercise

Select your pathway

🟩 LEVEL 1: 1, 2, 4, 7, 13	🟦 LEVEL 2: 5, 8, 10, 12, 14, 16	🟪 LEVEL 3: 3, 6, 9, 11, 15

Remember and understand

1. What is the difference between a green energy resource and a renewable energy resource?
2. Name two examples of green energy sources.
3. Why are biofuels better to use than petrol or natural gas?
4. Why is carbon capture important?
5. What are the three steps in geosequestration?
6. What is the benefit of growing forests?

Apply and analyse

7. Identify two disadvantages of using bioethanol as a fuel.
8. Explain why it is important for the world to address the problem of global warming.
9. Outline two problems in establishing a geothermal power station.
10. Discuss how recycling will help to slow global warming.
11. Discuss the advantages and disadvantages of electric vehicles versus petrol-fuelled vehicles.

Evaluate and create

12. SIS Is biogas a green fuel? Justify your answer.
13. SIS Discuss two issues in running a wind energy farm.
14. SIS How are the principles of green chemistry used to reduce or minimise global CO_2 emissions? Explain your response.
15. SIS Research and discuss the advantages and disadvantages of using green hydrogen.
16. Create a fact sheet about carbon capture and storage (CCS) and explain how various technologies may be used for this process.

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

LESSON
8.5 Thinking tools — Concept maps

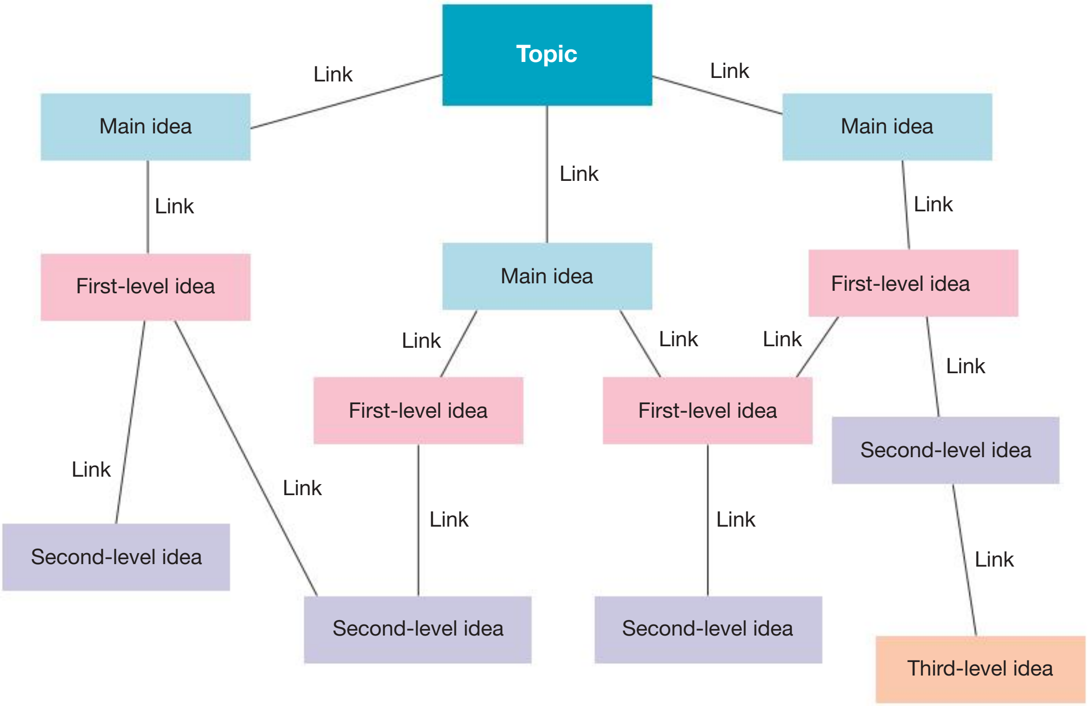
8.5.1 Tell me

What is a concept map?

A concept map is a flow chart that shows an understanding of different interconnected ideas, linking the topic to main ideas, and concepts within those ideas. An example of a concept map is shown in figure 8.45. It is also known as a knowledge map or concept web. It allows you to focus on two main questions:

- What do I understand about this particular topic?
- How do ideas link in this topic?

FIGURE 8.45 Concept map



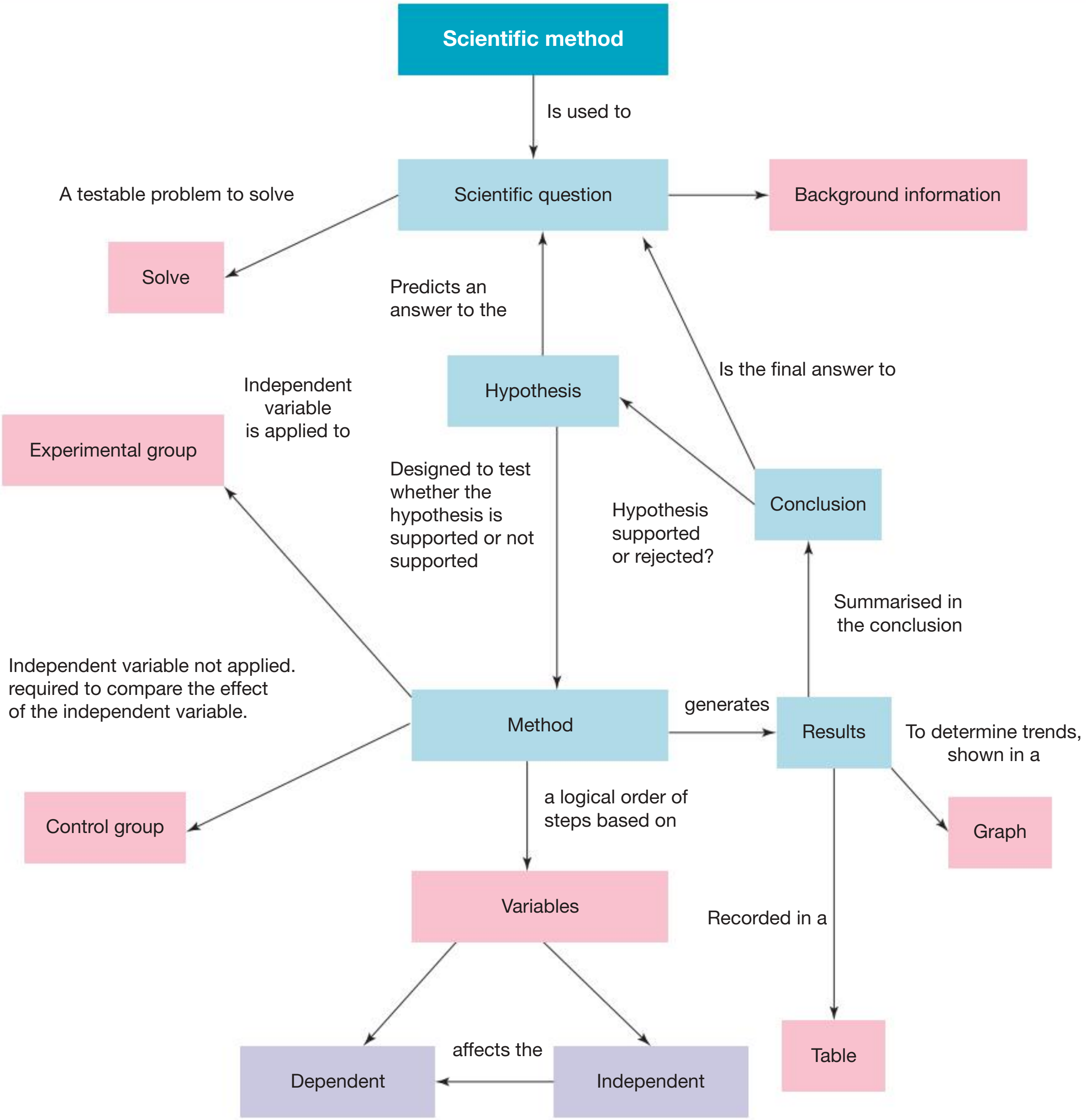
8.5.2 Show me

Creating a concept map

To create a concept map, such as the one shown in figure 8.46, complete the following steps.

1. On small pieces of paper, write down all the ideas you can think of about a particular topic (you may also do this digitally).
2. Start with your topic name and place this at the top of your page.
3. Select the most important ideas and arrange them appropriately under your topic name. Link these main ideas to your topic and write the relationship along the link.
4. When you have placed all your ideas, try to add links between the branches and write in the relationships.

FIGURE 8.46 An example of a concept map of the scientific method



8.5.3 Let me do it

8.5 Activity

Create a concept map for the following events.

a. Fire
b. Climate change
c. Reducing carbon foot print.

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

LESSON
8.6 Project — 2050 Carbon zero house

8.6.1 Scenario

Imagine it is the year 2050. The air quality is quite severe, and it is hard to breathe when you are outside. Many people are wearing air filter masks when they walk their dogs or exercise. In some places, the temperatures are very hot, and people often feel exhausted. There are 60 or more consecutive days of temperatures over 35 °C. Electricity from a gridline or sourced from a power station is limited. Meat, vegetables and milk products are very expensive.

8.6.2 Your task

The task is divided into two parts.

Part 1

Design an energy-efficient and zero-carbon house for the year 2050, using PowerPoint slides or a model.

A zero-carbon house does not emit carbon dioxide gas into the atmosphere. A positive carbon house produces more renewable energy than it needs. Any excess renewable energy that can be made is sold to electricity companies.

FIGURE 8.47 Future homes

The house must contain a minimum of three bedrooms and a garage space to fit at least one car. It will be built 50 kilometres from a city centre. You should consider and justify how you would incorporate the solutions to the following questions in your design.

- How is water treated so that it can be used for drinking, cleaning, showers (bathing), washing clothes and dishes?
- How is air purified?
- What is the energy source used to produce electricity and power?
- Which energy-efficient devices will be used around the house?
- Which building materials have a zero-carbon footprint?
- How can heat be trapped inside the house during winter, so that heaters are not frequently used?
- What can be done to reduce the cost of food?

Part 2

Each group of students will present their 2050 design to the rest of the class, justifying their solutions to each of the questions in part 1. The presentation should take no more than 10 minutes.

on Resources

ProjectsPLUS 2050 Carbon zero house (pro-0258)

LESSON
8.7 Review

Hey students! Now that it's time to revise this topic, go online to:

Review your results

Watch teacher-led videos

Practise questions with immediate feedback

Find all this and MORE in jacPLUS

on Resources

Access your topic review eWorkbooks

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-12547	ewbk-12549	ewbk-12551

8.7.1 Summary

Global systems

- Earth is made up of a number of interconnected systems.
- The biosphere, atmosphere, hydrosphere and geosphere (or lithosphere) are Earth's global systems.
- Interactions occur between Earth's global spheres with each other and the radiant energy of the Sun.
- The biosphere includes all living things (biota) and all ecosystems on Earth.
- The atmosphere (the air) is mostly made up of gases such as nitrogen, oxygen and carbon dioxide.
- The hydrosphere (the waters) includes the water above, on and under Earth's surface such as oceans and rivers.
- The geosphere (the soil) is also known as the lithosphere and includes Earth's outer crust, soil and rocks.
- Within ecosystems, materials are cycled between the atmosphere, hydrosphere and geosphere within the carbon, nitrogen, phosphorus and water cycles.
- The carbon cycle has a direct link to global warming and the enhanced greenhouse effect.
- Cellular respiration, photosynthesis and combustion are processes within the carbon cycle that can have an effect on the amount of carbon dioxide in the atmosphere.
- Human activities such as deforestation, mining, burning fossil fuels and travel can result in increased atmospheric carbon dioxide.

The greenhouse effect

- Carbon dioxide and other greenhouse gases trap the Sun's radiation. This phenomenon is known as the greenhouse effect.
- The enhanced greenhouse effect or global warming is due to the rise in global temperatures, since more carbon dioxide has been released over the past 50 years.
- Global warming has increased average air temperatures and increased sea levels, resulting in melting of ice in Antarctica, the destruction of coral reefs, drying of some areas leading to more frequent and intense bushfires and forcing some organisms into extinction.

Reducing carbon dioxide globally

- The Kyoto Protocol focuses on reducing greenhouse gases, such as carbon dioxide gas, by 5 per cent.
- The Paris Agreement focuses on reducing global temperatures by 1.5 °C and aims for net-zero carbon emissions after 2050.
- Green energy sources do not emit any carbon dioxide and are sustainable. Examples include solar energy, wind energy, hydroelectricity and geothermal energy.

- Bioethanol and biodiesel are examples of renewable energy sources and are biodegradable. Both fuels emit some carbon dioxide gas into the atmosphere, but not as much as non-renewable fuels such as petrol and natural gas.
- Geosequestration is a method used to capture carbon dioxide, transport it and store it as a liquid, 800 metres or more below Earth's surface.
- Carbon capture and storage (CCS) is a technique used to store CO_2 underground. It involves three steps: capturing of CO_2, transportation and storage.
- More people are buying electric vehicles because of the rising cost of petrol and diesel. EVs do not emit carbon dioxide gas.

8.7.2 Key terms

acid rain rainwater, snow or fog that contains dissolved chemicals that make it acidic

allotropes different forms of the same element; diamond and graphite are allotropes, which contain carbon

atmosphere the layer of gases (such as nitrogen, oxygen, methane and carbon dioxide) around Earth

biodiversity total variety of living things on Earth

biosphere the layer in which all living organisms (biota) exist, containing the atmosphere, geosphere and hydrosphere

biota the living things within a region or geological period

carbon capture a method used to collect carbon dioxide and store it

carbon footprint a measure of the amount of greenhouse gases (mainly carbon dioxide) that are released into the atmosphere

combustion a chemical reaction where a fuel reacts rapidly with oxygen to produce heat energy, carbon dioxide and water

cultural burning a fire management technique used by First Nations Australians to burn patches of low-lying vegetation or grass, leaving some parts unburnt and some parts burnt

decomposers small organisms that break down dead and decaying matter

deforestation the process of clearing trees to convert the land for other uses

desertification the process in which fertile regions become drier and more arid

detritivores organisms that feed on decomposing organic matter

enhanced greenhouse effect an intensification of the greenhouse effect caused by an increase in greenhouse gases in the atmosphere

firestick farming another term for cultural burning or cool burning

fossil fuel a fuel that is non-renewable and unsustainable (e.g. coal and natural gas)

geosequestration storage of liquid carbon dioxide well below Earth's surface

geosphere comprises of Earth's outer crust and upper most part of the mantle and includes soil and rocks; also lithosphere

geothermal energy a renewable energy source that uses heat from within Earth to produce steam, which drives turbines to form electricity

gigatonne 10^9 tonnes or 10^{12} kg

global warming increase in the surface temperature above Earth

greenhouse a building containing glass walls and a glass ceiling

greenhouse effect a natural effect of Earth's atmosphere trapping heat from the Sun, mainly by carbon dioxide, resulting in warmer temperatures

greenhouse gases gases found in the atmosphere that contribute to the greenhouse effect, trapping the Sun's heat

hydroelectricity a type of renewable energy that uses water overflowing from a dam to generate electricity

hydrosphere includes all the water above, on, and under Earth's surface such as the oceans, seas, lakes and rivers

infrared a type of energy wave that is part of the electromagnetic spectrum

limestone a sedimentary rock formed from the remains of sea organisms; it consists mainly of calcium carbonate (calcite)

marble a metamorphic rock formed as a result of great heat or pressure on limestone

metric tonne one metric tonne is equal to 1000 kg

nano plastics tiny plastic particles formed from the degradation of plastic products over many years

photosynthesis the process by which phototrophic organisms (such as plants) use light energy, carbon dioxide and water to make glucose and oxygen

phototrophic an organism that obtains energy from sunlight via photosynthesis
radiation a method of heat transfer that does not require particles to transfer heat from one place to another
respiration the process where glucose is broken down in the presence of oxygen to produce carbon dioxide, water and a form of energy that cells can use; also cellular respiration
supercritical a highly compressed liquid
ultraviolet (UV) a form of short-wave radiation, where energy comes from the Sun
unplastify a world organisation who educate students and provide projects to reduce plastic waste and carbon dioxide emissions

Resources

Digital document	Key terms glossary (doc-40143)
eWorkbooks	Study checklist (ewbk-12553) Reflection (ewbk-12554) Literacy builder (ewbk-12555) Crossword (ewbk-12557) Word search (ewbk-12559)
Solutions	Topic 8 Solutions (sol-1142)
Practical investigation eLogbook	Topic 8 Practical investigation eLogbook (elog-2343)

8.7 Activities

8.7 Review questions

Select your pathway

🟩 LEVEL 1:	🟦 LEVEL 2:	🟪 LEVEL 3:
1, 2, 3, 4, 10	5, 7, 8, 12, 13, 15	6, 9, 11, 14, 16, 17

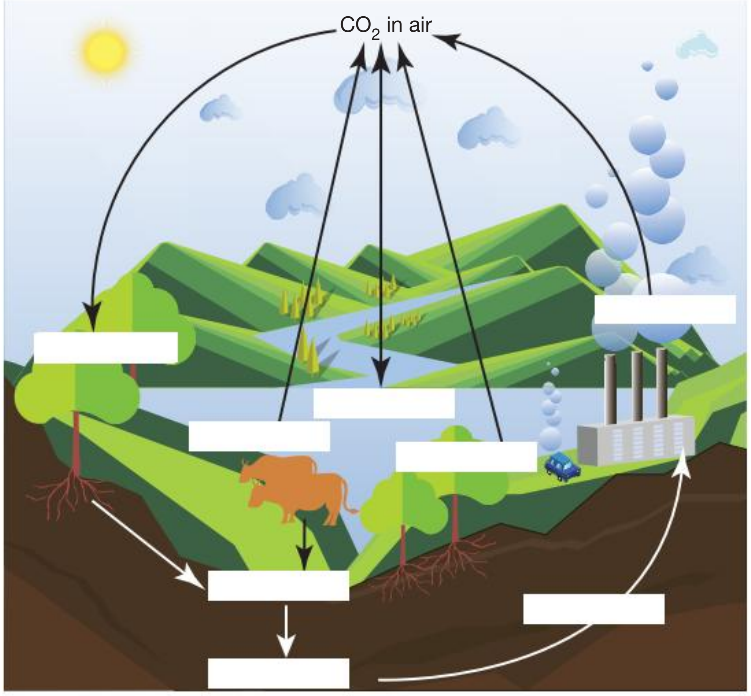
These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. Use the following word bank to label the chemical reactions/processes that occur in the carbon cycle.
Word bank: Photosynthesis, Extraction, Decomposition, Sedimentation, Animal respiration, Plant respiration, Combustion, Ocean uptake and release



2. Why is the carbon cycle important?
3. What are important benefits of the carbon cycle?
4. Is bioethanol a green energy source? Explain your answer.
5. How does deforestation affect the carbon cycle?
6. a. How does carbon sequestration affect global carbon dioxide emissions?
   b. Where does carbon sequestration occur?
   c. What is a major problem with carbon capture and storage strategies?
7. Outline six ways that everyone can help to reduce the carbon footprint.
8. How does desertification relate to the enhanced greenhouse effect?

Apply and analyse

9. Is the Paris Climate agreement enough to reduce global temperatures by 2050? Justify your answer.
10. The world is moving towards green energy, but does this mean that we stop using fossil fuels now? Justify your response by considering the benefits and disadvantages of using fossil fuels?
11. Construct a Venn diagram table showing the differences and similarities between cultural burning and controlled burning.

Different **Cultural burning**	***Same***	***Different*** **Controlled burning**

12. Discuss the environmental, social and economic reasons why reducing your carbon footprint is important.
13. Discuss the benefits of reducing carbon dioxide gas emissions.
14. Why do scientists agree that a global temperature rise of 1.5 °C is important to acknowledge?

Evaluate and create

15. Research carbon credit. Explain how the First Nations Australians use carbon credits to reduce CO_2 emissions.
16. **SIS** Does the internet create any carbon footprint? Explain your response.
17. **SIS** Consider the pros and cons of bioplastics. Could bioplastics reduce future carbon dioxide emissions? Justify your response.

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

Online Resources

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 (ewbk-12534)
- Starter activity (ewbk-12536)
- Student learning matrix (ewbk-12538)

Solutions

- Topic 8 Solutions (sol-1142)

Practical investigation eLogbook

- Topic 8 Practical investigation eLogbook (elog-2343)

Video eLesson

- Climate change protests (eles-4175)

Weblinks

- Cultural burning
- Fighting fire with fire
- Three things I know about fire management
- How to conduct a cool burn

8.2 Global systems

eWorkbooks

- Labelling the carbon cycle (ewbk-12539)
- Recycling carbon (ewbk-12541)

Practical investigation eLogbooks

- Investigation 8.1: Testing for photosynthesis (elog-2345)
- Investigation 8.2: Rate of melting ice on land and in the sea (elog-2347)

Video eLesson

- Excessive clearing and deforestation (eles-2905)

Interactivities

- The different biomes on Earth (int-8228)
- Labelling the carbon cycle (int-9188)
- Lake Urmia in 1998 and in 2011 (int-5605)

Weblinks

- Australian State of the Environment: Land
- Our world in data
- Working Together — Earth's Systems and Interactions

8.3 The greenhouse effect

Interactivity

- Sources of greenhouse gases (int-5884)

eWorkbook

- Global warming and the greenhouse effect (ewbk-12543)

Practical investigation eLogbooks

- Investigation 8.3: Modelling the greenhouse effect (elog-2418)
- Investigation 8.4: Effect of carbon dioxide on ocean acidity (elog-2349)
- Investigation 8.5: Carbon footprint activity (elog-2351)

Teacher-led video

- Modelling the greenhouse effect (tlvd-10807)

Video eLessons

- Global warming in Australia (eles-0057)

Weblinks

- Climate science investigations
- Coral reef bleaching
- 2010 Sustainable Cities Index
- 2022 Sustainable Cities Index
- WWF footprint calculator
- Sea rise satellite data

8.4 Reducing carbon dioxide globally

Practical investigation eLogbook

- Investigation 8.6: Measuring carbon storage in trees (field trip) (elog-2353)

Interactivity

- The survival game (int-0217)

Weblinks

- Measuring carbon storage
- Forest sequestration

8.6 Project — 2050 Carbon zero house

ProjectsPLUS

- 2050 Carbon zero house (pro-0258)

8.7 Review

eWorkbooks

- Topic review Level 1 (ewbk-12547)
- Topic review Level 2 (ewbk-12549)
- Topic review Level 3 (ewbk-12551)
- Study checklist (ewbk-12553)
- Literacy builder (ewbk-12555)
- Crossword (ewbk-12557)
- Word search (ewbk-12559)
- Reflection (ewbk-12554)

Digital document

Key terms glossary (doc-40143)

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

9 Energy transmission

CONTENT DESCRIPTION

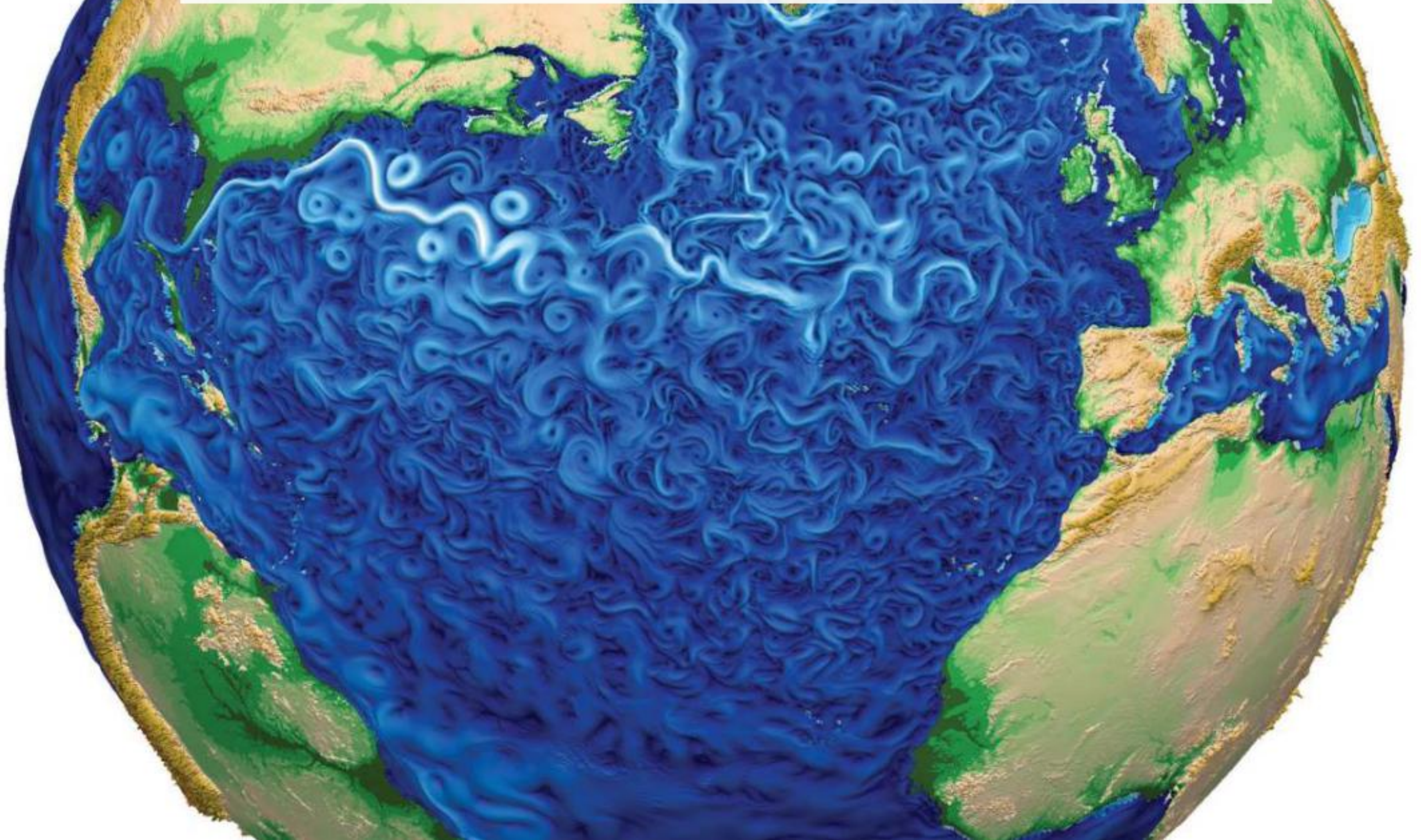
Use wave and particle models to describe energy transfer through different mediums and examine the usefulness of each model for explaining phenomena (AC9S9U04)

Source: F–10 Australian Curriculum 9.0 (2024–2029) extracts © Australian Curriculum, Assessment and Reporting Authority; reproduced by permission.

LESSON SEQUENCE

SCIENCE INQUIRY AND INVESTIGATIONS

Science inquiry is a central component of Science curriculum. Investigations, supported by a **Practical investigation eLogbook** and **teacher-led videos**, are included in this topic to provide opportunities to build Science inquiry skills through undertaking investigations and communicating findings.



LESSON
9.1 Overview

Hey students! Bring these pages to life online

Watch videos

Engage with interactivities

Answer questions and check results

Find all this and MORE in jacPLUS

9.1.1 Introduction

If you take apart a smartphone you will find plastic, glass, computer chips, copper wire and so on. You won't find the 'energy' as it is not a 'thing'. This makes it more difficult to understand and define, because it can't be seen, it doesn't take up space and it has no mass. Energy is a concept. Energy makes things happen. Everything in the Universe that has what we call energy is either moving or has been moved to a position where, with a nudge, movement can occur.

FIGURE 9.1 Your brain relies on energy transfers to communicate. The electrical impulses travel along the nerve fibres.

Think about the types of energy that you know. Electrical energy is the movement of electrons or potential for their movement (static electricity). Sound energy is the movement of particles in the air. Chemical energy is the energy stored in the bonds of chemical compounds. Kinetic energy is literally movement energy (the image that opens this topic shows the global ocean surface kinetic energy, 2015). If you put a ball on a shelf it has gravitational potential energy, which is, in essence, a way of storing energy. With a nudge, the ball can roll off the shelf and the stored energy is released and converted into kinetic energy as the ball falls.

We only really notice energy when it is transferred between objects or transformed into a different type of energy. When we touch fire, the heat energy in the flames (the quickly moving particles) is transferred to our skin (making our particles move more quickly). Strangely we cannot see a beam of light. It is only when the energy is converted to electrical impulses by our retina, and travel through the optic nerve to our brain, that we detect light. We detect sound waves when they transfer the kinetic energy of the air molecules to the moving parts in our ear.

Nothing in the Universe can happen without the transfer or transformation of energy. In this topic, we consider how energy transfers in the environment are responsible for our habitable world. We then discover how we communicate by means of energy transfer and how we have developed technologies to extend our communication networks around the world and beyond.

9.1.2 Think about energy transmission

1. Why is it that of all the planets, only Earth seems to support life?
2. Why do I feel so cold when I get out of the ocean even on a hot sunny day?
3. Why do some things emit light while others don't?
4. How does sound get from one smartphone to another?
5. Will we ever be able to improve on our eyes and ears?
6. How can the blind see?
7. How will we be communicating in the future?

9.1.3 Science inquiry

Using energy to communicate

Since prehistoric times, we have had a need to communicate over a distance. Our early ancestors would make noise to warn of approaching predators. The communication range was short but it was enough to serve the purpose.

Once humans started to make settlements, we started to see the need for a form of communication that could take information a greater distance. Smoke signals, large bonfires and drums were used to send simple messages. Anything more complex required the delivery of hand-written letters, which only happened after the invention of writing around 6000 years ago. Shortly after writing was invented came messenger services. Important messages would be given to runners who would hand-deliver news. Due to the likelihood of these messages being intercepted by an enemy, codes and encryption were also invented soon after.

FIGURE 9.2 Global communication began with ships.

With the invention of the ship for ocean navigation and the exploration of the globe, communication eventually became a global issue. In March 1791, Captain Arthur Phillip, Governor of New South Wales, wrote a letter to his employer, King George III in London, asking for some time off work. The only way to get the letter to London was by sailing ship. The letter took 8 months to get to King George III, and his reply took a further 8 months to reach Sydney. A faster technology was clearly needed if we were to regularly communicate around the planet.

Although the transmission of matter is a lot faster today, a letter sent from Sydney to London via airmail would still take about 5 days to arrive and at least another 5 days for the reply to be received in Sydney. A much faster method of communication is via telephone or email, which only take seconds for the reply to arrive. There is no longer any need for matter, such as letters, to be transported. The message sent between Sydney and London via the transmission of energy can be sent at the speed of light — 300 000 kilometres per second. Over long distances, there are many advantages of energy transmission without the transmission of matter.

Answer the following questions about how we use energy to communicate.

1. What has changed since 1791 to reduce the communication time from Sydney to London and back from 16 months to 10 days?
2. What are all of the options now available for sending a message from Sydney to London? Which options do not require the movement of matter from Sydney to London and back? How fast is this communication?
3. If matter does not move from one place to another when a message is sent over a long distance, what does move?

Even over a short distance the transmission of energy is faster than the transmission of matter. Imagine that you want to warn a couple of friends that they are about to be hit by an out-of-control skateboarder. Your options for saving them include:

A. yelling at them to get out of the way
B. yelling and pointing at the skateboarder
C. waving your arms in the air and pointing
D. holding up a sign that says 'Watch out!'
E. running across the road to push them out of the way.

4. Which of the options A–E involves:
   a. the transmission of matter
   b. the transmission of energy
   c. the transmission of both matter and energy?
5. In your opinion, which of the options A–E is the:
   a. fastest
   b. slowest
   c. least safe?
6. Write as much as you know about the following types of invisible waves.
   a. Sound
   b. Ultrasound
   c. Visible light
   d. Microwaves
   e. Infrared
   f. Radio waves

on Resources

eWorkbooks	Topic 9 eWorkbook (ewbk-12591) Student learning matrix (ewbk-12593) Starter activity (ewbk-12594)
Solutions	Topic 9 Solutions (sol-1152)
Practical investigation eLogbook	Topic 9 Practical investigation eLogbook (elog-2375)

LESSON
9.2 Heat transfer

First Nations Australian readers are advised that this lesson and relevant resources may contain images of and references to people who have died.

LEARNING INTENTION

At the end of this lesson you will be able to distinguish between heat and temperature, define absolute zero and describe the key mechanisms of energy transfer in terms of the particle model.

9.2.1 What is energy?

Have you ever felt like you were 'full of energy'? If so, you probably felt like moving around or doing something active. Objects can have energy too. We cannot always see the energy that they possess, but we can often observe the effects of objects gaining or losing energy. Winding up a toy or pulling back the string of an archery bow gives these objects lots of energy.

FIGURE 9.3 Winding up a toy or pulling back the string of an archer's bow provides these devices with energy to move and/or change.

Energy is defined as the ability to exert a force and cause change (such as moving or deforming an object).

Energy may cause an object or other nearby objects to move, such as winding up a toy or firing an arrow from a stretched bow. The energy of an object can also give objects the potential to move or to create sound, **heat** or light.

heat the total energy of a substance due to the movement of all of its particles

Types of energy	
Potential energy Stored energy that, when released, is converted to other forms such as sound, heat or light energy	**Other types of 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, when reacted together such as in burning reactions, release heat, sound or light 	**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 release energy slowly, such as in a nuclear reactor, or quickly, such as in a nuclear explosion 	**Sound** Energy carried by the air in a room and detected by the ear 
Electrical Energy stored by the build-up of charge 	Energy provided by the movement of electrons 
Magnetic Energy stored in magnets or metals placed in a magnetic field 	

FIGURE 9.4 The chemical energy in household batteries is an example of potential energy that powers many household devices, including remote controls.

FIGURE 9.5 All objects that are moving have kinetic energy. The faster an object moves, the more kinetic energy it has. Moving objects can do work by travelling distances or by colliding with other objects.

9.2.2 Transferring and transforming energy

Energy can be transferred, or passed on, to another object or to the surrounding environment. For example, if you hug a hot-water bottle, the heat is transferred from the bottle to you. The heat has been transferred from one object to another, but has not changed form.

elog-2377

INVESTIGATION 9.1

Popping corn

Aim

To investigate the transformation of energy

Materials

- saucepan with lid
- popping corn
- matches
- vegetable oil
- Bunsen burner
- heatproof mat

Method

1. Pour a little cooking oil in the saucepan.
2. Pour enough popping corn into the saucepan to cover the base and place the lid securely on top.
3. Light the Bunsen burner and heat the saucepan in a blue flame, making sure the flame is spread evenly over the base of the saucepan.
4. Heat the corn until the popping stops.
5. Turn off the Bunsen burner, put the saucepan on the heatproof mat to cool and take the lid off the saucepan to observe any changes.
6. Record your observations.

Discussion

1. What type of energy did the popping corn have before heating? What type did it have during heating?
2. Even though you could not see the corn when the lid was on, how do you know that an energy transformation took place?

Energy can also be transformed**,** or converted, into other forms of energy. For example, the electric motor in a hair dryer transforms electrical energy into kinetic energy: that is, the energy of the moving fan blades. Sometimes, during a transformation of energy, not all of the energy is transformed into useful forms.

Some of the energy may be transferred to the surrounding environment as unwanted heat, or transformed to light or sound. For example, not all of the energy you use to ride a bike up a very steep hill goes into making the pedals move. Some of the energy is 'wasted' as your body gives off heat, or as heat is produced by friction in the gears.

THE LAW OF CONSERVATION OF ENERGY

When objects stop moving, they no longer have kinetic energy. But the energy is not lost. Instead, it is converted (transformed) into another type of energy or passed on (transferred) to another object. The Law of Conservation of Energy tells us that the amount of energy in a system is always the same. Energy is never lost and energy is never created.

Sometimes it is difficult to track where the energy goes. For example, most of the kinetic energy when you clap your hands is transferred to air as sound, but you might also notice that your hands get warm. This demonstrates that some of the original energy is transformed to heat too.

FIGURE 9.6 Electrical energy supplied to the light globe is transformed into heat and light energy in the filament. The light is the desirable energy, but the heat is considered 'wasted' because it has no benefit to us.

FIGURE 9.7 In a game of pool, the white cue ball is struck, providing it with kinetic energy. The kinetic energy of the white ball is then *transferred* to the coloured ball.

FIGURE 9.8 A computer transforms electrical energy into light energy in the screen and sound energy when music and videos are played.

FIGURE 9.9 A stove top *transforms* electrical energy into heat energy in the glowing hotplate, which is then *transferred* to the pot and water.

9.2.3 Heat and temperature

The amount of heat energy (or thermal energy) that an object has is due to the total **kinetic energy** of every particle in the object. You may have seen in science fiction movies that space is cold. This is true; it is approximately –270 °C. At this temperature the particles have almost stopped moving. Just 3 degrees colder and the particles would stop completely. This is what we call **absolute zero**.
You cannot get colder than this.

The **temperature** of any substance is linked to the average kinetic energy of the particles of that substance. As the substance is heated, some of the absorbed energy is stored in the particles and some increases the motion of the particles. This causes an increase in the temperature of the substance.

kinetic energy energy due to the motion of an object

absolute zero the lowest temperature that is theoretically possible, at which the movement of particles stops. It is zero on the Kelvin scale, equivalent to –273.15 °C.

temperature the average kinetic energy of the particles in a substance

Temperature is a measure of the average kinetic energy of the particles, not the total energy in the object. This is vital to understand in the context of such issues as climate change. A rise in temperature of one degree doesn't sound like a lot, but when you think about all of the particles in the atmosphere you realise that this means a huge amount of extra energy will be in the atmosphere.

DISCUSSION

If you have an object at 0 °C and you double the energy content, do you just double the temperature?

Clearly there is a link between the idea of heat and temperature but they are not the same thing. A typical sparkler will throw off sparks with a temperature of over 1000 °C, but as the particles in the sparks have a small mass, their heat energy is quite low, making them practically harmless. The sparks are at a temperature that makes them glow with visible light. Each spark is safe, but the larger mass of the sparkler itself makes it dangerous to touch.

However, we know that if you spill boiling water on yourself it will burn you. The water at 100 °C is much cooler than the spark, but as there are so many more particles involved there will be a much greater heat energy. At any given temperature, not all the particles of any substance have the same kinetic energy. Instead the particles possess a wide range of kinetic energies. Temperature is only a measure of the average kinetic energy of the particles, not the total energy in the object.

FIGURE 9.10 Liquid nitrogen is comparatively warm compared to space at only –196 °C. Objects placed in liquid nitrogen will become brittle and may shatter as their particles slow down causing the object to contract.

ACTIVITY: Heat vs temperature

Investigate the difference between heat and temperature by filling two beakers with a different volume of water. Heat each beaker on an identical hot plate, on the same setting, for the same amount of time, thus supplying the same amount of heat energy to each beaker. Does an equal change in heat energy result in the same change in temperature?

FIGURE 9.11 The tiny sparks have a very high temperature, but their small mass means their heat energy is low.

FIGURE 9.12 Boiling water has a temperature of only 100 °C but there are many particles of boiling water.

on Resources

Weblink Video: Difference between temperature and heat

9.2.4 Heat flow

When an object is warmer than its surroundings, heat energy will flow out of it in one or more ways. These are **conduction**, **convection** and **radiation**.

conduction the transfer of heat through collisions between particles

convection the transfer of heat through the flow of particles

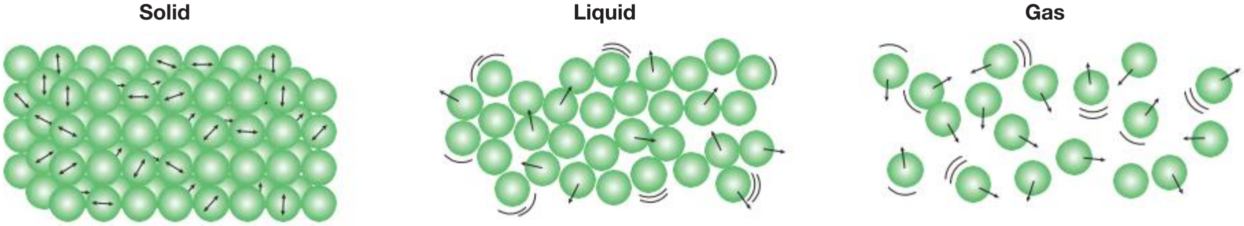
radiation a method of heat transfer that does not require particles to transfer heat from one place to another; the transfer of energy through electromagnetic waves

Conduction

Conduction occurs when a particle passes kinetic energy on to another particle. This can happen during collisions. For example, when an oxygen molecule in the air hits your arm, it will leave more quickly than it arrived as the faster particles in your arm transfer energy to the oxygen molecule.

More commonly, we think of conduction as heat transfer in a solid. Most solids are better conductors than liquids and gases because their particles are more tightly bound and closer together than those of liquids and gases. Conduction is a slow way to transfer energy in liquids and gases.

FIGURE 9.13 Heat transfer in a solid, a liquid and a gas



The particles in a solid are packed closely together. If some particles receive heat energy and begin to move faster, they collide easily with other particles nearby and pass the heat energy along.

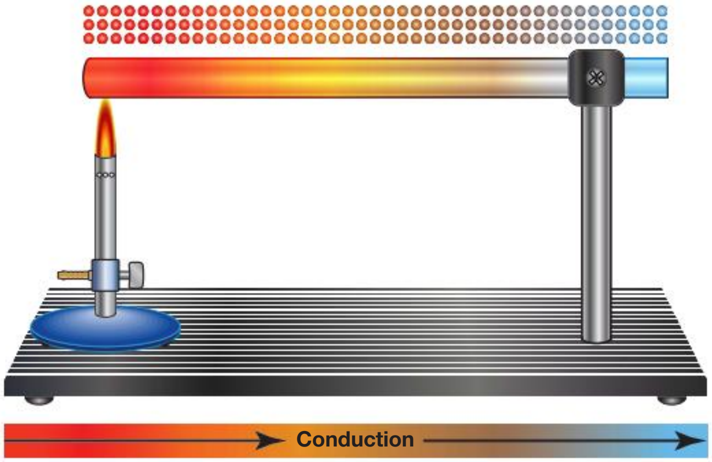
The particles in liquids are further apart than the particles in solids. When some particles receive heat energy and start to move faster, they collide with other particles. But the distance between the particles means that there are fewer collisions. So, heat is transferred by conduction more slowly in a liquid than in a solid.

The particles in a gas are far apart. Heat does not travel easily by conduction through gases.

The particles in a solid have bonds between them. These help to transfer the energy from the hot region to the cold region. Imagine one end of a metal bar is heated by contact with the hot gases from a Bunsen burner — let's consider what happens next:

- The particles at the warm end gain kinetic energy.
- This means they vibrate more.
- As the faster particles are connected to other particles by bonds, the neighbouring particles are pulled around more.
- This means that *energy has been transferred*.
- This transfer of energy continues down the bar towards the colder end.
- This will only stop when the bar is the same temperature at all points and the energy is shared evenly between the particles.

FIGURE 9.14 In a solid, heat energy will be transferred from a hot region to a cold region by conduction.



Metals are the best conductors of heat. The electrons of metals are freer to move than those of other solids and are therefore able to transfer their kinetic energy more readily to neighbouring electrons and atoms. We use metals to efficiently transfer heat in many situations. A common use is in computers and phones where metal **heat sinks** prevent the processors from overheating.

Materials that are poor conductors are called **insulators**. Materials such as polystyrene, foam, wool and fibreglass batts are effective insulators because they contain pockets of still air. Air is a very poor conductor of heat.

heat sink device that transfers the heat generated by an electronic or a mechanical component to a coolant, often the air or a liquid, where it can be taken away from the component

insulator material that has a very high resistance, allowing very little current to flow through it

on Resources

Weblinks Particle simulation of thermal conduction
Conduction simulation

First Nations Australians' heat conservation — possum-skin cloaks

Before colonisation, people living in the south-east regions of Australia wore possum skins to help them preserve their warmth in cold temperatures during the day (see figure 9.15), and as a covering during the night.

People living in warm climates mostly used single-layered cloaks or capes. These were made from marsupial skins, mostly kangaroo or wallaby. There is a close relationship between the geographical distribution of First Nations Australians' clothing and the climate. Possum cloaks were made in south-eastern Australia, including in Tasmania, because of the cold climate and large population of possums. The skins of possums were carefully removed and dried, and animal fat was rubbed on them to make them flexible and waterproof. The skins were then sewn together.

The possum-skin cloaks provide warmth by forming an insulating layer between the person's skin and the fur. The fur on the inside of the cloak traps body heat and prevents it from escaping. The trapped heat between the fur provides warmth to the body.

FIGURE 9.15 Teenminne, a Ngarrindjeri woman wearing a possum-skin cloak carrying a child on her back, South Australia, circa 1870

on Resources

Interactivity Insulating your body (int-3402)

CASE STUDY: Baking with ice cream!

Imagine putting a scoop of ice cream into a 230 °C oven for three minutes. That's exactly what you do when you make bombe Alaska, a dessert with a solid ice-cream centre on a sponge cake, covered with meringue. Bombe Alaska — ice-cream and all — is baked in a preheated 230 °C oven for 3 minutes. Yet the ice-cream doesn't melt! The secret to this is the insulating properties of the sponge and meringue. The bombe pictured here has strawberry (pink) and orange ice cream on top of the sponge cake. The white meringue has been cooked and has been changed to a brown colour by the heat of the oven. The poor conduction properties of the meringue have not been able to transfer heat to the ice cream.

elog-2379

INVESTIGATION 9.2

Heat conduction in solids

Aim

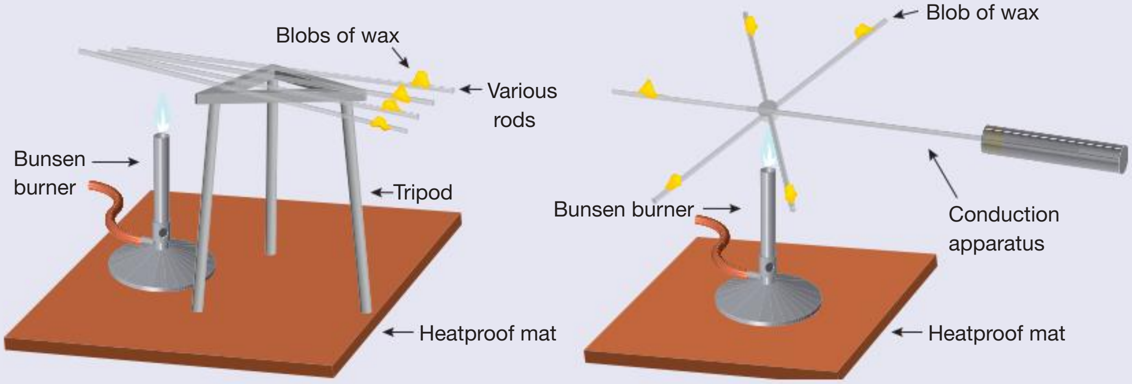
To compare the conduction of heat through different metals

Materials

- set of 3 or 4 metal rods (different metals but identical in size) or a heat conduction apparatus
- wax candle
- Bunsen burner and heatproof mat
- matches
- tripod
- ruler
- stopwatch

Method

1. Set up the tripod and rods or heat conduction apparatus as shown.
2. Light the candle and melt a blob of wax onto one end of each rod. Ensure that each wax blob is the same distance from the end that will be heated by the Bunsen burner flame.
3. Use the blue flame of the Bunsen burner to heat the end of each rod. Start the stopwatch at the instant that heating begins.
4. Record the time taken for each blob to produce its first droplet of wax.
5. Repeat steps 1–4 for each different metal rod.



Results

1. Record your data in a table.
2. Present your data as a bar or column graph. Consider why these are the best choices to plot your data.

Discussion

1. According to your data, which of the metals is the best conductor of heat?
2. According to your data, which of the metals is the poorest conductor of heat?
3. Identify the independent and dependant variables in your investigation.
4. Compare your data with that of others in your class. Comment on the consistency of the conclusions within your class. If there was inconsistency, suggest one or more reasons for it and suggestions to improve the experiment.

Conclusion

Write a conclusion to your investigation, remembering to refer back to the aim.

Convection

Unlike the particles that make up solids, those of liquids and gases are able to move around. In liquids and gases, heat can be transferred from one region to another by the actual movement of particles. This type of heat transfer is called convection.

FIGURE 9.16 Modelling heat transfer in air

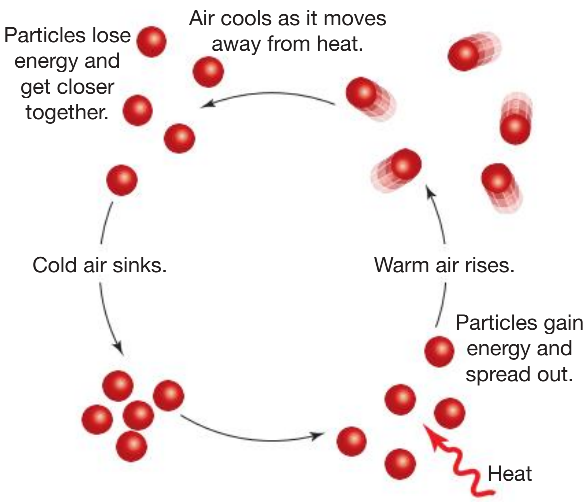


Figure 9.16 shows how convection takes place in air:

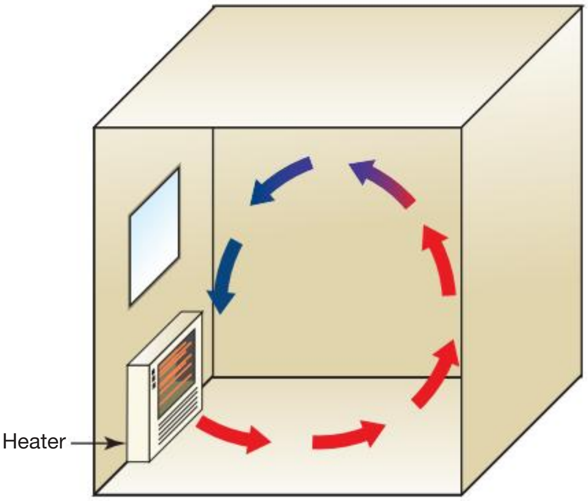
- Particles are heated. They gain *kinetic energy* and move around more.
- The heated air is now *less dense*.
- Less dense things float on more dense things and so the hot air rises.
- This also means that cold air must sink down to take the place of the hot air.
- As the faster moving particles rise, they collide with other particles sharing out the energy.
- The once hot air is now cooler and will now take up less space, become denser and sink.
- The process repeats until all of the air is the same temperature.
- We call this cycle of heat, rise, cool, fall, repeat a **convection current**.

In Earth's mantle, convection currents carry heat from Earth's core towards the surface. This heat from the core causes the rock in the mantle to expand and rise towards the surface, where the heated rock cools down, contracts, and then sinks back down towards the core. Once near the core again, the rocks are reheated and rise once more, and the cycle continues.

These convection currents enable the drift of the tectonic plates, which is why continents move.

Home heating systems create convection currents that move warm air around. When ducted heating vents are in the floor, warm air rises and circulates around the room until it cools and sinks, being replaced with more warm air. Powerful fans are not necessary. Gas wall heaters have fans to push warm air across the room near floor level so that it heats the entire room. Ducted heating vents in the ceiling require powerful fans to push the warm air downwards so that it can circulate more efficiently.

FIGURE 9.17 Convection currents circulate warm air pushed out by heaters around the room.



Hot summer days by the sea

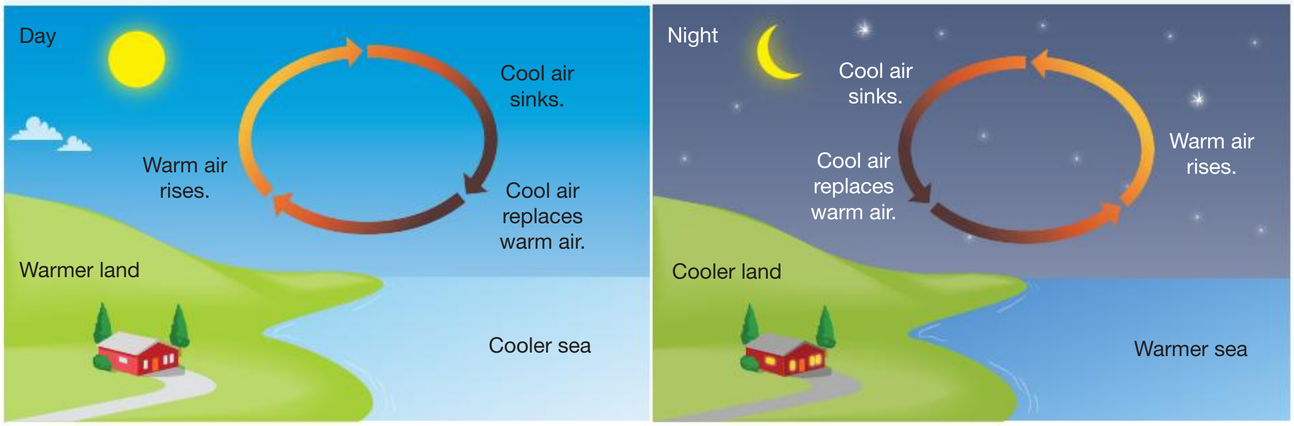
Coastal areas usually experience less extreme maximum temperatures on hot summer days as a result of **sea breezes**. This occurs by the following process:

- During hot summer days, radiant energy from the Sun heats the land and the sea.
- As a result of the different properties of the land and water, after a few hours the land has a higher temperature than the sea.
- The hot air over the land expands, becoming less dense than the cooler, denser air over the sea.
- The air over the land becomes hot as a result of conduction.
- The cooler air over the sea rushes in towards the land, replacing the rising warm air, causing a sea breeze. At night, if the sea temperature is higher than the land temperature, the convection currents move in the opposite direction, creating a flow of air towards the sea.

convection current the movement of particles in a liquid or gas resulting from a temperature of density difference

sea breeze the breeze that occurs when differences in air pressure cause air particles to flow from the ocean towards the land

FIGURE 9.18 A sea breeze is caused by convection currents in the air during warm summer days. At night the convection currents are reversed.



elog-2381

INVESTIGATION 9.3

Convection currents in a chimney box

Aim

To observe and understand convection currents by using a chimney box

Materials

- chimney box (a rectangular box with two chimneys on opposite sides and a removable, clear front panel)
- candle or heat source
- matches or lighter
- paper (scrunched into a small baton shape)

Method

Part A:

1. Set up the chimney box by setting it on a stable surface, ensuring the chimneys are unobstructed and closing the front panel.
2. Light the paper with a match and then extinguish it after a second or two, to produce smoke.
3. Hold the smoking paper above the first chimney.
4. Observe the movement of the smoke.

Part B:

1. Open/remove the front panel of the box.
2. Light the candle using a match.
3. Place the lit candle under the second chimney in the chimney box.
4. Close the front panel.
5. Wait 1–2 minutes for the candle to raise the temperature of the box slightly.
6. Re-light and extinguish the paper to produce smoke.
7. Hold the smoking paper above the first chimney.
8. Observe the movement of the smoke.

Results

1. Describe the motion of the smoke in Part A.
2. Describe the motion of the smoke in Part B.

Discussion

1. How does the experiment demonstrate the concept of convection?
2. Describe the movement of air within the chimney box. How does the heat source affect this movement?
3. What is the purpose of having two chimneys in the box?
4. What factors might affect the speed at which the air circulates within the chimney box?
5. In what real-life situations can you observe convection currents like this?

Conclusion

Write a conclusion to your investigation, remembering to refer back to the aim.

Radiation

Heat can be transferred without the presence of any particles at all, as electromagnetic radiation or light. Heat transferred in this way is called **radiant heat**. As you will see later in this topic, not all forms of light are visible to our eyes. One type of light that you can't see but can feel is *infra-red light*. If you hold your hand over a hot object you can feel the heat even if it is not glowing with visible light.

Heat from the Sun reaches the Earth by radiation, most of it in the form of infra-red radiation. There are not enough particles between the Sun and Earth for heat transfer by either conduction or convection.

radiant heat	heat that is transferred from one place to another by radiation
transmitted	light is passed on from one place to another through space or a non-opaque substance
absorbed	energy hitting an object is transferred to it. This will cause the atoms in the object to vibrate more and the temperature will rise.

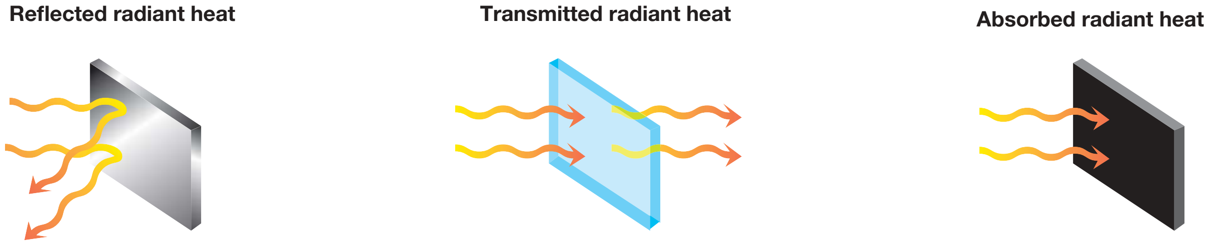
There are three things that can happen when electromagnetic radiation meets an object. As an analogy, let us imagine a bullet fired at a target. What could happen?

- If the energy of the bullet is too little it may just bounce off the target: it would be reflected.
- If the energy is high enough it may pass through the target: it would be **transmitted**.
- If the energy is within a narrow range it may stick in the target without passing through: it would be **absorbed**.

In a similar way, when the infra-red light waves that we call radiant heat meet an object, they can be reflected, transmitted or absorbed. How much energy is reflected, transmitted or absorbed depends on the properties, including colour, of the surface. The greenhouse effect (see lesson 8.3) is an example of the radiant heat from the Sun being absorbed and reflected by greenhouse gases, such as carbon dioxide, water vapour and methane, present in the atmosphere.

int-3400

FIGURE 9.19 Heat may be reflected, transmitted or absorbed.



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.

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 radiation.

Absorbed radiant heat

Dark-coloured objects tend to absorb light and radiant heat. Their temperatures increase quickly when heat reaches them by radiation.

elog-2383

INVESTIGATION 9.4

Radiating and absorbing radiant heat

Aim

To compare the radiation and absorption of heat through black surfaces and shiny surfaces

Materials

- heater or microscope lamp
- 2 identical shiny, empty, soft-drink cans
- matt black paint and paintbrush
- 2 thermometers or data logger and 2 temperature sensors

Method

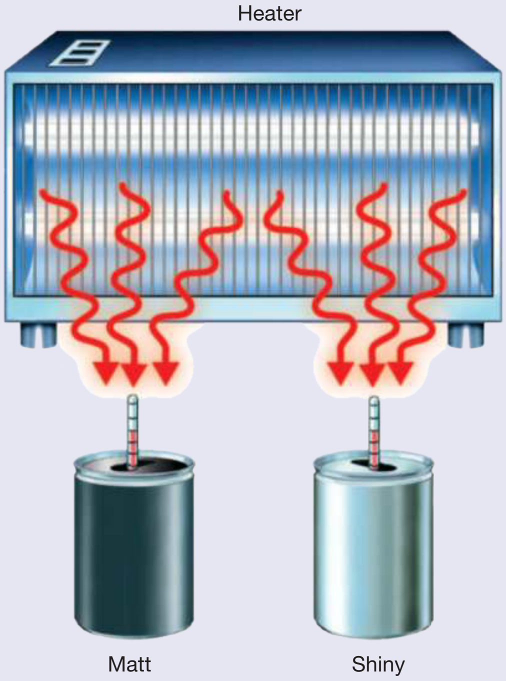
1. Paint one of the cans matt black and leave the other as it is.
2. Construct a table or spreadsheet headed ‘Part A: Radiating heat’ in which to record the temperature every 2 minutes for up to 14 minutes.
3. Make a prediction about your results and write down a hypothesis.

Part A: Radiating heat

4. Pour equal amounts of hot water into each can.
5. Place a thermometer or temperature probe into each can. Measure the initial temperature of the hot water and again every two minutes.
6. Empty the cans and pour equal amounts of cold tap water into each can.

Part B: Absorbing radiating heat

7. Construct a table or spreadsheet headed ‘Part B: Absorbing radiant heat’ in which to record the temperature every 2 minutes for up to 14 minutes.
8. Place a thermometer or temperature probe into each can. Measure the initial temperature of the water.
9. Place the two cans at equal distances from a heater or microscope lamp.
10. Measure and record your data into the table or spreadsheet every 2 minutes.



Results

1. Before you undertake the experiment, make a prediction about your results for Part A and Part B and write down a hypothesis for each part.
2. Enter your data into a table or spreadsheet.
3. Plot line graphs that show how the temperature changed over 14 minutes during the cooling and heating of the cans. You may wish to plot both graphs on the same set of axes.

Discussion

Part A: Radiating heat

1. Which can radiated heat more quickly?
2. Did your data support your hypothesis?

Part B: Absorbing radiating heat

3. Which can absorbed heat more quickly?
4. Did your data support your hypothesis?
5. Why was it important to use cans that were identical in size and shape?
6. What other variables had to be controlled during this experiment? Identify the independent, dependent and control variables.

Conclusion

Write a conclusion to your investigation, remembering to refer back to the aim.

9.2.5 Quantifying thermal conductivity

Have you ever wondered why your feet feel cold when walking barefoot on a tile floor after being on carpet even when these two surfaces are at the same temperature, in the same room?

It is due to different rates of heat transfer. The heat loss is greater from the skin on the tile floor compared to the carpet because tile is a better conductor of heat, so the temperature drop is greater on the tiles and they make your feet feel colder.

The average kinetic energy of any hot body is higher than a cold body and so the heat travels from a hotter body towards a cold body:

$$\text{Temperature difference} = \text{T}_{\text{HOT}} - \text{T}_{\text{COLD}}$$

Good conductors transfer heat energy faster than insulators. And the thickness of the material also affects the rate of heat transfer: the thicker the material, the more time it takes to transfer the same amount of heat. This explains why thicker possum-skin cloaks were worn to protect from the cold temperatures of the south-eastern Australian climate.

The rate of heat transfer also depends on the material properties described by the coefficient of thermal conductivity. The rate of heat transfer, $\frac{Q}{t}$, in watts (Joules per second) is given by:

$$\frac{Q}{t} = \frac{kA\,(T_2 - T_1)}{d}$$

Where:

Q is the heat transfer (in J)

t is the time taken by the transfer (in s)

k = thermal conductivity of the material

A = surface area in m^2

T_1 = the temperature on one side of the material (in °C)

T_2 = the temperature on the other side of the material (in °C)

d = the thickness of the material (in m).

on Resources

Weblink Video: Misconceptions about temperature

SCIENCE INQUIRY SKILLS: Choosing a graph

When drawing graphs you need to decide on the type of graph to be used. Different types of data are better suited to different types of graphs.

Quantitative data: numerical data that examines the quantity of something (for example, length or time).

Qualitative data: categorical data that examines the quality of something (for example, colour or gender) rather than numerical values.

Line graphs or scatterplots: use if both the independent and dependent variables are quantitative or data that is measured.

Bar graphs: use when one piece of data is qualitative and the other is quantitative or data that is counted.

Histograms: use when intervals and frequency are being explored.

Remember when drawing a graph to:

- include a title. This should link the dependent and independent variables that are shown in the graph.
- assign axes correctly. In most graph types (excluding pie graphs), the independent variables should be on the horizontal (x) axis, and the dependent variable on the vertical (y) axis.
- rule axes and label each clearly. Those displaying numerical variables should have a clearly marked scale and units.
- make sure your scale is suitable and the numbers are evenly distributed.
- use a line (or curve) of best fit as required. This is a smooth curve or line that passes as close as possible to all the plotted points.
- include the origin, the zero values for the variables, on both axes. You may need to use an axis break symbol if all the values you are plotting are clusttered around high values.

9.2 Activities

9.2 Quick quiz on

9.2 Exercise

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 2, 6, 7, 9, 13	3, 5, 8, 12, 14, 16	4, 10, 11, 15, 17

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. Recall four types of energy.
2. Identify the type of energy:
   a. a person has when running
   b. a spring has when it is stretched.
3. Use a suitable example to describe what is meant by an:
   a. energy transfer
   b. energy transformation.
4. Outline the Law of Conservation of Energy.
5. Identify the different types of energy involved in a trampoline jump.
6. Which form of energy do particles transfer to each other as heat flows through a conductor?
7. Fill in the blanks to complete the sentence.
   Solids such as polystyrene foam and wool are ______ conductors of heat because they have many small ______ filled with ______, which is an ______ because the molecules are so ______ apart that they hardly collide and so transfer very little ______ energy.
8. Explain why air near a wall furnace rises when it gets warmer. Name the process and explain how the process can keep going.
9. The three things that can happen to radiant heat when it arrives at any surface are that it can be **absorbed**, **reflected** or **transmitted**. For each of the following materials state which of the three behaviours is **most** likely.
   a. A mirror
   b. A black car seat
   c. A window

Apply and analyse

10. Imagine riding your bike along a flat gravel road. If you brake suddenly, the bike eventually stops. It no longer has kinetic energy. However, the energy is not lost. Describe what happens to the kinetic energy.
11. Explain, with the aid of a diagram, how a coastal sea breeze results from convection currents.
12. Explain whether a puddle is likely to dry out faster or slower if you spread it out more.
13. Suggest why metal saucepans usually have plastic or wooden handles.
14. Fill in the blanks: Many sportspeople wear ______ coloured clothing when competing on hot summer days because this colour tends to _______ the radiant heat from the Sun.

Evaluate and create

15. **SIS** Design a fair experiment to investigate the relationship between the material of a camp oven and the time taken to cook a roast. Identify three experimental variables that need to be controlled and make a prediction about the expected outcome.
16. **SIS** During an experiment investigating the time taken to heat frying pans of various thicknesses, the following data were obtained.

TABLE Frying pan thickness and heating time

Frying pan thickness (mm)	Heating time (seconds)
2	110
4	215
6	330
8	445
10	540
12	650

  a. Produce a line graph of the data. State what the trend shows and predict the amount of time it would take to heat a 1 mm frying pan.
  b. Use your scientific knowledge to:
    i. explain why a 12 mm pan takes longer to heat
    ii. suggest what effect a thick 12 mm pan might have on cooking time for an egg when compared to a thin 2 mm pan, if they are both heated to the same hot temperature before adding the egg.

17. To which form of heat transfer do the following statements apply?
  a. Energy is transferred at the speed of light.
  b. Particles move from one place to another.
  c. No particles are required for energy transfer.
  d. Free electrons in metals improve the efficiency of this type of heat transfer.
  e. The fastest particles leave the substance and cool it in this type of energy transfer.

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

LESSON
9.3 Matter and energy — waves

LEARNING INTENTION

At the end of this lesson you will be able to describe a wave in terms of its nature, frequency and amplitude.

9.3.1 Transmitting energy with waves

When a wave is made in a still lake by dropping a rock into it, the wave spreads out. However, the particles of water do not move along the surface — they just move up and down. A duck sitting on the pond will just bob up and down when the wave hits it. Energy has been transmitted from the rock to the duck by the wave, without any movement of the matter in between. A **wave** is able to transmit energy from one place to another without moving any matter over the same distance.

wave the transmitter of energy without the movement of particles from place to place. The vibration of particles or energy fields is involved.

DISCUSSION

Why do you sometimes see people in movies fishing using dynamite? What is the connection between this situation and waves?

9.3.2 Two types of vibrations

Waves travel through vibrations of particles or energy. Vibrations can be either forwards and backwards or up and down.

Transverse waves

If a vibration goes up and down sending a wave out at right angles to the vibration, we call this a **transverse wave**. Transverse waves can be made on a slinky. As shown in the figure 9.20, the moving particles in a transverse wave travel at right angles to the direction of energy transfer.

transverse wave a wave involving the vibration of particles perpendicular to the direction of energy transfer

longitudinal wave *see* compression wave

compression wave a wave involving the vibration of particles in the same direction as energy transfer

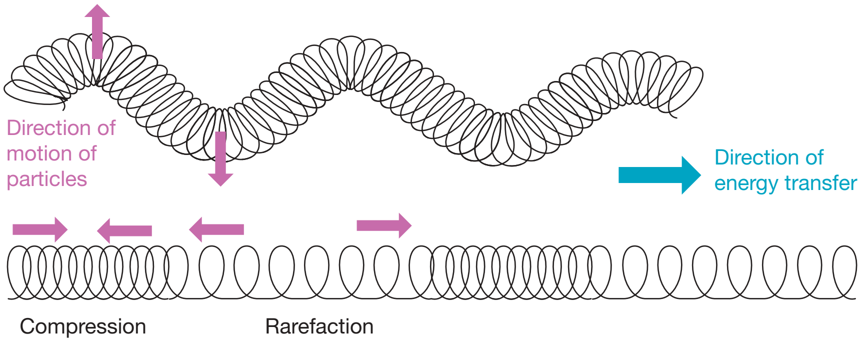
Examples of transverse waves are:
- ripples on a pond
- vibrations of the string
- light
- S-waves in earthquakes (shakes buildings side to side).

Longitudinal waves

If a vibration goes forwards and backwards and the energy is carried away in the same direction, we call this a **longitudinal wave**. It is sometimes called **acompression wave** as the particles need to be compressed to send a pulse.

Examples of longitudinal waves are:
- shock waves
- P-waves in earthquakes (pushes buildings up and down)
- sound waves.

FIGURE 9.20 Two types of energy transfer: a transverse wave (top) and a compression wave (bottom). The transfer of sound energy can be modelled using compression waves in a slinky.



elog-2385

INVESTIGATION 9.5

Moving energy without matter

Aim

To model sound using waves on water and a slinky

Materials

- deep tray
- small cork
- eye dropper
- ribbon
- slinky
- water

Method

Part A

1. Half fill the tray with water and place a small cork on the water's surface.
2. Use the eye dropper to release drops of water near the cork.
3. Observe the motion of the small waves made by the drops.
4. Observe the motion of the cork.

Part B

1. Tie a ribbon around a coil near the centre of the slinky.
2. Take your slinky with your partner and stretch it out, with each person holding one end of the slinky. The other person should not move or wiggle the slinky.
3. Use a quick flick of the wrist to lift up your end of the string and then bring it back to the original height in a fraction of a second.
4. Keep making waves in the slinky.
5. Observe the motion of the wave in the slinky.
6. Observe the motion of the ribbon.

Part C

1. Make a different type of wave by quickly pushing your end of the slinky just a few inches toward the person holding the other end of the slinky and then bring it back to the original length in a fraction of a second.
2. Keep making waves in the slinky.
3. Observe the motion of the wave in the slinky.
4. Observe the motion of the ribbon.

Results

1. Describe the motion of the cork on the small waves.
2. Describe the motion of the ribbon as the waves made by flicking move along the slinky.
3. Describe the motion of the ribbon as the compression wave moves along the slinky.

Discussion

1. Is there any evidence to suggest that any water moves in the same direction as the waves?
2. In each of the slinky waves produced in this experiment, energy is transferred from one end of the slinky to the other.
   a. Where is the ribbon after the wave has passed in each case?
   b. Has any particle on the slinky moved from one end to the other?
3. Which properties of sound waves can be modelled by waves on water?
4. Identify strengths and limitations of this model.

Conclusion

What conclusions can you make about the similarity of sound waves and water waves?

9.3.3 Two types of waves

Another distinction that is useful in waves is their method of transport for the energy.

- **Mechanical waves** require particles to carry the energy.
- **Electromagnetic waves** do not need particles to carry the wave. They transfer their energy using **fields**, as we will see later.

If a wave requires particles to carry the energy, those particles are referred to as the **medium**. For instance, sound waves cannot travel in a vacuum, a medium, such as air or water, is required.

mechanical waves waves carried by the vibration of particles of matter

electromagnetic waves electromagnetic energy that is transmitted as moving electric and magnetic fields. There are many different types of electromagnetic energy; for example, light, microwaves, radio waves.

fields regions around an object in which each point is affected by a force of some type

medium a material through which a wave moves

9.3.4 Measuring waves

As always in science, we need to measure something before we can figure out how it works and how we can use it. Imagine a world where nobody had done this. We would have none of the modern communication technology that we enjoy today.

The most important properties of a wave to measure are **wavelength**, **frequency** and **amplitude**. How they are measured in transverse and longitudinal waves is shown in figure 9.21.

wavelength distance between two neighbouring crests or troughs of a wave. This is the distance between two particles vibrating in step.

frequency the number of vibrations in one second, or the number of wavelengths passing in one second

amplitude the maximum distance that a particle moves away from its undisturbed position

compression a region in which the particles are closer than when not disturbed by a wave; a squeezing force

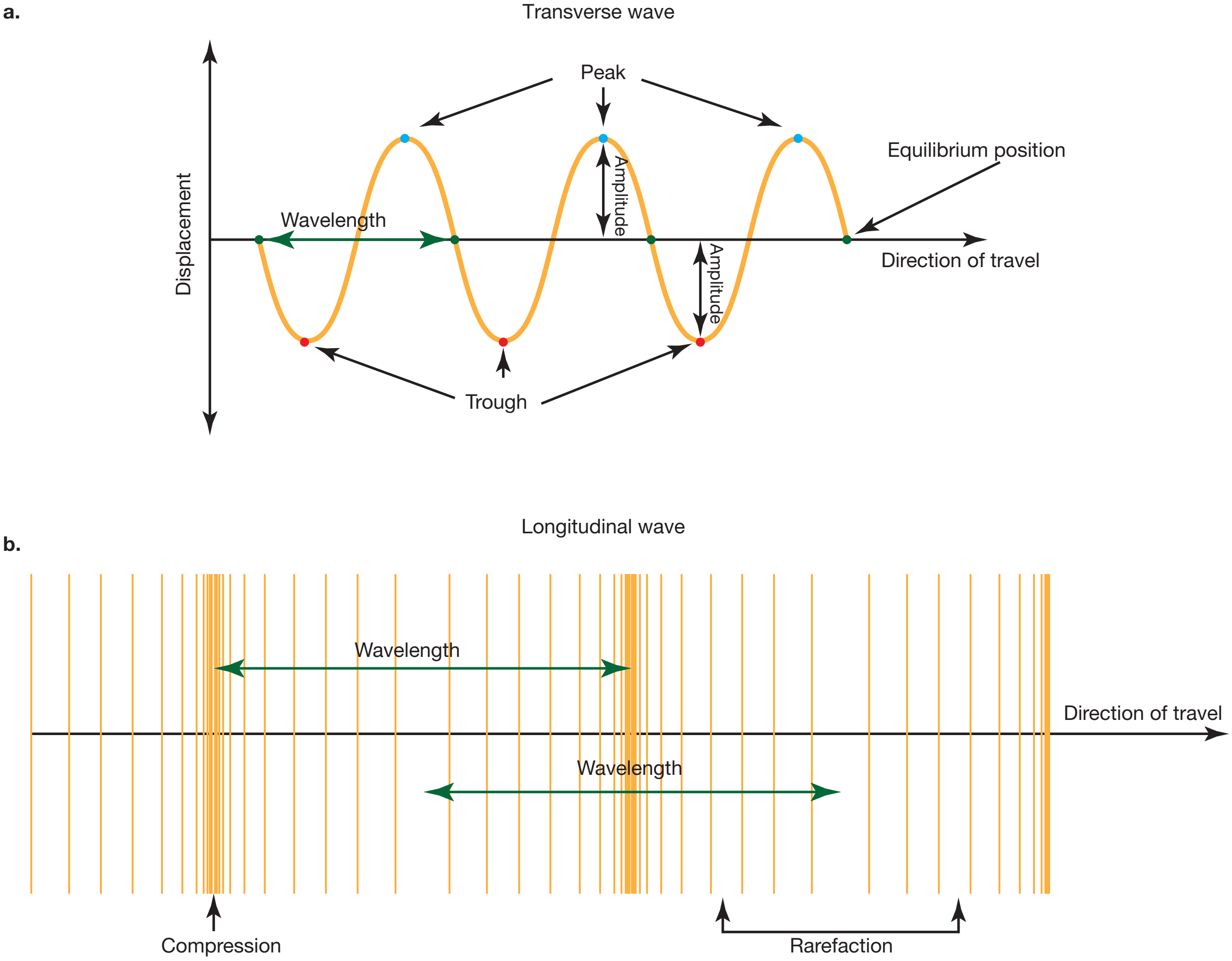
rarefaction a region in which the particles are further apart than when not disturbed by a wave

Wavelength

When a vibration occurs in a transverse wave, something is vibrating up and down. In one vibration it will make one wave. How far that wave travelled in that time is the wavelength. To find the wavelength, you measure the distance between two peaks, or two troughs, or the distance between any two corresponding points on neighbouring waves (figure 9.21).

In the case of a compression wave, the wavelength is the distance between the centre of two neighbouring **compressions** (high pressure), or two neighbouring **rarefactions** (low pressure). The wavelength of sound made during normal speech varies between approximately 5 centimetres and 2.5 metres.

FIGURE 9.21 Representations of **a.** transverse and **b.** longitudinal waves



Frequency

How often do you eat a meal? If you eat breakfast, lunch and dinner then you have a meal frequency of three meals per day.

In the same way, the frequency of a vibration or wave is the number of complete vibrations or waves made in one second. In everyday language, we call the frequency of sound waves **pitch**. High-frequency vibrations produce high pitch, and low-frequency vibrations produce low pitch. The unit of frequency is the hertz (Hz). A frequency of 1 Hz means one vibration per second.

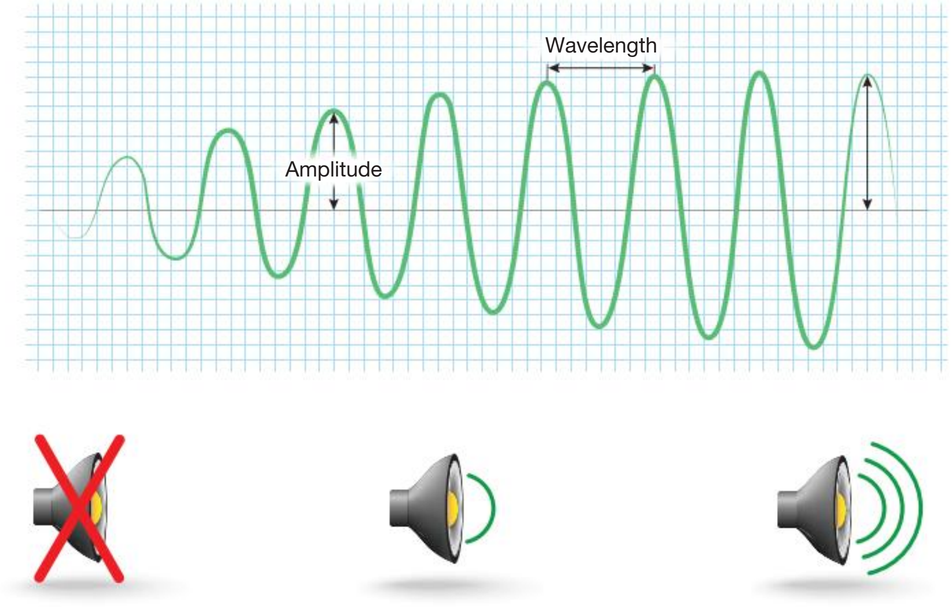
pitch how our hearing interprets frequency. High frequency vibrations are perceived as high pitch, low frequency waves are perceived as low pitch.

As the frequency of a sound gets higher, that is, as more compressions are produced per second, the compressions become closer together.

Amplitude

The amplitude of a wave is the maximum distance that each particle moves away from its usual resting position. In sound waves, higher amplitudes correspond with louder sounds due to the higher pressure in the compressions. If we plot a graph of how pressure changes, we can represent a longitudinal wave as a transverse wave (figure 9.22).

FIGURE 9.22 Longitudinal wave represented as a transverse wave showing how the amplitude changes as the volume of a sound increases.



As amplitude requires a particle to move, it only really makes sense to measure this in mechanical waves.

on Resources

eWorkbook Waves (ewbk-12596)

Weblinks Video: Wave motion
Simulation: Wave on a string

9.3 Activities

9.3 Quick quiz on

9.3 Exercise

Select your pathway

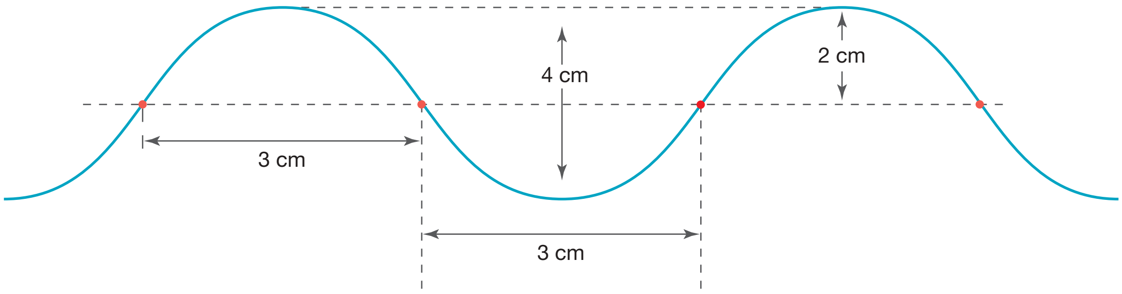
🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 2	3, 5	4, 6

Remember and understand

1. MC What causes all sound waves? Select all correct answers.
   - A. Vibrations
   - B. Echoes
   - C. Compressions
   - D. Rarefactions
2. Fill in the blanks to complete the sentence.
   A compression is a region of _________ pressure where the particles are _________ together, and a rarefaction is a region of _________ pressure where the particles are more _________ apart.
3. MC What is the unit of frequency and what does it measure?
   - A. Hertz (Hz) — the length of the wave
   - B. Metres (m) — the length of the wave
   - C. Hertz (Hz) — the loudness of the wave
   - D. Hertz (Hz) — the number of vibrations per second

Apply and analyse

4. MC How does the amplitude of a wave affect energy transfer?
   - A. Higher amplitude leads to higher energy transfer.
   - B. Lower amplitude leads to higher energy transfer.
   - C. Amplitude does not affect energy transfer.
   - D. Energy transfer is dependent on wave frequency, not amplitude.
5. What is the wavelength and amplitude of the transverse wave shown in the diagram?



Evaluate and create

6. a. Draw and label a wave with twice the frequency but the same amplitude as the wave in question 4.
   b. Draw and label a wave with half the frequency and twice the amplitude as the wave in question 4.

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

LESSON
9.4 Energy transfer by sound

First Nations Australian readers are advised that this lesson and relevant resources may contain images of and references to people who have died.

LEARNING INTENTION

At the end of this lesson you will be able to describe sound as a pressure wave in a medium and calculate its speed.

9.4.1 A happy medium

Imagine that you are on a spacecraft on the way to Mars and a passing asteroid explodes. Would you hear the explosion before or after you saw it? Or would you even hear it at all?

Because sound is transmitted as a compression wave, it can travel only through a medium that contains particles that can be forced closer together or further apart. Sound cannot be transmitted in a vacuum because there are no particles to push closer together or spread out.

As sound travels through a medium, some of its energy is absorbed by the particles in the medium and is not transmitted to neighbouring particles. Sound moves more effectively through elastic materials, like metals, rather than through inelastic materials, like foam. In elastic materials, the particles tend to return to their original positions with minimal energy loss, allowing sound to travel efficiently. However, in inelastic materials, the sound wave rapidly loses its energy, making it less effective for transmitting sound.

9.4.2 Sound waves

Sound is a compression wave. All sounds are caused by **vibrations**. Vibrations cause air to compress (like the lower wave pattern shown in figure 9.23). As the particles vibrate, they move neighbouring particles, transmitting the sound further through the medium. Figure 9.24 shows how a vibrating ruler makes compression waves in air. As the ruler moves up, a *compression* is created as air particles above the ruler are pushed together. Air particles below the ruler are spread out, creating a *rarefaction*. When the ruler moves down, a rarefaction is created above the ruler, while a compression is created below it. Each vibration of the ruler creates new compressions and rarefactions to replace those that are moving through the air.

vibrations repeated, fast back-and-forth movements

FIGURE 9.23 Modelisation of sound waves

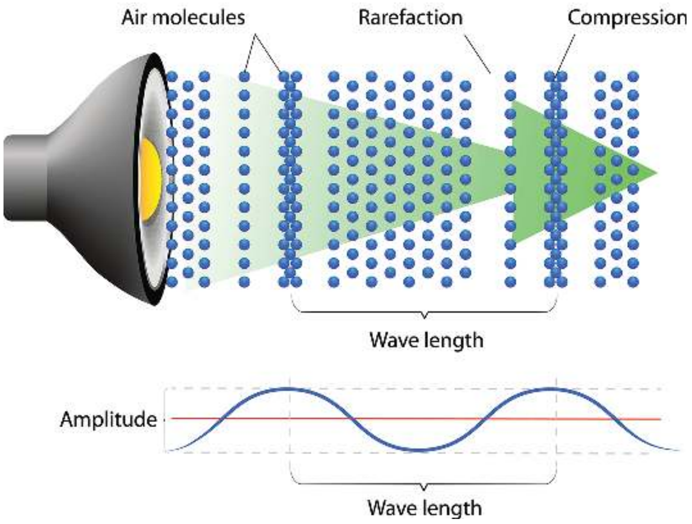
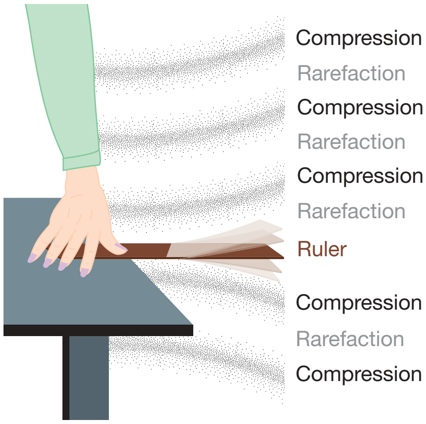


FIGURE 9.24 Sound is a compression wave caused by vibrations.



ACTIVITY: Creating different tones

Position a ruler on the table with a portion overhanging the edge. Place your hand firmly on the ruler to fix it in position on the table. Flick the overhanging side of the ruler to create a sound. Change the length of the overhang to create different tones.

What do you notice about the length of overhang and the tone produced?

on Resources

Weblinks Video: Creating different tones with a ruler — explained
Simulation: Waves intro

9.4.3 Speed of sound

The speed of sound in a particular medium depends on how close the particles are to each other and how easy they are to push closer together. In liquids and solids, the speed is much greater because the particles are more closely bound together. Table 9.1 shows the speed of sound in some common substances at 0 °C.

TABLE 9.1 Speed of sound in some common substances

Substance	Speed of sound (metres per second)
Carbon dioxide (at 0 °C)	260
Dry air (at 0 °C)	330
Hydrogen (at 0 °C)	1300
Water	1400
Sea water	1500
Wood	4000–5000
Glass	4500–5500
Steel	5000
Aluminium	5000
Granite	About 6000

SAMPLE PROBLEM 1 Finding the distance from a sound

If we see a distant flash of light from, for example, a firework, we can calculate how far away it is by timing how long it takes the sound to get to us. As light travels at 300 000 000 metres per second, we can assume that the time it takes for the light to reach us is zero.
If it takes 2 seconds to pass between flash and bang, how far away is the firework?

THINK	WRITE
1. Use the simple equation for velocity.	$\text{velocity} = \dfrac{\text{distance}}{\text{time}}$
2. Rearrange the equation to find the distance.	$\text{distance} = \text{velocity} \times \text{time}$
3. If the air is dry, the speed is 330 m/s.	$\text{distance} = 330 \times 3$
4. This means the distance to the firework is:	990 m.

The speed of sound changes

When people say 'the speed of sound', which speed do they mean? Speed is different in all substances. Even when just talking about air, the speed of sound can change a lot depending on atmospheric conditions. The speed of sound in air is greater at higher temperatures. At sea level in dry air at 0 °C, it is about 330 metres per second. At a temperature of 25 °C, it is about 350 metres per second. The speed of sound in air is lower at higher altitudes. At an altitude of 10 kilometres above sea level, it is about 310 metres per second.

FIGURE 9.25 A jet flying faster than the speed of sound can form a condensation cloud.

DISCUSSION

Why is the speed of sound slower at higher altitudes than at lower ones?

elog-2387

INVESTIGATION 9.6

Sound in different media

Aim

To investigate the transmission of sound in different media

Materials

- ticking watch
- metre ruler
- teaspoon (or spatula)
- cotton thread (or light string)

Method

1. Place a ticking watch against your ear and listen to the tick. Have your partner slowly move the watch away from your ear until you can no longer hear the ticking.

Transmitting sound

2. Measure and record the distance from your ear to this point.
3. Place a metre ruler gently against the same ear and rest the watch on it against the ear. Have your partner slowly slide the watch along the ruler to a point where you can no longer hear the ticking.
4. Measure and record the distance from your ear to this point.
5. Tie about 80 cm of cotton thread to a teaspoon. Swing the teaspoon slowly so that it gently strikes the side of a bench, wall or cupboard. Listen to the sound made.
6. Place the free end of the cotton thread carefully against your ear and again gently strike the teaspoon against the same surface. Listen to the sound made.

Results

1. Record the distance from the ticking watch to your ear when you can no longer hear the sound.
2. Record the distance on the metre ruler when you can no longer hear the watch ticking.
3. What did you observe when the cotton thread and spoon was struck against the bench, and when the thread was placed against your ear and the spoon was struck against the bench?

Discussion

1. What effect did the ruler have on the distance over which you could hear the sound of the ticking watch?
2. What difference does the cotton thread make to the sound heard when the spoon strikes a surface?
3. Is sound conducted better through air or through solids?
4. What property of the solids do you think makes the difference?

Conclusion

What conclusion can you make about how sound travels in different mediums?

on Resources

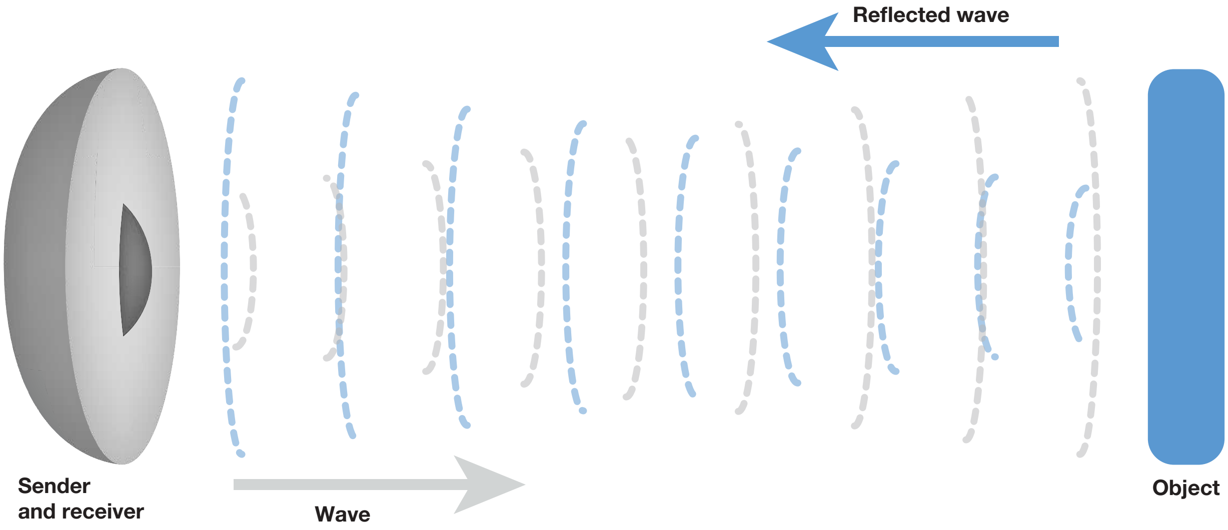
eWorkbook Sound energy (ewbk-12598)

9.4.4 Echoes in nature

An **echo** is what we call the reflection of a sound wave. We can estimate the distance between ourselves and a large object by shouting and timing how long it takes for the echo to return.

echo sound caused by the reflection of sound waves

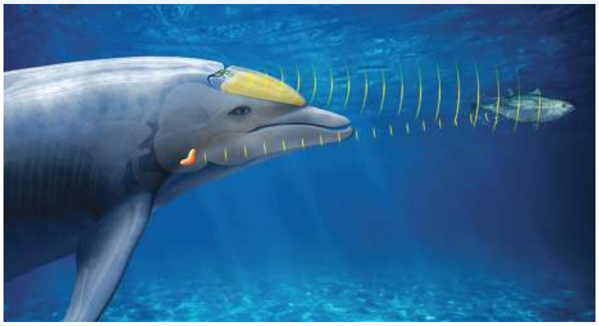
FIGURE 9.26 In all echoes a sound that is sent out is reflected from an object and detected by the object that originally produced the sound.



The only difference between finding the distance to an object making a noise and an object reflecting a noise is that we must *halve* the time measurement as the distance the wave travels is *twice* the distance between the sound emitter and the sound reflector.

Many animals use echoes to find their way in the dark or to hunt their prey. This is called **echolocation** and is used by animals such as bats and dolphins.

FIGURE 9.27 Dolphins hunt in deep, dark water by mapping their surroundings using echoes.



DISCUSSION

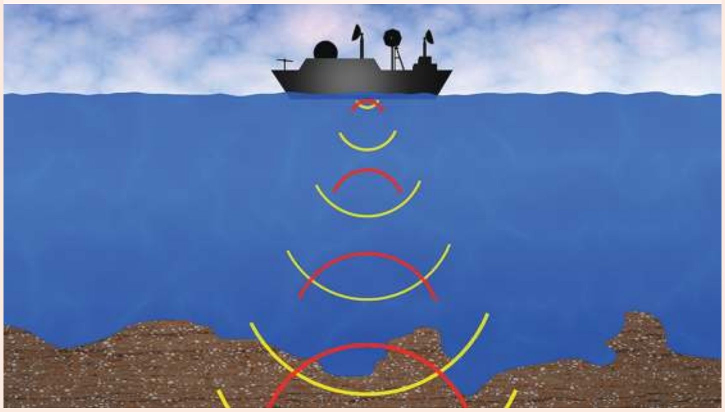
How can bats hunt their prey in complete darkness?

9.4.5 Technology and echoes

SCIENCE AS A HUMAN ENDEAVOUR: Using echoes

We could not have learned about the movement of Earth's crust if we had not mapped the bottom of the oceans. The technology allowed us to understand the structure of the planet, the formation of Earth's magnetic field and allowed us to map 70 per cent of the planet's surface, which is hidden under the water. That exact same technology is also used to see inside the womb and build pictures of a baby without causing harm, and is now being used to let the blind see.

FIGURE 9.28 SONAR mapping the sea floor



SONAR

A knowledge of the speed of sound is used in **SONAR**. SONAR (Sound Navigation And Ranging) is used on ships to map the ocean floor, detect schools of fish, and locate other underwater objects such as shipwrecks and submarines. The process is as follows:

- transmit high-frequency sound from the ship
- measure the time taken for the echo to return to the ship
- use the speed of sound in water to calculate the distance to the floor of the ocean or to the underwater object
- remember that the time taken is the time for the pulse to go to the sea-bed (floor) and back so it must be halved
- add many measurements to map the sea floor
- use higher frequency waves, which have smaller wavelengths so can be used to form an image in more detail.

echolocation the use of sound to locate objects by detecting echoes

SONAR the use of reflected sound waves to locate objects under water (sound navigation and ranging)

Ultrasound

Although called by a different name, echolocation is also used by engineers to locate cracks in metals; and it is used extensively in medicine. The high-frequency sound used in industry and in medicine is called **ultrasound**. Ultrasound has frequencies higher than humans can hear. Echolocation with ultrasound is used in medicine to produce images of unborn babies in the womb during pregnancy, to search for circulation problems, remove some cancers, treat an eye condition called glaucoma, shatter kidney stones and gallstones in a process called shockwave therapy, and speed up the healing of muscle damage. It can also be used to clean surfaces, mix paint, homogenise milk and cut into glass and steel.

FIGURE 9.29 A modern 3-dimensional ultrasound is used to produce an image of the face of a full-term baby in the womb.

Humans can echolocate

There have been cases of humans who can echolocate. A growing number of people with severe vision impairment have begun clicking with their tongues. Their brains adapt to become able to perceive the slight difference in the sound when reflected back at them from different surfaces. Some become so good at the talent that they can ride a bike down a street while safely detecting and avoiding obstacles. Try echolocating yourself by closing your eyes and clicking your tongue in an empty space, then do it again while holding a book in front of your face. You should be able to hear the difference. There are also glasses in development that use echolocation to activate pins in a pad stuck to the tongue. This effectively prints a picture of the world on the tongue, which the brain learns to interpret as an image.

on Resources

Weblink TED-Ed: How to see with sound

SAMPLE PROBLEM 2: Using SONAR to determine depth of the water

A SONAR pulse is sent from a ship and returns 0.5 seconds later. Given the speed of sound in sea water is 1500 m/s, what is the distance to the sea-bed?

THINK	WRITE
1. Use the simple equation for velocity.	$\text{velocity} = \dfrac{\text{distance}}{\text{time}}$
2. Rearrange the equation to find the distance.	$\text{distance} = \text{velocity} \times \text{time}$
3. The SONAR pulse took 0.5 seconds to reach the sea-bed and return to the ship. If we halve the time we know how long it took for the pulse from the ship to reach the sea-bed.	$\dfrac{0.5}{2} = 0.25$ seconds
4. The speed of sound in sea water is 1500 m/s.	$\text{distance} = 1500 \times 0.25$
5. The distance from the ship to the sea bed is:	375 m.

9.4.6 The ear

The energy of sound waves is transformed by your ear into electrical signals that are sent to your brain. Each of your ears has three distinct parts — the outer ear, middle ear and inner ear. Each part has its own special job to do.

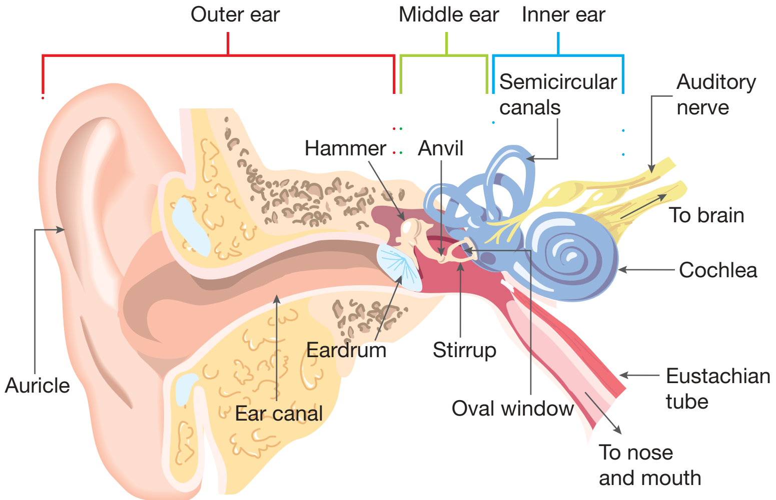
ultrasound sound with frequencies too high for humans to hear

ewbk-12600

eles-2636

int-8176

FIGURE 9.30 Parts of the human ear



Outer ear

The fleshy, outer part of the ear is called the **auricle**. This collects the sound energy more efficiently than a simple hole in the head would. The outer ear funnels the energy of the vibrating air through the **ear canal** to the **eardrum**. The eardrum is a thin flap of skin, or **membrane**, which vibrates in response to the changing pressure of the vibrating air particles.

Middle ear

The middle ear contains three small bones called the hammer, the anvil and the stirrup. These three tiny bones (known as the **ossicles**) pass on the vibrations to the inner ear through the **oval window**.

Inner ear

The inner ear contains the **cochlea** and the **semicircular canals**. The cochlea is a spiral-shaped system of tubes full of fluid. When vibrations are passed through the oval window by the stirrup, the fluid moves tiny hair-like cells inside the cochlea. The hairs respond to specific frequencies only so that we can make sense of the different sounds that we hear. These hairs are attached to the receptor nerve cells that send messages on their way to the brain through the **auditory nerve**.

The limits of hearing

For a human, the range of frequencies that we can hear, assuming normal hearing, is from 20 Hz to 2000 Hz. As you age you begin to lose the ability to hear the high frequencies as those haircells become damaged over time.

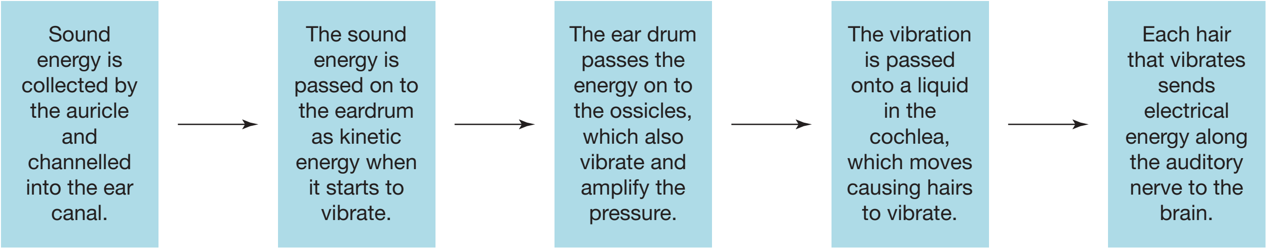
Other animals have different ranges of hearing. That is why dog whistles sound silent for us but loud for dogs. They can hear much higher frequencies than we can.

The semicircular canals

The semicircular canals also contain a fluid. However, they are not involved in hearing sound. When you move your head, the fluid in the semicircular canals moves hairs that send signals to your brain. The signals provide your brain with information to help you keep your balance.

auricle	the fleshy outside part of the ear
ear canal	the tube that leads from the outside of the ear to the eardrum
eardrum	a thin piece of stretched skin inside the ear that vibrates when sound waves reach it
membrane	a thin layer of tissue
ossicles	a set of three tiny bones that send vibrations from the eardrum to the inner ear. They also make the vibrations larger.
oval window	an egg-shaped hole covered with a thin tissue. It is the entrance from the middle ear to the outer ear.
cochlea	the snail-shaped part of the inner ear in which receptors are stimulated
semicircular canals	three curved tubes, filled with fluid, in the inner ear that control your sense of balance
auditory nerve	a large nerve that sends signals to the brain from the hearing receptors in the cochlea

FIGURE 9.31 Energy flow from sound wave to brain



Sound energy is collected by the auricle and channelled into the ear canal.

The sound energy is passed on to the eardrum as kinetic energy when it starts to vibrate.

The ear drum passes the energy on to the ossicles, which also vibrate and amplify the pressure.

The vibration is passed onto a liquid in the cochlea, which moves causing hairs to vibrate.

Each hair that vibrates sends electrical energy along the auditory nerve to the brain.

Resources

Weblink TED-Ed: The science of hearing

DISCUSSION

Beethoven was a famous composer of classical music who gradually lost his hearing. When he was completely deaf he could still compose music, but he did it with a pencil in his mouth that touched the piano. Discuss why you think he did this.

CASE STUDY: Animal hearing

- The African elephant's ears enable them to hear low-pitched sounds from other elephants over 4 kilometres away. They also use their giant ears to release heat, sometimes flapping them to cool down more quickly.
- Some insects have ears but they are not on their heads. The ears are membranes like eardrums on the surface of their bodies. A cricket has an ear just below the knee of each of its front legs. A grasshopper has an ear on each side of its body just below the wing. Most other insects do not have ears but detect vibrations with sensitive hairs on their antennae or other parts of their bodies.

CASE STUDY: Why your ears pop on a plane

When you are landing or taking off in a plane, or even travelling in a lift, your ears 'pop'. If you climb steeply, the air pressure inside your middle ear remains the same while the air pressure outside drops. The air inside pushes on the eardrum causing an uncomfortable feeling. The 'popping' is caused as the Eustachian tube, which is normally closed, opens. This allows air to rush out of your middle ear to your nose and mouth. The pressure is then the same on both sides of the eardrum. When you descend quickly, the 'popping' occurs as the air rushes into your middle ear to balance the increasing pressure outside. If you swallow hard, you can make the 'popping' happen sooner.

9.4.7 Loudness

Sound makes your eardrums vibrate. But if the sound is too loud, the vibrations can cause pain and even permanently damage your ear. That's because loud sounds carry more energy, disturbing the air — and your eardrums — more than soft sounds.

Although loudness can be a matter of opinion, the disturbance to the air can be measured.

- The measurement is called the **relative sound intensity**, or sound level.
- The unit of measurement is the **decibel (dB)**. The number of decibels gives a good indication of the loudness of a sound. It's not a perfectly accurate measure of loudness, because your ear is more sensitive to some pitches than others.
- The **threshold of hearing** is the smallest sound level that can be heard when the air is vibrating at 1000 Hz. For most people it's about 0 dB.
- The **threshold of pain** is the smallest sound level that causes pain. Sound levels of more than about 130 dB can cause pain and permanent ear damage. Sound levels of even 80 dB can cause damage to your ears if you are exposed to the sound for long enough.

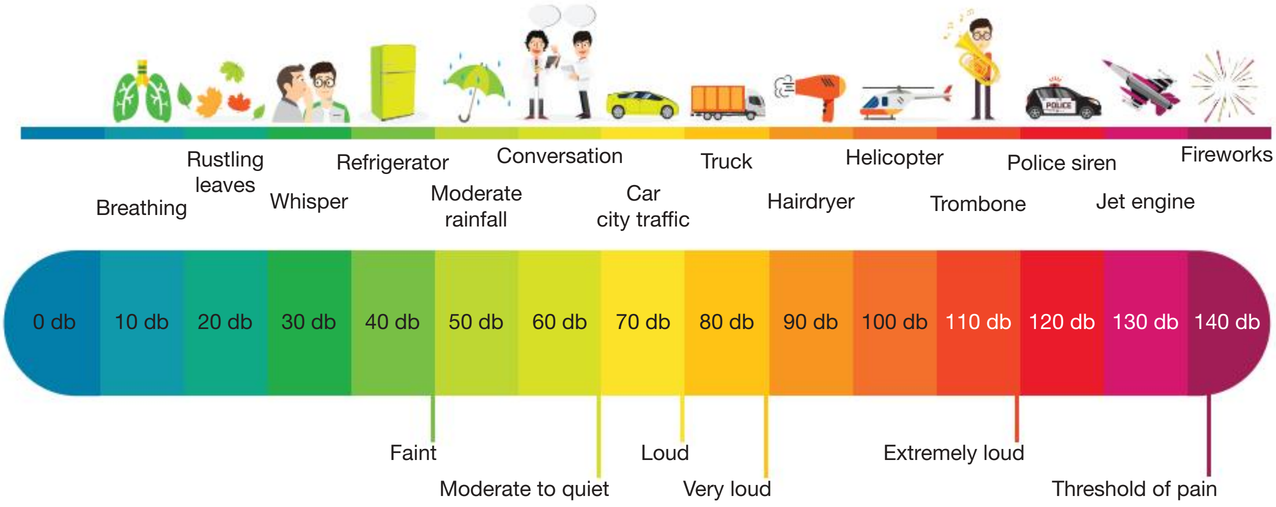
relative sound intensity is a measure of the energy of a sound, which provides an indication of loudness. It is measured in decibels (dB) and is often referred to as sound level.

decibel (dB) a unit of measurement of relative sound intensity

threshold of hearing the lowest level of sound that can be heard by the human ear

threshold of hearing the lowest level of sound that can be heard by the human ear

FIGURE 9.32 Sound level is measured in decibels (dB).



Hearing loss

There are many reasons why a person may not be able to hear. Temporary hearing loss may result from an infection, a build-up of earwax, a blow on the head or a loud noise. Permanent hearing loss can be due to any of the middle or inner ear structures becoming damaged or not forming correctly at birth.

Hearing aids have been used for many years to make sounds louder for those with impaired hearing. The battery-operated hearing aid that some people wear amplifies the vibrations so that they can reach a properly working cochlea. Another type of hearing aid 'bends' the vibrations so that they go through a bone behind the ear to the cochlea (see 'Science as a human endeavour: The cochlear implant').

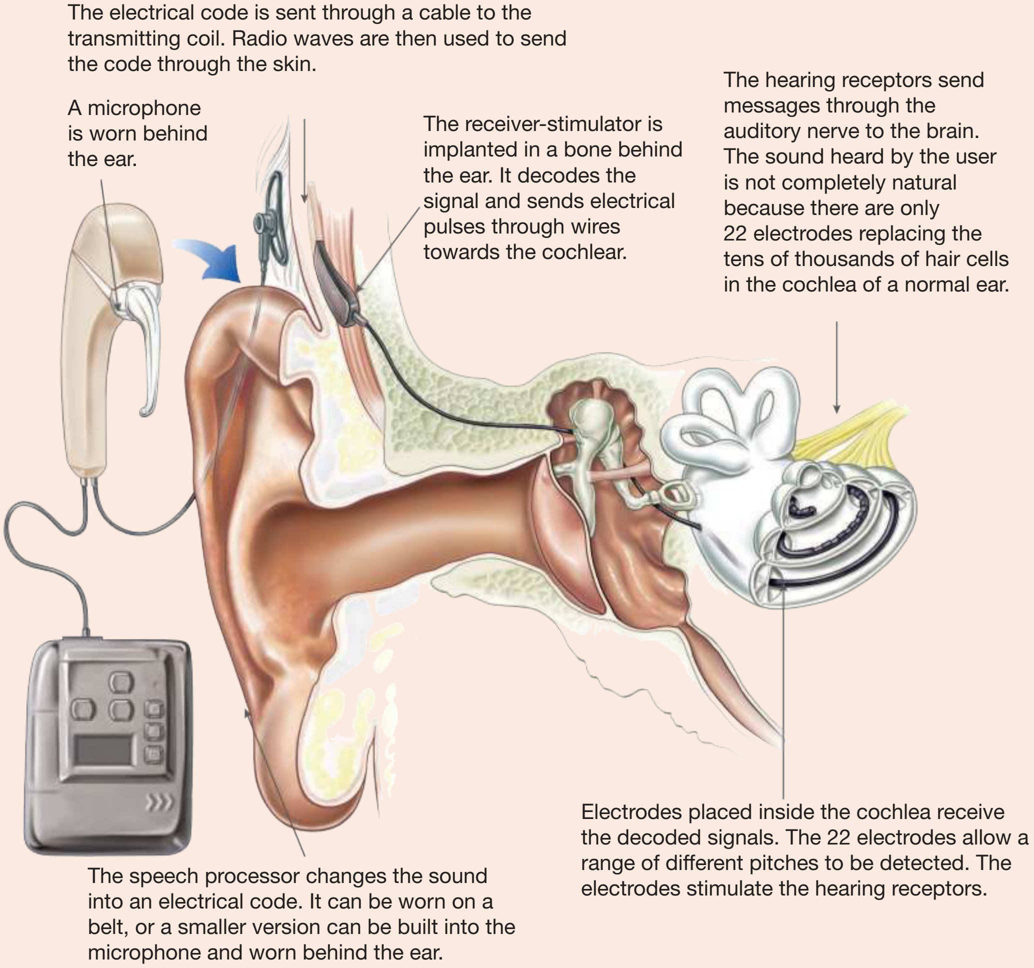
SCIENCE AS A HUMAN ENDEAVOUR: The cochlear implant

Many people who have severely or profoundly impaired hearing are unable to benefit from hearing aids. Profoundly hearing-impaired people hear no sounds at all.

Nearly 50 years ago, Australian scientists developed a device that has allowed some people, who are profoundly hearing impaired, to detect sound for the first time in their lives. The first cochlear implant, or bionic ear, was surgically placed inside the ear. A microphone worn behind the ear detected sound and sent a signal to the speech processor (a small computer worn in a pocket or on a belt). It converted the sound into an electrical signal that was sent to a receiver behind the ear and on to the implant in the cochlea. The signal then travelled along the auditory nerve to the brain. Nowadays, the processor is built into the headset.

FIGURE 9.33 Bionic ear headset and speech processor

FIGURE 9.34 How the first cochlear implants worked



The electrical code is sent through a cable to the transmitting coil. Radio waves are then used to send the code through the skin.

A microphone is worn behind the ear.

The receiver-stimulator is implanted in a bone behind the ear. It decodes the signal and sends electrical pulses through wires towards the cochlear.

The hearing receptors send messages through the auditory nerve to the brain. The sound heard by the user is not completely natural because there are only 22 electrodes replacing the tens of thousands of hair cells in the cochlea of a normal ear.

The speech processor changes the sound into an electrical code. It can be worn on a belt, or a smaller version can be built into the microphone and worn behind the ear.

Electrodes placed inside the cochlea receive the decoded signals. The 22 electrodes allow a range of different pitches to be detected. The electrodes stimulate the hearing receptors.

CASE STUDY: Ringing in your ears

If you've ever been to a really loud concert, you may have experienced ringing in your ears afterwards. You would also have had trouble hearing. Even after you had gone home to bed and the house was silent, the ringing would still have been there.

This ringing in your ears is called **tinnitus** (sometimes pronounced tin-*eye*-tus). Some of the cells in your inner ear — the ones that detect vibrations — have been damaged. Fortunately, your ears are likely to recover. The ringing will stop and your hearing will return to normal — hopefully in a few hours, but maybe in a day or two. If you listen to loud music for too long or too often, the cells don't recover. Your hearing can be permanently damaged. It's a good idea to avoid this by wearing earplugs at loud concerts.

tinnitus a ringing or similar sensation of sound in the ears, caused by damage to the cells of the inner ear

FIGURE 9.35 Ear protection is needed when working with noisy machinery, including racing cars.

elog-2389

INVESTIGATION 9.7

Making it seem louder

Aim

To investigate a method of making a sound seem louder

Materials

- ticking watch
- sheet of paper, about A4 size
- metre ruler
- blindfold

CAUTION

Take care not to put the funnel into the ear canal.

Method

1. Blindfold your partner and have them sit on a chair.
2. Hold a ticking watch close to your partner's right ear. The left ear should be covered with an open palm.
3. Move slowly away until your partner indicates that the sound of the ticking watch can no longer be heard.
4. Measure and record the approximate distance from the watch to your partner's right ear.
5. Make a funnel with a sheet of paper. Place the narrow end of the funnel close to, but not touching, your partner's right ear. Your partner should be able to hold it in place.
6. Again, move the ticking watch slowly away from your partner, starting near the wide end of the funnel, until it can no longer be heard.
7. Measure and record the approximate distance between the watch and your partner's right ear.

Results

1. Record the distance from the watch to your partner's ear without the funnel.
2. Record the distance from the watch to your partner's ear with the funnel.

Discussion

1. What difference does the funnel make?
2. How does the funnel work?
3. Look at your own ears. Why do you think they are that shape?

Conclusion

What can you conclude about the ability to make a sound seem louder?

elog-2391

INVESTIGATION 9.8

Sound proofing

Aim

To investigate the effect of different materials on the transmission of sound

Materials

- variety of materials to test (such as wood, fabric, glass and cardboard)
- source of sound (such as an MP3 player)
- sound level meter or data logger and sound probe

Method

Design an experiment to investigate the most effective material to insulate against noise.

Results

Record your results in a suitable table and graph.

Conclusion

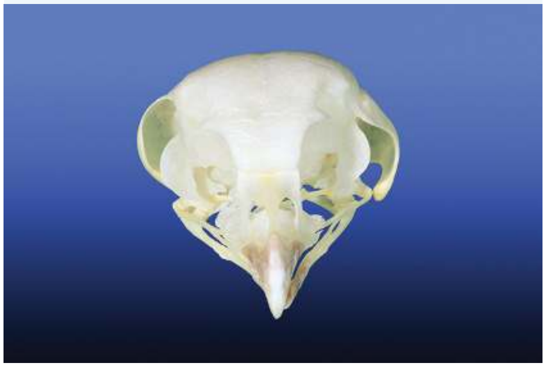
Analyse your results to draw an appropriate conclusion.

Why do we have two ears?

Incredibly our brains can tell the difference in arrival time of a sound between our two ears. This allows us to figure out roughly where a sound is coming from. This is called **binaural hearing**.

Owls have taken this one step further. Their ears are at different heights, giving them a 3-dimensional sense of sound. They can target the squeaks of a bat, not just to the left and right but also up and down.

FIGURE 9.36 Adult skull of a boreal owl (*Aegolius funereus*) showing the marked asymmetry of the ears



9.4.8 Why do we like music but dislike noise?

Musical notes make repeating patterns that are predictable. The human brain likes to detect patterns and most cultures seem to have discovered music very early in their development.

binaural hearing sound detection in creatures with two ears in order to locate the source of a sound

However, noise has no repeated pattern in the frequencies and amplitudes of the sounds received by our brains. Noise puts us on edge. Imagine our early ancestors being hunted through the African savanna. Noise would make it hard to hear a predator. We have learned to use some noises to our advantage, warning sirens and alarms for instance.

Unfortunately, one of the 'side effects' of living in an industrialised world is noise. Some of this noise is loud enough to damage your ears. But some of it is just annoying. The offending noises come from sources that include:

- transport, such as aeroplanes, trains, trams, trucks, cars, buses and cars
- heavy machinery, such as tractors, bulldozers, harvesters and jackhammers
- entertainment venues, such as rock concerts, nightclubs and sporting events
- domestic sources, such as mowers, power tools and much, much more.

FIGURE 9.37 The effect of freeway noise on nearby residents is reduced by barriers that absorb and reflect sound energy.

With good planning and zoning, the noise of traffic, factories and entertainment venues can be kept away from residential areas, hospitals and schools. Sound barriers are built and trees planted beside freeways to reduce the noise heard by nearby residents. Sound barriers are designed to reflect and absorb sound energy. Trees are great natural absorbers of sound energy. State and local government laws restrict times when you can use mowers, power tools and other noisy items like air-conditioners and swimming-pool pumps. These laws vary from state to state and between local councils.

CASE STUDY: Noise-cancelling headphones

Noise-cancelling headphones work by listening to your surroundings and playing a noise into your ears that almost completely cancels out the sound that you would normally hear. If it detects a compression, it produces a rarefaction of the same amplitude. They are enjoyable to use for listening to your music in your bedroom without having to hear the vacuum cleaner downstairs. They are vital for the concentration of people in high pressure and noisy jobs, such as fighter pilots.

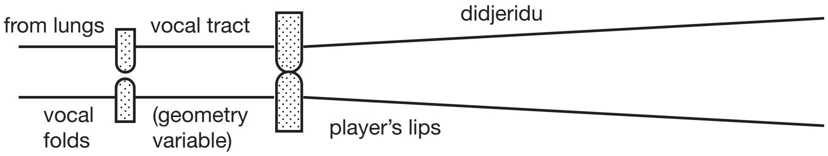
9.4.9 First Nations Australians' traditional musical instruments — the didjeridu

FIGURE 9.38 A collection of didjeridus

Music and dance are important to the cultures of First Nations Australians, and they developed three important musical instruments: the didjeridu, the bullroarer, and the gum-leaf. The most common instrument is the didjeridu, which is a simple wooden hollow tube about 1.2 to 1.5 m long with a ring of beeswax around the mouthpiece for sealing. The didjeridu originates in the northern parts of Australia but did make its way south through trade, and was typically only played by men.

A didjeridu can produce a range of sounds. It is closed at one end by the player's lips, and the sound produced by the player travels into the instrument and also travels into the vocal tract. The frequency is determined by the shape of the tract, position and shape of the tongue and the vocal chords. The player uses circular breathing. With this technique, air is stored in the mouth by inflating the cheeks, and is used to blow the instrument while at the same time, air is breathed in through the nose. This enables the player to sustain a tone for an extended period of time.

FIGURE 9.39 A schematic diagram of the acoustic system of a didjeridu



on Resources

Weblink Traditional Didgeridoo rhythms by Lewis Burns, Aboriginal Australian artist

9.4 Activities

learnon

9.4 Quick quiz on

9.4 Exercise

Select your pathway

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

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS ▶

Remember and understand

1. **MC** Why is the sound level measured in decibels not regarded as a completely accurate measure of loudness?
   A. You may be standing at different distances from the object.
   B. Everyone has different ears and hearing.
   C. Decibels are not as accurate as millibels.
   D. Your ears are more sensitive to some pitches than others.
2. **MC** The threshold of hearing is defined as:
   A. the closest you can stand in front of something making a loud sound.
   B. the smallest sound level the typical ear can hear.
   C. the highest sound level that you can listen to without pain.
   D. the highest sound level that you can listen to without damage.
3. Complete the following table to describe some of the important structures of the human ear.

TABLE Structures of the human ear

Structure	Description	Purpose
Eardrum		
	Three small bones in the middle ear	
	An opening into the inner ear	Allows vibrations to pass into the cochlea
Cochlea		Contains receptor cells for hearing
		Allows air to move between the middle ear and the mouth and nose

4. Why are sound waves unable to travel through a vacuum?
5. What is ultrasound and how is it useful?

Apply and analyse

6. Explain why luggage handlers who work on the tarmac at airports are required to wear ear protection.
7. Describe tinnitus and explain how it can be avoided.
8. Explain how the bionic ear is different from a normal hearing aid.
9. When you clap your hands, a sound is heard. Put these sentences in order to explain how the energy of the sound gets from your hands, through the air, through your ear and finally to your brain.
   a. The electrical impulses travel through the auditory nerve to the brain.
   b. When vibrations are passed through the oval window, they pass into the fluid in the cochlea, which moves tiny hairs.
   c. The eardrum vibrates in response to the vibrating air particles.
   d. When you clap your hands, air particles are displaced, forming a wave of changing air pressure.
   e. These hairs are attached to nerve cells that send messages in the form of electrical impulses
   f. The vibrating eardrum causes vibration in the ossicles that pass on the vibrations to the inner ear through the oval window.
   g. These vibrations travel through the air to the auricle of the ear, which channels the energy of the vibrating air through the ear canal to the eardrum.

▶

Use the data given in table 9.1 to answer questions 10, 11 and 12.

10. SIS In general, how does the speed of sound in solids compare with that in liquids and gases?

11. SIS Identify the substance that doesn't seem to fit the pattern. Give comparison values to demonstrate why this value seems anomalous.

12. SIS Why do you think such a large range of speeds is given for wood? How could you investigate whether your answer is correct?

13. Why do you think ultrasounds (high frequency sound waves), of a fetus in the womb for instance, give good detailed pictures?

14. Suggest why the speed of sound depends on altitude and temperature.

Evaluate and create

15. SIS The table shows the safe amount of time that you can continuously listen to noises at different decibel levels.

- **a.** Plot the data as a chart.
- **b.** Describe the trend that you observe.
- **c.** Use your prediction to suggest how long you could safely listen to a 90 dB noise.

TABLE Noise level permissible exposure time

Continuous decibels (dB)	Permissible exposure time (hours)
85	8
88	4
91	2
94	1
97	0.5
100	0.25
103	0.125

16. Imagine that you are one of two astronauts walking on the Moon.

- **a.** Would you be able to conduct a conversation with your partner without radios? Explain why.
- **b.** Imagine that both of your radios stopped working because you forgot to recharge the batteries. Explain how you would still be able to speak with your partner (no sign language or writing allowed).

17. Imagine that you are standing near a steep, rocky cliff. You shout 'Hello' and one second later you hear the echo. The air temperature is about 25 °C, so you estimate that the speed of sound is about 350 m/s. How far are you from the cliff?

18. A ship sends a SONAR pulse down into the water. After 0.2 seconds an echo is detected. You estimate that the speed of sound is about 1500 m/s. How deep is the water?

19. The speed of sound in air at a temperature of 25 °C is about 350 m/s. How long would it take for sound waves to travel from Melbourne to Sydney, a straight distance of about 700 km, when the air temperature is 25 °C?

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

LESSON
9.5 Energy transfer by light

LEARNING INTENTION

At the end of this lesson you will be able to describe light as an electromagnetic wave and name the key regions of the spectrum. You should be able to describe the link between energy and frequency of the light.

9.5.1 Using models to understand natural phenomena

The representation of light as waves is an example of a **model**. A model provides a useful way of investigating the properties and behaviour of something that you can't see.

During the seventeenth century, there were two 'opposing' models of light. One was a wave model similar to the one we use today. The other model, a particle model proposed by Sir Isaac Newton, was more popular at the time. Newton proposed that light consisted of a stream of tiny particles that he called corpuscles. This model successfully explained the reflection of light. However, the only way that Newton's model could explain light bending when it moves from air to water was if it travelled faster in water. Of course, at that time there was no way to measure the speed of light in water. We now know that light travels more slowly in water.

model simplified description, often a mathematical one, of a process

photon a particle such as a quantum of light or electromagnetism

wave-particle duality model that treats all objects as having both wave-like and particle-like properties. The property observed depends on the observation method chosen.

The wave model is successful at explaining most properties of light. However, in the early twentieth century, Albert Einstein, more famous for his theories of relativity, explained how light could also be seen as a stream of particles, which were later named **photons**. Photons are 'packets of energy' that have properties of both particles and waves. We say that photons have **wave-particle duality**.

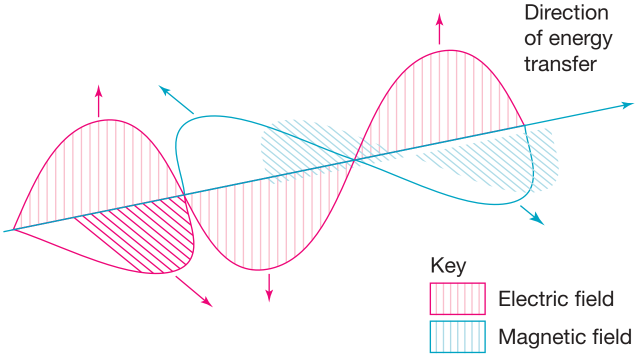
9.5.2 What is radiation?

Radiation is a method of heat transfer that does not require particles to transfer heat from one place to another; rather, the energy is transferred through electromagnetic waves. Light and heat are examples of radiation. Around any charged particle there is an electric field. If that charge moves, the electric field moves too, sending a 'ripple' through the field. We will see in a later topic that when you get a changing electric field you make a changing magnetic field. A changing magnetic field causes a changing electric field and so on.

This means that whenever a charged particle vibrates, for instance because it has heat energy, it will be producing a changing electromagnetic field that carries energy away. When this wave hits another charged particle it will be absorbed, causing the particle to vibrate.

The energy produced radiates away, i.e. travels in a straight line as if along a radius of a circle. That is why this form of energy is referred to as electromagnetic radiation. Visible light is one type of electromagnetic radiation.

FIGURE 9.40 A representation of part of an electromagnetic wave



9.5.3 The electromagnetic spectrum

Take a pen and draw a low-frequency wave from one side of a piece of paper to another. Use a stopwatch to time yourself doing this. When you are done, draw another wave of much higher frequency but the same amplitude *and taking the same amount of time*. Which drawing required more energy?

You should have found that high-frequency waves are also high-energy waves.

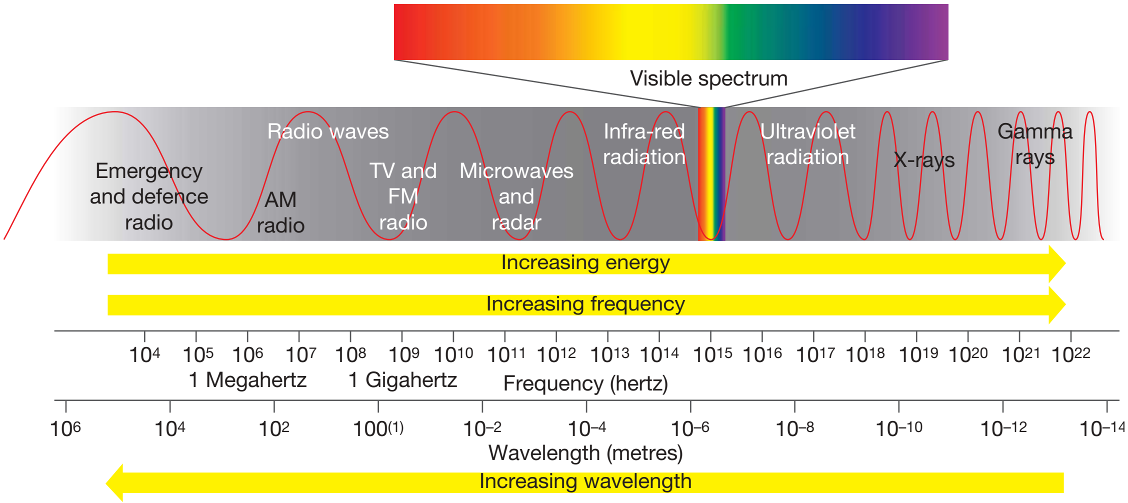
- Objects that are cold have little energy to lose and so produce long wavelengths, low-frequency electromagnetic radiation waves.
- The hotter an object is the higher the frequency, higher the energy and shorter the wavelength produced.

Despite their different energies, all types of light travel at the same speed in a vacuum. The speed of light and all other types of electromagnetic radiation is approximately 300 000 000 m/s. However, it does slow down when passing through matter. For example, light travels through glass at a leisurely 200 000 000 m/s.

There is a huge range, or *spectrum*, of energies of electromagnetic radiation that can be produced. These include:

- radio waves
- infrared radiation
- visible light
- ultraviolet radiation
- x-rays
- gamma rays.

FIGURE 9.41 The electromagnetic spectrum



Radio waves

Radio waves include the low-energy waves that are used to communicate over long distances through radio and television. They also include radar and the microwaves used in microwave ovens for cooking.

radio waves low-energy electromagnetic waves with a much lower frequency and longer wavelength than visible light

EXTENSION: Can you hear the Big Bang?

Radio waves and microwaves are low energy and generally quite safe. You are constantly bathed in radiation left over from the Big Bang! You can hear evidence of this radiation when you tune a radio between stations.

Microwaves that are used to cook are actually tuned to be exactly the right frequency to be absorbed by water, making the water hotter and cooking the food from the inside.

Infrared radiation

Infrared radiation, invisible to the human eye, is emitted by all objects and is sensed as heat. The amount of infrared radiation emitted by an object increases as its temperature increases.

FIGURE 9.42 A gentle push of the button sends infrared radiation to the television set at 300 million metres per second.

Visible light

Visible light represents only a very small part of the electromagnetic spectrum. It is necessary for the sense of sight. The process of photosynthesis in green plants cannot take place without visible light.

Ultraviolet radiation

Like infrared 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 as it has enough energy to penetrate the outer layers of skin and damage the delicate tissues underneath.

WHAT DOES IT MEAN?

The words *ultraviolet* and *ultrasound* are derived from the Latin term *ultra*, meaning ‘beyond’. Ultraviolet radiation has frequencies beyond those of the colour violet, and ultrasound has frequencies beyond those of sounds we can hear.

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 structure 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.

CT scanners (or CAT scanners) consist of x-ray machines that are rotated around the patient being examined.

FIGURE 9.43 X-ray showing a fracture of a radius and ulna in a forearm

infrared radiation invisible radiation emitted by all warm objects. You feel infrared radiation as heat.

visible light a very small part of the electromagnetic spectrum to which our eyes are sensitive

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 their structure

Gamma rays

gamma rays high-energy electromagnetic radiation produced during nuclear reactions. They have no mass and travel at the speed of light.

Gamma rays are unusual in that they are not made in the same way as other forms of light. Rather than being produced by vibrating atoms or accelerating electrons, they are made in nuclear decay. They 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.

SCIENCE AS A HUMAN ENDEAVOUR: Using gamma rays in medicine

Gamma cameras are used in PET scans (see lesson 6.4) to obtain images of some organs. To obtain a PET scan, a radioactive substance that produces anti-matter versions of electrons, called positrons, is injected into the body (or in some cases, inhaled). As it passes through the organ being examined, the positrons collide with electrons and annihilate each other in a microscopic nuclear explosion! This sounds bad, but the energies involved are small and you feel nothing. The explosion produces gamma rays, which are detected by the camera.

FIGURE 9.44 A patient undergoing a PET scan of her brain

DISCUSSION

If light can travel forever until absorbed and the Universe is infinite, then there must be stars in every direction that we look. So why is the night sky black?

on Resources

Weblink NASA Interactive: Electromagnetic spectrum

9.5.4 Comparing light and sound

Some differences between sound waves and electromagnetic waves are summarised in table 9.2.

TABLE 9.2 Comparison of sound waves and electromagnetic waves

Sound waves	Electromagnetic waves
Compression (longitudinal) waves	Transverse waves
Travel through all solids, liquids and gases, but are unable to travel through a vacuum	Unable to travel through some substances but travel through a vacuum
Speed in air between about 330 m/s and 350 m/s, depending on temperature	Speed in air about 300 000 000 m/s

9.5 Activities

9.5 Quick quiz on

9.5 Exercise

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 2, 3, 8	4, 5, 7	6, 9, 10

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. **MC** Electromagnetic waves are:
   A. longitudinal waves.
   B. compression waves.
   C. transverse waves.
   D. mechanical waves.
2. Fill in the blanks to complete the sentence.
   All electromagnetic waves have a number of things in common. They are all __________ waves, they can all travel through a __________ with a speed of approximately __________ m/s.
3. Fill in the blanks to complete the sentence.
   There are differences between sound waves and electromagnetic waves.
   Sound waves are __________ waves, whereas electromagnetic waves are __________ waves; sound waves need __________ to travel through, whereas electromagnetic waves do not; the speed of sound is much __________ than the speed of electromagnetic waves.
4. Arrange the following regions of the electromagnetic spectrum in order from the lowest energy to the highest energy.
   X–ray Infrared Ultraviolet Gamma ray Visible light Radio waves
5. Arrange the following regions of the electromagnetic spectrum in order from the highest to the lowest frequency.
   X–ray Infrared Ultraviolet Gamma ray Visible light Radio waves
6. Arrange the following regions of the electromagnetic spectrum in order from the longest wavelength to the shortest wavelength.
   X–ray Infrared Ultraviolet Gamma ray Visible light Radio waves

Apply and analyse

7. Explain why you always hear thunder after you see the lightning that caused it.
8. High doses of x-rays can have detrimental health effects. X-rays have enough energy to pass through human flesh but cannot go through 0.5 mm of lead.
   Explain why x-ray technicians wear lead aprons in medical facilities.

Evaluate and create

9. **MC** Select the three properties of sound waves that make them different from electromagnetic waves.
   A. They are compression waves.
   B. They are transverse waves.
   C. They need particles to travel.
   D. They do not need particles to travel.
   E. The speed of sound is much smaller.
   F. The speed of sound is much larger.
10. Explain why the behaviour of electromagnetic waves cannot be modelled using compression waves in a gas or a slinky.

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

LESSON
9.6 Wave behaviour of light

LEARNING INTENTION

At the end of this lesson you will be able to describe the behaviour of light during reflection and refraction.

9.6.1 Understanding water waves to understand light

In the distant past, people living at the coast observed that the waves in the ocean showed some predictable behaviour.

- Waves could *reflect* from a rock.
- As the water depth changed, waves would slow and often change direction in a process called *refraction*.
- Water waves clearly carried *energy*.

Eventually it occurred to scientists that as light also could reflect, refract and carry energy, maybe it too was a wave. In this section we look at how we can use the wave behaviour of light to our advantage.

FIGURE 9.45 Waves reflect, refract and carry energy.

9.6.2 Ray tracing

DISCUSSION

What devices can you think of that redirect light for a useful purpose? How do they work?

Most of the objects that you see are **non-luminous**. **Luminous** objects are those that emit their own visible light. The Sun and the flame of a burning match are examples of luminous objects. However, non-luminous objects will still produce light of lower energies that our eyes cannot see. Once this light has been emitted, how can we determine where it will go?

non-luminous objects that release no visible light of their own

luminous object that releases its own light

Light travels in straight lines as it travels through empty space or through transparent substances like air or water. The lines that are used to show the path of light are called **rays**. You cannot see a single light ray. A stream of light rays is called a **beam**. A beam of white light will contain countless individual waves usually with a range of energies.

rays narrow beams of light

beam a wide stream of light rays, all moving in the same direction

By knowing how to guide a beam of light we can make a huge array of optical devices from the simple mirror to the Hubble Space Telescope.

Seeing beams of light

You can see beams of light only when particles in substances like air scatter the light as shown in the photograph in figure 9.46. Some of the scattered light enters your eye, allowing you to see the particles within the beam.

FIGURE 9.46 Beams of light can be seen in fog.

A beam of light can be seen if there is smoke or fog in the air. Light is scattered by the tiny particles. Some of the scattered light enters your eye, allowing you to see the particles within the beam.

SCIENCE AS A HUMAN ENDEAVOUR: Computer graphics

Modern computers can calculate the paths of millions of light rays from the simulated light sources in computer games. Game engines require the programmers to have an extensive understanding of the physics of light so that reflection, refraction and scattering can be taken into account to produce realistic surfaces, water effects and atmospheric effects. The most difficult challenge is to reproduce the way faces reflect light in multiple ways at different depths of the skin. When a face looks nearly real, but not quite, it is said to fall into the 'uncanny valley'. Even with the best graphics available this often produces an unrealistic look — for now.

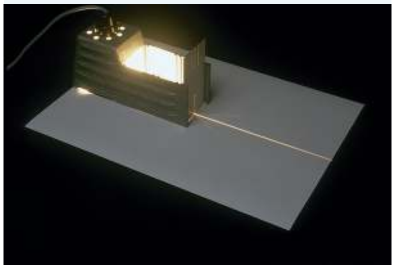
FIGURE 9.47 A face that looks nearly real, but not quite.

Ray boxes

The ray box shown in figure 9.48 provides a way of tracing the path of light. It contains a light source and a lens that can be moved to produce a narrow or wide beam of light that spreads out, converges or has parallel edges. The light box is placed on a sheet of white paper, making the beam visible as some of the light is reflected from the paper into your eyes.

Black plastic slides can be placed in front of the source to produce a single thin beam or several thin beams. The beams are narrow enough to trace with a fine pencil onto the white paper. The fine pencil line can be used to represent a single ray. You can think of a single ray as the path of a photon. This convention of representing the path of light is based on the particle model of light.

FIGURE 9.48 A ray box provides a way of tracing the path of light.



9.6.3 Light interacting with matter

When light meets a boundary between two different substances, as we have seen above, a number of things can happen.

On the rebound

The light may bounce off the surface of the substance. This is called **reflection**, and is what allows you to see non-luminous objects. Light can also be reflected from particles within substances. This is called **scattering** because the light bounces off in so many different directions. Light is scattered by the particles of fog, dust and smoke in the atmosphere. Scattering is also evident in cloudy water. A luminous object in very deep or dirty water is not visible from the surface because all of the light is scattered before it can emerge. The same object is more likely to be visible on the surface of shallower or cleaner water because less light would be scattered.

Just passing through

The light may travel through the substance. Some light is always reflected when light crosses a boundary between two substances. If most of the light travels through the substance, the surface is called **transparent** because enough light gets through for you to be able to see objects clearly on the other side (figure 9.49a). Some materials let just enough light through to enable you to detect objects on the other side, but scatter so much light that you can’t see them clearly. The frosted glass used in some shower screens is an example. Such materials are said to be **translucent** (figure 9.49b).

Lost inside

The light may be absorbed, transferring its energy to the particles in the substance. Substances that absorb or reflect all the light striking them are said to be opaque. Most objects in your classroom are **opaque** (figure 9.49c).

reflection bouncing off the surface of a substance

scattering light sent in many directions by small particles within a substance

transparent a substance that allows most light to pass through it. Objects can be seen clearly through transparent substances.

translucent allowing light to come through imperfectly, as in frosted glass

opaque a substance that does not allow any light to pass through it

FIGURE 9.49 a. Transparent, **b.** translucent and **c.** opaque materials

ACTIVITY: Scavenger hunt

Find three items that are transparent, three that are translucent and three that are opaque and share these with the class.

9.6.4 Reflections

Whenever light is reflected from a smooth surface, it bounces away from the surface at the same angle from which it came. More scientifically we say that the angle of incidence equals the angle of reflection. This observation is known as the **Law of Reflection**.

Law of Reflection the angle of incidence must equal the angle of reflection

ACTIVITY: Law of Reflection

Investigate the Law of Reflection by rolling a ball against a wall, or a ball on a pool table, at different angles. Observe how the outgoing angle relates to the incoming angle each time.

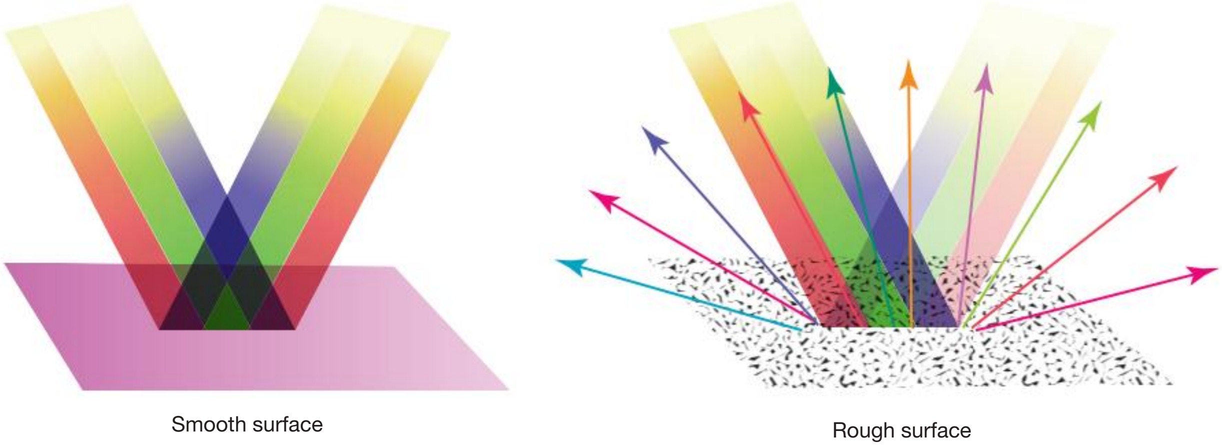
When you look in a mirror you see an image of yourself. If the mirror is a plane or flat mirror, the image will be very much like the real you. If the mirror is curved, the image might be quite strange.

The images in mirrors are formed when light is reflected from a very smooth, shiny metal surface behind a sheet of glass. Early mirrors were polished metal. If you could not afford a mirror, you could see your image reflected on the surface of water in a bucket.

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. 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.

FIGURE 9.50 Rays of light reflect off very smooth surfaces all at the same angle. Rough surfaces scatter light in various directions.



9.6.5 Using mirrors

The Law of Reflection can be used to find out where your image is when you look into a mirror.

Figure 9.51 shows how the Law of Reflection works. To help us measure angles correctly, we draw an imaginary line at right angles to the surface of the mirror. We call this the **normal**. Note that we measure the **angle of incidence** from the **incident ray** to the normal NOT to the surface of the mirror. We measure the **angle of reflection** from the **reflected ray** to the normal also.

Almost all of the light coming from the object 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 is the same distance behind the mirror as the object is in front of the mirror and it is the same size. However, it is also laterally inverted. For example, if you wave at your reflexion with your right hand, it appears to be your left hand.

normal is a line drawn perpendicular to a surface at the point where a light ray meets it

angle of incidence the angle between an incident ray on a surface and the line perpendicular to the surface at the point of incidence, called the normal

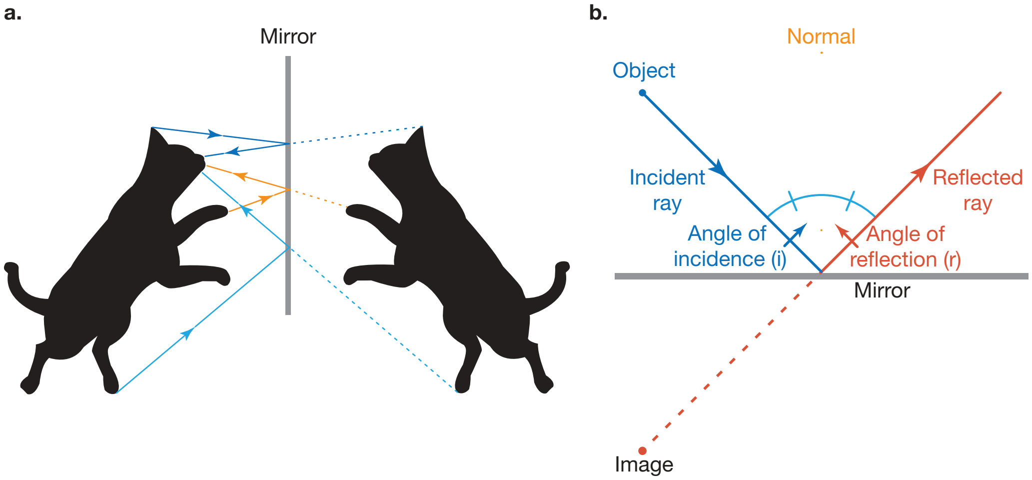
incident ray the ray that approaches the mirror

angle of reflection the angle measured from the reflected ray to the normal

reflected ray the ray that leaves the surface of the mirror

lateral inversion reversed sideways

FIGURE 9.51 a. The reflected light appears to be coming from just one place. The image seems to be behind the mirror. **b.** The angle of incidence is equal to the angle of reflection.



The Law of Reflection: the angle of incidence equals the angle of reflection.

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 the photograph on the right is printed so that drivers in front of it can easily read the word ‘AMBULANCE’ in their rear-view mirrors.

FIGURE 9.52 Why is the word ‘AMBULANCE’ printed in reverse?

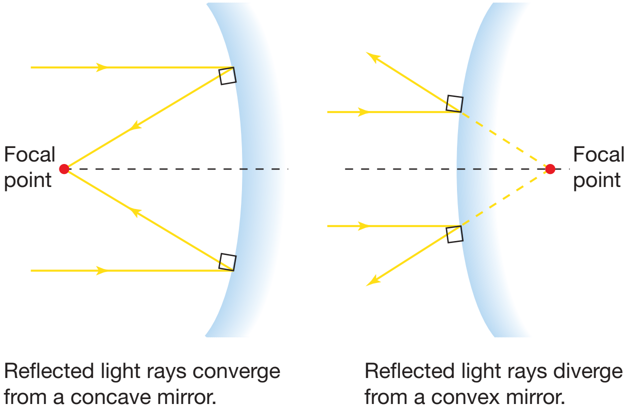
Reflection from curved mirrors

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 9.53.

Images in convex mirrors are upright but distorted and smaller. They can reflect light from a wide range of angles. This means they are useful as security mirrors in shops or as wing mirrors on cars.

Images in concave mirrors are usually upside down until you get closer when they give a magnified image. This makes them useful as shaving or make-up mirrors. They can also be used to redirect light forward in a beam, as in a torch or headlights.

FIGURE 9.53 Reflection of light from convex and concave mirrors



Reflected light rays converge from a concave mirror.

Reflected light rays diverge from a convex mirror.

FIGURE 9.54 Uses of convex and concave mirrors

on Resources

eWorkbooks Reflection and scattering of light (ewbk-12602)
Curved mirrors (ewbk-12604)

concave curved inwards
convex curved outwards
focal point the focus for a beam of light rays

elog-2393

INVESTIGATION 9.9

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. Is the image small or large? Right-side up or upside down? Is there anything strange about the image? Record your observations in a table like the one provided.
2. 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. Record your observations in the table.
3. 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.
4. 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.
5. Write down how you think an image of the word REFLECTION would look in the mirror. Test your hypothesis about the image of the word REFLECTION.

Results

TABLE Observations using convex and concave mirrors

	Observations of image		
	First observation	**When you move closer**	**When you move further away**
Convex side			
Concave side			

Discussion

1. 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 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

What can you conclude about the images formed in plane compared to those in curved mirrors?

9.6.6 Refraction

When a wave enters a region where it meets resistance it slows down. The waves ‘bunch up’ and the wavelength decreases. This happens to water waves as they approach the beach. Sound waves slow down when moving into cooler air and light waves slow down below the speed of light in transparent and translucent substances. The frequency of the waves, however, does not change.

When the light hits the new substance head on, the beam slows down but stays in a straight line. Things change when the light hits the new substance at an angle. Here one side of the beam slows down before the other. The effect of this is that the beam changes direction. This is **refraction**.

refraction the bending of light when passing from one medium into another

To describe the change in direction, we measure the angles between the light beam or ray and the normal.

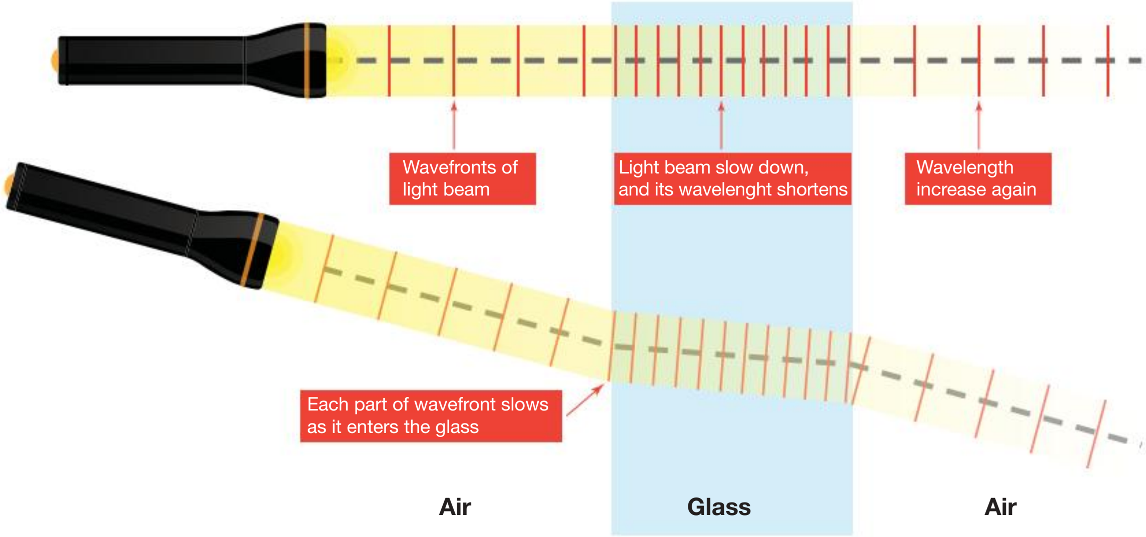
- When a beam enters the glass it will refract *towards* the normal.
- When the beam leaves the glass it will move *away from* the normal.

TIP: Use can the acronym **FAST** to remember the changes in direction in refraction:
Faster = **A**way from normal
Slower = **T**oward normal

Refraction effects

Water can make a bowl of water, a swimming pool or any body of clear water appear shallower than it is. Light leaving the surface of the water changes direction. The eye sees the light appearing to travel in a straight line. This gives the illusion that the water is not as deep as it is. Objects that are part in the water and part out can appear broken from some angles, as the light travelling through the water will enter your eyes from a different angle to the light from the part of the object sticking out of the water.

FIGURE 9.55 The wavefront is a line connecting the crests of the waves in the beam that were emitted at the same time. The wavelength is the distance between wavefronts. The wavefronts 'bunch up' in the glass because the wave slows down.



int-0673

FIGURE 9.56 A ray of light will refract towards the normal when it enters a substance that slows the light.

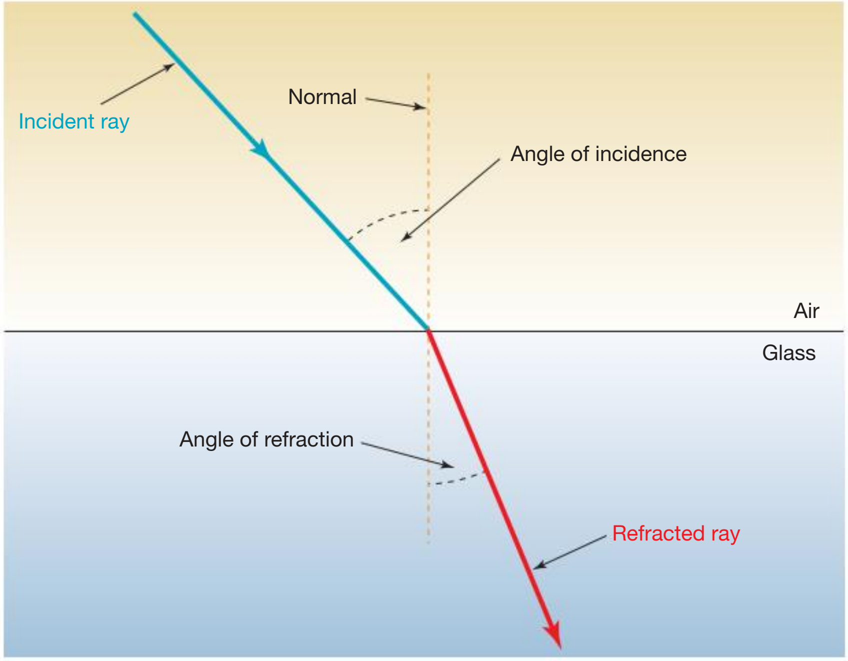
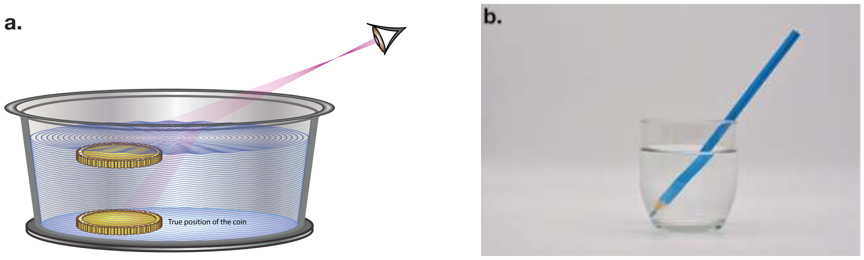


FIGURE 9.57 a. The coin appears to be higher in the water than it is due to refraction. **b.** The pencil appears broken due to refraction.



on Resources

eWorkbook Refraction (ewbk-12606)

Video eLesson Twinkle, twinkle (eles-0071)

How much a material bends light is called the **refractive index**.

refractive index the measure of the bending of light when it is passed through a material

elog-2395

INVESTIGATION 9.10

How much does it bend?

Aim

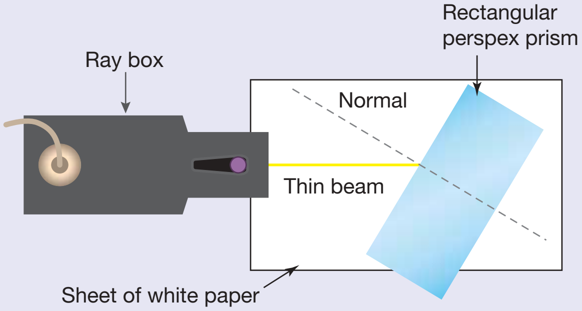
To investigate the refraction of light as it travels into and out of a rectangular prism

Materials

- ray box kit
- power supply
- sheet of white paper

Method

Connect the ray box to the power supply. Place a sheet of white paper in front of the ray box. Project a single thin beam of white light towards a rectangular perspex prism as shown in the diagram.



Results

1. Does the light bend towards or away from the normal as it enters the perspex? (Remember that the normal is a line that can be drawn at right angles to the boundary. It is shown as a dotted line in the diagram. You don't need to draw it — just imagine that it's there.)
2. Imagine a normal at the boundary where the light leaves the perspex to go back into the air. Which way does the light bend as it re-enters the air — towards or away from the normal?
3. Does all of the light travelling through the perspex re-enter the air? If not, what happens to it?
4. Look at the light beam as it enters and leaves the perspex. What do you notice about the direction of the incoming and emerging beam?
5. Turn the prism without moving the ray box so that the light enters the perspex at different angles.
   a. How can you make the incoming light bend less when it enters the perspex?
   b. How can you make the incoming light bend more when it enters the perspex?

Conclusion

How does light behave when it travels through air and through perspex?

elog-2397

INVESTIGATION 9.11

Floating coins

Aim

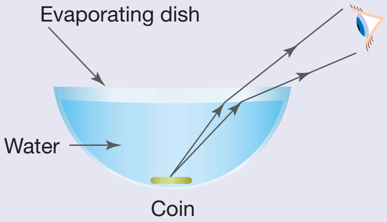
To observe the refraction of light

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

1. Make a copy of the diagram shown. 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.
2. Is the image of the coin above or below the actual coin?
3. What appears to happen to the coin while water is added to the evaporating dish?

Conclusion

What can you conclude about the behaviour of light through air and through water?

on Resources

Weblink Simulation: Bending light

9.6.7 Refraction and lenses

Lenses are usually made of glass or plastic. When light passes through them it slows down as usual and bends. The slowing down is refraction. Due to their special shapes, the light can be guided to a point where it may be projected on a screen.

A common shape of lens is **biconvex** (convex lens) — 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.

Another type of lens is a **diverging lens** (concave 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.

biconvex a convex lens with both sides curved outwards

diverging lens lens that bend rays so that they spread out. Diverging lenses are thinner in the middle than at the edges.

virtual focal point a common point from which rays appear to have come before passing through a concave lens

FIGURE 9.58 a. Biconvex lenses converge light on a focal point. **b.** Biconcave lenses spread light outwards.

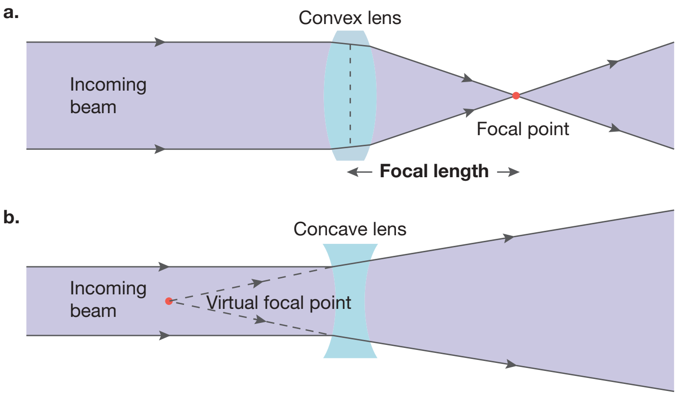
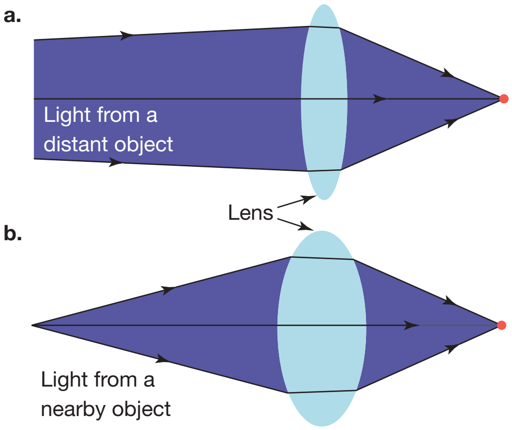


FIGURE 9.59 a. The light coming from a nearby object needs to be bent more than the light coming from a distant object. **b.** The lens in your eye becomes thicker when you look at nearby objects.



on Resources

Video eLesson Galileo and the telescope (eles-1765)

Interactivity Lenses (int-1017)

elog-2399

tlvd-10800

INVESTIGATION 9.12

Seeing the light

Aim

To investigate the reflection of light and its transmission through a prism and lens

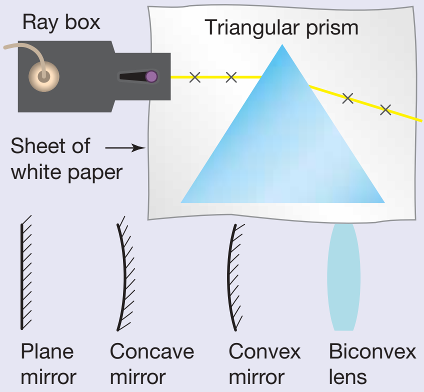
Materials

- ray box kit
- power supply
- several sheets of white paper
- ruler and 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 provided. 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'.

Tracing the path of a beam of light



Results

1. Record the path of the single beam of light.
2. Record the path of the parallel beams of light.

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. Describe your observations of the path followed by the three parallel beams when they meet each of the mirrors and the lens.

Conclusion

What can you conclude about the behaviour of light in this investigation?

elog-2401

INVESTIGATION 9.13

Focusing on light

Aim

To investigate the transmission of light through different lenses

Materials

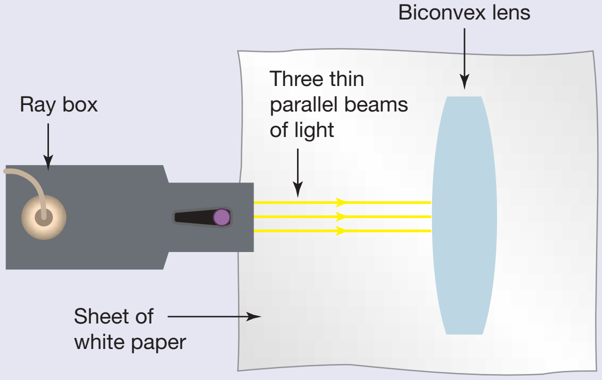
- ray box kit
- sheet of white paper
- 12 V DC power supply
- ruler and fine pencil

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 out 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

Part A: Biconvex lenses

Record the paths of the beams of light through the biconvex lens.

Part B: Biconcave lenses

Record the paths of the beams of light through the biconcave lens.

Discussion

1. State the focal length (distance from the focal point to the centre of the lens) for each lens.
2. Which of the biconvex lenses bends light more, the thin one or the thicker one?
3. Explain why the middle light ray does not bend.
4. How many times do each of the other rays bend before arriving at the focal point?
5. Do the diverging rays come to a focus?
6. Do the diverging rays appear to be coming from the same direction? Use dotted lines on your diagram to check.
7. 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

What can you conclude about the behaviour of light through biconvex and biconcave lenses?

on Resources

Weblink TED-Ed: How do glasses help us see?

9.6.8 EXTENSION: Piping light

SCIENCE AS A HUMAN ENDEAVOUR: Piping light for use in medicine

The photograph in figure 9.60 shows the inside of a human stomach. It has been photographed through a long, flexible tube called an **endoscope**. Inside the endoscope are two bundles of narrow glass strands called **optical fibres**.

A beam of bright light is directed through one bundle of fibres, illuminating the inside of the stomach. Some of the light is reflected through the other bundle of fibres. A lens at the end of this bundle allows an image to be viewed, photographed or videotaped.

FIGURE 9.60 Optical fibres allow us to see inside the human body via an endoscope.

Endoscopes can be used to look at many different parts of the body. Different types of endoscopes include:

- gastroscopes, which are used to examine the stomach and other parts of the digestive system
- arthroscopes, which are used to search for problems in joints like shoulders and knees
- bronchoscopes, which are used to see inside the lungs.

Endoscopes can also be used in laser surgery. Intense laser beams can be directed into the optical fibres. The heat of the laser beams can be used to seal broken blood vessels or destroy abnormal tissue inside the body.

The glass in optical fibres is made so that light is unable to emerge from the glass. As light travels from a substance such as glass into air, it bends away from the normal. As the incident angle gets larger, the light bends more and more. Eventually the angle becomes so great that the incident light just can't bend any more. This angle is called the **critical angle**. When it is reached the light doesn't emerge from the glass, it will just travel along the boundary.

If the light hits the boundary at an angle greater than the critical angle, instead of leaving the glass, it is reflected back into it. This process is called **total internal reflection**. Figure 9.62 shows how total internal reflection occurs in an optical fibre.

endoscope a long, flexible tube with one optical fibre to carry light to an area inside the body and another optical fibre to carry light from the body to a lens. The image formed by the lens is examined or recorded.

optical fibres narrow strands made of two concentric glass layers so that the light is internally reflected along the fibres

critical angle when the incident angle becomes so great that the incident light can't bend any more

total internal reflection the complete reflection of a light beam that may occur when the angle between a boundary and a beam of light is small

FIGURE 9.61 A bundle of optical fibres. The light can be seen through the ends.

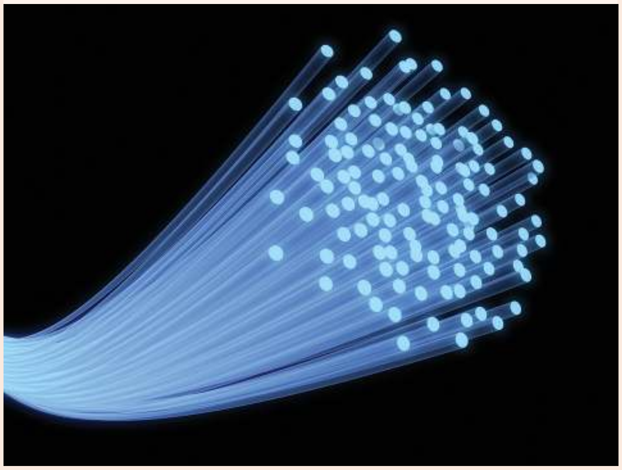
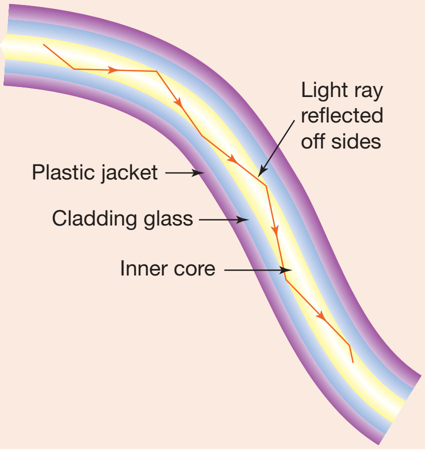


FIGURE 9.62 Total internal reflection in an optical fibre



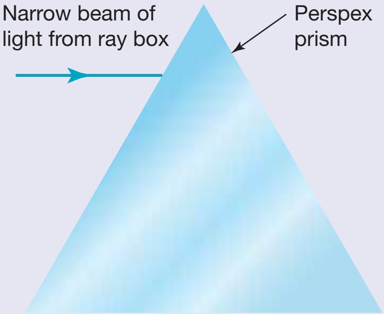
on Resources

Video eLesson Light pipes (eles-1087)

elog-2403

INVESTIGATION 9.14

Total internal reflection



Aim

To investigate total internal reflection in a triangular prism

Materials

- ray box kit
- 12 V DC power supply
- perspex triangular prism

Method

1. Connect the ray box to the power supply. Place the ray box over a page of your notebook. Use one of the black plastic slides in the ray box kit to produce a single thin beam of light that is clearly visible on the white paper.
2. Place a perspex triangular prism on your notebook and direct the thin beam of light towards it as shown in the diagram provided. Observe the beam as it passes through the prism.
3. Turn the prism slightly anticlockwise, closely observing the thin light beam as it travels from the perspex prism back into the air. Continue to turn the prism until the beam no longer emerges from the prism.

Results

1. Describe what happens to the thin light beam as it passes from air into the perspex prism and back into the air.
2. What happens to the beam of light when it no longer emerges from the prism?

Discussion

1. Draw a series of two or three diagrams showing how the path taken by the beam of light changed as you turned the prism.
2. Explain how the amount of light reflected changes as the prism is turned.

Conclusion

What can you conclude about the behaviour of light within a perspex prism?

elog-2405

INVESTIGATION 9.15

Optical fibres

Aim

To model the transmission of light through an optic fibre

Materials

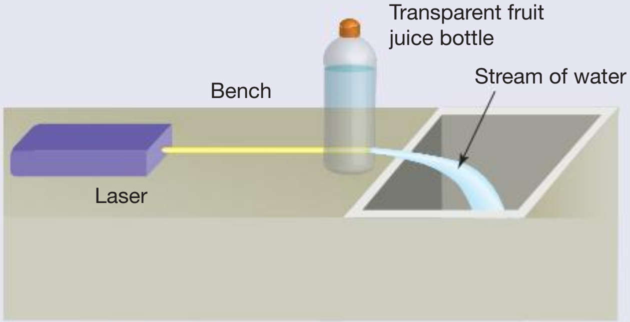
- transparent 2–3 L fruit juice container
- large nail
- laser (class 1)
- demonstration optical fibre cable or light pipe

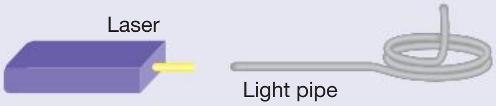
CAUTION

Class 1 and class 2 lasers have a relatively low power output and so are safe for classroom use under direct supervision of the teacher. Laser beams should not be pointed towards others in the room because of the sensitivity of the retina of the eye. Ensure that those viewing this demonstration are positioned on either side of the stream of water to eliminate the possibility of the laser beam being directed towards them.

Method

1. Use the nail to poke a narrow 5 mm hole into the front of a fruit juice container, approximately 5 cm from the bottom.
2. Darken the room.
3. Fill the container to the top with water and position it on the edge of a sink so that a thin stream of water flows from the container into the sink.
4. Direct a laser beam into the container and out through the centre of the stream of water.
5. Shine a laser beam down a length of ‘light pipe’ or loop of optical fibre.





Results

1. Describe the path of the laser beam through the stream of water.
2. Describe the laser beam down the length of optical fibre cable or light pipe.

Discussion

1. Explain why the laser beam took the path of light observed in these demonstrations.
2. Compare the speed of light in air to that in water or the material making up the optical fibre core.
3. Explain how these demonstrations rely on the difference in the speed of light through these media.

Conclusion

What can you conclude about the transmission of light through different media?

EXTENSION: Why diamonds sparkle

Diamonds can sparkle with coloured light, each of its surfaces producing a dazzling display. Diamond is the most optically dense, naturally occurring material on Earth. This means that light entering a diamond through each of its facets (or geometrically cut sides) is refracted by a huge angle, causing light inside the gemstone to bounce back and forth several times before it strikes a facet with an angle straight enough to escape. Because the light has travelled so far, the spectrum of colours that make up light have dispersed (or separated) so significantly that a stunning display of colours is produced.

9.6 Activities

9.6 Quick quiz on | **9.6 Exercise**

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 2, 5, 7, 9, 10	3, 4, 6, 12, 13	8, 11, 14, 15

Remember and understand

1. **MC** You cannot usually see light as it travels through the air. What makes it possible to see a beam of light?
   A. When particles in the air scatter the light
   B. When the beam is very bright
   C. When the beam contrasts well with the background
   D. When the light waves have a very long wavelength
2. What happens to light when it travels through air and meets:
   a. a transparent surface
   b. a translucent surface
   c. an opaque surface?
3. What will the angle of reflection be in each of these cases?
   a. The angle of incidence is 35°.
   b. The angle between the reflected ray and the mirror is 40°.
   c. The angle between the incident ray and the mirror is 20°.
4. In which type of mirror can your image be:
   a. upside down
   b. magnified
   c. the right way up, unmagnified and laterally inverted?
5. Sketch the word LIGHT but laterally inverted.

6. When a beam of light enters a denser medium (for example, from air into water) will the following properties of the beam increase, decrease or stay the same?
   - a. Wavelength
   - b. Speed
   - c. Frequency
   - d. Angle between the ray and the normal

Apply and analyse

7. The illustration shows a ray of light emerging from still water after it has been reflected from a fish. Should the spear be aimed in front of or behind the image of the fish? Use a diagram to explain why.

8. Are photons particles or waves? Explain your answer.
9. 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.
10. **MC** What is the focal length of a converging lens a measure of?
    - A. How long the image will be
    - B. The distance between the focus (the point to which parallel rays of light converge) and the lens
    - C. The distance between the object and the image
    - D. The distance you must place the object at to form an image.
11. Explain why the focal point of a diverging lens is called a virtual focal point.
12. Explain how optical fibres allow light to travel along a bent tube.
13. Explain how an endoscope works, listing three medical uses.
14. Can total internal reflection occur when light travels from air into glass? Explain your answer.

Evaluate and create

15. **SIS** You are presented with three different transparent materials and you are asked to determine which of them slows light down the most. Plan an experiment stating the independent, dependant and controlled variables that you would use. State the equipment that you would use to make any measurements. Explain how your readings could determine which substance slowed light down the most.

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

LESSON
9.7 Static electricity

LEARNING INTENTION

At the end of this lesson you will be able to use the particle model to explain static electricity.

9.7.1 Charge!

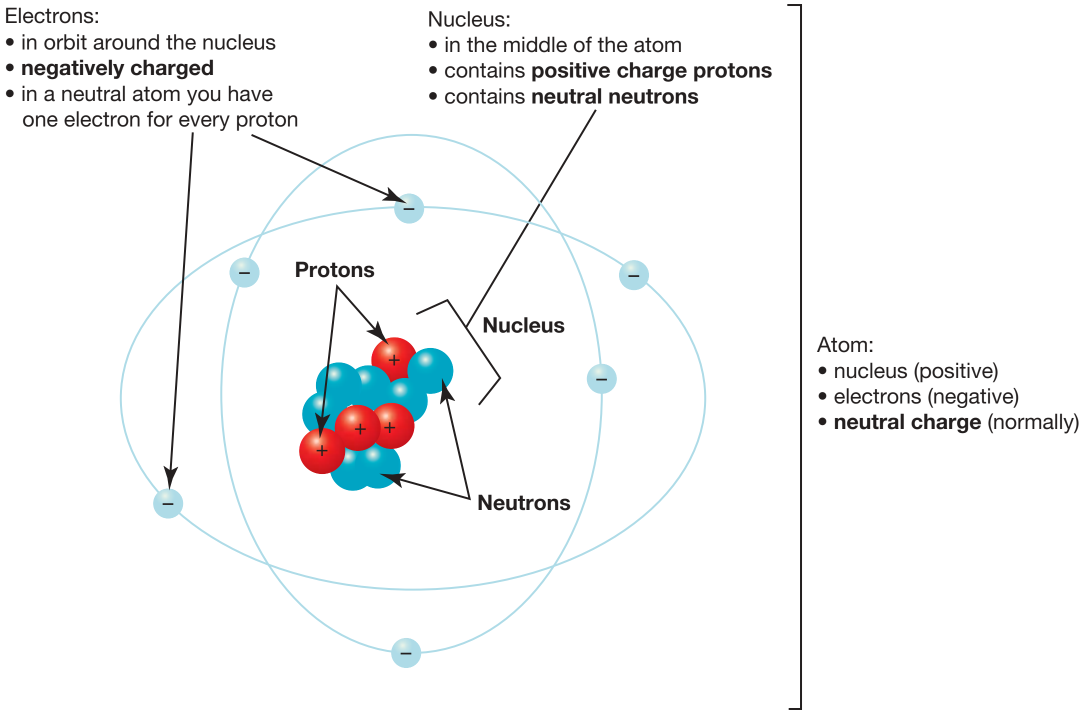
electric charge physical property of matter that causes it to experience a force when near other electrically charged matter. Electric charge can be positive or negative.

When we say that we need to charge our phones, we mean that we have to fill a battery with electrical energy. However, as we will see, electricity doesn't just sit there in a battery. You cannot hold a handful of electricity. We only see electricity doing something when the electrons collide with atoms in the wire and transfer their energy. What causes the motion in the first place is the fact that electrons have a property called **electric charge**.

There are two types of electric charge: positive and negative. If a particle has no charge, or the same amount of positive and negative charge, we say it is neutral.

All matter is made up of atoms. It used to be thought that they were the smallest possible pieces of matter but we now know that they are made of smaller pieces. Recall that atoms are made of 3 types of sub atomic particles: protons, neutrons and electrons. Protons and neutrons are located in the nucleus of the atom and electrons are located outside the nucleus.

FIGURE 9.63 A neutral atom contains an equal number of protons (red) and electrons (purple). (Two of the protons are hidden in this diagram.) This diagram represents a carbon atom (6 protons and 6 electrons). The number of neutrons is not always the same as the number of protons.



DISCUSSION

Why is it that sometimes your clothes crackle and you may get a small shock when you remove a jumper over your head?

Typically protons in the nucleus don't move so all of the electricity concepts that we will study are due to the movements of electrons.

All electricity is due to the movement or position of electrons.

There are two ways of using electrons. In **static electricity**, the electrons build up in one space and are not allowed to move (static means 'not moving'). If we create a pathway for electrons to flow through, we can create **current electricity** — this is how circuits work. Current electricity is really just a type of movement (kinetic) energy.

static electricity a build-up of charge in one place

current electricity the flow of electrons through a region

FIGURE 9.64 a. Electrons, which are negatively charged, can be removed from atoms. This produces free electrons and positively charged atoms (ions). **b.** These electrons are able to travel through wires.

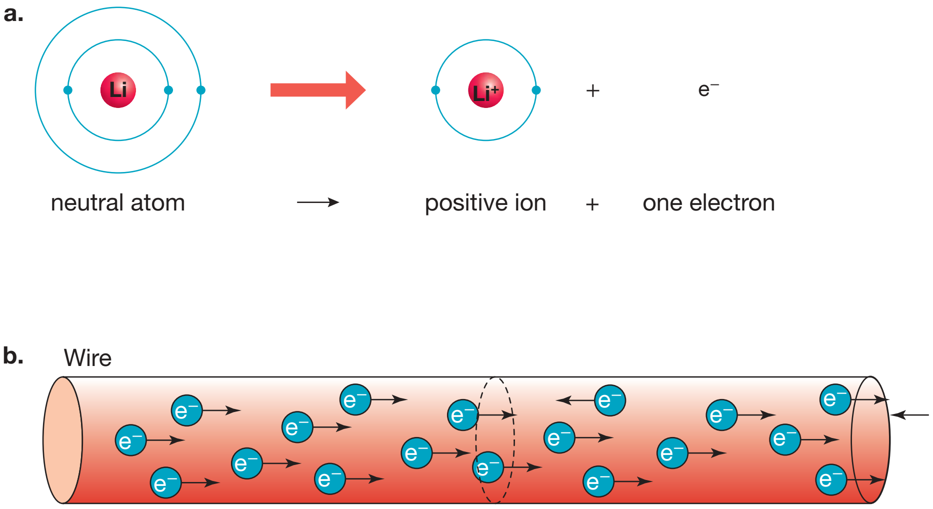


FIGURE 9.65 The cords to earbud headphones carry electricity, not sound. Each cord actually contains two wires. The jack that plugs into the player is composed of four wires, two per earbud.

9.7.2 Electric fields

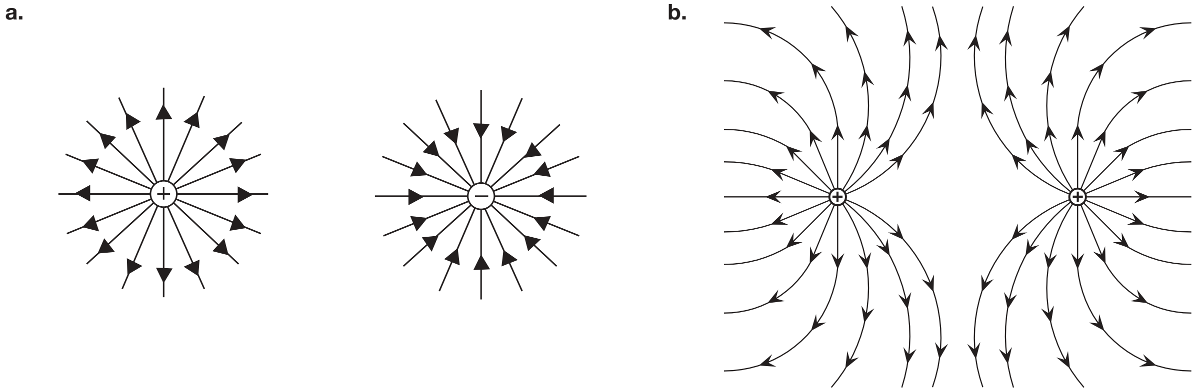
Perhaps the most important observation in all of electricity is the interaction between charges of the same and opposite signs.

Two objects with the same charge will repel, but two objects with different charges will attract.

Just as magnets are surrounded by an invisible magnetic field, all charged objects have an electric field around them. If we bring two different types of charges together the fields will join, which leads to attraction. If the charges are of the same sign, the fields cannot join and will push each other apart. This is a little bit like magnets where two north poles would repel but a north and south pole will attract. Be careful, though, not to mix up electricity and magnetism.

It is this idea that causes most of the electrical phenomena that we see.

FIGURE 9.66 a. All charged objects have an electric field around them. **b.** Two fields with the same charge will repel each other.



9.7.3 Charging by friction

Materials can be divided into:

- **electrical conductors** — these are usually metals where the presence of many free electrons allows for easy electron flow
- **electrical insulators** — can attract or leak charge slightly, but generally do not allow it to flow. Charge can move from one insulator to another when two different insulators are rubbed together.

Some materials can steal electrons from other materials when you rub them together. The object that gains the extra electrons now has more negative charges so we say it is **negatively charged**. The object that lost the electrons now has more positive charges than negative so it is **positively charged**. This movement of electrons and attraction and repulsion between charged objects is demonstrated by the experiment in figure 9.67. The attraction between opposite charges also explains how lightning works (figure 9.68).

electrical conductors materials through which electricity flows easily

electrical insulators materials which do not allow electricity to flow easily

negatively charged having more electrons than protons (more negative charges than positive charges)

positively charged having more protons than electrons (more positive charges than negative charges)

FIGURE 9.67 When a rubber rod is rubbed with a cloth, it gains electrons. When a glass rod is rubbed with a cloth, it loses electrons. We can see the attraction and repulsion between objects when the charged rods are suspended and brought near each other.

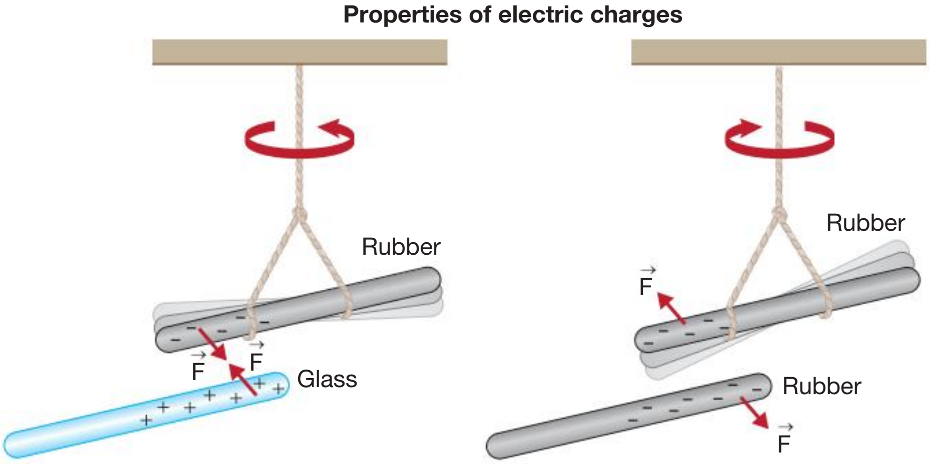
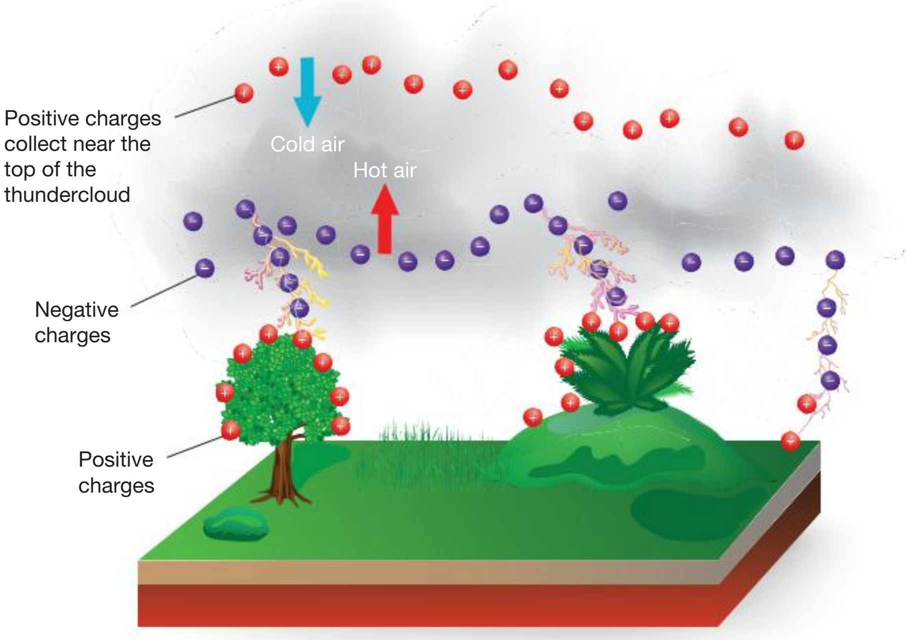


FIGURE 9.68 How lightning works. Attraction between opposite charges causes the particles to move towards one another, creating lightning.

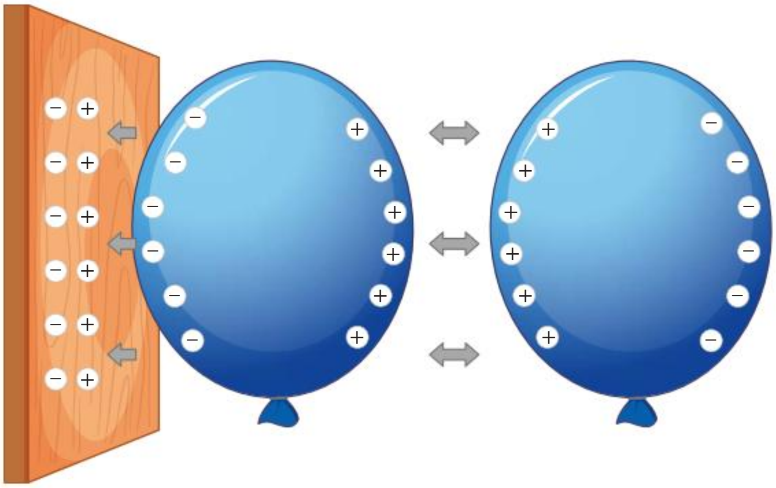


9.7.4 Charging by induction

Charged objects can attract neutral objects. If a charged object is placed near a neutral one, the electric field can repel or attract electrons in the neutral object.

- A positive charged object attracts the electrons to one side and stick to them.
- A negatively charged object repels the electrons leaving the region close to the charged object positively charged, so again they can stick (figure 9.69).

FIGURE 9.69 A pair of balloons charged by friction will repel each other if placed with positive charge facing positive charge. If the negative side of a balloon is placed near a wall, electrons in the wall are pushed slightly away. This leaves the surface of the wall slightly positively charged, so the balloon can now stick to the wall.

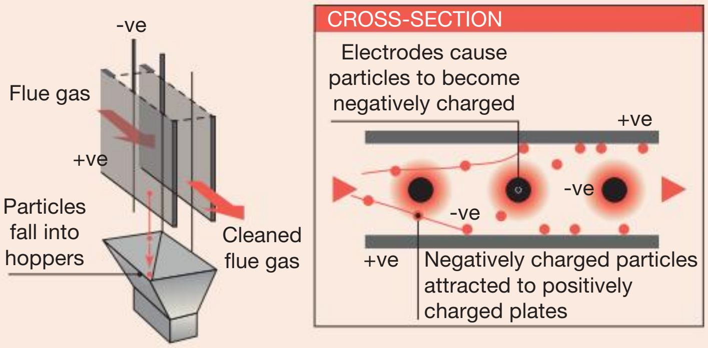


SCIENCE AS A HUMAN ENDEAVOUR: Electrostatic precipitator

Smoke rising from chimneys in power stations used to be a serious pollutant and health hazard. One of the technologies that was developed to clean up our environment is the electrostatic precipitator. Smoke particles in the waste gases pass through a series of negatively charged wires. The smoke particles pick up electrons, becoming negatively charged. They then stick to positively charged metal plates on the inside of the chimney.

The smoke no longer escapes into the atmosphere; instead it builds up into large chunks of material that can be collected and used as a building material.

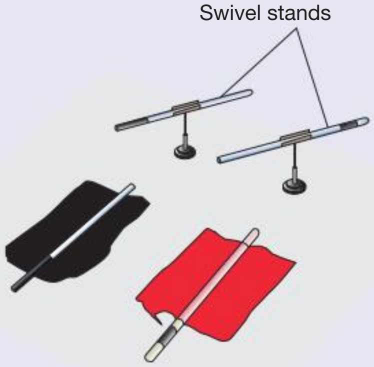
FIGURE 9.70 An electrostatic precipitator is a filtration device that removes fine particles, like dust and smoke, from a flowing gas.



elog-2407

INVESTIGATION 9.16

Producing different charges



Aim

To investigate how different materials can be charged

Materials

- 2 glass rods
- 2 plastic rods
- wool cloth
- silk cloth
- 2 retort stands or swivel stands

Method

1. Place a glass rod and a plastic rod on separate swivel stands.
2. Put the glass rod next to the plastic rod on the swivel stand and record your observations.

3. Put the glass rod next to the other glass rod on the swivel stand and record your observations.
4. Repeat steps 2 and 3 for the plastic rod.
5. Rub the second glass rod with a silk cloth. Bring it close to the glass rod on the swivel stand and record your observations.
6. Rub the second glass rod with a silk cloth again. Bring it close to the plastic rod on the swivel stand and record your observations.
7. Repeat steps 2 and 3 for the plastic rod and a wool cloth.

Results

1. Record your observations in the table.

TABLE Observations of investigation 9.16

Material	Glass rod on swivel stand	Plastic rod on swivel stand
Glass rod		
Plastic rod		
Glass rod and silk cloth		
Plastic rod and wool cloth		

2. When the glass rod is rubbed with silk, the rod carries a positive charge. Draw a sketch of the charges on both rods when:
   a. glass rod rubbed with silk cloth is brought next to the glass rod on swivel stand
   b. glass rod rubbed with silk cloth is brought next to the plastic rod on swivel stand
   c. plastic rod rubbed with wool cloth is brought next to the glass rod on swivel stand
   d. plastic rod rubbed with wool cloth is brought next to the plastic rod on swivel stand.

Discussion

1. Explain your observations when the rods that had not been rubbed were placed next to the rods on the swivel stands.
2. When the glass rod was rubbed with silk cloth, what charges moved?
3. When the plastic rod was rubbed with wool cloth, what charges moved?
4. What are the positive charges and what are the negative charges?
5. When two rods of the same material were brought close to each other, explain what happened in terms of attraction and repulsion.
6. Give an example of electrostatic charge you see in everyday life.

Conclusion

What conclusions can you make about how charges form and move on different objects?

on Resources

Weblink Weblink Simulation: Balloons and static electricity

9.7.5 Sparks

Normally in static electricity, the electrons in a negatively charged object stay in one place — they are literally static. As the electrons all have the same negative charge the law of electrostatics says that they will be repelling each other. If there are enough electrons, the repulsion is big enough to actually push the electrons through the air to a nearby object, or often the ground. This is a spark. The object will be **discharged** or **earthed** if we allow the electrons to flow to the ground.

If the object was originally positively charged, the protons do not move; but if there is enough charge present, electrons from nearby objects or the ground can jump *into* the object. When enough electrons flow in to balance out the positive charge, again we say the object is discharged.

discharged excess charge is removed from an object, either by removing the charged particles, or adding an equal amount of charge of the opposite sign

earthed excess charge is taken away from the object, by connecting it to the ground

Sometimes when we get out of a car or remove an item of clothing quickly, we may feel a spark. These sparks happen because there is enough force to move electrons quickly across a gap. The **voltage** is a measure of the energy available to push the electrons. The bigger the charge the higher the voltage. Typically a spark will have thousands of volts pushing the electrons, but this should do you no harm. The **electric current** is a measure of the amount of charge flowing per second and for such sparks, this is a tiny amount. Lightning is also an electrical discharge, but on a much larger scale, and involves very high currents and voltages. Current is what causes damage and voltage causes electricity to push through materials. For more information on voltage, current and electrical circuits, see topic 10.

voltage the amount of energy that is pushing electrons around a circuit

electric current a measure of the number of electrons flowing through a circuit every second

FIGURE 9.71 Static electricity is the build up of charge on an object. This electrical energy can be transferred from the negatively charged object to the positively charged object, and some energy is transformed into light and sound. This may be **a.** a small amount of energy in a spark, or **b.** a large amount of energy in lightning.

on Resources

Video eLesson Static electricity (eles-2671)

9.7 Activities

learnon

9.7 Quick quiz **on**

9.7 Exercise

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 2, 8	3, 5, 6	4, 7, 9

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. **MC** How can we make a negatively charged plastic rod?
   A. Remove electrons
   B. Remove protons
   C. Add electrons
   D. Add protons

2. **MC** How can we make a positively charged plastic rod?
   - **A.** Remove electrons
   - **B.** Remove protons
   - **C.** Add electrons
   - **D.** Add protons
3. **MC** A plastic rod is rubbed with a glass rod. The glass rod becomes negatively charged. When the glass rod is held above the plastic rod, what will happen?
   - **A.** The rods will repel.
   - **B.** The rods will attract.
   - **C.** The rods will exchange charges and neutralise.
   - **D.** Nothing
4. **MC** A plastic rod is rubbed with a glass rod. The glass rod becomes negatively charged. When the glass rod is held above some small pieces of paper, what will happen?
   - **A.** The pieces of paper will repel.
   - **B.** The pieces of paper will attract.
   - **C.** The pieces of paper will exchange charges and neutralise.
   - **D.** Nothing
5. **MC** One end of a plastic rod is rubbed with a cloth. That end of the rod becomes negatively charged. What will be the charge at the other end of the rod?
   - **A.** Positive
   - **B.** Negative
   - **C.** Neutral
   - **D.** It depends on the type of plastic.

Apply and analyse

6. **MC** One end of a metal rod becomes negatively charged when it touches a charged wire. What will be the charge at the other end of the rod?
   - **A.** Positive
   - **B.** Negative
   - **C.** Neutral
   - **D.** It depends on the type of metal.
7. **MC** Which of the following explains why two balloons, when rubbed on wool, repel each other?
   - **A.** The balloons acquire a positive charge and like charges repel each other.
   - **B.** The balloons acquire a negative charge and opposite charges attract each other.
   - **C.** The friction between the balloons and the wool generates a magnetic force that repels the balloons.
   - **D.** The balloons become magnetised and repel each other due to their magnetic fields.

Evaluate and create

8. Sketch and label a neutral atom with three electrons.
9. **SIS** Design an experiment to investigate the relationship between the amount of time a charged balloon will stick to a wall and the amount of time charging by friction occurs.
   You should:
   - develop a hypothesis
   - identify your dependent, independent and controlled variables
   - produce a suitable table
   - conduct your experiment (only take five readings)
   - plot a suitable graph of your results
   - evaluate your findings. Discuss whether your hypothesis was correct.

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

LESSON

9.8 Transforming electrical energy

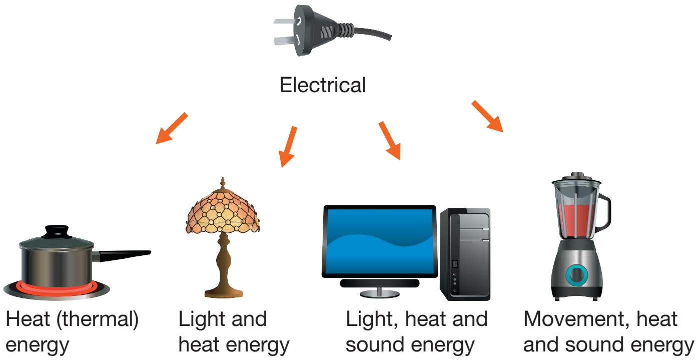
LEARNING INTENTION

At the end of this lesson you will be able to explain the transformation and transfer of energy in electrical appliances.

9.8.1 Electrical appliances — transforming electrical energy

Where would we be without electrical appliances? Our homes are full of them: in the kitchen you may have a toaster, blender, dishwasher, fridge, cooktop and oven. In the laundry you probably have a washing machine and clothes dryer. Not to mention the variety of personal communication and entertainment devices throughout the home. Each of these appliances transforms electric energy to other useful forms of energy.

FIGURE 9.72 Electrical appliances transform electrical energy to other useful forms.



9.8.2 Electric motors

What do a hair dryer, a food processor, a clothes dryer and an electric drill all have in common? The obvious answer is that they all use electrical energy. Another thing that these appliances have in common is an **electric motor**.

electric motor device that converts electrical energy into kinetic energy of a rotating shaft

Step by step … how a motor works

- An electric motor contains coils of wire surrounded by two or more magnets.
- The coil produces a magnetic field when electric current flows through it.
- There is a motor effect when this field interacts with the field of the magnets that surrounds the coil.
- One side of the coil is pushed down and the other side is pushed up.
- The coil rotates.

FIGURE 9.73 An electric motor converts electrical energy into kinetic energy. This conversion can only take place because of the magnetic effects of electric current.

DISCUSSION

Motors make things rotate. How did we perform this function before motors? Give some examples.

Parts of a DC electric motor

The electric current supplied by a cell or battery is called direct current (DC). It flows in one direction only. The electric current provided to your home by power stations is called **alternating current** (AC), which reverses direction multiple times per second. Small motors usually work using DC (figure 9.74).

- The **armature** is the turning part of the motor on which coils of wire are wound. The coils are called rotor coils because they cause the armature to rotate.
- When electric current flows through the **rotor coils**, a magnetic field is produced. The magnetic field produced by these coils interacts with the magnetic field produced by the field magnets.
- The **field magnets** are permanent magnets that do not move. In larger commercial motors they are replaced with a separate coil (called a field coil), which provides a stationary electromagnet.
- The **brushes** are connected to the power supply and lightly touch the commutator as the armature turns. This allows current to travel through the rotor coils.
- The **shaft** is part of the motor that is attached to the device the motor is turning, like a fan or gear wheel. As the armature turns, the shaft turns.
- As each rotor coil turns through 180 degrees to face the opposite field magnet, the force on it would change direction, turning it back the other way. The **commutator** consists of a split metal ring. As the armature turns, the commutator turns with it while the brushes remain still. When the armature has turned through 180 degrees, the opposite side of the commutator makes contact with the brush connected to the positive terminal of the power supply. The direction of the current in each rotor coil reverses. This allows the armature to keep rotating in the same direction, rather than spinning first one way, then the other. Alternating current motors don't need a commutator as the current reverses itself as the motor rotates.

alternating current current that changes direction along a wire a number of times per second

armature the turning part of an electric motor on which coils of wire are wound

rotor coils coils of a motor that turn when a current flows through them

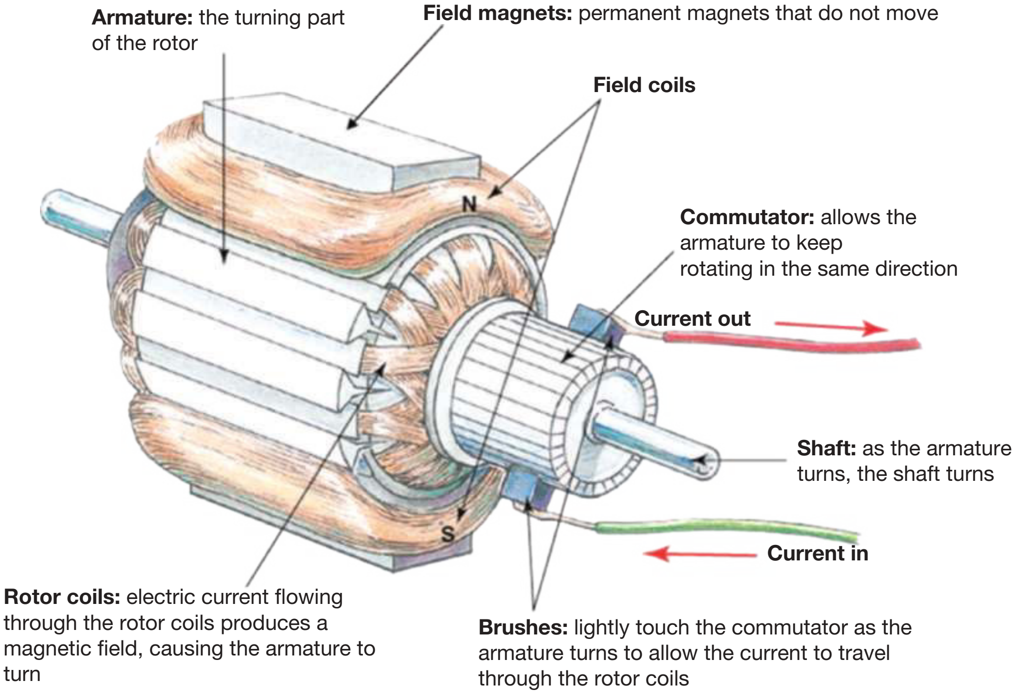
field magnets magnets producing a magnetic field that acts on the rotor coils

brushes part of an electric motor that allows current to travel through the rotor coils by being connected to the power supply and lightly touching the commutator

shaft central rotating rod of the motor that transmits the kinetic energy

commutator device attached to the rotor shaft that receives the current. In most motors it is a metal ring split into sections.

FIGURE 9.74 A commercial DC motor



elog-2409

INVESTIGATION 9.17

A model motor

Aim

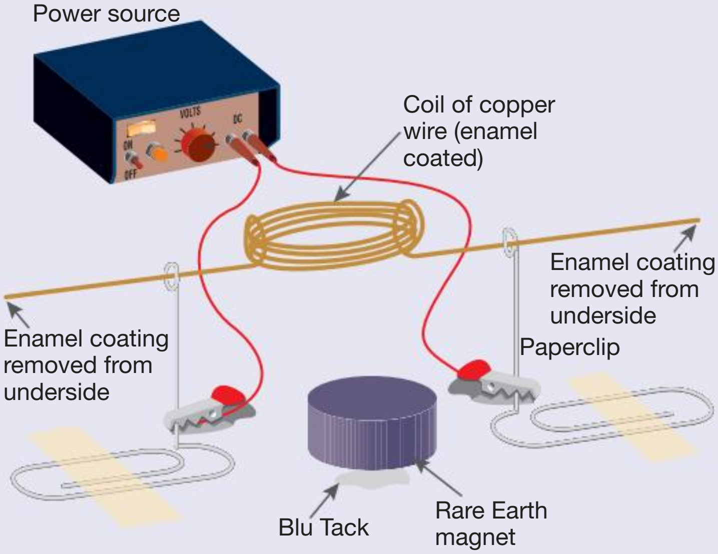
To construct an electric motor

Materials

- DC power source
- 2 large paperclips
- sticky tape
- Blu Tack
- 1 m of enamel-coated copper wire
- a strong (rare Earth) magnet
- large test tube
- emery paper

Method

1. Wind the copper wire around a large test tube leaving a 3–4 cm length of straight wire at each end of the coil. Loop each end of the wire around each side of the coil to hold the coil together and extend the two ends of wire horizontally.
2. Remove the enamel coating from the bottom side of each end of the wire using the emery paper.
3. Bend the two paperclips as shown in the diagram and tape the base of each to the bench to create a stand to support the coil.
4. Fix the rare Earth magnet to the bench using Blu Tack in a position directly below the coil.
5. Connect wire leads to each paperclip stand, being careful to keep the alligator clips well away from the magnet to prevent them attracting.
6. Connect the leads to a 6 V DC power source.
7. Switch the power on. You may need to give the coil a gentle push to start it spinning.



Results

Record your observations.

Discussion

1. Outline the energy transformation taking place in this model motor.
2. Explain what causes the motion of the coil.
3. Identify the component of your model motor that acts as the:
   a. rotor
   b. brushes
   c. field magnet
   d. commutator.

Conclusion

Summarise the findings of this investigation in 2-3 sentences.

9.8.3 Producing sound through a loudspeaker

Microphones, telephones, radios and television sets produce changing electric currents. These changing currents are so small that they need to be amplified before being sent to a loudspeaker.

As a coil of wire carrying electric current produces a magnetic field, it is not surprising that the same coil of wire moves when it is in the region of another magnet. Just as two magnets attract or repel each other, the coil can be attracted to or repelled by a magnet. Loudspeakers rely on this interaction to convert the changing electric currents into the kinetic energy of vibrating air that allows you to hear sound.

FIGURE 9.75 The process of producing or reproducing sound through a loudspeaker

Inside a speaker

Inside a speaker, the electric current flows through the copper wire coil that is tightly wound around the base of the cone. The coil, known as the **voice coil**, and the base of the cone sit inside a cylindrical permanent magnet. Like any coil carrying an electric current, it produces its own magnetic field. However, in a speaker the electric current is rapidly changing direction. The coil moves backwards and forwards as it is alternately repelled and attracted to the base of the cylindrical magnet. The cone of the speaker, also known as the **diaphragm**, vibrates as the coil moves, causing the air nearby to vibrate and so producing sound.

voice coil coil of wire in a loudspeaker that vibrates at the frequency of the electrical signal. This frequency matches the frequency of the sound produced by the cone.

diaphragm cone of a loudspeaker that vibrates to produce a sound wave

on Resources

Video eLesson This speaker has some sand on it, which allows us to see its movement (eles-2675)

9.8 Activities

learnon

9.8 Quick quiz on | **9.8 Exercise**

Select your pathway

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

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

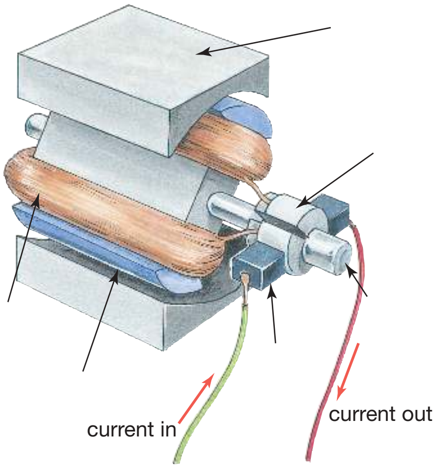
1. MC Which of the following energy transformations occurs in an electric heater?
   A. Electrical energy to mechanical energy
   B. Electrical energy to thermal energy
   C. Thermal energy to electrical energy
   D. Mechanical energy to electrical energy
2. MC Which of the following devices is an example of transforming electrical energy into light energy?
   A. Electric motor
   B. Solar panel
   C. Incandescent bulb
   D. Circuit breaker
3. a. Into what form of energy do motors convert electrical energy?
   b. How does this differ from the energy transformations in microphones and speakers?
4. Explain the difference between AC and DC.
5. Construct a table to group all the parts of an electric motor into ‘moving’ and ‘non-moving’ parts.

Apply and analyse

6. What is the role of a permanent magnet in a loud speaker?
7. Explain why the voice coil in a speaker is attached to the cone.
8. Why doesn't an AC motor need a commutator?
9. A saucepan of water is heated to boiling on an electric hotplate. For this situation, list three examples of the ways that energy is transformed or transferred.
10. Consider the diagram of the DC electric motor.
    - a. Complete the labelling of the diagram.
    - b. Complete the table to indicate the role of each of the parts of the motor listed.

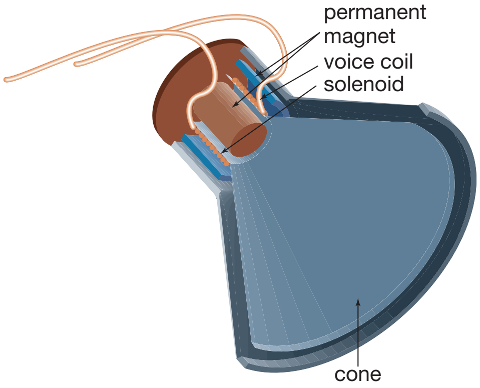
TABLE Motor parts and purpose

Part	Purpose
field magnets	
armature	
rotor coil	
shaft	
brushes	
commutator	



Evaluate and create

11. **SIS** Create a flow chart to show how a moving coil speaker transforms electrical energy into the sound energy that you hear.



12. Imagine you were advertising in the employment pages of a newspaper for the parts of a DC electric motor. Write a job description for each part.
13. Construct a poster to outline the different energy types that are involved in the operation of an appliance such as a hair dryer. Add labels to your poster showing where the different types of energy are used or produced.

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

LESSON
9.9 Communication

LEARNING INTENTION

In this lesson you will explore the effect that communication has on our world. You will be able to describe AM, FM and television as radio wave transmissions and the difference between analogue and digital signals. You will understand the benefits that digital technologies bring including mobile and satellite-based communication.

9.9.1 Early communication

As you explored in 9.1.3 Science inquiry, we have come a long way in human-to-human communication — from smoke signals to writing, which was soon followed by using codes, through to email today, which also relies on codes. In this section we will explore how we use energy transmission to communicate with many people instantaneously.

9.9.2 Radio

Radio waves were discovered by Heinrich Hertz in 1887, and after a few years of clever work by the Italian engineer Guglielmo Marconi, it became possible to send messages over long distances at the speed of light.

Radio waves are emitted naturally by many objects in space from the cool gas of the interstellar medium to stars and even whole galaxies, blasting beams of radio waves across the universe. When you hear the background hiss on a radio between stations, you are hearing evidence of radio waves left over from the Big Bang itself.

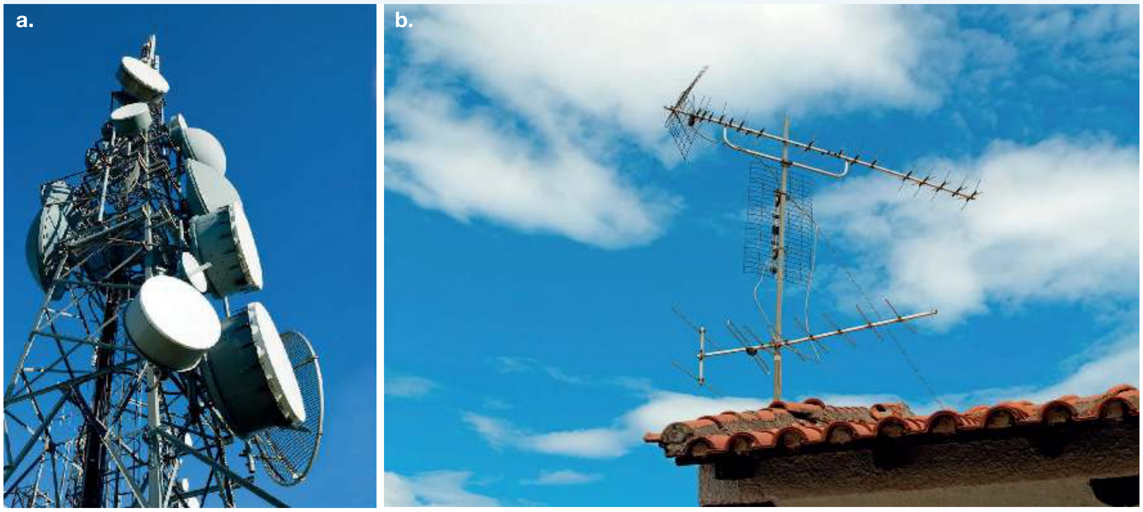
Natural radio waves allow us to study the universe, but they are usually a nuisance when it comes to communication. For this we need technology to generate radio waves in a controlled fashion.

This is done by making electrons in a metal rod vibrate rapidly. This metal rod is called a **transmitting antenna** or transmitter (figure 9.76a). These vibrations cause radio waves to travel through the air (at about 300 000 kilometres per second). The radio waves can be detected by a **receiving antenna** (figure 9.76b), which is a metal rod just like the transmitter. The radio waves cause electrons in the receiving antenna to vibrate rapidly, producing an electrical signal.

transmitting antenna a metal structure in which vibrating electrons cause radio waves to travel through the air

receiving antenna a metal structure in which electrons are made to vibrate by radio waves or microwaves in the atmosphere

FIGURE 9.76 Compare the sizes of these a. transmitting and b. receiving antennae. Why are they different?



AM radio and FM radio

Each AM and FM radio station has a particular frequency of radio waves on which it transmits sound signals.

- The sound signal must firstly be changed to an electrical signal.
- This electrical signal is called an **audio** signal.
- The waves on which messages are sent are called **carrier waves**.
- The audio signal is added to the carrier wave, producing a modulated wave, as shown in figure 9.77.
- The receiving antenna of your radio detects the modulated wave. Your radio then 'subtracts' the carrier wave from the signal, leaving just the audio signal.
- The audio signal is amplified by an audio amplifier inside the radio and sent to speakers.
- In the speakers, the changing electric current is used to make the surrounding air vibrate to produce sound.
- FM carrier frequencies are much greater than AM radio frequencies.

audio waves with a frequency range of sounds audible to people

carrier waves are radio waves that are altered in a precise way so that they contain an audio signal

A comparision of AM and FM radio signals can be seen in table 9.3 and in figure 9.77.

TABLE 9.3 Comparison of AM and FM radio

	AM	FM
Frequency	540–1600 kHz	88–108 MHz
Signal transmission on carrier wave	Amplitude modulation: audio signal changes the amplitude of the carrier wave.	Frequency modulation: audio signal changes the frequency of the carrier wave.
Example	ABC Local Radio Melbourne has a carrier wave with a frequency of 774 kilohertz.	Triple J in Melbourne has a carrier wave with a frequency of 107.5 megahertz.

FM radio waves are affected less by electrical interference than AM radio waves and therefore provide a higher quality transmission of sound. However, they have a shorter range than AM waves and are less able to travel around obstacles such as hills and large buildings.

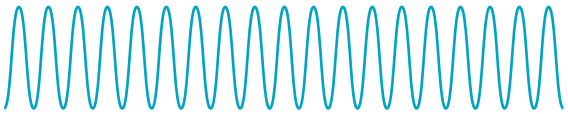
Digital radio

Digital radio began in 2009. Digital signals are different from AM or FM radio signals, and are discussed in section 9.9.4.

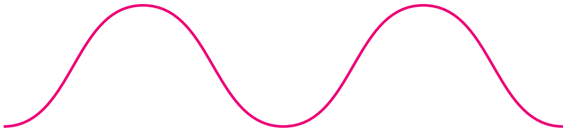
9.9.3 Television

It used to be that television signals were transmitted as radio waves on two separate carrier waves. The visual signal was added onto one carrier wave using amplitude modulation. The audio signal was carried on a separate carrier wave using frequency modulation. When you tuned your television set to a particular channel, you were selecting the visual and audio carrier waves that you wished to receive. Your television set then completed the task of removing the carrier waves and translating the signals sent into a picture and sound. This was quite a complex task, as you might imagine. Not only that, picture interference was a regular problem and due to the wide range of frequencies allocated to each channel, viewing options were limited. However, with the invention of the internet and processor power becoming cheap enough to be available for home use, the era of digital transmission of data had arrived.

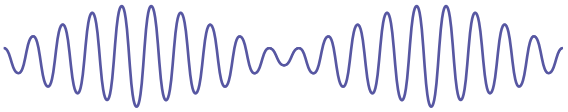
FIGURE 9.77 Comparison of AM and FM radio transmission



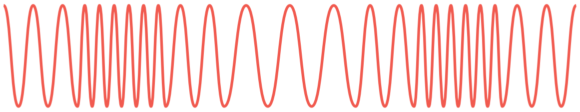
Carrier wave



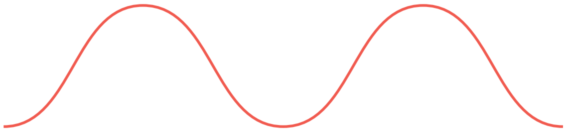
Audio signal



AM signal: amplitude-modulated wave



FM signal: frequency-modulated wave



Audio signal after the carrier wave is subtracted

Digital television commenced transmission in Australian capital cities in 2001. The phasing out of analogue signals began in 2010 and was completed in December 2014. A digital TV set-top box can be used to convert the digital signals back to an analogue form. This means that nobody had to replace their old analogue TV sets with digital TV sets unless they chose to.

9.9.4 Analogue and digital

So, what is the difference between an analogue and a digital signal?

- **Analogue** quantities are those that can have any value and can change continually over time.
- **Digital** quantities are those that can have only particular values and are represented by numbers.

Whereas analogue radio and television signals are carried as continuously changing amplitudes or frequencies, digital signals are carried as a series of 'on' and 'off' pulses. The signals can have only two values — 'on' or 'off'. The original audio and video (sound and vision) are sampled and converted into pulses. Audio signals are sampled about 40 000 times every second. Video signals are sampled more than 13 million times every second. The pulses are added to the carrier waves for transmission.

What's the advantage of digital?

Both analogue and digital television signals fade away as they travel through the air. Like all other waves, the energy they carry spreads out. So, as they travel over distance their intensity, or strength, decreases. As the continuous analogue becomes weaker, the background radiation and signals from other sources have a greater effect on the amplitude of the wave. It becomes distorted. The result is a fuzzy picture and poor-quality sound. Because digital signals can be only 'on' or 'off' pulses, background radiation and signals from other sources cannot interfere with them — even as they become weaker. The rapidly pulsating signals are still either 'on' or 'off' until the 'on' signals have faded away to nothing.

As a result, digital television has several advantages over analogue television. It provides:

- sharper images and 'ghost free' reception
- widescreen pictures
- better quality sound
- capability of 'surround' sound
- access to the internet and email
- capability of interactive television, allowing the viewer to see different camera views or even different programs on the same channel
- Electronic Program Guides (EPGs) that can provide 'now' and 'next' information about programs.

9.9.5 Using codes: Morse code and binary signals

Morse code

Before radio waves, we used optical telegraph, where flashes of light from a lantern were detected by telescope. The flashes were coded information that could be transmitted over long distances. It would be too slow to have a different code for each word so the letters were encoded as flashes. These could then build up words. This was overtaken by the electric telegraph that sent electrical signals across huge distances, making the network of telescope observation towers redundant. There were cables stretched across oceans allowing coded information from the London Stock Exchange to get to New York before their markets opened. The cost of laying a cable across the Atlantic was huge at the time, but it was seen as worth it for the more efficient, and profitable, trading that it allowed.

Morse code was a common way of encoding signals for a long time. Long and short pulses were combined to represent the letters and numbers.

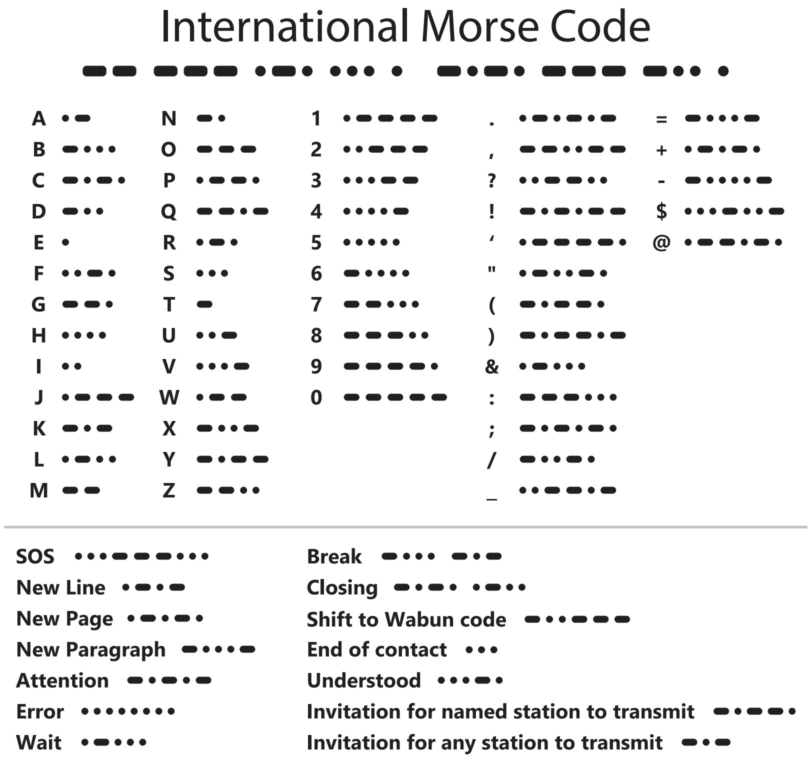
analogue quantities that can have any value and change continuously over time

digital quantities that can have only particular values and are represented by numbers

DISCUSSION

List as many technologies for human communication as you can think of. Can you put them in order of development? What science had to be discovered before these technologies could be made?

FIGURE 9.78 International Morse code showing the long and short pulses that represent the usual letters, numbers and symbols that would be used in communication.



International Morse Code

▬▬ ▬▬▬ •▬• ••• •   ▬•▬• ▬▬▬ ▬•• •

A	•▬	N	▬•	1	•▬▬▬▬	.	•▬•▬•▬	=	▬•••▬
B	▬•••	O	▬▬▬	2	••▬▬▬	,	▬▬••▬▬	+	•▬•▬•
C	▬•▬•	P	•▬▬•	3	•••▬▬	?	••▬▬••	-	▬••••▬
D	▬••	Q	▬▬•▬	4	••••▬	!	▬•▬•▬▬	$	•••▬••▬
E	•	R	•▬•	5	•••••	‘	•▬▬▬▬•	@	•▬▬•▬•
F	••▬•	S	•••	6	▬••••	"	•▬••▬•		
G	▬▬•	T	▬	7	▬▬•••	(	▬•▬▬•		
H	••••	U	••▬	8	▬▬▬••	)	▬•▬▬•▬		
I	••	V	•••▬	9	▬▬▬▬•	&	•▬•••		
J	•▬▬▬	W	•▬▬	0	▬▬▬▬▬	:	▬▬▬•••		
K	▬•▬	X	▬••▬			;	▬•▬•▬•		
L	•▬••	Y	▬•▬▬			/	▬••▬•		
M	▬▬	Z	▬▬••			_	••▬▬•▬		

SOS	•••▬▬▬•••	Break	▬••• ▬•▬
New Line	•▬•▬	Closing	▬•▬• •▬••
New Page	•▬•▬•	Shift to Wabun code	▬••▬▬▬
New Paragraph	▬•••▬	End of contact	•••
Attention	▬•▬•▬	Understood	•••▬•
Error	••••••••	Invitation for named station to transmit	▬•▬▬•
Wait	•▬•••	Invitation for any station to transmit	▬•▬

on Resources

eWorkbook Investigating Morse code (ewbk-12608)

Binary code

In the modern era we use **binary code** to transmit information as electrical pulses in ADSL systems using the phone line, or as pulses of light if optical fibre networks are used. At a very basic level, computers use circuits that have only two states, on or off. Mathematically we represent on with a 1 and off with a zero. Using these two numbers we can represent all letters, numbers and symbols using codes similar to Morse code. Sounds can be **sampled**, broken into fast measurements of wave amplitude. These measurements are converted to numbers and the numbers send as a binary code. Pictures and video can be broken down into a string of numbers representing which pixels are on and what their colour is. Essentially, we are using the same ideas of encoding messages that we have used for thousands of years. We now transmit those codes at the speed of light, all the way around the planet and now think nothing of the huge amount of research and infrastructure building that allow us to video chat with our families and friends around the world.

binary code use of the digits 0 and 1 to represent a letter, number, or other character

sampled in the context of music, means to measure the amplitude at regular intervals in order to convert a sound into a string of numbers for digital transmission

9.9.6 Long-distance communication

Australia is covered with a network of microwave and radio repeater towers, coaxial cables, optical fibres and satellite dishes. This network allows us to transmit television and radio signals, telephone calls, facsimiles and computer data across our massive continent.

Television and radio signals, computer data and telephone messages can be transmitted over long distances using **microwaves**. Microwaves can carry many signals at the same time. However, **repeater stations** need to be used so that the signal does not fade away before it reaches its destination. Antennas on the repeater stations receive the microwave signals and send them on to the next station.

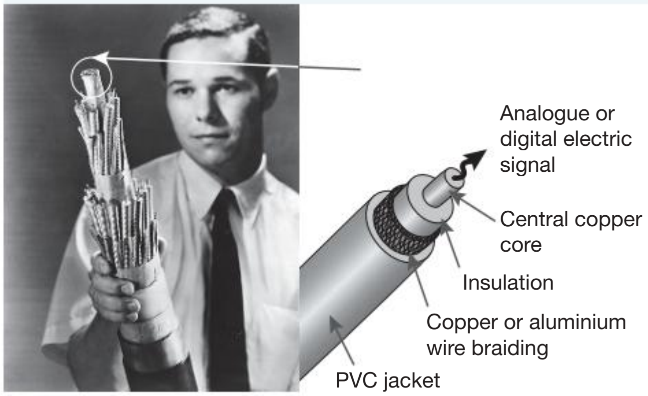
Each repeater tower needs to be within sight of the next one because microwaves, like visible light, travel in straight lines. So, the repeater towers are built on the top of hills wherever possible.

The electric way

Coaxial cables allow sound, pictures and data to be transmitted as pulses of electric current rather than as electromagnetic waves. The signals are carried along conducting wires inside tubes. The thin wire is held in the centre of the tube by a plastic insulating disc. Most Australian coaxial cables contain four, six or twelve tubes. Smaller conductor wires in the cable are used to provide links to small towns along the length of the cable. They are also used to control the system. Coaxial cables are buried under the ground or laid on the ocean floor.

The first major coaxial cable in Australia was laid between Sydney, Melbourne and Canberra in 1962. Coaxial cables can simultaneously transmit many more telephone calls and television signals than earlier cables were able to. As with the microwave system, repeater stations need to be used along the length of the coaxial cable so that the signal does not fade away. Coaxial cable repeater stations need to be even closer together than microwave repeater stations.

FIGURE 9.79 A coaxial cable contains many conducting wires in up to 22 tubes. They are designed to minimise interference from outside the cable and to prevent the many signals being carried from interfering with each other.



The light fantastic

Table 9.4 shows that optical fibres can transmit more messages at one time than coaxial cable or microwaves. Electrical signals from a microphone, television camera, computer or facsimile machine are converted into pulses of light. These pulses are produced when an electrical signal is used to turn the light on and off millions of times per second.

TABLE 9.4 Options for long-distance communication over land

Type of link	Number of two-way conversations at once
Copper cable	600
Coaxial cable	2700
Microwave	2000
Optical fibres	30 000

microwave an electromagnetic wave of very high frequency

repeater station retransmits communication signals with increased energy so the signal does not fade away

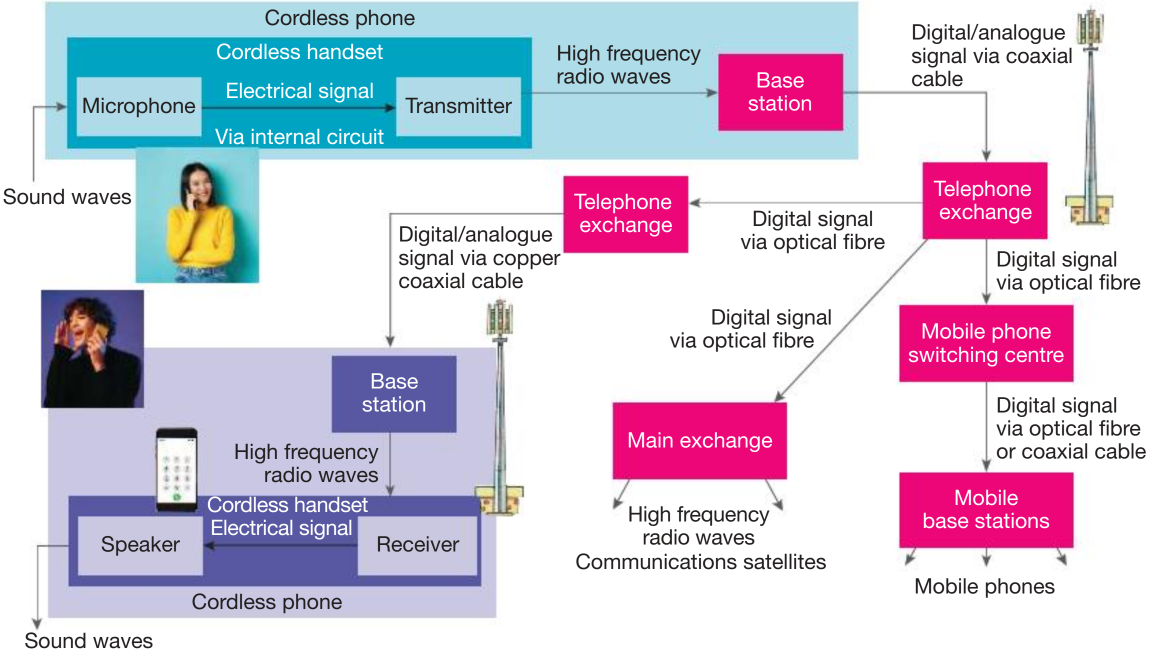
coaxial cables wires that can transmit a number of different signals as electrical pulses

The light pulses received at the other end are converted back into electrical signals that can be fed into speakers, a television set, computer or facsimile machine. The messages can also be retransmitted as microwaves or radio waves if necessary.

The idea of using visible light energy to transmit messages over long distances was not feasible until the invention of the laser in 1958. The word 'laser' is an acronym, standing for light amplification by stimulated emission of radiation. A laser produces an intense light beam of one pure colour. As the beam travels through the optical fibre, the glass absorbs some energy. Repeaters are needed every 35 to 55 kilometres along optical fibre cables to boost the signal. The light loses energy less quickly than normal light would, because a laser beam spreads out very little.

The first successful glass optical fibres were made in 1973. The advantages of optical fibres are so great that Australia already has a network of fibre cables between all capital cities. Optical fibres can be laid under the ground or under water. They are smaller, lighter, more flexible and cheaper than the electrical cables previously used for long-distance telephone, radio and television communication. Light pulses cannot be interfered with by radio waves, so there is no 'static'.

FIGURE 9.80 A landline is part of the communications network.



9.9.7 Mobile communication

Since the first major mobile phone service was introduced in Australia in 1987, millions of Australians have purchased mobile phones.

How mobile phones work

Your phone will break down your speech, video signal or internet communication into a digital signal that it will send as radio waves to a **base station**, which consists of several antennas at the top of a large tower or on top of a tall building. The base station is connected to a **switching centre**. Each switching centre is, in turn, connected to many base stations. The switching centre switches the call to other mobile phones through the **cellular system** or the fixed telephone system.

base station consists of antennas on top of a large tower that transmit signals from mobile phones to a switching centre

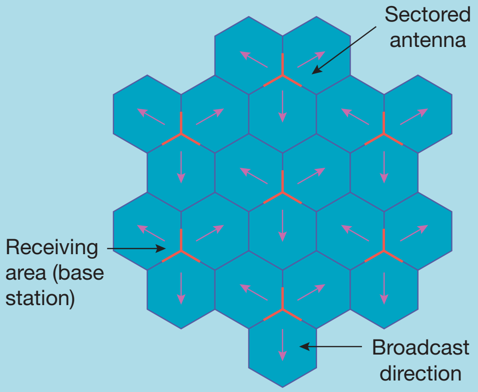
switching centres switches mobile phone calls to other base stations or to a fixed telephone system

cellular system a mobile phone system

A network of cells

Mobile phones are also called **cellular phones**. That is because the base stations are set up in a network of hexagonal cells as shown in figure 9.81. The cells range in size from 100 metres across to over 30 kilometres across. The base stations receive and transmit mobile phone signals from the cells that adjoin them. A mobile phone signal moves from cell to cell until it reaches its destination base station.

FIGURE 9.81 The base stations are placed at the intersection of three cells.



DISCUSSION

Discuss the impact on the world if all of our modern technologies were made inoperable due to a massive solar flare (an unlikely but possible scenario).

9.9.8 Satellite communication

Communications **satellites** allow radio waves and microwaves to be transmitted at the speed of light from continent to continent. In Australia, satellites are used to transmit radio, television and telephone signals from cities to remote areas.

Signals are transmitted to a communications satellite in **geostationary orbit** (figure 9.82). The signals are then sent back to other parts of Australia, or to other satellites which, in turn, transmit the signals to other continents. The energy needed to amplify and retransmit the signals is mostly provided by the Sun. Solar panels on the satellite collect solar energy, which is either used straight away or stored in batteries for later use.

A geostationary satellite is one that orbits the Earth once every 24 hours, thus remaining over the same point on Earth at all times. In order for the satellite to orbit at that rate, it must be located about 36 000 kilometres above the equator. Tracking stations on Earth use radio signals to activate small rockets on the satellites to keep them in the correct orbit.

Dish antennas, such as the ones in figure 9.83, are aimed at a particular satellite ready to receive signals. The shape of the dish allows for the collection of a large amount of electromagnetic energy, which is focused towards the antenna.

cellular phones or mobile phones; so called because base stations that receive mobile phone transmissions are arranged in a network of hexagonal cells

satellite an object that orbits another object. The moon is the Earth's satellite. Scientists have made and launched many artificial satellites.

geostationary orbit describes the path of a satellite that remains above the same location of the Earth's surface

eles-2668

FIGURE 9.82 Geostationary satellites relay radio signals to other locations.

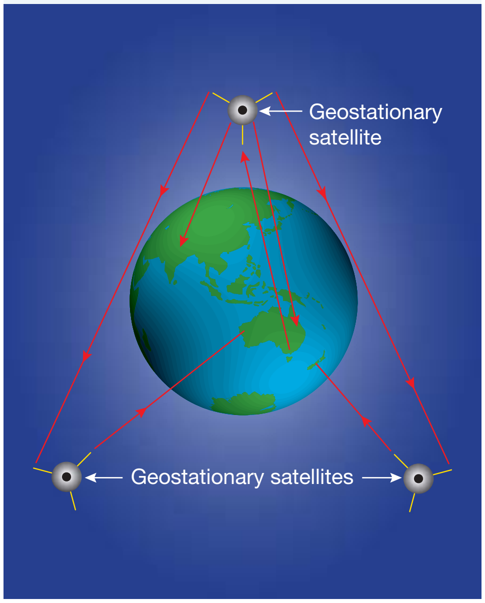
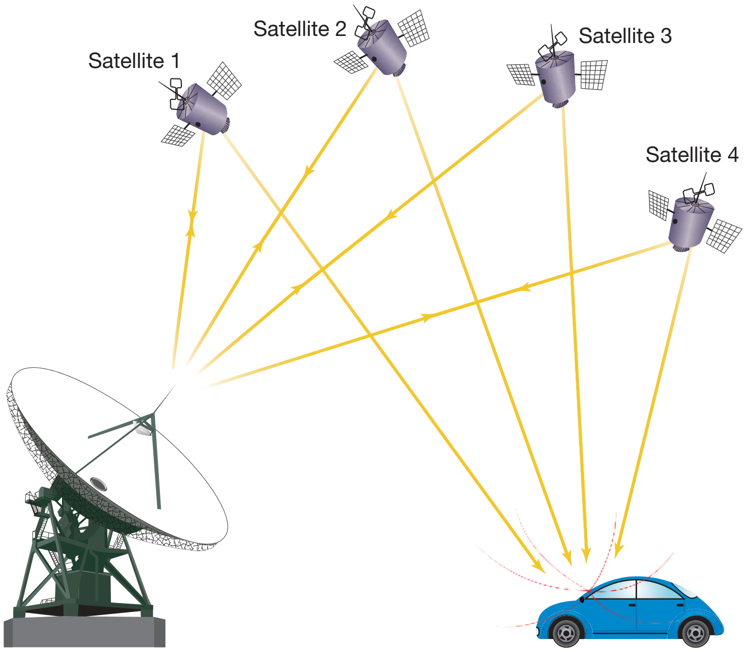


FIGURE 9.83 These antennas receive signals that have been retransmitted by a geostationary satellite.

Navigating by satellite

FIGURE 9.84 A GPS system in a car using at least four satellites to determine your position



The Global Positioning System (GPS) makes use of up to 32 satellites orbiting the Earth twice each day. GPS satellites orbit the Earth on different paths, all located about 20 000 kilometres above the Earth's surface. A GPS receiver uses radio signals from at least four of these satellites to accurately calculate and map your position. It can also calculate your speed, direction of movement and the distance to your destination.

The GPS system was originally developed for military purposes by the US Department of Defense. The first GPS satellite was launched in 1978 and the general public became aware of its existence when it was used extensively during the Gulf War (1990–1991). It was successfully used by soldiers to locate their own position and that of other soldiers plus tanks and other vehicles. Since 1993, the GPS system has been available for use by the public free of charge and has many applications. With a GPS receiver you can now find your way around the road system, locate places of interest and even find lost dogs.

CASE STUDY: Extraterrestrial communication

You may be used to seeing science fiction shows on television where a distant spaceship communicates with Earth. Conversation happens as though the people, or aliens, are in the same room. This is, unfortunately, not possible. Space is big. Even at the maximum speed possible, the speed of light, it still takes over 8 minutes for light from the Sun to reach Earth. If a future starship were to send a signal from our nearest neighbouring star system Alpha Centauri, it would take approximately 4.25 *years* to reach Earth. The reply would take the same time to return. This essentially means that communication over galactic distances will likely never be possible. That hasn't stopped us trying, though. Radio waves made on Earth are spreading out from us into space. They could in theory be detected in the distant future by some advanced civilisation. Similarly, we are using large radio telescopes to try to listen for a signal from the depths of space. So far, we have heard nothing …

on Resources

eWorkbook Communications (ewbk-12610)

9.9 Activities

learnon

9.9 Quick quiz on | **9.9 Exercise**

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 2, 6, 10, 12, 14	3, 5, 7, 9, 11, 15	4, 8, 13, 16, 17

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS ▶

Remember and understand

1. **MC** How are radio waves produced artificially?
   A. Electrons in a metal rod vibrate rapidly.
   B. Cold materials emit them.
   C. Metals emit them.
   D. Metal rods vibrate rapidly.
2. **MC** Sound waves cannot be directly transmitted through the air over long distances. What has to happen to them before they can be transmitted on radio waves?
   A. The sound must be added to a carrier wave
   B. The sound must be converted to an electrical signal
   C. The sound must be amplitude modulated
   D. The sound must be frequency modulated.
3. Sequence the events for the transmission of an AM signal. (You may use the phrases one or more times.)
   a. Electrical signal makes electrons vibrate in transmitter
   b. Sound energy is turned into an electrical signal with a microphone
   c. A radio wave is emitted
   d. The amplitude of the carrier wave is modified to carry the signal
   e. In FM transmissions
   f. In AM transmissions
   g. The frequency of the carrier wave is modified to carry the signal
   h. The radio wave produced before the signal is added is called the carrier wave

4. Sequence the events for the transmission of an FM signal. (You may use the phrases one or more times.)
   a. Electrical signal makes electrons vibrate in transmitter
   b. Sound energy is turned into an electrical signal with a microphone
   c. A radio wave is emitted
   d. The amplitude of the carrier wave is modified to carry the signal
   e. In FM transmissions
   f. In AM transmissions
   g. The frequency of the carrier wave is modified to carry the signal
   h. The radio wave produced before the signal is added is called the carrier wave
5. **MC** Which statement is true when comparing FM radio and AM radio?

   A. AM radio waves are less affected by electrical interference but AM radio waves are less able to travel around obstacles
   B. FM radio waves are less affected by electrical interference but FM radio waves are less able to travel around obstacles
   C. FM radio waves are less affected by electrical interference and AM radio waves are less able to travel around obstacles
   D. AM radio waves are less affected by electrical interference and FM radio waves are less able to travel around obstacles.
6. **MC** How are television signals carried by radio waves?
   A. The visual signal is carried on AM radio waves, and the audio signal is carried separately on FM radio waves
   B. The visual signal is carried on AM radio waves, and the audio signal is carried separately on AM radio waves
   C. The visual signal is carried on FM radio waves, and the audio signal is carried separately on FM radio waves
   D. The visual signal is carried on FM radio waves, and the audio signal is carried separately on AM radio waves.
7. Express the frequency of the following radio stations in Hz. (A frequency of 1 Hz corresponds to one complete wave being produced each second.)
   a. Triple M (FM), Melbourne: 105.1 MHz
   b. Gold AM, Bendigo: 1071 kHz
   c. Triple J (FM), Shepparton: 94.5 MHz
   d. Triple J (FM), Latrobe Valley: 96.7 MHz
   e. ABC (AM), Sale: 828 kHz
8. The wavelength (λ) of a wave is related to the frequency (f) of the wave by the equation:

$$v = f\lambda$$

   where v is the speed of the wave. The speed of radio waves in air is 300 000 000 m/s.
   Use this equation to calculate the wavelength of the carrier waves used by radio stations Triple M, Melbourne (105.1 MHz), and Gold AM, Bendigo (1071 kHz).
9. Summarise the differences between the digital and analogue signals that are added to carrier waves for television transmission.
10. How are all mobile phones different from fixed telephones in the way that they transmit and receive voice messages?

11. What are the three regions of the electromagnetic spectrum that are used to transmit data around Australia?
12. **MC** Why are repeater stations necessary for the transmission of microwaves, other radio waves and electrical signals in coaxial cables?
    A. Repeater stations receive the signals and send them on. They are only used for re-runs saving the normal stations for new programs.
    B. Repeater stations receive the signals and send them on. Without them, signals only reach one receiver.
    C. Repeater stations receive the signals and send them back to complete a circuit.
    D. Repeater stations receive the signals and send them on. Without them, signals would fade away and fail to reach their destinations.

Apply and analyse

13. Why are microwaves and other radio waves preferred for communication in the outback rather than optical fibres or coaxial cables?
14. Why are communication satellites placed in geostationary orbit?

Evaluate and create

15. The term ‘global village’ has been used to describe Earth in recent times.
    a. Why do you think this term has been used?
    b. How has the development of long-distance communication changed the lifestyles of Australians during the past 40 years?
16. Should we be trying to communicate with alien life? How else might we look for them besides using radio waves?
17. **SIS** The table shows how many mobile phone contracts per 100 people existed in Australia between 1986 and 2006.
    a. Chart the data.
    b. Interpret the data to describe what was occurring between 1994 and 2006.
    c. Interpret the data to describe what was occurring after 2008.
    d. At some point over this period there was a slowdown in the economy. From the data can you hypothesise why this may have happened? Explain your choice.

TABLE Mobile phones per 100 people in Australia by year

Year	Number of mobile phones per 100 people
1986	0.0
1988	0.2
1990	1.0
1992	3.0
1994	7.0
1996	22.0
1998	26.0
2000	45.0
2002	65.0
2004	83.0
2006	96.0
2008	104.0
2010	102.0
2012	107.0
2014	107.0
2016	111.0

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

LESSON
9.10 Thinking tools — Plus, minus, interesting charts

9.10.1 Tell me

What is a plus, minus, interesting chart?

A plus, minus, interesting chart (PMI chart) encourages you to look at optional viewpoints before making a decision.

They are useful to help you prepare to make a decision on something. What are the pluses, minuses and interesting points of this problem or topic?

They are also called pros, cons and interesting points.

Comparing PMI charts to target maps

PMI charts and target maps both help you to think about ways to classify ideas related to the topic. Target maps sort out relevant from non-relevant material, while PMI charts show your opinions.

FIGURE 9.85 PMI chart

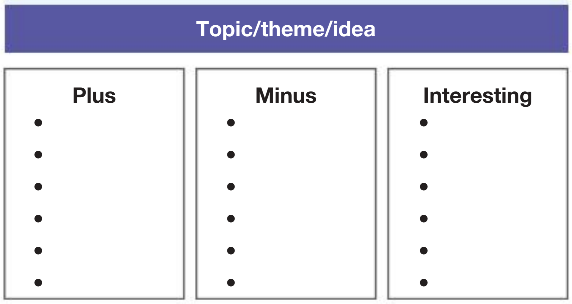
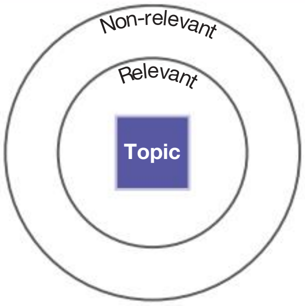


FIGURE 9.86 Target map



9.10.2 Show me

'Snail mail' may be slow, but it has some advantages over the faster methods of sending and receiving information such as phone, email and chatting over the internet. Creating PMI charts can help you reflect on the different ways of communicating.

1. Draw a box and write your topic or problem in it.
2. Draw three long boxes underneath your topic or problem box.
3. Fill in the three long boxes with good things and bad things about the topic, and things that you find interesting but are neither good nor bad.

FIGURE 9.87 How often do you use snail mail?

FIGURE 9.88 PMI chart example of communication by mail

Communication by post ('snail mail')

Plus	Minus	Interesting
• Receive a hard copy • Receive goods, not only information • Nice to see a friend or family member's handwriting	• Slow • Can get lost or delayed	• Handwriting began in 4 places independently - Mesopotamia (3400–3100 BC) - Egypt (3250 BC) - China (2000 BC) - Mesoamerica (650 BC)

9.10.3 Let me do it

9.10 Activity

1. With a partner or in a small group, discuss the positive, negative and interesting aspects of each of the following forms of energy transmission. Work together to create a PMI chart for each type of energy transmission to summarise your discussions.
   a. Sound
   b. Light
   c. Microwaves
   d. X-rays
2. Create a PMI chart to illustrate the positive, negative and interesting aspects of each of the following methods of communication.
   a. Mobile phones
   b. Landlines
   c. Internet
3. Create a target map on each of the following topics using the words in the box and at least three additional words that are relevant.

light
longitudinal waves
reflection
pitch
cochlea
ultraviolet
infra-red
sound waves
retina
Lens
compression
300 000 km/s
rarefaction
x-rays
transverse waves
particles
ultrasound
frequency
wavelength
microwaves
gamma rays
AM radio
FM radio

   a. Sound
   b. Radio waves
   c. Long-distance communication
   d. Medical diagnosis or treatment
4. Work with a partner or in a small group to create a large target map on the topic of digital communication using both words and images. Start by brainstorming a collection of words and pictures related to both digital and analogue communication.

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

LESSON

9.11 Project — Did you hear that?

Scenario

Since the invention of the Walkman — a portable cassette tape player — in 1979, through to the modern smartphone, we have loved to carry our favourite music around with us everywhere we go. Wherever you look, you'll see people walking the dog, riding the bus, going for a run, hitting the books or just sitting around hooked into an audio device of some form. With more than 220 million iPods alone sold since their release in 2001 and now the ability to listen to music on our mobile phones, more and more people are spending time plugged in. But for every person who loves having their music always available, there's another who'll be warning them that channelling all that sound directly into their ears will have long-term effects on their hearing. Your fifty-year-old principal wonders whether there aren't short-term effects as well, because she finds it difficult to hear her mobile ringing for about ten minutes after she has stopped listening to music using headphones. She comes to your science class (known for their cleverness) for some possible answers. One clever classmate suggests that maybe the type of music she was listening to had lots of high frequency sounds in it and that this had somehow affected her ear's ability to pick up the high frequencies of her mobile ring tone. Another clever classmate thinks that maybe she had the volume up too high on her headphones and that this might have caused some temporary deafness. A cheeky classmate suggests that maybe she can't hear it because she's old! Somewhat grumpy with that last comment, your principal decides that maybe she should just ban all phones in the school unless you can provide her with some thorough scientific evidence that something other than age can have short-term effects on hearing range after headphone use.

Your task

Using mobile phone music players and online hearing tests, your group will perform a series of scientific investigations to explore the short-term effects to hearing range of listening to music with headphones. You will then present your findings in the form of a scientific report suitable for sending to the principal.

Suggested factors to consider include:

- volume used
- hearing range differences between males and females
- type of music (for example, classical, jazz, R&B or pop).

Note: You will need to minimise any risk of permanently causing damage to the hearing of your human subjects by ensuring that the volume does not exceed 90 dB, and limiting trial durations to a few minutes.

on Resources

ProjectsPLUS Did you hear that? (pro-0109)

LESSON
9.12 Review

Hey students! Now that it's time to revise this topic, go online to:

Review your results

Watch teacher-led videos

Practise questions with immediate feedback

Find all this and MORE in jacPLUS

Access your topic review eWorkbooks

on Resources

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-12612	ewbk-12614	ewbk-12616

9.12.1 Summary

Heat transfer

- The amount of heat energy an object has is due to the total kinetic energy of the particles of which it is made.
- At absolute zero (–273 °C) all particle movement stops.
- Temperature is a measure of the average kinetic energy of the particles, not the total energy in the object.
- Conduction occurs when a particle passes kinetic energy onto another particle.
- Materials that are poor conductors are insulators.
- Solids are usually better conductors than liquids or gases because their particles are more tightly bound and closer together.
- Convection is the movement of heat by the movement of particles. The cycle of heat movement is called a convection current.
- Sea breezes are an example of a convection current. During the day, the warm air over the land rises and the cool air over the sea rushes towards the land replacing the hot air.
- Heat can be transferred without the presence of any particles at all, as electromagnetic radiation.
- Electromagnetic radiation can be:
  - reflected
  - transmitted
  - absorbed.

Matter and energy — waves

- Waves need vibration to travel.
- Transverse waves vibrate up and down, at right angles to the vibration.
- Longitudinal waves vibrate forward and backwards, in the same direction as the wave movement.
- Mechanical waves require particles to carry the energy.
- Electromagnetic waves do not need particles to carry the wave. They transfer their energy using fields.
- A wave can be measured by wavelength, frequency and amplitude.
- Compressions are regions of high pressure; rarefaction are regions of low pressure.

Energy transfer by sound

- Sound is a compression wave caused by vibrations.
- Sound waves require a medium to travel through and the speed changes on the medium.
- Echoes are a reflection of sound waves.

- When calculating the distance to an object, such as the depth to the sea floor, the velocity equation that follows can be used: velocity $= \frac{\text{distance}}{\text{time}}$. Remember to halve the time taken.
- Ultrasound uses echolocation to produce images for medicine.
- The distance to an object can be calculated using the concept of echolocation.
- The human ear transforms sound waves into electrical signals that are sent to the brain.
- The outer ear collects sound like a funnel, and sends it through to the ear drum. The middle ear passes these vibrations, using the hammer, anvil and stirrup, to the inner ear. The hair-like cells of the cochlea attached to the receptor nerve cells send messages on their way to the brain through the auditory nerve.
- Loudness is measured in decibels (dB).
- Hearing loss can be temporary (infections, earwax build-up, a blow to the head or loud noise) or permanent (the middle or inner ear structures are incorrectly formed or damaged).
- People who have severely or profoundly impaired hearing are unable to benefit from hearing aids and may benefit from a cochlear implant, which uses a microphone to pick up sounds that are then sent as a signal to the cochlear within the inner ear.
- Most animals have two ears, which allows the brain to recognise the difference in arrival time of sound to the ears. This lets them tell where sound is coming from.

Energy transfer by light

- Any charged particle has an electric field, and if the particle moves it creates a magnetic field. Whenever a charged particle vibrates, it produces a changing electro-magnetic field.
- Electromagnetic radiation occurring across a spectrum describe the properties and uses of the waves that make up the electromagnetic spectrum: radio waves, infrared radiation, visible light, ultraviolet radiations, x-rays and gamma rays.
- Models are used to understand natural phenomena.
- Wave models describe most properties of light.
- Light can also be modelled as a stream of particles, called photons, which are ‘packets of energy’.

Wave behaviour of light

- Luminous objects are those that emit their own visible light.
- A path of light is a ray, a stream of light rays is a beam. Beams of light are only visible when they pass through a substance that scatters the particles in the beam.
- Transparent substances allow light to pass through.
- Translucent substances scatter the light so objects cannot be seen clearly.
- Opaque substances absorb or reflect all the light striking them.
- The Law of Reflection — that the angle of incidence equals the angle of reflection.
- Refraction — when a beam enters a substance where it travels slower, it bends towards the normal. If it enters a substance where it travels faster, it bends away from the normal.
- The shape of a lens alters the way light passes through it. A biconvex lens converges the light to a focal point. A diverging lens (concave lens) spreads the light out; the focal point can only be traced backwards to a virtual focal point.
- Endoscopes allow light to be bent by passing it through narrow glass strands called optical fibres. They have many uses in medicine.

Static electricity

- Objects can have positive or negative charge or be neutral.
- Two objects with the same charge will repel, but two objects with different charge will attract.
- Charges are surrounded by electric fields, represented by lines of force. Around a point charge these are radial and the spacing represents the strength of the field. Arrows on the lines show the direction a positive charge would feel a force in the field.
- Insulators can be charged by friction if rubbed with another insulator.
- Charged objects can attract neutral objects by inducing a charge in them.

Transforming electrical energy

- An electric motor is a device that converts electrical energy into kinetic energy.
- Step by step … how a motor works:
  - An electric motor contains coils of wire surrounded by two or more magnets.
  - The coil produces a magnetic field when electric current flows through it.
  - There is a motor effect when this field interacts with the field of the magnets that surrounds the coil.
  - One side of the coil is pushed down and the other side is pushed up.
  - The coil rotates.
- The armature is the turning part of the motor on which coils of wire are wound.
- When electric current flows through the rotor coils, a magnetic field is produced.
- The field magnets are permanent magnets that do not move.
- The brushes allow current to travel through the rotor coils as they are connected to power and lightly touch the commutator as the armature turns.
- The shaft is part of the motor that is attached to the device the motor is turning, like a fan or gear wheel.
- The commutator allows the armature to keep rotating in the one direction.

Communication

- Radio waves are made up of the audio signal that is added to carrier waves.
- Receiving antennae remove the carrier wave, leaving the audio signal.
- Analogue quantities are those that can have any value and can change continually over time.
- Digital quantities are those that can have only particular values and are represented by numbers (binary code).
- Digital signals are either ‘on’ or ‘off’. They do not experience interference like analogue signals.
- Long-distance communication of radio, television, telephone calls, facsimiles and computer data are carried over long distances using repeater stations (microwaves), coaxial cables or optical fibres (pulses of electric current).
- Mobile phones send digital signals as radio waves to a base station and switching centre and onto the correct base station to recieve the call. The base stations are a network of hexagonal cells.
- Communication via satellite occurs through signals transmitted though satellites in geostationary orbit, which orbit Earth once every 24 hours, and so remain over the same point of Earth at all times. Dish antennas receive the satellite signals.

9.12.2 Key terms

absolute zero the lowest temperature that is theoretically possible, at which the movement of particles stops. It is zero on the Kelvin scale, equivalent to −273.15 °C.
absorbed energy hitting an object is transferred to it. This will cause the atoms in the object to vibrate more and the temperature will rise.
amplitude the maximum distance that a particle moves away from its undisturbed position
analogue quantities that can have any value and change continuously over time
angle of incidence the angle between an incident ray on a surface and the line perpendicular to the surface at the point of incidence, called the normal
angle of reflection the angle measured from the reflected ray to the normal
alternating current current that changes direction along a wire a number of times per second
armature the turning part of an electric motor on which coils of wire are wound
audio waves with a frequency range of sounds audible to people
auditory nerve a large nerve that sends signals to the brain from the hearing receptors in the cochlea
auricle the fleshy outside part of the ear
base station consists of antennas on top of a large tower that transmit signals from mobile phones to a switching centre
beam a wide stream of light rays, all moving in the same direction
biconvex a convex lens with both sides curved outwards
binary code use of the digits 0 and 1 to represent a letter, number, or other character
binaural hearing sound detection in creatures with two ears in order to locate the source of a sound

brushes part of an electric motor that allows current to travel through the rotor coils by being connected to the power supply and lightly touching the commutator
carrier waves are radio waves that are altered in a precise way so that they contain an audio signal
cellular phones or mobile phones; so called because base stations that receive mobile phone transmissions are arranged in a network of hexagonal cells
cellular system a mobile phone system
coaxial cables wires that can transmit a number of different signals as electrical pulses
cochlea the snail-shaped part of the inner ear in which receptors are stimulated
commutator device attached to the rotor shaft that receives the current. In most motors it is a metal ring split into sections.
compression a region in which the particles are closer than when not disturbed by a wave; a squeezing force
compression wave a wave involving the vibration of particles in the same direction as energy transfer
concave curved inwards
conduction the transfer of heat through collisions between particles
convection the transfer of heat through the flow of particles
convection current the movement of particles in a liquid or gas resulting from a temperature of density difference
convex curved outwards
critical angle when the incident angle becomes so great that the incident light can't bend any more
current electricity the flow of electrons through a region
decibel (dB) a unit of measurement of relative sound intensity
diaphragm cone of a loudspeaker that vibrates to produce a sound wave
digital quantities that can have only particular values and are represented by numbers
discharged excess charge is removed from an object, either by removing the charged particles, or adding an equal amount of charge of the opposite sign
diverging lens lens that bend rays so that they spread out. Diverging lenses are thinner in the middle than at the edges.
ear canal the tube that leads from the outside of the ear to the eardrum
eardrum a thin piece of stretched skin inside the ear that vibrates when sound waves reach it
earthed excess charge is taken away from the object, by connecting it to the ground
echo sound caused by the reflection of sound waves
echolocation the use of sound to locate objects by detecting echoes
electrical conductors materials through which electricity flows easily
electrical insulators materials which do not allow electricity to flow easily
electric charge physical property of matter that causes it to experience a force when near other electrically charged matter. Electric charge can be positive or negative.
electric current a measure of the number of electrons flowing through a circuit every second
electric motor device that converts electrical energy into kinetic energy of a rotating shaft
electromagnetic waves electromagnetic energy that is transmitted as moving electric and magnetic fields. There are many different types of electromagnetic energy; for example, light, microwaves, radio waves.
endoscope a long, flexible tube with one optical fibre to carry light to an area inside the body and another optical fibre to carry light from the body to a lens. The image formed by the lens is examined or recorded.
field magnets magnets producing a magnetic field that acts on the rotor coils
fields regions around an object in which each point is affected by a force of some type
focal point the focus for a beam of light rays
frequency the number of vibrations in one second, or the number of wavelengths passing in one second
gamma rays high-energy electromagnetic radiation produced during nuclear reactions. They have no mass and travel at the speed of light.
geostationary orbit describes the path of a satellite that remains above the same location of the Earth's surface
heat the total energy of a substance due to the movement of all of its particles
heat sink device that transfers the heat generated by an electronic or a mechanical component to a coolant, often the air or a liquid, where it can be taken away from the component
incident ray the ray that approaches the mirror
infrared radiation invisible radiation emitted by all warm objects. You feel infrared radiation as heat.
insulator material that has a very high resistance, allowing very little current to flow through it
kinetic energy energy due to the motion of an object
lateral inversion reversed sideways

Law of Reflection the angle of incidence must equal the angle of reflection

longitudinal wave *see* compression wave

luminous object that releases its own light

mechanical waves waves carried by the vibration of particles of matter

medium a material through which a wave moves

membrane a thin layer of tissue

microwave an electromagnetic wave of very high frequency

model simplified description, often a mathematical one, of a process

negatively charged having more electrons than protons (more negative charges than positive charges)

non-luminous objects that release no visible light of their own

normal is a line drawn perpendicular to a surface at the point where a light ray meets it

opaque a substance that does not allow any light to pass through it

optical fibres narrow strands made of two concentric glass layers so that the light is internally reflected along the fibres

ossicles a set of three tiny bones that send vibrations from the eardrum to the inner ear. They also make the vibrations larger.

oval window an egg-shaped hole covered with a thin tissue. It is the entrance from the middle ear to the outer ear.

photon a particle such as a quantum of light or electromagnetism

pitch how our hearing interprets frequency. High frequency vibrations are perceived as high pitch, low frequency waves are perceived as low pitch.

positively charged having more protons than electrons (more positive charges than negative charges)

radiant heat heat that is transferred from one place to another by radiation

radiation a method of heat transfer that does not require particles to transfer heat from one place to another; the transfer of energy through electromagnetic waves

radio waves low-energy electromagnetic waves with a much lower frequency and longer wavelength than visible light

rarefaction a region in which the particles are further apart than when not disturbed by a wave

rays narrow beams of light

receiving antenna a metal structure in which electrons are made to vibrate by radio waves or microwaves in the atmosphere

reflected ray the ray that leaves the surface of the mirror

reflection bouncing off the surface of a substance

refraction the bending of light when passing from one medium into another

refractive index the measure of the bending of light when it is passed through a material

relative sound intensity is a measure of the energy of a sound, which provides an indication of loudness. It is measured in decibels (dB) and is often referred to as sound level.

repeater station retransmits communication signals with increased energy so the signal does not fade away

rotor coils coils of a motor that turn when a current flows through them

sampled in the context of music, means to measure the amplitude at regular intervals in order to convert a sound into a string of numbers for digital transmission

satellite an object that orbits another object. The moon is the Earth's satellite. Scientists have made and launched many artificial satellites.

scattering light sent in many directions by small particles within a substance

sea breeze the breeze that occurs when differences in air pressure cause air particles to flow from the ocean towards the land

semicircular canals three curved tubes, filled with fluid, in the inner ear that control your sense of balance

shaft central rotating rod of the motor that transmits the kinetic energy

SONAR the use of reflected sound waves to locate objects under water (sound navigation and ranging)

switching centres switches mobile phone calls to other base stations or to a fixed telephone system

static electricity a build-up of charge in one place

temperature the average kinetic energy of the particles in a substance

threshold of hearing the lowest level of sound that can be heard by the human ear

threshold of pain the lowest level of sound that causes pain to the human ear

tinnitus a ringing or similar sensation of sound in the ears, caused by damage to the cells of the inner ear

total internal reflection the complete reflection of a light beam that may occur when the angle between a boundary and a beam of light is small

translucent allowing light to come through imperfectly, as in frosted glass
transmitted light is passed on from one place to another through space or a non-opaque substance
transmitting antenna a metal structure in which vibrating electrons cause radio waves to travel through the air
transparent a substance that allows most light to pass through it. Objects can be seen clearly through transparent substances.
transverse wave a wave involving the vibration of particles perpendicular to the direction of energy transfer
ultrasound sound with frequencies too high for humans to hear
ultraviolet radiation invisible radiation similar to light but with a slightly higher frequency and more energy
voice coil coil of wire in a loudspeaker that vibrates at the frequency of the electrical signal. This frequency matches the frequency of the sound produced by the cone.
voltage the amount of energy that is pushing electrons around a circuit
vibrations repeated, fast back-and-forth movements
virtual focal point a common point from which rays appear to have come before passing through a concave lens
visible light a very small part of the electromagnetic spectrum to which our eyes are sensitive
wave the transmitter of energy without the movement of particles from place to place. The vibration of particles or energy fields is involved.
wavelength distance between two neighbouring crests or troughs of a wave. This is the distance between two particles vibrating in step.
wave-particle duality model that treats all objects as having both wave-like and particle-like properties. The property observed depends on the observation method chosen.
x-rays high-energy electromagnetic waves that can be transmitted through solids and provide information about their structure

on Resources

eWorkbooks	Study checklist (ewbk-12618) Reflection (ewbk-12625) Literacy builder (ewbk-12619) Crossword (ewbk-12621) Word search (ewbk-12623)
Solutions	Topic 9 Solutions (sol-1152)
Practical investigation eLogbook	Topic 9 Practical investigation eLogbook (elog-2375)
Digital document	Key terms glossary (doc-40153)

9.10 Activities

learnon

9.10 Review questions

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 4, 6, 13, 14, 15, 16, 18, 21, 25	2, 5, 7, 12, 17, 20, 24, 26, 28, 30	3, 8, 9, 10, 11, 19, 22, 23, 27, 29

These questions are even better in jacPLUS!

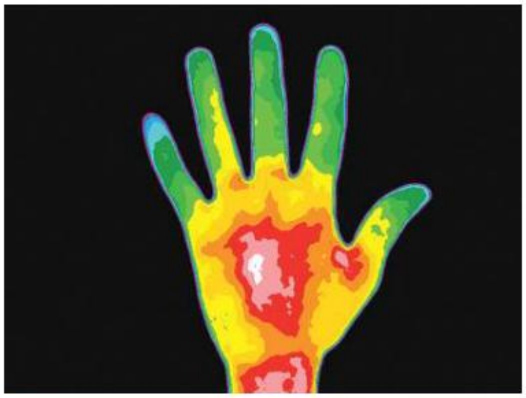
- Receive immediate feedback
- Access sample responses
- Track results and progress

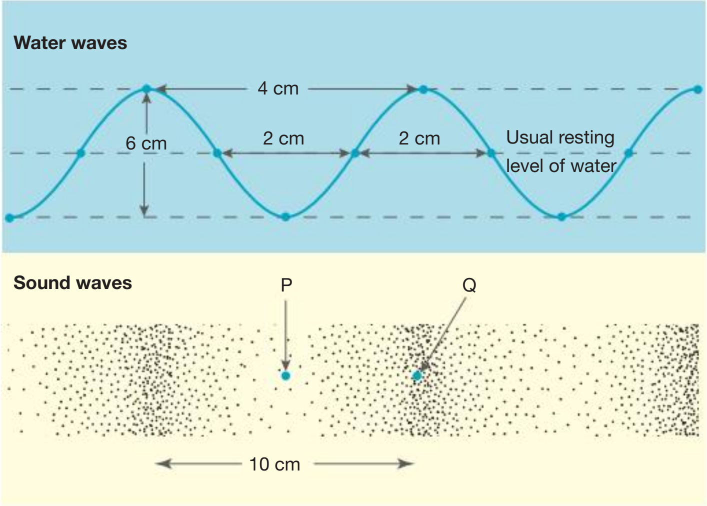
Find all this and MORE in jacPLUS

Remember and understand

1. Briefly describe how heat is transferred from one region to another by:
   a. conduction
   b. convection
   c. radiation.
2. Identify the main method or methods by which heat is transferred to the human body by:
   a. a gas wall furnace
   b. the Sun
   c. holding a hot plate
   d. an open fireplace
   e. walking on hot coals.

3. Explain why cooks often cover meat with aluminium foil instead of plastic.
4. Explain why solids such as polystyrene, foam and wool do not conduct heat as well as most other solids.
5. Heat is always transferred from a region of high temperature to a region with a lower temperature. Explain how your body is able to keep its core temperature at 37 °C even when the air temperature is greater than 37 °C.
6. Explain how the wearing of light, loose-fitting clothes protects your body from overheating in hot weather.
7. Why do your blood vessels get larger in hot weather?
8. Explain how fibreglass batts are able to reduce the loss of heat through the ceiling by both conduction and convection.
9. Why do coastal areas experience less extreme high and low temperatures than inland regions?
10. Explain what causes the movement of continents.
11. Explain the following statement in terms of heat transfer: 'Greenhouse gases in Earth's atmosphere trap heat from the Sun'.
12. Explain the difference between a transverse wave and a compression wave. List two examples of each type.
13. Refer to the water wave and sound wave shown in the figure below to answer the following questions.
    - a. What is the amplitude of the water wave?
    - b. What is the wavelength of the water wave?
    - c. What is the wavelength of the sound wave?
    - d. Which of the points P and Q is in the centre of a rarefaction?





14. How are ultrasound waves different from the sound waves that you can hear?
15. List some of the uses of ultrasound.
16. Replace each of the following descriptions with a single word.
    - a. Regions of air in which the particles in the air are brought closer together than usual by sound waves
    - b. Regions of air in which the particles in the air are moved further apart than usual by sound waves
    - c. The effect of sound reflected from a hard surface over and over again
    - d. What you see when you look in a mirror — even when you are not directly in front of it
17. When an object vibrates faster, what happens to the pitch of the sound it produces?
18. Explain why a hearing aid is of no use to some hearing-impaired people.
19. Which aspect of sound and light can easily be modelled with both particles and waves?

20. **a.** Complete the table.

Electromagnetic wave type	Wavelengths (m)	Properties
Infrared radiation		
Gamma rays		
Ultraviolet radiation		
Light		
X-rays		
Radio		

b. State three differences between sound waves and all of the waves listed in the table.
c. What two properties do all of the waves listed in the table have in common?
d. To which type of electromagnetic waves listed in the table do microwaves belong?
e. Which of the electromagnetic waves listed in the table:
i. can be produced artificially **ii.** transmits the most energy?

Apply and analyse

22. Which type of electromagnetic radiation is used in remote control devices?

23. What is the major use to society of:
a. x-rays **b.** ultraviolet radiation **c.** gamma rays?

24. If there were no visible light coming from the Sun, it is obvious that we wouldn't be able to see. But the lack of visible light would cause a much greater problem. What is that problem?

25. Explain the difference in the meaning of each of the following pairs of words.
a. Ray and beam
b. Reflection and scattering

26. When a light ray passes from air to glass and back into air again, how does its speed change when it:
a. enters the glass
b. emerges back into the air?

27. Use a diagram to explain why your legs appear to be shorter when you stand in clear, shallow water.

28. Use labelled diagrams to explain how visible light is used to transmit sound along optical fibres.

29. Describe how digital radio signals are different from analogue radio signals.

30. What does the digital transmission of television signals have in common with the analogue transmission of television signals?

Evaluate and create

31. Although electromagnetic radiation has many uses in society, there are also dangers associated with it.
a. What danger does ultraviolet radiation pose to the human body and what measures should be taken to protect against it?
b. Find out what precautions must be taken by the operators of x-ray equipment in hospitals.

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

Online Resources

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-12591)
- Student learning matrix (ewbk-12593)
- Starter activity (ewbk-12594)

Solutions
- Topic 9 Solutions (sol-1152)

Practical investigation eLogbook
- Topic 9 Practical investigation eLogbook (elog-2375)

9.2 Heat transfer

Practical investigation eLogbooks
- Investigation 9.1: Popping corn (elog-2377)
- Investigation 9.2: Heat conduction in solids (elog-2379)
- Investigation 9.3: Convection currents in a chimney box (elog-2381)
- Investigation 9.4: Radiating and absorbing radiant heat (elog-2383)

Interactivities
- Insulating your body (int-3402)
- Heat may be reflected, transmitted or absorbed (int-3400)

Weblinks
- Video: Difference between temperature and heat
- Particle simulation of thermal conduction
- Conduction simulation
- Video: Misconceptions about temperature

9.3 Matter and energy — waves

eWorkbook
- Waves (ewbk-12596)

Practical investigation eLogbook
- Investigation 9.5: Moving energy without matter (elog-2385)

Weblinks
- Video: Wave motion
- Simulation: Wave on a string

9.4 Energy transfer by sound

eWorkbooks
- Labeling parts of the human ear (ewbk-12600)
- Sound energy (ewbk-12598)

Weblinks
- Video: Creating different tones with a ruler — explained
- Simulation: Waves intro
- TED-Ed: How to see with sound
- TED-Ed: The science of hearing

Practical investigation eLogbooks
- Investigation 9.6: Sound in different media (elog-2387)
- Investigation 9.7: Making it seem louder (elog-2389)
- Investigation 9.8: Sound proofing (elog-2391)

Video eLesson
- Mechanism of hearing (eles-2636)

Interactivity
- Labelling parts of the human ear (int-8176)

9.5 Energy transfer by light

Weblink
- NASA Interactive: Electromagnetic spectrum

9.6 Wave behaviour of light

eWorkbooks
- Reflection and scattering of light (ewbk-12602)
- Curved mirrors (ewbk-12604)
- Refraction (ewbk-12606)

Practical investigation eLogbooks
- Investigation 9.9: Looking at images (elog-2393)
- Investigation 9.10: How much does it bend? (elog-2395)
- Investigation 9.11: Floating coins (elog-2397)
- Investigation 9.12: Seeing the light (elog-2399)
- Investigation 9.13: Focusing on light (elog-2401)
- Investigation 9.14: Total internal reflection (elog-2403)
- Investigation 9.15: Optical fibres (elog-2405)

Teacher-led video
- Investigation 9.12: Seeing the light (tlvd-10800)

Video eLessons
- Twinkle, twinkle (eles-0071)
- Light pipes (eles-1087)
- Galileo and the telescope (eles-1765)

Interactivities
- Bend it (int-0673)
- Lenses (int-1017)

Weblinks
- Simulation: Bending light
- TED-Ed: How do glasses help us see?

9.7 Static electricity

Practical investigation eLogbooks
- Investigation 9.16: Producing different charges (elog-2407)

Video eLesson
- Static electricity (eles-2671)

Weblinks
- Weblink Simulation: Balloons and static electricity

9.8 Transforming electrical energy

Practical investigation eLogbooks
- Investigation 9.17: A model motor (elog-2409)

Video eLesson
- This speaker has some sand on it, which allows us to see its movement (eles-2675)

9.9 Communication

eWorkbooks
- Investigating Morse code (ewbk-12608)
- Communications (ewbk-12610)

Video eLesson
- Communication satellite (eles-2668)

9.11 Project — Did you hear that?

ProjectsPLUS
- Did you hear that? (pro-0109)

9.12 Review

eWorkbooks
- Topic review Level 1 (ewbk-12612)
- Topic review Level 2 (ewbk-12614)
- Topic review Level 3 (ewbk-12616)
- Study checklist (ewbk-12618)
- Reflection (ewbk-12625)
- Literacy builder (ewbk-12619)
- Crossword (ewbk-12621)
- Word search (ewbk-12623)

Digital document
- Key terms glossary (doc-40153)

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

10 Electricity and efficiency

KEY KNOWLEDGE

Use wave and particle models to describe energy transfer through different mediums and examine the usefulness of each model for explaining phenomena (AC9S9U04)

Applying the Law of Conservation of Energy to analyse system efficiency in terms of energy inputs, outputs, transfers and transformations (AC9S9U05)

Source: F–10 Australian Curriculum 9.0 (2024–2029) extracts © Australian Curriculum, Assessment and Reporting Authority; reproduced by permission.

LESSON SEQUENCE

SCIENCE INQUIRY AND INVESTIGATIONS

Science inquiry is a central component of Science curriculum. Investigations, supported by a **Practical investigation eLogbook** and **teacher-led videos**, are included in this topic to provide opportunities to build Science inquiry skills through undertaking investigations and communicating findings.

LESSON
10.1 Overview

Hey students! Bring these pages to life online

Watch videos

Engage with interactivities

Answer questions and check results

Find all this and MORE in jacPLUS

10.1.1 Introduction

FIGURE 10.1 Deep brain electrical stimulation for treatment of Parkinson's disease

Electricity had fascinated, and terrified, humankind for thousands of years before we learned to harness the power of the electron. To early humans, lightning was sent from the gods. It brought fire, which, though it often led to destruction, could provide a burning branch to return to the family and give light, heat and protection. There is some evidence that early civilisations made simple batteries and they certainly produced static electricity, though they likely only saw it as an entertaining trick. As civilisation progressed, scientists noticed the link between magnetism and electricity, paving the way for motors and generators. The link between biology and electricity came when a simple experiment showed that electricity could make frog legs twitch, proving that signals to muscles are carried by electricity.

Today we use electricity for everything from a simple circuit, to the most complex electronics, from cleaning the waste gases in a power station, to stimulating brains as a treatment for neurodegenerative disorders. Figure 10.1 shows doctors implanting electrodes in a patient with Parkinson's disease. These electrodes provide deep brain stimulation (DBS) as a continuous electric current. This blocks the signals that cause the tremors of Parkinson's disease. Electricity has literally changed the world.

Resources

Video eLesson Building electronic circuit boards (eles-4152)

Sophisticated technology allows us to create circuit boards that run a huge variety of equipment, which we use in all aspects of our lives.

10.1.2 Think about electricity

1. Why do some devices use batteries and others need to be plugged in?
2. Why do we have different types of batteries?
3. Why do we have different types of plugs (two or three pins)?
4. Why are some batteries rechargeable and others aren't?
5. When did we first start to use electricity?
6. Does electricity occur in nature or is it just a technology?
7. What would happen if we continue to burn fossil fuels?
8. Do we have an alternative to fossil fuels?
9. Will robots take our jobs?

10.1.3 Science inquiry

DATA ANALYSIS: Electricity in Mali

In Australia, most people take electricity for granted — we know when we flick a switch, the lights will come on. We have a reliable electricity source that makes our lives much more comfortable and easier than if we did not have this luxury.

Not all countries in the world have access to reliable power. In 2016, a study of 39 African countries reported that while electricity providers could supply power in the majority of these countries, individual households could not access the electricity. At that time, the study estimated that one in three Africans did not have access to a reliable source of electricity.

In this task, we will examine data for the country of Mali. Mali is the eighth-largest country in Africa and has a population of 21.22 million people, which is growing at about 3 per cent per year. In the middle ages, Mali was the centre of an empire, but it was colonised by the French in the nineteenth century. It gained independence from France in 1960, but for much of the second half of the twentieth century, it suffered devastating famines and political upheaval. The twenty-first century has seen ongoing and serious conflicts within the country and the rise of terrorism. Mali is rich in natural resources, and agriculture, livestock and gold are its main exports.

FIGURE 10.2 Mali, in the colours of its flag

TABLE 10.1 Electricity access in Mali

Year	Year People with access to electricity (millions)	People without access to electricity (millions)
1990	0.00	8.50
1992	0.01	8.90
1994	0.10	9.30
1996	0.60	9.50
1998	0.64	9.98
2000	1.08	10.16
2002	1.56	10.39
2004	2.10	10.65
2006	2.26	11.36
2008	3.41	11.14
2010	4.18	11.35
2012	4.23	12.29
2014	5.99	11.56
2016	7.25	11.45
2018	10.15	9.79
2020	10.73	10.49

Your task is to represent these data points in a suitable graph or chart. When you have finished, answer the following questions.

1. Describe what your data shows regarding the electricity infrastructure in Mali. Remember to consider both sets of data.
2. Interpret your data to find the changing percentage of the population with electricity. Use this data to evaluate whether things are getting better.
3. Mali has a rapidly growing population but is one of the poorest countries in the world. It is listed as 'Do not travel' by most governments due to high crime rates. Use your data to make a case for humanitarian aid for Mali. Discuss the benefits that increased access to electricity could bring.

on Resources

eWorkbooks	Topic 10 eWorkbook (ewbk-12563) Student learning matrix (ewbk-12562) Starter activity (ewbk-12565)
Solutions	Topic 10 Solutions (sol-1151)
Practical investigation eLogbook	Topic 10 Practical investigation eLogbook (elog-2355)

LESSON
10.2 Electrical circuits

LEARNING INTENTION

At the end of this lesson you will be able to identify the components in a circuit, define voltage and current, and know the symbols for many components. You will understand the difference between series and parallel circuits and how voltage and current behave in them. You will be able to build these circuits.

10.2.1 What is a circuit?

Electricity is very crucial for our way of life. Electricity can be defined as either the energy stored or the flow of energy in a body. As mentioned in topic 9, **static electricity** is caused by the build up of charges on the surface of an object. The term 'static' means not moving. If we create a pathway for electrons to flow through, we can create **current electricity** — this is how circuits work.

All electric circuits consist of three essential items:

- a **power supply** to provide the electrical energy
- a **load** (or loads) in which electrical energy is converted into other useful forms of energy
- a **conducting path** that allows **electric charge** to flow around the circuit.

static electricity a build-up of charge in one place

current electricity the flow of electrons through a region

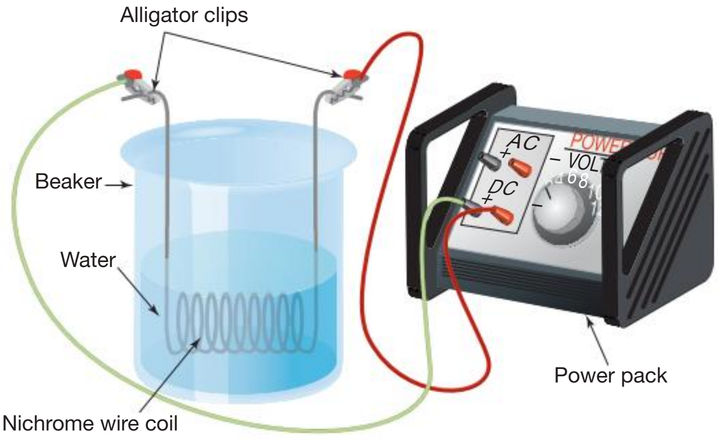
power supply a device that can provide an electric current

load device that uses electrical energy and converts it into other forms of energy

conducting path connected series of materials along which an electric current can flow

electric charge physical property of matter that causes it to experience a force when near other electrically charged matter. Electric charge can be positive or negative.

FIGURE 10.3 This electric circuit is a model of an electric kettle. The wire coil, or the loading coil, will heat up when electrical energy is passed through it.



Power supplies

The job of a power supply is to provide a supply of electrons and push them through a wire.

Different types of power supplies include:

- batteries (one on its own is called a **cell**), used in torches and many other devices, *store chemical energy* in the substances inside them. The chemical energy is transformed into electrical energy when a **chemical reaction** takes place inside the cell. Many battery-operated devices use more than one battery connected in **series**. They are connected end-to-end. It is important to ensure that the positive end of one battery is connected to the negative end of the other.
- generators at power stations. The electrical energy that is used when you turn on a light switch or an appliance connected to a power point comes from a power station.
- a solar panel, which can take the energy of sunlight and convert it directly into a flow of electrons in a circuit.

cell a single battery

chemical reaction a chemical change in which one or more new chemical substances are produced

series a formation of electricity-generating or using devices whereby the electricity passes from one device to the next in a single conducting loop, one after the other

transducer a device that converts energy from one form into another form

filament coil of wire made from a metal that glows brightly when it gets hot

resistance measure of the electrical energy required for an electric current to pass through an object, measured in ohms (Ω)

switch device that opens and closes the conducting path through which a current flows

DISCUSSION

Do we need wires to transfer electrical energy? If not, why do we use them?

Loads

The load in an electric circuit is an energy converter (**transducer**). It is here that most of the electrical energy carried by electric charge is transformed into useful forms of energy such as light, heat, sound and movement. In specialist light globes the load is the **filament** (figure 10.4), a coiled tungsten wire inside the globe. The filament glows brightly when it gets hot and here the load converts electrical energy into light (and thermal) energy. In a hairdryer there are two loads: a heater and a fan motor. Loads ‘push back’ against the power supply. We call this **resistance**. The greater the resistance, the less current can flow in the circuit.

FIGURE 10.4 The filament in this light globe is an example of a load in an electric circuit. The word filament comes from the Latin term *filamentum*, meaning ‘spin’.

Conducting path

The electrical energy provided by batteries and power outlets is transformed into other forms of energy *only* when the conducting path is complete, which allows electric charge to flow through the circuit.

Conducting paths have the following features.

- In an efficient electric circuit most of the electrical energy provided by the power supply is transformed in the load.
- Some of the electrical energy is transformed in the conducting path, heating the path and its surroundings. The more this occurs, the less efficient the circuit.
- The conducting paths in the electric circuits in appliances are usually made of metals such as copper so that they have little resistance to the flow of electric charge. The conducting path in a torch consists of copper wires covered with an insulating layer of plastic.
- Any kind of break in the path such as a broken wire or burned-out component will stop the current flowing.
- A deliberate break in a circuit can be made using a **switch**. This allows you to have control over whether or not the conducting path is complete.

10.2.2 Current in circuits

The flow of electric charge is called **electric current**.

- An electric current is a measure of the amount of electric charge passing a particular point in an electric circuit every second.
- The unit of current is the ampere (A) or amp for short.

The electric current in wires and most electrical devices is caused by the flow of negatively charged electrons. The electric current is said to flow through the circuit from the positive terminal of the power supply to the negative terminal.

electric current a measure of the number of electrons flowing through a circuit every second

voltage the amount of energy that is pushing electrons around a circuit, per coulomb of charge that flows between two points

potential difference also known as voltage, is the change in the amount of energy stored in electrons as they move through a component or a circuit

circuit diagram diagram using symbols to show the parts of an electric circuit

10.2.3 Voltage in circuits

Voltage is the amount of energy that is pushing electrons around a circuit. The voltage of an entire circuit is the amount of energy provided by the power supply.

Electrons use all of this energy as they pass around the circuit, returning to the power supply with zero voltage.

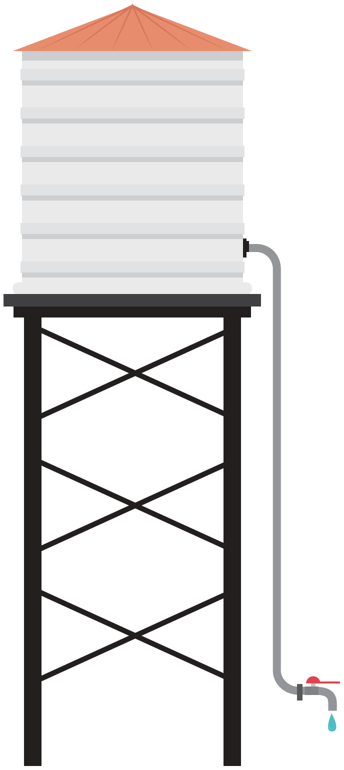
The voltage that is used up in each component is also known as the **potential difference** because it is the change in potential (stored) energy of the electrons as they move through the component.

10.2.4 Circuits — a water analogy

The water/hose analogy is a useful way to explain the difference between voltage, current, and resistance in an electric circuit. Imagine you have a hose connected to a water tank.

- **Voltage** is like the water pressure in the hose. It represents the force or 'push' that causes the water to flow. Higher water pressure corresponds to a higher voltage, which leads to a stronger flow.
- **Current** is like the flow rate of water through the hose. The current is equivalent to the volume of water flowing through the hose per second.
- **Charge** is like the amount of water stored in the tank. The more water there is in the tank, the more charge there is in the circuit.
- **Resistance** is another factor affecting flow in a circuit (see lesson 10.4). Resistance is like a constriction or obstruction of the hose that restricts the flow of water. Higher resistance means it is more difficult for the water to flow through the hose.

FIGURE 10.5 A water analogy can be used to better understand voltage, current, charge and resistance in electrical circuits.



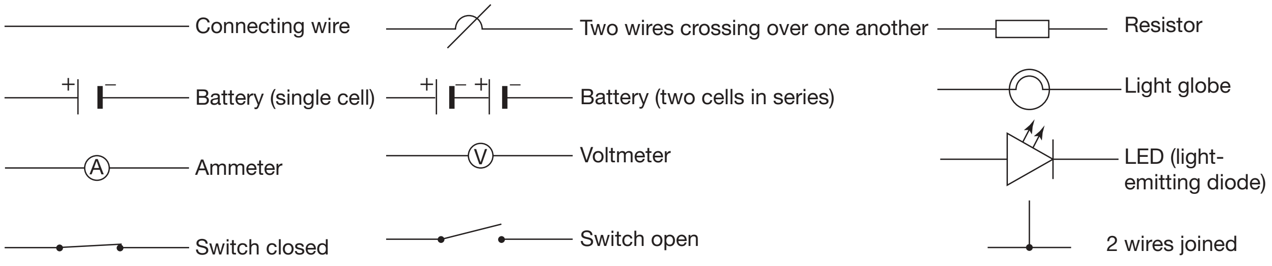
The water analogy

Voltage is the water pressure, current is the flow rate of water, charge is the amount of water available, and resistance is any obstacle that hinders the flow of water. Just as the flow of water depends on these factors, the flow of electric current depends on voltage, charge and resistance in an electrical circuit.

10.2.5 Circuit diagrams: A common language

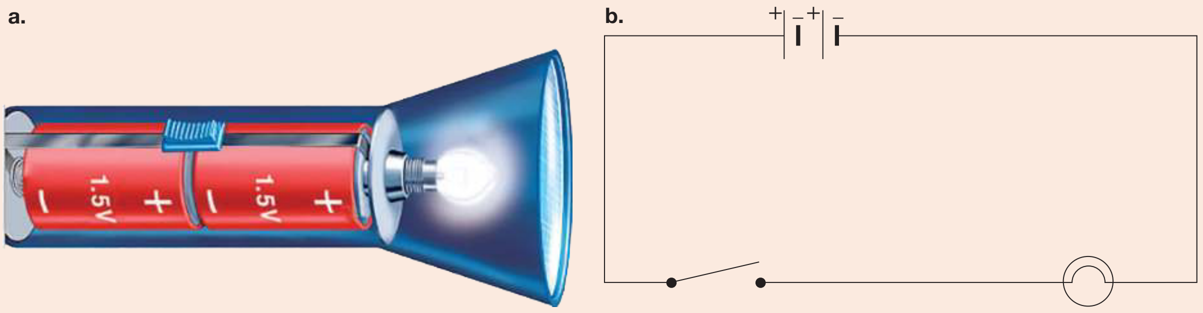
Maps of electric circuits need to be drawn so that people all over the world can read them. These maps are called **circuit diagrams**. Circuit diagrams use straight lines for connecting leads and symbols for other parts of circuits.

FIGURE 10.6 Some circuit diagram symbols



CASE STUDY: Circuit diagram of a torch with an incandescent globe.

FIGURE 10.7 a. Components of a torch **b.** Circuit diagram for a torch



Features of the torch circuit:

- The power supply of a torch usually consists of two or more 1.5-volt batteries connected in series. When two 1.5-volt batteries are connected in series, the total voltage is 3.0 volts. Twice as much electrical energy is available to move the electric charge around the circuit.
- The load in a torch circuit is the globe or a LED (light-emitting diode).
- When the switch is closed, electric current flows around the circuit.
- As electric charge passes through the globe, its electrical energy is released as heat in the filament. The filament is the coiled wire inside the globe. It is made of the metal tungsten and glows brightly when it gets hot. In an LED torch, almost all of the electrical energy is transformed directly to light.
- The conducting path consists of a conducting wire, the switch and an incandescent globe or LED.

on Resources

eWorkbooks Conductors and insulators (ewbk-12567)
Simple circuits (ewbk-12569)

10.2.6 Series and parallel circuits

The parts of the torch circuit shown in figure 10.7 — the batteries, the switch and the globe — were all connected one after the other. This type of circuit is a **series circuit**. Series circuits are usually easy to connect. However, if any one part of the circuit is faulty, the connecting path is broken and nothing in the circuit will work. For example, if the Christmas tree lights in figure 10.8 were connected in series, a single faulty globe would cause all of the globes to stop glowing.

series circuit a circuit with the components joined one after the other in a single continuous loop

In a **parallel circuit**, each component is connected in a separate conducting path. This means if one part of the circuit is faulty, the other parts will still work. It also means that adding extra pathways allows more current from the power supply, effectively lowering the resistance. This would drain batteries more quickly, but would mean that all components can work at full power, rather than sharing voltage or using a lower current.

If the Christmas tree lights shown in figure 10.8 were connected in parallel, and one globe was faulty, the other globes would still glow. Their conducting paths would not be affected.

FIGURE 10.9 a. Series circuit **b.** Parallel circuit

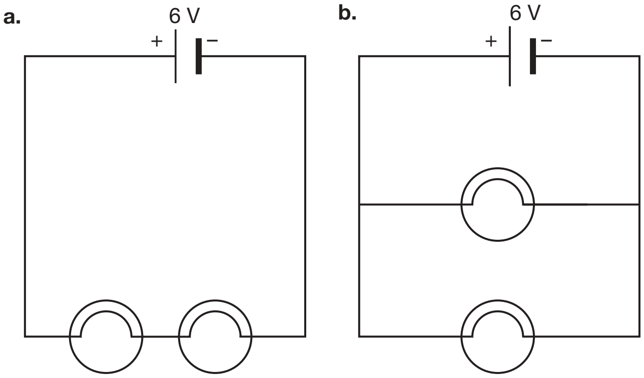


FIGURE 10.8 Christmas lights

parallel circuit a circuit that has more than one path for electricity to flow through. If one of the paths has a break in it, the others will still work.

10.2.7 Voltage, current and power in series and parallel circuits

The brightness of light globes in electric circuits depends on how quickly energy flows through the globe. There are two factors that affect how quickly the energy flows:

- the amount of energy transformed by each electron as it passes through the globe. The voltage across the globe is a measure of this.
- the number of electrons passing through the globe each second. The electric current passing through the globe is a measure of this.

We can change the brightness of two bulbs by arranging them in series or parallel. We must first think about what happens to voltage and current in series and parallel circuits.

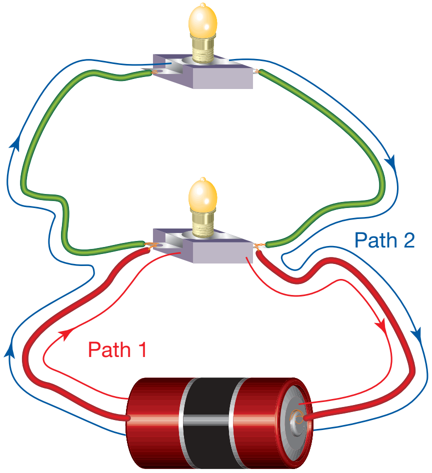
Series circuits

- Current is the same at all points in the circuit.
- Adding more globes means resistance increases so less current can flow in the circuit.
- The voltage of the supply must equal the sum of the voltages across the loads. When more components are added the voltage across each component must decrease.

Parallel circuits

- Adding more loops to the circuit lowers the resistance of the circuit.
- More current leaves the power supply.
- Current splits up at each branch and recombines when the wires reconnect.
- Voltage is the same across each loop of the circuit as the power supply.

FIGURE 10.10 A parallel circuit has more than one conducting path.



This means that:

- identical globes in a series circuit have the same brightness but will be dimmer because they have to share the voltage equally and all globes have the same electric current passing through them
- identical globes in a parallel circuit have the same brightness because each branch of the circuit will have the same voltage across it. They equally share the electric current passing through the power supply.

The lights in your home are connected in parallel. Each light has the same voltage across it. Each electron gets the same amount of energy from the power supply. But different globes, bulbs and fluorescent tubes allow different amounts of electric current through. Because the brightness depends on both voltage and electric current, the brightness of the lights can differ.

FIGURE 10.11 These lights are connected in parallel. Why?

on Resources

Video eLessons The hydraulic model of current (eles-0029)
Parallel circuits (eles-2672)

Interactivity Voltage rises and falls in a simple circuit (int-5776)

DISCUSSION

If you had a bucket full of water but had a hole in the bottom, the weight of the water would provide the energy to push the water out; this is acting like the voltage. The water flowing per second is the current. What would happen to the voltage and current for this hole if a second hole (of the same size) was punched in the bottom of the bucket? How would the voltage and current compare between the holes now that there are two holes?

elog-2357

INVESTIGATION 10.1

Series and parallel circuits

Aim

To compare series and parallel circuits

Materials

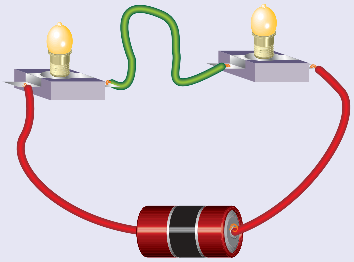
- three 2.5-volt or 3.0-volt torch globes
- 1.5-volt battery
- 6 connecting leads

Method

Part A: Series circuits

1. Connect one globe and the battery together with wire leads so that the globe lights up.
2. Add a second globe in series with the first globe as shown in the diagram.
3. Remove one globe from its holder.
4. Replace the globe that was removed, and then remove the other one.

Globes connected in series



Part B: Parallel circuits

5. Connect the two globes, battery and wire leads as shown in the diagram.
6. Remove one globe from its holder.
7. Replace the globe that was removed, and then remove the other one.

Results

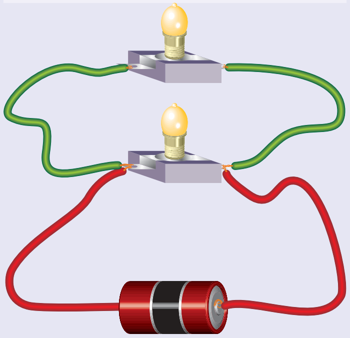
Part A: Series circuits

1. Draw a circuit diagram to represent the circuit that you have connected.
2. How does the brightness of the two globes compare with the brightness of a single globe connected to the same battery?
3. What effect does the removal of one globe have on the other globe when the battery is connected?
4. Does it matter which globe is removed?

Part B: Parallel circuits

5. Draw a circuit diagram to represent the circuit that you have connected.
6. How does the brightness of the two globes compare with the brightness of a single globe connected to the same battery?
7. What effect does the removal of one globe have on the other globe?
8. Does it matter which globe is removed?
9. Outline whether the removal of one globe has any effect on the other globe?
10. What would be the effect on the other globes if a third globe was added in parallel? Design a circuit to test your prediction.

Globes connected in parallel



Discussion

Part A: Series circuits

1. What would be the effect on the other globes if a third globe was added in series? Test your prediction.
2. Can electric current flow in this series circuit when either globe is removed?
3. Would it be sensible to have all of the ceiling lights in your home connected in series? Give a reason for your answer.

Part B: Parallel circuits

4. Can electric current flow in this parallel circuit when either globe is removed?
5. Would it be sensible to have all the ceiling lights in your home connected in parallel? Give a reason for your answer.

Conclusion

What can you conclude about the flow of current in series and parallel circuits?

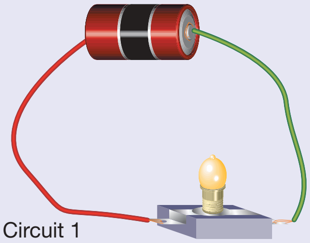
elog-2359

INVESTIGATION 10.2

Switched-on circuits

Aim

To compare the effect of a single switch with two switches connected in parallel

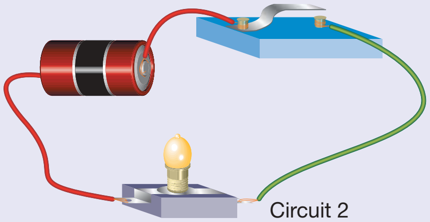

Circuit 1

Materials

- 2.5-volt globe and holder
- 1.5-volt battery and holder
- 5 connecting leads with alligator clips or banana plugs
- 2 tapping switches

Method

1. Connect circuit 1 as shown.
2. Connect circuit 2 as shown.
3. Close the switch.
4. If nothing happens, open the switch, check that your circuit is connected properly and try again. If nothing happens this time, replace the globe.
5. Add a second switch as shown in circuit 3.


Circuit 2

Discussion

Circuit 1

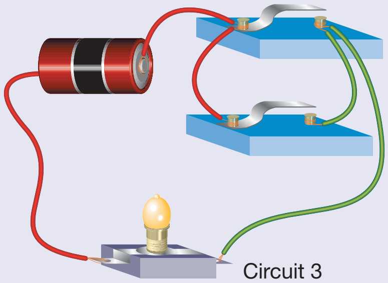
1. How can you stop the globe in circuit 1 from glowing?

Circuit 2

2. Describe what happens to the globe in circuit 2 when the switch is closed.

Circuit 3

3. Describe what happens to the light globe in circuit 3 when:
   a. neither of the switches is closed
   b. either one of the switches is closed
   c. both of the switches are closed.



Circuit 3

Conclusion

What can you conclude about the effect of adding switches in parallel to an electrical circuit?

on Resources

eWorkbook Series and parallel circuits (ewbk-12571)

10.2 Activities

learnon

10.2 Quick quiz on | **10.2 Exercise**

Select your pathway

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

These questions are even better in jacPLUS!
- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

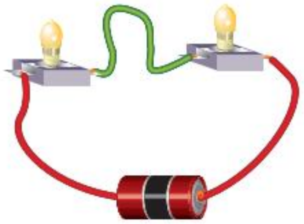
Remember and understand

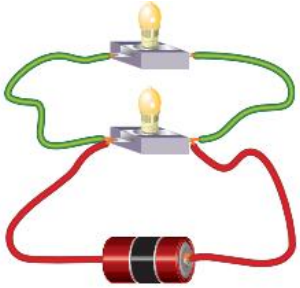
1. Match the components to the three essential features of all electric circuits.

Component	Essential features
a. Resistor	A. Power supply
b. Wires	B. Load
c. Battery	C. Conducting path

2. MC Which of the following correctly describes electric current and voltage?
   A. Electric current is a measure of the amount of energy passing a particular point in an electric circuit every second; voltage is a measure of the amount of electrons gained or lost by the power supply.
   B. Electric current is a measure of the amount of electric charge passing a particular point in an electric circuit every second; voltage is a measure of the amount of electrical energy in the power supply.
   C. Electric current is a measure of the amount of electric charge in the power supply; voltage is a measure of the amount of electrical energy gained or lost by electric charge as it moves through the circuit.
   D. Electric current is a measure of the amount of electric charge passing a particular point in an electric circuit every second; voltage is a measure of the amount of electrical energy gained or lost by electric charge as it moves through the circuit.
3. Some torches use three 1.5-volt batteries. What is the total voltage of such torches?
4. Complete the following sentences, by choosing the correct word from the pair of words in italics.
   a. When light globes are connected in *series/parallel*, the same electric current flows through each globe. The globes share the voltage of the power supply.
   b. When light globes are connected in *series/parallel*, the electric current splits to be shared by the globes. Each globe uses the same voltage.

5. Draw a circuit diagram of each of the circuits shown.





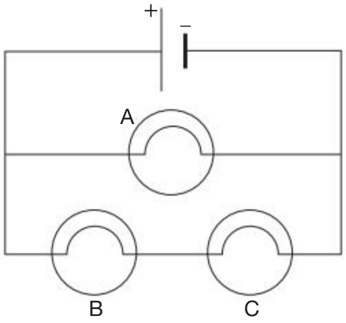
6. Explain, in words and without the use of a diagram, the difference between a circuit with two light globes in series and a circuit with two light globes in parallel.
7. Draw circuit diagrams for the following circuits. Make sure you include a switch so that you can turn the lights on and off.
   a. a cell connected to two light globes connected in series
   b. a cell connected to two light globes connected but not in series.

Apply and analyse

8. Match the device to its purpose.

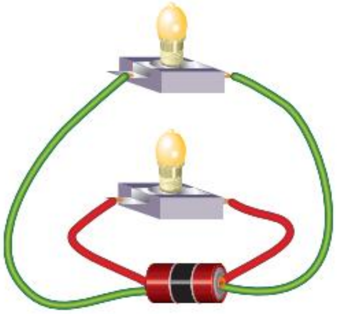
Device	Purpose
a. Switch	**A.** Transducer turning electrical energy into light and heat
b. Globe	**B.** A means of measuring a current at a point in a circuit
c. Ammeter	**C.** A way of turning the current in a circuit on or off

9. Why is voltage also known as potential difference?
10. Why are connecting wires usually made of copper?
11. In a small shop, the six light globes are in series. One switch is used to switch all the lights on or off at once. Draw a circuit diagram of this circuit.
12. Examine the circuit diagram shown and answer the following questions.
    a. If the filament of globe A breaks, which globes, if any, remain working?
    b. If the filament of globe B breaks, which globes, if any, remain working?
    c. If the filament of globe C breaks, which globes, if any, remain working?
13. In a house, six light globes are in parallel. However, the lights are in separate rooms. This means that a separate switch is needed for each globe. Draw a circuit diagram of this circuit.



Evaluate and create

14. Describe how a torch works. Ensure that the words 'current', 'energy' and 'circuit' appear in your description.
15. Explain the difference between the transfer of electrical energy in a bolt of lightning and the transfer of electrical energy in an electric circuit.
16. Construct a circuit diagram of a two-battery torch with a closed switch.
17. Examine the circuit shown.
    a. If the two globes are identical, how much of the current that flows through the battery flows through each globe?
    b. In what way is this circuit similar to the one in part B of Investigation 10.1?
    c. In what way is this circuit different from the one in part B of Investigation 10.1?
18. **SIS** Design a circuit with two switches and an electric bell, so that the bell rings only when both switches are closed. Draw a picture and circuit diagram of your circuit. Invent your own symbol for the bell. If a bell is not available, use a light globe instead.



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

LESSON
10.3 Measuring electricity

LEARNING INTENTION

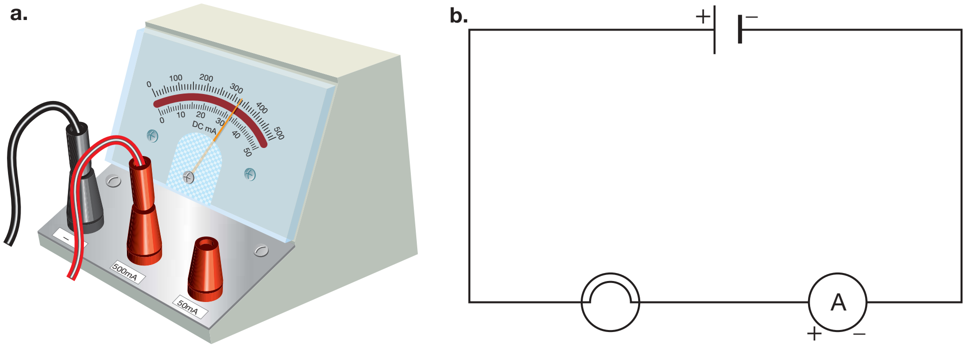
At the end of this lesson you will understand where to place ammeters and voltmeters in a circuit. You will also be able to identify any potential source for an error in a reading.

10.3.1 Ammeters

Like the currents of water in rivers and the sea, electric current can be measured.

Water currents in a river or the sea can be measured by determining the amount of water that passes a particular point every second. Likewise, the size of the electric current in an electric circuit can be measured by finding the amount of electric charge passing a particular point in an electric circuit every second.

FIGURE 10.12 a. An ammeter is used to measure electric current. **b.** Circuit diagram showing how an ammeter is used to measure the electric current through a light globe



An **ammeter** is used to measure the size of electric current flowing in an electric circuit. An ammeter measures electric current in amperes (A) or in one-thousandths of an ampere, which are called milliamperes (mA).

Most ammeters have two positive terminals. This allows the ammeter to provide readings over a large range of currents. There is always one scale per positive terminal. Make sure you are using the scale that corresponds to the positive terminal you have plugged in.

ammeter device used to measure the amount of current in a circuit. Ammeters are placed in series with other components in a circuit.

SCIENCE INQUIRY SKILLS: Using an ammeter

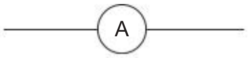
Most ammeters used in school laboratories have one (black) negative terminal and two or more (red) positive terminals. The following points are important when using ammeters. Refer to them whenever using ammeters in an investigation.

- The positive terminal of the ammeter should always be connected in series so that it is closer to the positive terminal of the power supply than the negative terminal of the power supply.
- Use the positive terminal with the highest value first. If the measured current in your circuit is smaller than the value shown on one of the other terminals, you may change the connection to the positive terminal with the smaller value.

CAUTION

Ammeters are easily damaged. If the current reading is off the scale switch the circuit off immediately.

- The scale has at least two sets of numbers on it. Use the set that matches the connected positive terminal.
- An ammeter is represented by the symbol:



- Always read an ammeter from directly in front. The error obtained by not reading from directly in front is called a **parallax error**.

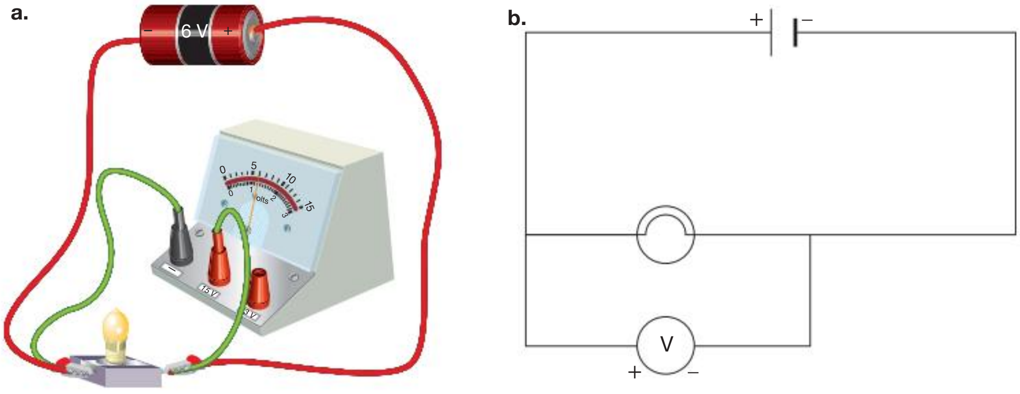
10.3.2 Voltmeters

A **voltmeter** is used to measure the voltage gain across the terminals of a power supply or voltage drop across parts of an electric circuit. Voltage is measured in volts (V).

parallax error error caused by reading a scale at an angle rather than placing it directly in front of the eye

voltmeter device used to measure the voltage across a component in a circuit. Voltmeters are placed in parallel with the components.

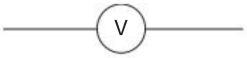
FIGURE 10.13 a. A voltmeter is used to measure the voltage gain or drop across two parts of an electric circuit. This voltmeter is being used to measure the voltage across the light globe. **b.** Circuit diagram showing how a voltmeter is used to measure the voltage drop across a light globe



SCIENCE INQUIRY SKILLS: Using a voltmeter

Like ammeters, most voltmeters used in school laboratories have one (black) negative terminal and two or more (red) positive terminals. Remember the following points when using voltmeters.

- A voltmeter should be connected in parallel with the part of the circuit across which the voltage is being measured. The positive terminal should always be connected so that it is closer to the positive terminal of the power supply than the negative terminal of the power supply.
- Use the positive terminal with the highest value first. If the measured voltage in the circuit is smaller than the value shown on one of the other terminals, you may change the connection to the positive terminal with the smaller value.
- The scale has at least two sets of numbers on it. Use the set that matches the connected positive terminal.
- A voltmeter is represented by the symbol:



- Always read a voltmeter from directly in front to avoid parallax error.

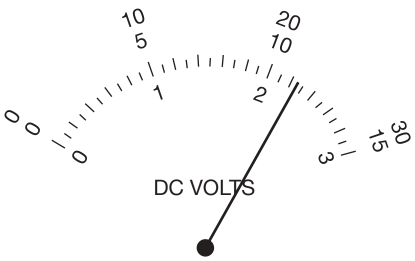
10.3.3 Errors of measurement

SCIENCE INQUIRY SKILLS: Types of error and how to avoid them

No matter how much care you take with your measurements, there will always be errors because of limitations of your equipment. In addition, when you are reading scales such as those on a ruler, a mercury or alcohol thermometer, or an ammeter or a voltmeter, you always have to make an estimate. The size of the error will depend on the size of the smallest subdivision shown on the scale. Generally, you should be able to read a scale to the nearest marking, making the error half of the smallest subdivision.

For example, on the 3-volt scale of the voltmeter shown in figure 10.14 the smallest division is 0.1 volt. With care, the scale can be read with an uncertainty of about 0.05 volts. The needle is between the 2.3 marking and the 2.2 marking, so the voltage can be recorded as 2.25 volts.

FIGURE 10.14 There is always a degree of error when reading a scale like this.



Random errors

Errors that occur due to estimation when reading scales are called **random errors**. Random errors also occur when the quantity being measured changes randomly. For example, when the temperature of the water in a saucepan is being measured, it may increase or decrease slightly due to the convection currents in the water. Random errors affect the **precision** of the measurement.

Systematic errors

Errors that are consistently high or low due to the incorrect use or limitations of equipment are called **systematic errors**. Parallax errors caused by consistently reading the scale of an ammeter or voltmeter from one side instead of directly in front are systematic errors. An incorrect zero reading when there is no current or voltage, or uneven scales, is also a systematic error. Systematic errors affect the **accuracy** of the measurement.

Reducing errors

Random errors can be reduced by repeating measurements numerous times and calculating an average. But this is not always possible or practical. Such errors can never be totally eliminated. Some systematic errors can be eliminated by knowing how to use the equipment correctly. If a measuring instrument does not read zero when it should, the error can be eliminated by calibrating the equipment before use. But there will always be systematic errors, because no scale or measuring instrument is perfect.

random errors an error that occurs due to estimation when reading scales, or when the quantity being measured changes randomly

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

systematic errors errors that are consistently high or low due to the incorrect use or limitations of equipment

accuracy how close a measurement is to the true value

elog-2361

INVESTIGATION 10.3

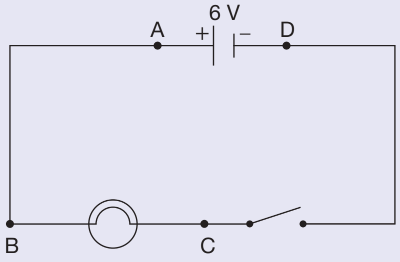
Probing a simple circuit

Aim

To investigate the current and voltage within an open and closed circuit

Materials

- power supply (set to 6 volts)
- 6-volt light globe and holder
- 6 connecting leads with alligator clips or banana plugs
- very long connecting lead (at least 2 m long)
- switch
- ammeter
- voltmeter



Method

Part A: Switch closed

1. Set up the circuit shown in the diagram. You should be able to set it up using only three connecting leads.
2. Use the ammeter to measure the electric current at each of the points A, B, C and D. Record your measurements in the table.

CAUTION

Check that the ammeter is connected properly before closing the switch. Ask your teacher if you are not sure.

3. Remove the ammeter from the circuit.
4. With the switch closed, use the voltmeter to measure the voltage across:
   a. the power supply (across points A and D)
   b. the light globe (across points B and C)
   c. the switch (across points C and D)
   d. one of the connecting leads (across points A and B).

Part B: Switch open

5. With the switch open, use the ammeter to measure the electric current at each of the points A, B, C and D. Before you connect the ammeter, make a prediction of the electric current at each of the four points.
6. With the switch open, use the voltmeter to measure the voltage across:
   a. the power supply (across points A and D)
   b. the light globe (across points B and C)
   c. the switch (across points C and D)
   d. one of the connecting leads (across points A and B).

   Before you connect the voltmeter, make a prediction of the voltage across each of the four items.

Results

TABLE Currents and voltages around a simple circuit

	Using the ammeter		Using the voltmeter	
	Location in circuit	**Electric current (mA)**	**Item**	**Voltage (V)**
Switch closed	A		Power supply	
	B		Light globe	
	C		Switch	
	D		Connecting lead	
Switch open	A		Power supply	
	B		Light globe	
	C		Switch	
	D		Connecting lead	

Discussion

Part A: Switch closed

1. Is there any difference between the amount of current travelling through the points A, B, C and D?
2. How does the voltage across the terminals of the power supply compare with the voltage across the light globe when the switch is closed?
3. Where is most of the electrical energy generated by the power supply lost?

Part B: Switch open

4. Were your predictions correct?
5. Why has the voltage across the switch changed so much?
6. Explain how a voltage drop can occur even though the circuit is not closed. (*Hint*: Think about what voltage measures.)

Conclusion

What can you conclude about ammeter and voltmeter readings in circuits with open and closed switches?

on Resources

eWorkbook Ammeters and voltmeters (ewbk-12573)

10.3 Activities

learn**on**

10.3 Quick quiz on

10.3 Exercise

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 2, 5, 7, 8	3, 6, 10, 11, 13, 16	4, 9, 12, 14, 15

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. **MC** Which device measures the charge flowing past a point in a circuit per second?

A. A motor
B. A thermistor
C. An ammeter
D. A voltmeter

2. **MC** Which device measures potential difference?

A. A motor
B. A thermistor
C. An ammeter
D. A voltmeter

3. Describe how an ammeter must be connected in an electric circuit and state which terminal of the ammeter must be connected closest to the positive terminal of a battery.

4. Describe how a voltmeter must be connected to the part of a circuit across which the voltage is to be measured.

5. **MC** What is 0.350 A when expressed in mA?

A. 3.5 mA
B. 35 mA
C. 350 mA
D. 3500 mA

6. Explain why voltmeters and ammeters have two or three scales.

Apply and analyse

7. **MC** What is the correct measurement on the ammeter shown?

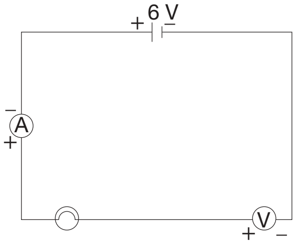
A. 305 mA
B. 30.5 mA
C. 3.05 mA
D. 3.05 A

8. **SIS** Describe one way in which random errors can be reduced.

9. **SIS** Describe two causes of systematic errors when using a voltmeter or ammeter.

10. **SIS** Describe two causes of random errors that occur when reading scales to measure any physical quantity.

11. **SIS** Identify two errors in the circuit shown in the figure.

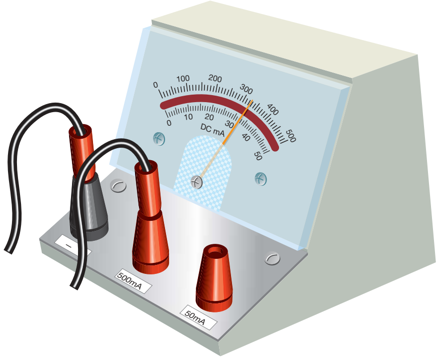


12. When using an ammeter, you are advised to use the positive terminal with the highest value scale first. If you can choose between a 50 mA and a 500 mA scale, which one should you connect first? Explain your answer.
13. **SIS** Is a parallax error a random or systematic error? Explain your answer.
14. **SIS** Can random errors be eliminated by using digital measuring instruments? Explain your answer.
15. **SIS** Explain why it is never possible to completely eliminate errors when measuring physical quantities.

Evaluate and create

16. **SIS** **a.** Why can't you accurately read the electric current measure on the ammeter shown?

    b. Estimate the reading.



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

LESSON

10.4 Resisting the electrons!

LEARNING INTENTION

At the end of this lesson you will understand the meaning of electrical resistance and how to calculate it.

10.4.1 Resistance

Imagine you are at a party with a group of friends. You all need to leave but to do so you have to push your way through a crowd of people. They are all dancing and keep getting in your way. Sometimes they bump into you. It slows you down and saps your energy. If you stop, you will be pushed by the people behind you and be made to move again. Near the exit is a corridor full of people dancing. You squeeze through but with reduced space you are pushed around more than ever! Believe it or not, this is very similar to how electrons travel through circuits.

FIGURE 10.15 Resistance is like a constriction or obstruction that hinders the flow of water. Higher resistance means it is more difficult for the current to flow through the circuit. If the current is kept constant, the voltage (water pressure) is increased.

The negatively charged electrons moving in an electric circuit have to make their way past the atoms in the connecting leads and devices that make up the circuit. The atoms are constantly vibrating and collisions between electron and atom are common. Electrical resistance is a measure of how difficult it is for electrons to flow through part of a circuit. The resistance to the flow of electric charge limits the electric current, just as the resistance of a narrow and crowded corridor limits the number of people that can pass through in a given time interval. Electrical resistance also determines how much energy is lost by electric charge as it moves through a circuit.

10.4.2 Calculating resistance

- **Electrical conductors** have very little resistance. They allow large electric currents to flow with little loss of energy.
- **Electrical insulators** have a very large electrical resistance. They allow very little electric current to flow.

The letter R is used to represent resistance and its unit is the ohm (Ω).

The value of the resistance, R, of part of an electric circuit is defined by:

$$R = \frac{V}{I}$$

where:
R is the resistance in ohms
V is the voltage drop in volts
I is the electric current in amperes

A torch globe carrying an electric current of 0.2 amps with a voltage drop of 3 volts therefore has a resistance of:

$$\begin{aligned} R &= \frac{V}{I} \\ &= \frac{3}{0.2} \\ &= 15\,\Omega \end{aligned}$$

electrical conductors materials through which electricity flows easily

electrical insulators materials which do not allow electricity to flow easily

Ohm's Law states that the current in a conductor is proportional to the voltage drop across the conductor

ohmic describes conductors that obey Ohm's Law

10.4.3 Ohm's Law

In 1827, German physicist Georg Simon Ohm discovered if the voltage across a metallic conductor was doubled, the current doubled. If the voltage was tripled, the current tripled.

Ohm's Law states that the electric current in metallic conductors is proportional to the voltage drop across the conductor.

Materials that obey Ohm's Law are said to be **ohmic**. Metals and carbon are ohmic materials as long as the temperature remains fairly constant. The filament in a light globe is not ohmic.

One way of working out whether a material is ohmic is to draw a graph of voltage drop versus electric current. Recall that resistance is defined as:

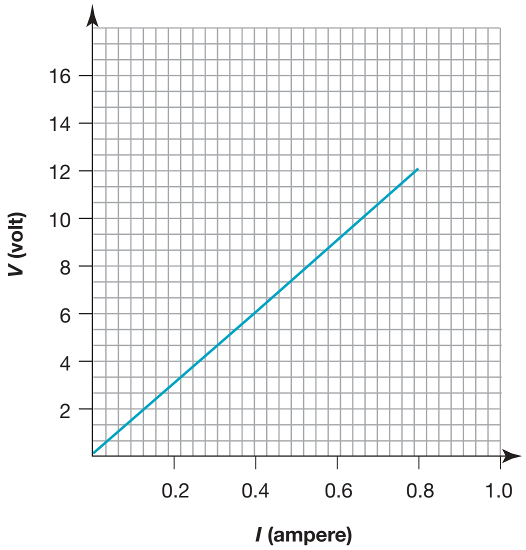
$$R = \frac{V}{I}$$

$$\therefore V = RI$$

If the material is ohmic, R is constant. A graph of V versus I yields a straight line (figure 10.16).

Non-ohmic materials will have curved voltage-current graphs. So if you see a curve in the graph you can immediately know that the material is non-ohmic.

FIGURE 10.16 Graph of voltage drop (V) versus electric current (I) for an ohmic conductor



on Resources

Video eLesson Four different resistors (eles-2674)

elog-2363

INVESTIGATION 10.4

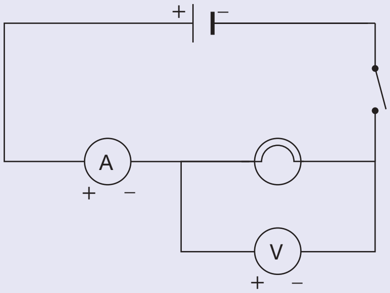
Changing resistance

Aim

To investigate the relationship between voltage and resistance of a light globe

Materials

- power supply (variable)
- 9-volt light globe and holder
- 6 connecting leads with alligator clips or banana plugs
- switch
- ammeter
- voltmeter



Method

Part A

1. Set up the circuit shown in the diagram and leave the switch open.
2. Construct a table as shown in the Results section to record your measurements of the electric current flowing through the light globe, the voltage drop across the globe and the calculated resistance.
3. Set the power supply to 2 volts.
4. Close the switch and quickly read the meters, recording the electric current and voltage drop in your table. Ensure that the electric current is recorded in amperes (not milliamperes).
5. With the switch closed, set the power supply to 4 volts.
6. Quickly measure and record the electric current and voltage displayed on the meters.
7. Set the power supply to 6 volts (again not opening the switch) and quickly measure and record the electric current and voltage displayed on the meters.

Part B

8. Repeat the experiment; however, this time start with the power supply set to 6 volts. Then decrease it to 4 volts and then 2 volts.

Results

TABLE Part A Results

Power supply setting (volts)	Electric current (amperes)	Voltage drop (volts)	Resistance (ohms)
2			
4			
6			

TABLE Part B Results

Power supply setting (volts)	Electric current (amperes)	Voltage drop (volts)	Resistance (ohms)
6			
4			
2			

1. Calculate the resistance of the globe for each of the three power supply settings and record them in your table.
2. Plot a graph of voltage drop (V) versus electric current (I) for the light globe.
3. Plot a second graph of the voltage drop versus electric current on the same set of axes as the first graph, in a different colour.

Discussion

1. Does the resistance increase or decrease during the first part of the experiment, when the power supply setting is being increased?
2. How is the change in resistance different during the second part of the experiment, when the power supply setting is being decreased?
3. What changing property of the filament do you think caused the resistance of the light globe to change?
4. Explain any difference between the shape of the first graph and that of the second graph.

Conclusion

What can you conclude about the relationship between voltage and resistance?

on Resources

eWorkbook Ohm's Law (ewbk-12575)

10.4 Activities

learnon

10.4 Quick quiz on

10.4 Exercise

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 2, 5	3, 4, 7, 10	6, 8, 9, 11, 12

Remember and understand

1. **MC** Which of the following statements about insulators is true?
   - **A.** Insulators have no electrons so current cannot flow.
   - **B.** Electrons in insulators repel the electrons in the current, so it cannot flow.
   - **C.** Insulators have an infinitely large resistance so current cannot flow.
   - **D.** Insulators have a very large electrical resistance so only tiny currents can flow unless the voltage is high.
2. What does Ohm's Law say about the relationship between electric current in and voltage across metallic conductors?
3. What happens to the electric current flowing through a light globe when the resistance of a variable resistor in series with the globe increases?

Apply and analyse

4. Compile a list of all devices that you would expect to contain light or heat sensors. For each item, briefly state why you believe it contains light or heat sensors and how the device responds to changes in light intensity or temperature.
5. What is the voltage drop across a 100 Ω resistor when the electric current flowing through it is measured at 250 mA?
6. The electric current flowing through a light globe is measured to be 200 mA when the voltage across the globe is 1.5 volts. When the voltage is increased to 3.0 volts, the current is measured to be 360 mA.
   - **a.** What is the resistance of the light globe when the electric current is 200 mA?
   - **b.** Is the light globe ohmic? Explain how you know.
   - **c.** If the light globe were ohmic, what would happen to the electric current flowing through that light globe if the voltage across it were doubled?
7. A light-dependent resistor (LDR) is an electronic components that can detect light. It does not obey Ohm's Law, its resistance decreases when the intensity of light it detects increases.
   What happens to the electric current flowing through a light globe connected in series with an LDR if the light level in the room goes down? Explain your answer.

8. A thermistor is a type of resistor sensitive to temperature. It does not obey Ohm's Law, its resistance decreases rapidly when the temperature increases. What happens to the electric current flowing through a light globe connected in series with a thermistor if the temperature in the room goes up? Explain your answer.
9. Some resistors are quite small, others may have the same resistance value but be much larger and covered in ceramic. Why do you think the larger resistors are designed that way?

Evaluate and create

10. **SIS** Consider the following data. Sketch a graph and explain whether it represents an ohmic conductor or not. Explain your answer.

TABLE Voltage and current for a conductor

Voltage (V)	Current (A)
0	0
1	1
2	2
3	3
4	4

11. **SIS** Consider the following data. Sketch a graph and explain whether it represents an ohmic conductor or not. Explain your answer.

TABLE Voltage and current for a conductor

Voltage (V)	Current (A)
1	0
2	1
3	2
4	3
5	4

12. Answer these questions about the ohmic conductor.
    - a. Use the graph in figure 10.16 to predict the voltage drop across the conductor when the electric current is 1.0 ampere.
    - b. What electric current (in mA) flows through the conductor when the voltage drop across it is 6 volts?
    - c. Calculate the resistance of the conductor.
    - d. Explain how you know that the conductor is ohmic.

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

LESSON
10.5 Energy efficiency

LEARNING INTENTION

At the end of this lesson you will be able to explain what a power rating is and evaluate the energy ratings of electrical appliances.

10.5.1 Counting the cost

Energy transfer involves the change of energy from one form to another and the total energy remains constant. It cannot be created nor destroyed; however, it can be stored or transferred in different forms. Energy transfers are happening all the time in the universe. Therefore, the law of conservation of energy states that the energy input, in this case in the form of electrical energy, is equal to the energy output in an energy transformation.

When energy is converted from one form to another, some of it is lost. For example, when energy in a battery is used to power an electronic device, chemical energy is transformed into electrical energy. In electrical appliances, electrical energy is transformed to other forms. Some forms are useful, such as the light produced by an incandescent (filament) light globe, while other forms represent wasted energy such as the heat produced by these globes. Electrical power is measured in watts (W) and is equivalent to joules per second. A 75-W incandescent light globe uses 75 joules of energy per second and would be more costly to run than an 18-W compact fluorescent light which uses 18 joules/second and provides approximately the same amount of light.

elog-2365

INVESTIGATION 10.5

Comparing electrical appliances

Aim

To compare the power use and energy conversion in a range of electrical appliances and devices

Materials

a range of electrical appliances and devices; e.g. radio, hair dryer, blender, laptop, fluorescent light, incandescent light, hot water kettle

Method

Examine each of the devices, preferably while they are operating.

Results

For each device, record in a suitably designed table the:

- type of energy input
- useful energy output (there may be more than one)
- wasted energy output (there may be more than one)
- operating power in watts (this should be labelled on the device).

Discussion

1. Which appliance/device consumes:
   a. the most power?
   b. the least power?
2. Which device do you consider would be the:
   a. most efficient, producing the least wasted energy?
   b. least efficient, producing the most wasted energy?
3. Account for the higher operating power of some of the devices in terms of the type of energy transformation that takes place.

Conclusion

Summarise the findings of this investigation in 2-3 sentences.

Table 10.2 provides the power rating of common appliances.

The power rating can be used to determine the electrical energy used by an appliance as follows:

$$\text{Electrical energy use (joules)} =$$

$$\text{electrical power (watts)} \times \text{time in use (seconds)}$$

For example, using a desktop computer for half an hour would use:

$$120 \text{ W} \times 30 \text{ min} \times 60 \text{ s/min}$$

$$= 120 \text{ J/s} \times 1800 \text{ s}$$

$$= 216\,000 \text{ joules}$$

$$= 216 \text{ kilojoules of energy}$$

TABLE 10.2 Typical power ratings of household appliances

Appliance	Power rating (W)
Fluorescent light	20
Notebook computer	20
Desktop computer	120
Television	200
Toaster	1000
Hair dryer	1500
Electric kettle	1700
Air conditioner (medium size)	5000

An electricity meter located in your home's meter box monitors your energy usage in kilowatt-hours.

The joule is a very small unit of energy, so electricity suppliers charge us in units called kilowatt-hours (kWh). A kilowatt-hour is the energy used by a 1 kilowatt appliance for an hour. The power use of an appliance depends on the type of energy conversion it carries out. Low-power appliances include fluorescent lights and laptops and usually convert electrical energy to light and sound energy. High-power applances such as electric kettles and toasters generally convert electrical energy to heat and cost more to run.

Electricity suppliers charge us for the amount of energy we consume in our homes.

FIGURE 10.17 Electricity meters measure the number of kilowatt-hours of energy used in homes.

FIGURE 10.18 Energy companies measure the amount of electrical energy used by a household in kilowatt-hours. Every three months, the meter box is read so that the energy company knows how much electricity the customer has used. Households are charged a fixed amount for every kilowatt-hour of electricity they use. This customer was charged 20.6 cents per kilowatt-hour.

Energy Used and Costs

METER ID	−	THIS READING	=	LAST READING	×	USAGE SPLIT	×	RATE	=	COST
Single Energy Rate – Contract (12/01/17 – 11/04/17)										
		46851.0		45998.0		First 853.0 kWh		853.0*20.600c		$175.72
Electricity Service Availability Charge								91Days 48.000c/Day		$43.68
*based on 19.1781 kWh/billing day										
Total Electricity before GST 853.0 kWh $219.40										

10.5.2 What is energy efficiency?

Energy efficiency is using less energy to do the same amount of work. Appliances can be responsible for around 30 per cent of home energy use, so choosing the most energy-efficient appliance is important as it can save a lot of money in the long term. In Australia, the Equipment Energy Efficiency (E3) program gives information about a range of products to help consumers increase their energy efficiency and reduce greenhouse gas emissions.

Some of the energy rated appliances are dishwashers, fridges, freezers, washing machines and TVs. When choosing an electrical appliance, there are a few things to consider, including comparing the running cost with other models to choose the most energy efficient appliance to save money. Since appliances are such big users of household energy, it is also important that all appliances except fridges and freezers can be switched off when not in use to save energy. Dishwashers with good drying power usually consume more energy and so they are less energy efficient.

Energy efficiency of an appliance can be calculated by:

$$\%\ \text{Efficiency} = \frac{\text{Useful energy output} \times 100}{\text{Total energy input}}$$

Sankey diagrams

According to the Law of Conservation of Energy, energy can neither be created nor destroyed, but it can be transferred and converted from one form to another. This energy conversion can be represented by Sankey diagrams. Sankey diagrams are used to show the flow of energy by identifying energy stores, energy transfers and wasted energy. They provide information about energy quantitative input, useful and wasted energy.

In 1898, an Irish man called Matthew Sankey used a flow chart to represent the energy efficiency of a steam engine. These types of flow charts, known as Sankey diagrams, are very useful to show the energy transfers and efficiency of any system.

In a Sankey diagram, arrows are used to represent the energy transfer, and the width of the arrow shows the amount of energy involved. As shown in figure 10.19 the input energy is always shown on the left, the useful output energy on the right and the wasted energy below.

FIGURE 10.19 Features of a Sankey diagram

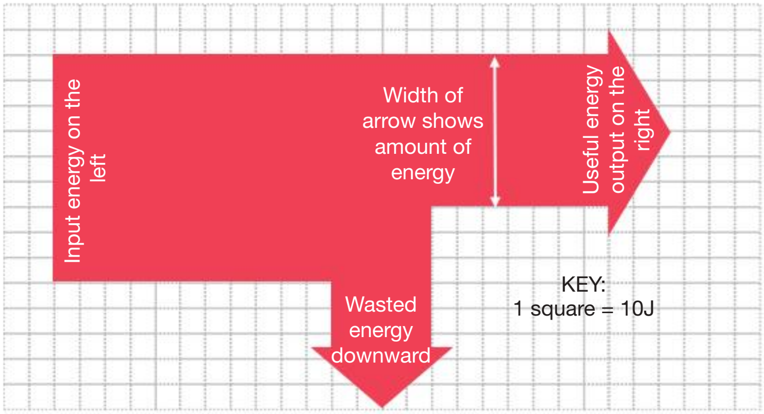
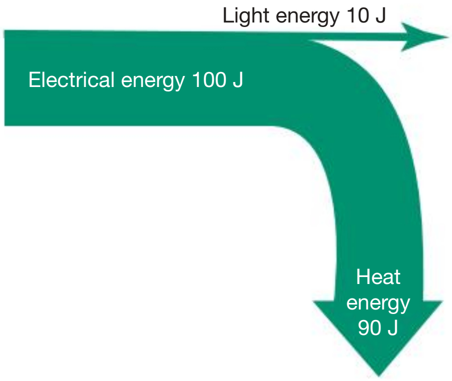


FIGURE 10.20 Energy output of an incandescent light globe



For example, figure 10.20 shows the Sankey diagram of an electric light bulb. In this Sankey diagram, 100 J of electrical energy is supplied to the bulb. Of this, only 10 J is transferred to the surroundings as light energy and the remainder, 90 J (100 J – 10 J) is transferred to the surroundings as heat energy.

10.5.3 Energy efficient appliances

The light globes used for many years in Australian homes are called incandescent globes. In incandescent globes, electricity passes through a thin filament, generally made of tungsten metal, causing it to glow white hot. These are relatively inefficient devices for lighting as only 10 per cent of the supplied electrical energy is converted to light; the rest is released as heat.

To encourage the use of more energy efficient lighting, the sale of incandescent light globes was phased out from 2010 and replaced by more energy efficient alternatives that produce at least 15 lumens per watt of electricity used. Lumens (lm) are a measure of light output. These energy efficient alternatives include compact fluorescent lamps (CFLs) and light emitting diodes (LEDs) which convert closer to 70 per cent of electricity energy to light.

CFLs and LEDS represent a technological advancement in lighting. CFLs consist of a coiled glass tube filled with argon gas and a small amount of mercury vapour.

FIGURE 10.21 CFLs and LEDs are energy efficient alternatives for lighting.

	 Incandescent light bulbs	 Compact fluorescent lamps (CFLs)	 Light emitting diodes LEDs
Electrical power use equivalent to 60 W incandescent light bulb	60 watts	13–15 watts	6–8 watts
Electrical energy use per year based on 20 lights operating 8 hours per day	3506 kWh/yr	760 kWh/yr	350 kWh/yr
Approximate annual operating cost at 21 cents per kWh	$736	$160	$74

An electric current passes through the gas-filled tube, causing the mercury atoms to emit ultraviolet light, which in turn excites a fluorescent phosphor coating on the inside of the tube, producing the visible light. A CFL's ballast regulates the current when the electricity starts flowing.

LEDs contain an electronic component called a semiconductor diode, similar to the miniature electrical components contained in an integrated circuit. When electricity flows through an LED, the electrical energy is converted to light energy very efficiently with minimal heat produced. One individual LED does not produce as much light as one CFL or one incandescent globe, so many small LEDs are often used together for lighting purposes.

FIGURE 10.22 The components of a CFL

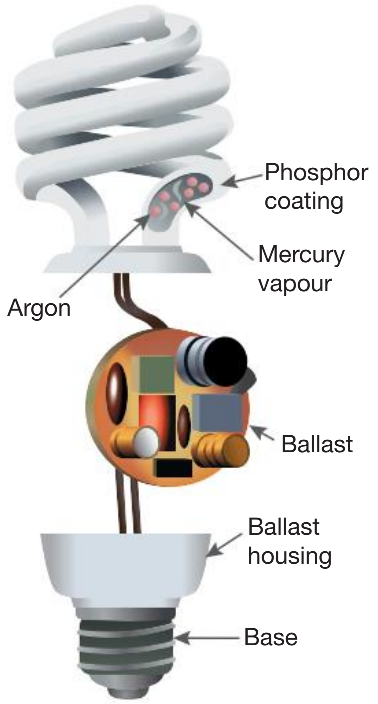
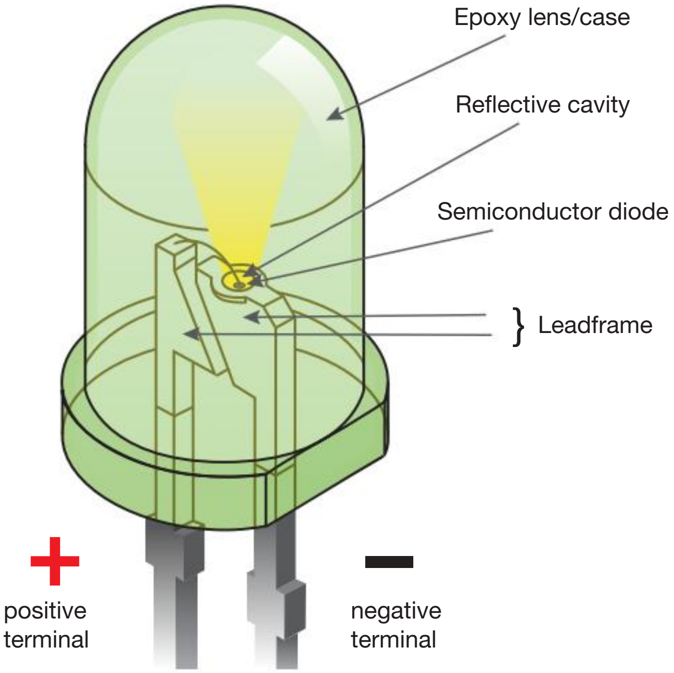


FIGURE 10.23 The components of an LED

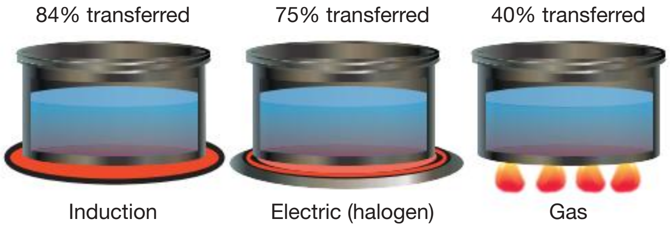


Advances in cooking

Along with developments in lighting, there have also been technological advances in energy-efficient cooking appliances. Traditional cooking uses a gas or electric hotplate. Induction cooking is a recently developed technology that transfers energy from the cooktop to the saucepan more efficiently than any other cooking appliance. In gas cooking, only 40 per cent of the heat supplied by the gas flame is transferred directly to heat the contents of a saucepan. The rest of the heat energy is wasted as light or heat to the surrounding air. Modern electric hotplates are more efficient with 70 per cent of the heat energy transferred to heat involved in cooking. Induction cooking, however, can achieve close to 85 per cent energy efficiency. Electricity supplied to metal coils within an induction cooktop creates an oscillating magnetic field that directly heats any saucepan placed on it, as long as it is made of a magnetic metal, such as stainless steel. With induction cooking, energy is supplied directly to the saucepan by the magnetic field; therefore, the cooktop itself does not get hot and so almost all of the source energy is transferred to the saucepan.

FIGURE 10.24 In an induction cooktop, only the saucepan gets hot, resulting in less wasted heat and greater energy efficiency.

FIGURE 10.25 A comparison of the energy efficiencies of various cooktop technologies



elog-2367

tlvd-10803

INVESTIGATION 10.6

Light globe efficiency

Aim

To compare the efficiency of an incandescent light with a CFL

Materials

- cardboard box
- data logger
- temperature sensor
- light sensor (optional)
- portable lamp
- an incandescent light and CFL of equivalent light output, as follows:

Incandescent light	CFL
40 watts	9–13 watts
60 watts	13–15 watts
75 watts	18–25 watts
100 watts	23–30 watts

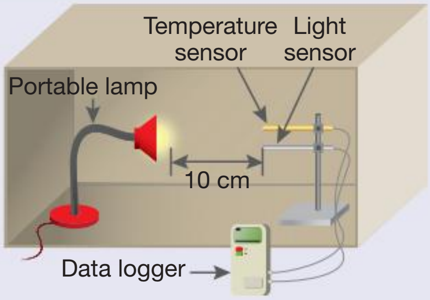
Method

1. Insert the incandescent globe into the portable lamp.

CAUTION

Ensure that the lamp is not connected to the power outlet while light globes are inserted or removed.

2. Connect the temperature sensor and light sensor (if available) to the data logger.
3. Position two sensors 10 cm away from the lamp within the cardboard box and record the temperature and light intensity each minute over a 10-minute period.
4. Repeat the experiment with a CFL.



Results

Record your results in an appropriate table.

Discussion

1. Compare the temperature change due to the incandescent light and the CFL.
2. Compare the light intensity of the incandescent light and the CFL.
3. Which light globe is the most energy efficient? Explain in terms of the data collected.
4. Calculate the:
   a. energy use for each globe in kWh if each was run for 8 hours
   b. annual cost of running each lamp 8 hours per day assuming a tariff of 21c per KWh.

Conclusion

Summarise the findings of this investigation in 2-3 sentences.

10.5.4 Rating energy efficiency

Energy rating labels provide information about the energy efficiency of products. The labels show the energy performance of electrical appliances so that customers understand how energy efficient a particular model is and what it will cost to run. The energy rating label system is a government initiative to encourage customers to buy energy efficient appliances and save money in the long term.

In Australia it is mandatory for electrical appliances such as refrigerators, washing machines, dishwashers, air conditioners and televisions to carry an energy rating label. The label provides each appliance with a star rating: the greater the number of stars, the higher the energy efficiency of the appliance, compared to others of a similar size or capacity. This rating is based on the appliance's estimated annual energy use (measured in kilowatt hours) calculated from its power consumption and information about the typical use of the appliance in the home.

The rating system enables consumers to compare the energy efficiency of appliances and provides incentive for manufacturers to improve the energy performance of their products through research and development.

FIGURE 10.26 The more stars on an energy rating label, the more energy efficient the product is.

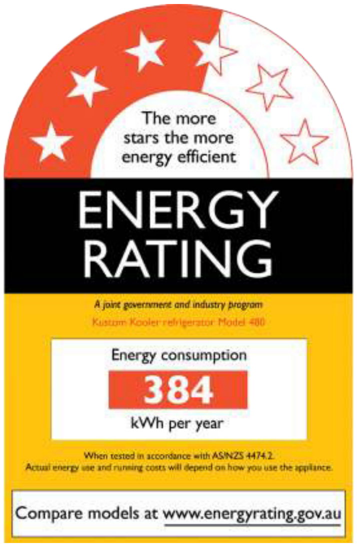
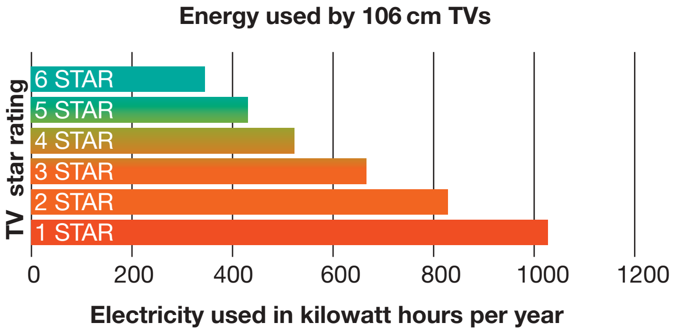


FIGURE 10.27 The higher the energy efficiency rating of an appliance like a TV, the less electrical energy consumed per year.



elog-2369

INVESTIGATION 10.7

Investigating energy efficiency

Aim

To calculate the energy efficiency of an electrical appliance

Materials

- electric kettle
- 100 mL measuring cylinder
- data logger and temperature probe
- stopwatch

Method

1. Use the measuring cylinder to measure and pour 500 mL of water into the electric kettle.
2. Place the tip of the temperature probe into the kettle and record the initial temperature of the water.
3. Remove the temperature probe then switch on the kettle and heat the water for 60 seconds.
4. Insert the temperature probe again to record the new water temperature.
5. Calculate the temperature rise over the 60-second period and record your data.
6. Refer to the label on the kettle to identify and record the power use of the kettle.

Results

Record your data in the following table:

Liquid	Volume of water (mL)	Initial temperature (°C)	Final temperature (°C)	Change in temperature (°C)	Time (s)	Power use of kettle (W)
Water						

Discussion

1. Calculate the input of electrical energy to the kettle over the 60-second period:

   Electrical energy input (J) = Power (watts) × operating time (s)

2. Calculate the output of heat energy gained by the water in the kettle as follows:

   Heat energy output (J) = volume of water (mL) × 4.2 × temperature rise (°C)

3. Calculate the efficiency of the kettle as follows:

$$\text{Efficiency } (\%) = \frac{\text{Heat energy output}}{\text{Electrical energy input}} \times 100$$

4. Explain why the efficiency of the kettle is well below 100 per cent in terms of transformation of electrical energy and the transfer of heat energy generated.

Conclusion

Summarise the findings of this investigation in 2-3 sentences.

10.5.5 Efficiency of ground ovens

Some of the traditional ways that First Nations Australians have of cooking involve roasting it on hot coals, baking it in ashes and steaming it in ground ovens. Earth or ground ovens were often used and involved heating stones or burning clay lumps and placing them in a hole in the ground.

The heat-retaining ground ovens use convection, conduction and radiation for cooking and steaming the food.

ACTIVITY: Using ground ovens for cooking

Research the information about the ground ovens used by First Nations Australians for cooking.

- How is a ground oven made?
- How does a ground oven work?
- Draw a diagrammatic representation of a ground oven.
- How did First Nations Australians use ground ovens for cooking?

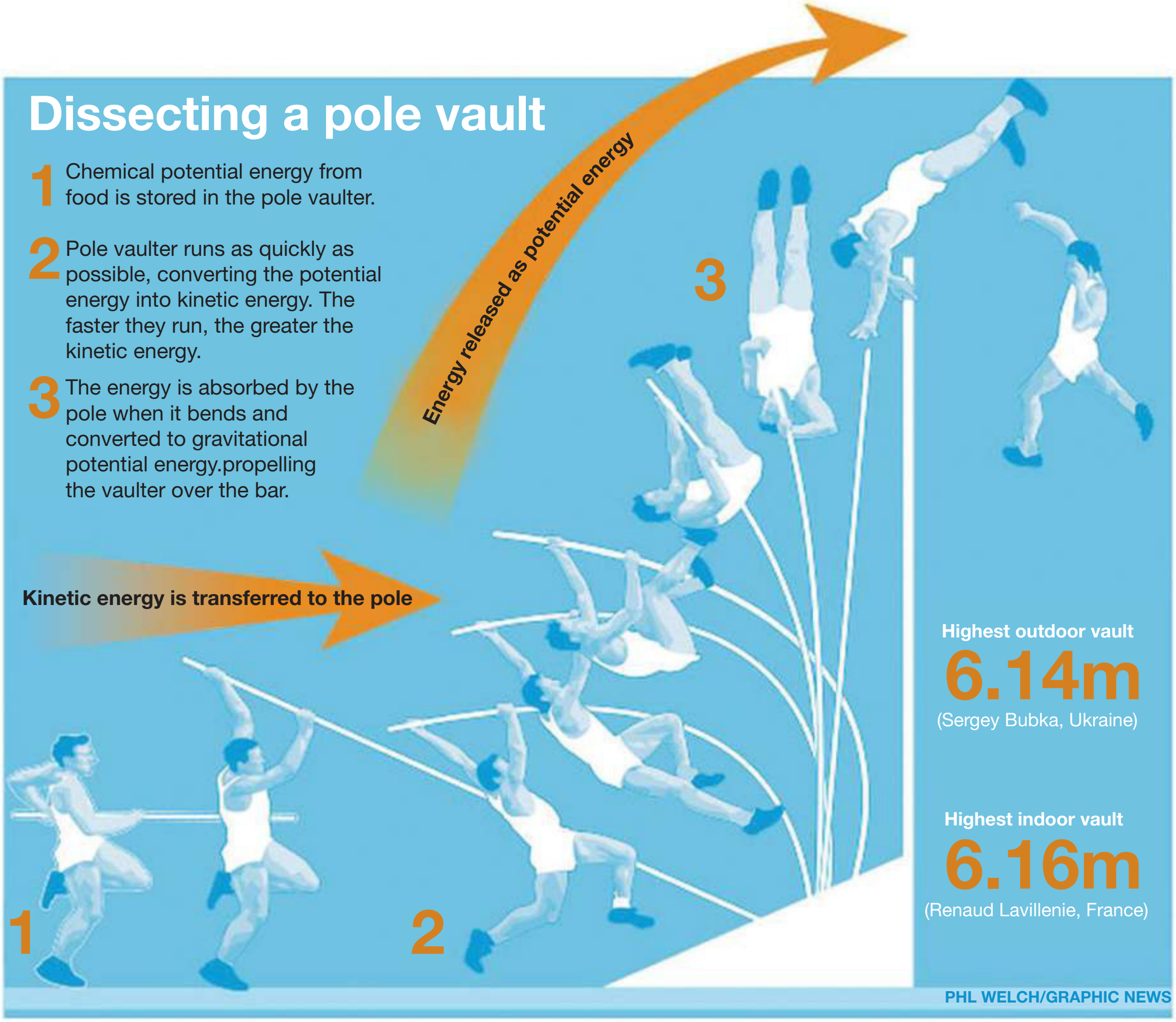
10.5.6 Energy efficiency in sports

The Law of Conservation of Energy states that energy can neither be created nor destroyed, it can only transform from one form to another or be transferred to another object or substance.

Energy efficiency in sports refers to how much energy is used while moving at a given speed; for example, while running or swimming. Increased efficiency means that less energy is required to sustain the athlete at a particular speed. Athletes undertake training sessions to maximise energy transformation. Such transformations convert chemical potential energy into heat and kinetic energy.

The pole vault is an example of how athletes use conversion of energy to rise to increased heights. The activity of pole vaulting involves multiple energy conversions as shown in figure 10.28. First, the athlete converts stored chemical energy into kinetic energy as they speed up while running on the track. Some of this kinetic energy is converted into elastic potential energy as the pole is placed on the ground and bends. As the pole straightens, it pulls the athlete upwards and the athlete gains kinetic and gravitational energy from the pole. At the top of the pole, the athlete has maximum gravitational potential energy, which then again changes into kinetic energy when they come back down.

FIGURE 10.28 Energy conversion in pole vaulting



Energy efficiency is crucial for successful performance in many sports. Examples of efficient energy transfer and transformations in pole vaulting include:

- Athletes must optimise their speed, stride length, and rhythm to generate sufficient kinetic energy for the jump. Proper running mechanics and a well-timed take-off maximise the transfer of energy into the pole.
- A stiffer pole can store more elastic potential energy, which can be effectively converted into kinetic energy to propel the athlete upwards.
- The bending action of the pole during the vault is a key element in energy transfer. As the pole bends, it stores potential energy. The athlete must utilise this stored energy by transitioning smoothly from the take-off to the swing phase, transferring the energy into upward momentum.
- Efficient body positioning and technique during the vault allow the athlete to convert potential energy into kinetic energy effectively. Properly extending the body and utilising the pole's recoil energy through proper pole drop and grip techniques can maximise the energy transfer and propel the athlete over the bar.

10.5 Activities

10.5 Quick quiz on | 10.5 Exercise

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 3, 5, 6	2, 4, 8, 11	7, 9, 10, 12

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. **MC** What is energy efficiency?
   - A. Using less energy to perform the same task
   - B. Using more energy to perform the same task
   - C. Using the same amount of energy to perform a different task
   - D. Using less water to perform the same task
2. **MC** Which of the following is an energy-efficient appliance?
   - A. An incandescent light bulb
   - B. A refrigerator with a 1 star on the energy rating label
   - C. A washing machine with 4 stars on an energy rating label
   - D. D. A kettle that has a useful energy output of 10%
3. **MC** How can you improve energy efficiency at home?
   - A. by using energy-efficient appliances
   - B. by leaving windows and doors open when heating or cooling your home
   - C. by taking long showers
   - D. by using incandescent light bulbs
4. Explain why incandescent lights have been phased out in preference for compact fluorescent lights and LEDs.

Apply and analyse

5. What types of home appliances have the greater power use? Explain why.
6. **MC** Which of the following is an example of an energy-efficient archery technique?
   - A. Pulling the bowstring back with maximum force
   - B. Using heavy arrows to maximize kinetic energy
   - C. Incorporating proper body alignment and posture
   - D. Increasing the draw weight of the bow for stronger shots
7. A child sitting at the top of a playground slide has 2000 joules of gravitational potential energy. They fly off the end of the slide with 1200 joules of kinetic energy.
   - a. Calculate the amount of energy transformed to types of energy other than kinetic energy.
   - b. Suggest what these other energy types might be.
8. How much electrical energy (in joules) is transformed by each of the following appliances:
   - a. an 18 watt light globe in 6 hours?
   - b. a 2000 watt toaster used to toast a slice of bread for 2 minutes?
9. a. If a 60-watt incandescent light bulb is used for 5 hours per day, how much energy does it use per week?
   - b. How much energy would a 15-watt LED bulb (which produces the same amount of light) use in one week?
10. How much would it cost to operate each of the following appliances if the cost of electrical energy is 21 cents per kilowatt-hour? (Remember, 1 kW = 1000 W.)
    - a. A 5000 watt air conditioner for 30 minutes
    - b. A 1500 watt electric blanket for 8 hours
11. If a solar panel system generates 5 kWh of electricity per day and the cost of electricity from the grid is $0.20 per kWh, how much money will the solar panel system save in one year (365 days)?
12. Assuming that the cost of electrical energy is 21 cents per kilowatt-hour, use the data in table 10.2 to calculate how much it costs to:
    - a. use a medium-size air conditioner to cool a room for four hours
    - b. watch television for two hours every day for a week.

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

LESSON
10.6 Electricity generation

LEARNING INTENTION

At the end of this lesson you will be able to outline the process of electricity generation and compare renewable and non-renewable resources for generating power.

10.6.1 Electricity generation from fossil fuels

In coal-fired power stations electrical energy is transformed from the chemical energy stored in coal. Similarly, in oil and gas power stations, electrical energy is transformed from the chemical energy stored in the oil or gas. Oil, coal and gas are collectively known as fossil fuels as they are the remains of long-dead plants and micro-organisms. In all fossil-fuelled power stations the energy production process is as follows.

- Chemical energy in the fuel is released as heat and light energy by combustion (burning).
- Heat energy is transferred to water, which produces steam.
- Steam is under pressure and the temperature is up to 400 °C. It hits a turbine (fan-like blades) at high velocity.
- Heat energy of the steam is converted to kinetic energy of the turbine.
- The turbine is connected to the coils in a generator. The coils rotate rapidly inside huge electromagnets.
- The motion of the coils in the magnetic field produces a large voltage.
- When the generator is connected to a load a large electric current flows.

Generators work on the principle that a coil of wire moving in a magnetic field creates a current of electricity. This can be demonstrated with a simple hand generator.

In 2011, about 90 per cent of Australia's electrical energy was generated by coal-fired or gas-fired power stations. These fossil fuels are examples of non-renewable energy resources. Most of the remaining 10 per cent was provided by renewable energy, which is increasing year on year. Australia relies so heavily on coal in particular because coal is a relatively cheap energy source in Australia and coal reserves are relatively abundant along the eastern seaboard, where the majority of electricity is generated and consumed. Twenty years later, about 70 percent of Australia's electrical energy was generated by non renewable energy resources (see figure 10.30).

FIGURE 10.29 A model generator demonstrates that motion between a coil of wire and a magnetic field creates a current in the coil.

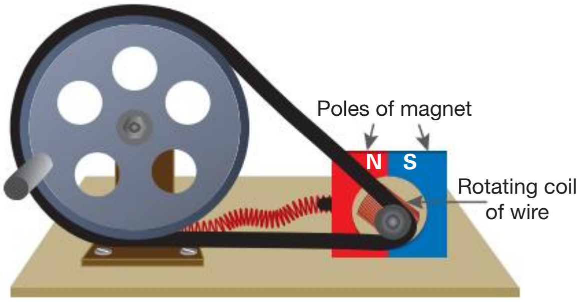


FIGURE 10.30 Energy sources used in electricity generation in Australia in 2021. Fossil fuels including coal, gas and oil now account for approximately 70 per cent.

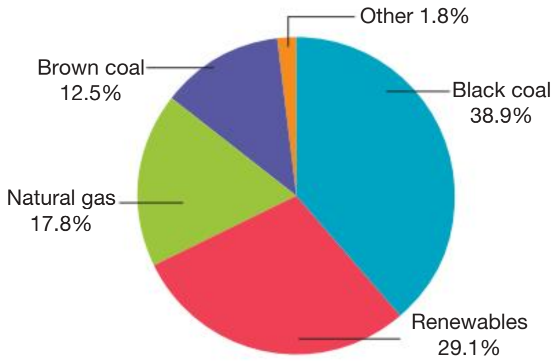
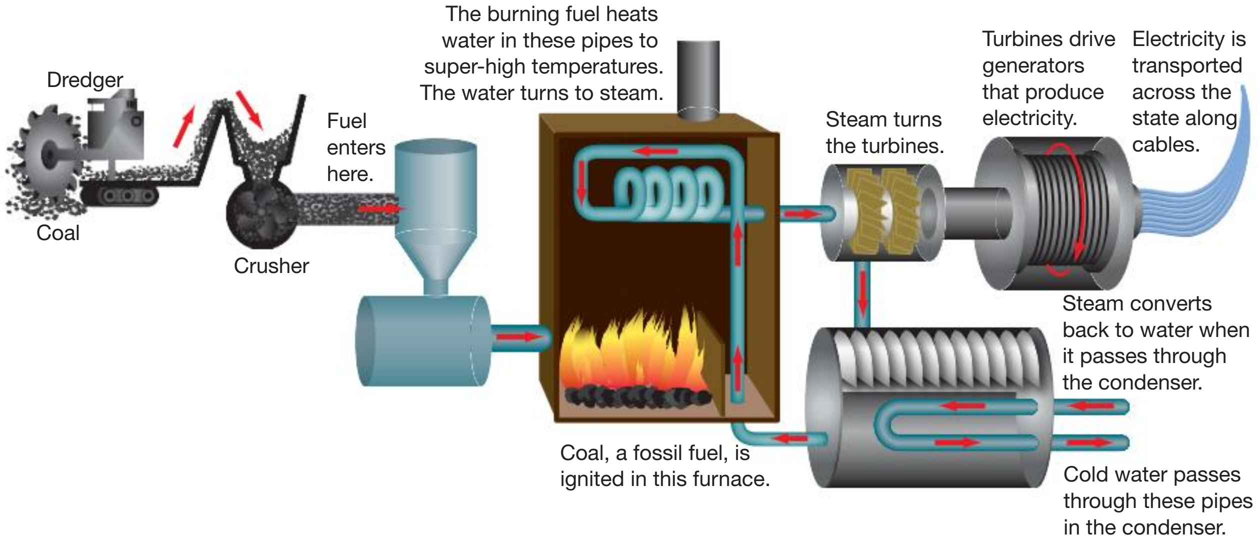


FIGURE 10.31 The chemical energy contained in fossil fuels such as coal is used to generate electricity in power stations.



elog-2373

INVESTIGATION 10.8

Electricity generation

Aim

To investigate the principles of electricity generation

Materials

- solenoid or coil of laminated wire wound around a cardboard cylinder
- micro-ammeter
- 2 wire leads
- 2 bar magnets
- rubber band
- handheld generator
- data logger and voltage sensor

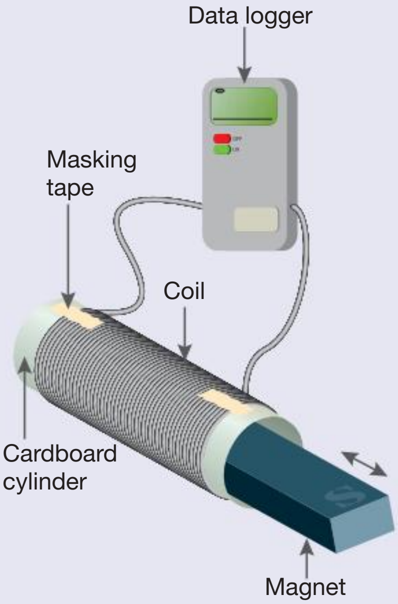
Method

Part A: Current produced by a solenoid

Construct the solenoid if required and connect to the micro-ammeter.

Part B: Voltage produced by a hand generator

Connect the voltage sensor to the data logger and connect the leads of the voltage sensor to the terminals of the hand generator.



Results

Part A: Current produced by a solenoid

1. Move the north pole of the bar magnet quickly into an end of the solenoid and record the current produced — both its magnitude and whether it is positive or negative.
2. Remove the bar magnet quickly and record the current again.
3. Carry out each of the following investigations and record your observations for each of the following:
   a. the effect of moving the magnet in and out more rapidly
   b. whether holding the bar magnet stationary in the solenoid generates a current
   c. the effect of increasing the strength of the magnet — this can be done by attaching the north poles of two bar magnets together using a rubber band.

Part B: Voltage produced by a hand generator

1. Record the voltage produced as the handle of the generator is turned. You may be able to generate AC or DC or both. Monitor the effect of spinning the generator faster and slower.

Discussion

1. What magnitude of current is generated by moving the bar magnet in and out of the solenoid? Don't forget to include scientific units.
2. Is the direction of the current affected by the direction of the moving magnet? Are you generating AC or DC electricity? Explain.
3. Is motion required for a current to be generated? Refer to your observations.
4. Do the speed of the magnet and the strength of the magnet affect the size of the current? Discuss.
5. Did your generator create AC or DC electricity? How do you know?
6. What energy transformation is taking place in the hand generator? What takes the place of your hand in the turbine of a coal power station?
7. How does the speed of the generator affect the voltage produced? Are there parallels with the activity examining the current in a solenoid?

Conclusion

Summarise the findings of this investigation in 2-3 sentences.

10.6.2 Power generation from other sources

Our dependence on coal and gas to generate electricity brings with it certain responsibilities — for government, industry, power companies and individuals. The first step is to be aware of the problems caused by using fossil fuels and the alternative methods of generating electricity.

As mentioned in topics 7 and 8, one of the products of the combustion of fossil fuels in power stations is carbon dioxide. Increased levels of carbon dioxide in the atmosphere is contributing to global warming which could have significant consequences for the climate and the biosphere in the years ahead. In addition, some of the chemicals in the coal burnt in power stations produce gases like sulfur dioxide and various nitrogen oxides, causing air pollution. These gases may also dissolve in water vapour in the atmosphere, creating acid rain. Acid rain speeds up the weathering of rocks, eats into building materials, and threatens plants and other living things that depend on the plants.

However, there is another form of pollution that is not so obvious. During electricity generation heat energy is transferred to the surroundings, increasing the temperature of the air and waterways. This increase in the temperature of the environment is known as thermal pollution. Thermal pollution of lakes is a serious problem as the increased temperature (even one or two degrees Celsius) decreases the amount of oxygen dissolved in the water, threatening organisms that live in the water and within the ecosystem.

There are many ways to turn a turbine that do not require the burning of fossil fuels.

- In nuclear power stations the energy required to boil water to produce the steam that turns the turbine blades is released in nuclear reactions.
- In hydroelectric power stations the energy used to turn the turbines is transformed from gravitational potential energy. Water falling from a great height turns the turbines directly with no need for high-pressure steam.
- Wind power directly transforms kinetic energy in the wind into rotation of the turbine.
- Wave power uses waves to compress columns of air in tubes, which turns small turbines.
- Geothermal power uses steam produced by pumping water into a hole drilled into the ground in geologically active areas. The heat of the rocks deep underground boils the water with no need for fuel.

FIGURE 10.32 The generation of household electricity in power plants and by wind turbines depends on the close relationship between electricity and magnetism.

Looking for alternatives

The demand for electrical energy is increasing, both in Australia and worldwide and so the supply of fossil fuels such as coal, natural gas and oil used in power stations is diminishing.

TABLE 10.3 Reserves of fossil fuels

Fossil fuel	Known reserves based on current rates of production and use (years)	
	Australasia	Global
Coal	53	112
Oil	14	54
Natural gas	35	64

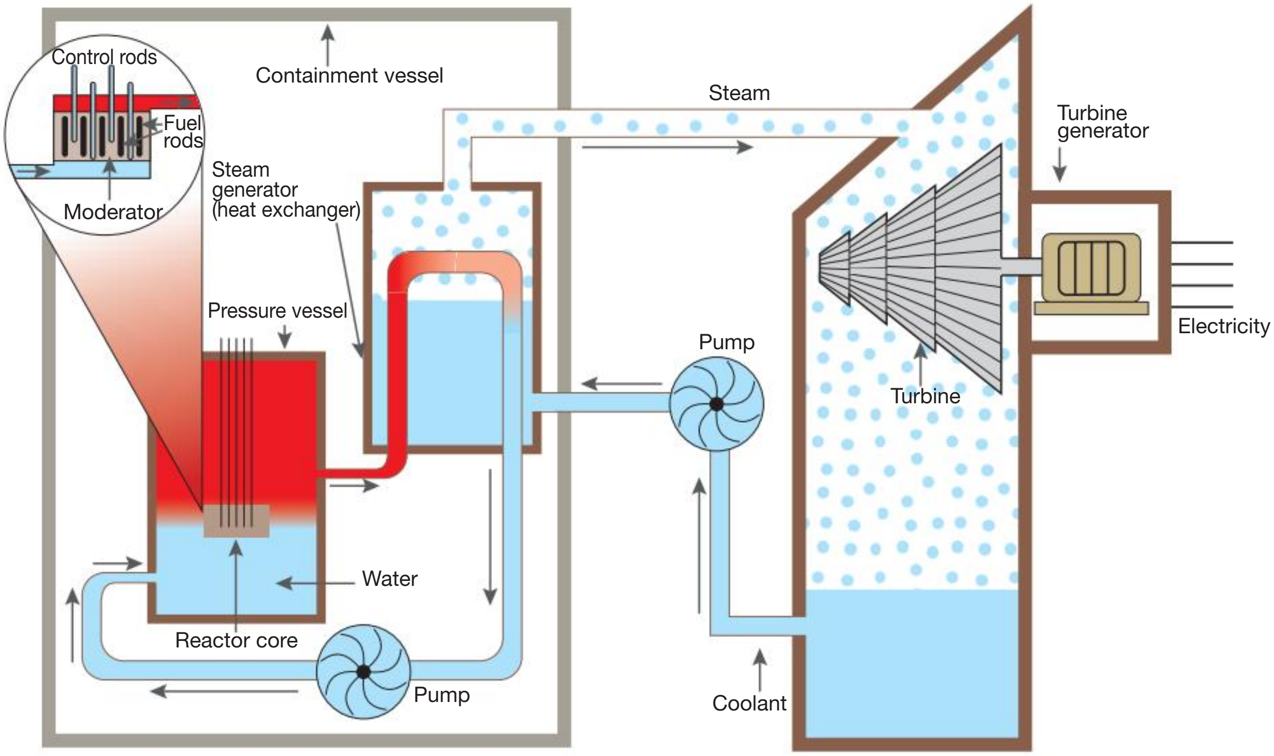
The air, water and thermal pollution caused by burning fossil fuels to generate electricity is not acceptable to many people. So even though the cost of electricity production using fossil fuels is low by comparison with newer non-renewable technologies, many governments throughout the world are supporting research and the development of alternative methods for electricity generation.

Nuclear energy

Nuclear power stations use energy released from the nuclear fission of radioisotopes such as uranium to drive turbines that generate electricity in the same way that fossil fuel power plants operate. Like fossil fuels, uranium is a non-renewable resource, but because nuclear power plants do not rely on the combustion of fossil fuels to generate electricity, greenhouse gases are not emitted. The critics of nuclear power object to this alternative because the nuclear waste produced must be stored for many years and because of the risk of nuclear accidents.

int-7129

FIGURE 10.33 In a nuclear power plant fuel rods, generally of uranium oxide, are placed within the reactor core. The rods are bombarded with neutrons to initiate a fission reaction that liberates huge quantities of heat energy and further neutrons. A moderator within the core, usually water or graphite, slows the neutrons released from fission so that they cause more fission. Control rods, made of neutron-absorbing material such as boron, are inserted or withdrawn from the core to control the rate of reaction. A liquid or gas is circulated through the core to transfer the heat produced to the steam generator from which high pressure steam is used to drive a turbine and generate electricity.



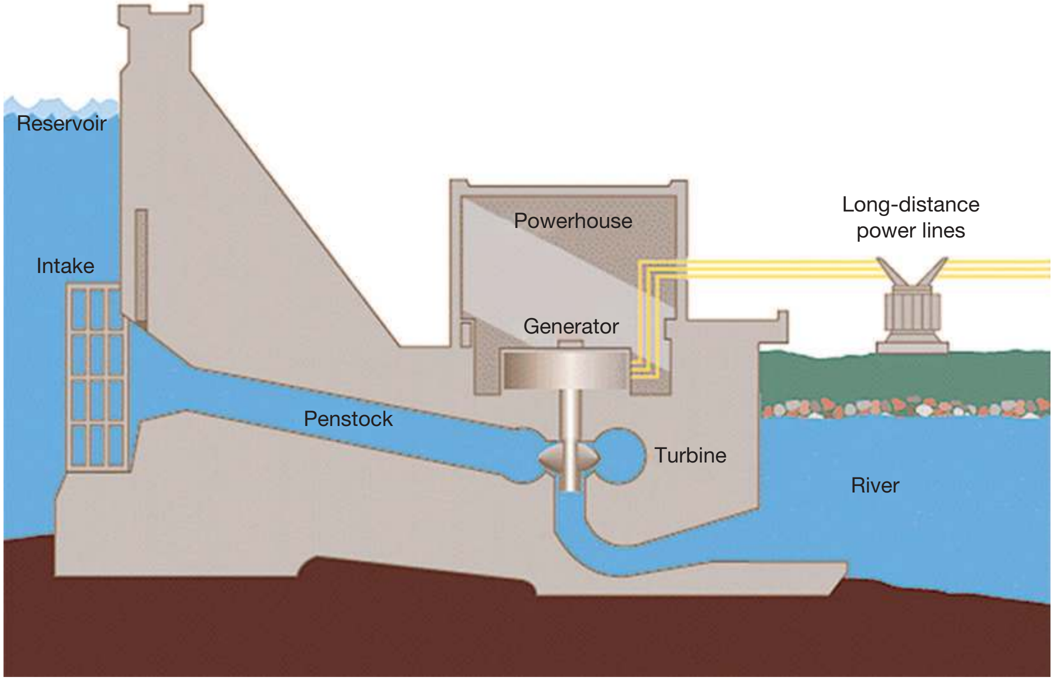
While Australia is yet to utilise this technology for generating electricity, there are 439 nuclear reactors operating in 30 countries that account for around 17 per cent of world electricity production. Nuclear power accounts for a large proportion of the electricity supply in many parts of Europe, Japan and the USA.

Hydroelectricity

A small proportion of Australia's electricity is generated by hydroelectric power plants, a renewable source of energy. As water stored in a dam at high elevation falls through pipes, it gains kinetic energy. This kinetic energy is used to turn turbines that generate electricity. This does not involve combustion of a fossil fuel and so does not generate greenhouse gases. A disadvantage of hydroelectricity is that it involves damming river systems and thus alters ecosystems and they also require a large amount of concrete during their construction, which results in an initial contribution to carbon dioxide emissions.

FIGURE 10.34 The Tumut Hydroelectric Power Station (part of the Snowy Mountains Scheme), NSW

FIGURE 10.35 Turbines in a hydroelectric power plant are driven by the kinetic energy of water.



Resources

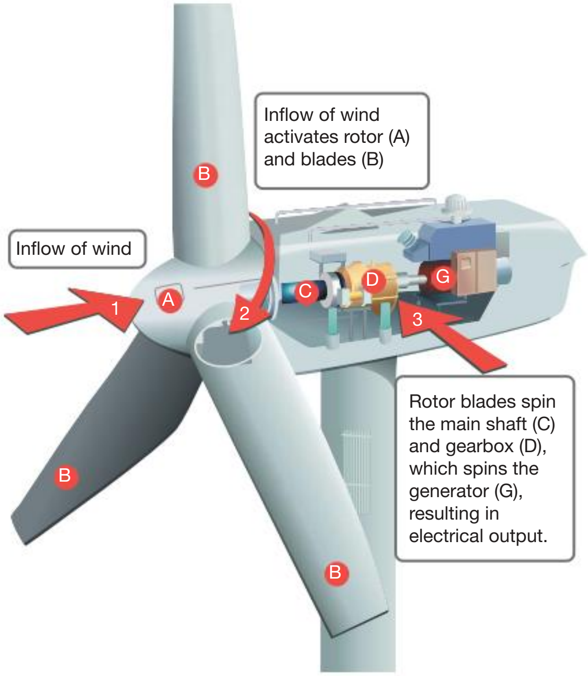
Video eLessons Hydroelectricity (eles-2793)

Wind energy

eles-2794 Wind 'farms' dotted with wind turbines can be found in many countries throughout the world, including Australia. There are currently in Australia 94 operational wind farms, with a combined capacity of approximately 9000 megawatts. In comparison, Australia's largest coal-fired power station, Eraring Power Station in New South Wales, has a capacity of approximately 2900 megawatts. Several wind energy projects have been commissioned in Australia, with the objective of powering nearly 2.2 million Australian homes annually in the coming years.

FIGURE 10.36 A row of wind turbines in Albany, Western Australia

FIGURE 10.37 How a wind turbine works



Resources

Weblink TED-Ed: How do wind turbines work?

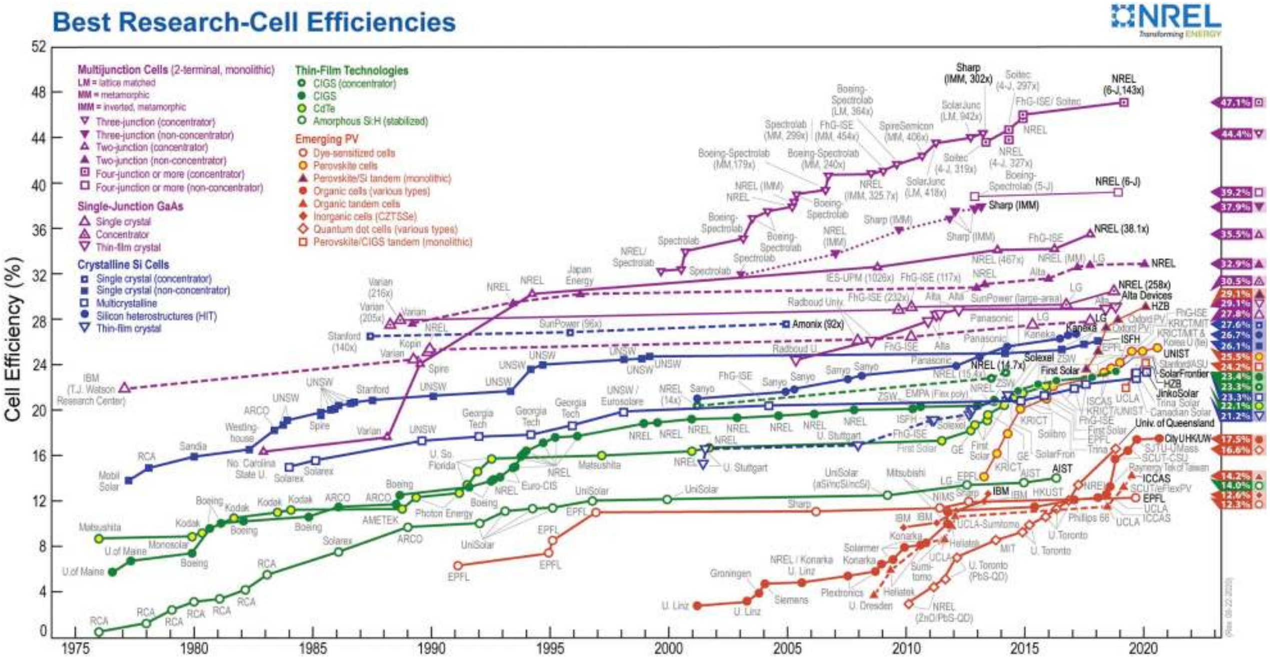
Solar energy

eles-2795 Electricity can be generated by solar energy in two different ways. Photovoltaic cells, often called solar cells, like those on the house in figure 10.38, consist of silicon wafers, with impurities of other elements added like boron and phosphorus. When sunlight falls on the cells, electrons are emitted from the wafers creating an electric current. The most advanced solar cells convert over 40 per cent of incident solar radiation to electrical energy. Scientists and engineers worldwide are endeavouring to develop more efficient photovoltaic cells.

Another solar technology, solar thermal power stations, uses arrays of curved mirrors to reflect sunlight onto tubes filled with oil. The hot oil is used to heat water to form steam which drives turbines just like those in coal-fired power stations.

FIGURE 10.38 Six to eight solar roof panels generate approximately 2300 KWh of electricity per year.

FIGURE 10.39 Competition between research institutions worldwide has led to new breakthroughs in photovoltaic technology and has resulted in greatly increased efficiency in the more advanced solar cells.



Biomass

Biomass is an energy source that involves burning waste vegetation or burning methane, the biogas produced by the breakdown of organic matter to drive small generators. In Australia biomass accounts for 15 per cent of the electricity generated from renewable sources. In Queensland and northern New South Wales the waste vegetation from sugar production is used in commercial power generation. Small amounts of energy are also produced by burning wood waste at some timber mills.

Methane-powered generators at rubbish tips such as Woodlawn near Goulburn have taken in over 2.2 million tonnes of waste from the Sydney metropolitan area and Goulburn surrounds, producing up to 3000 KWh of green electricity.

FIGURE 10.40 Woodlawn waste complex and its biogas generator. Woodlawn is a worked out copper, lead and zinc mine and as a landfill site has capacity for 70 years of Sydney's waste.

Resources

Video eLessons Biomass generator system (eles-2796)

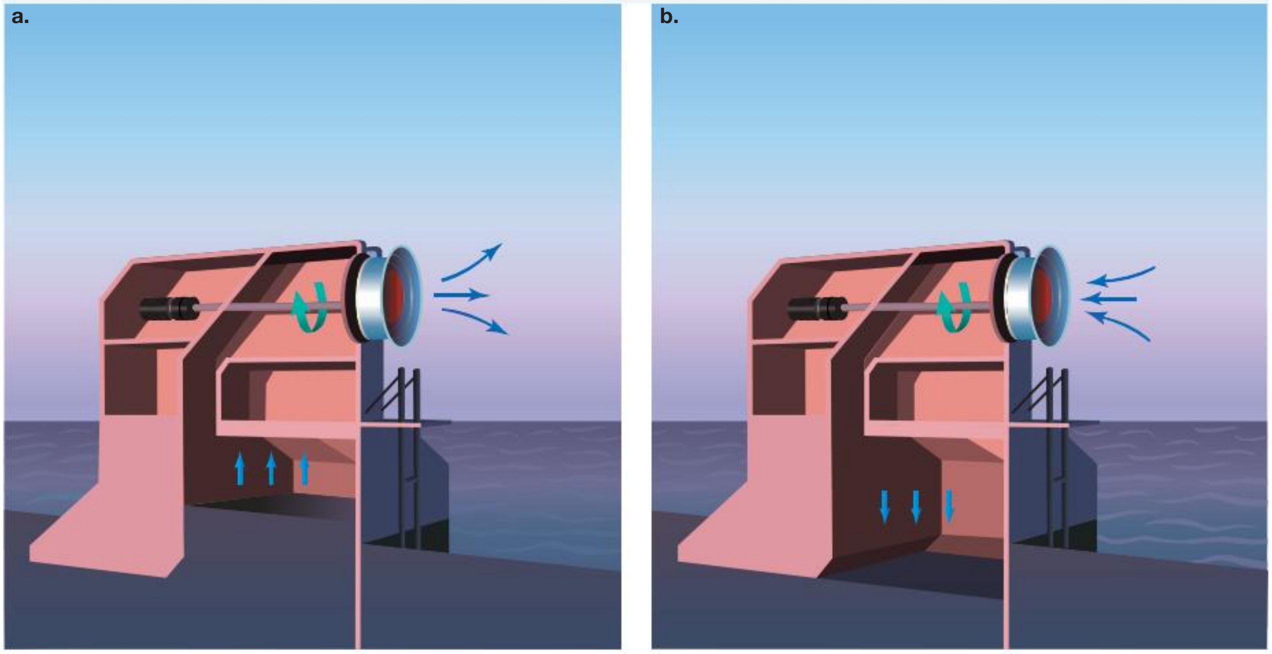
Ocean energy

Electricity can be generated using a range of ocean energy sources including tides, waves, marine currents, thermal layering and salt gradients. Only two of these sources are being investigated for development in Australia — tides and waves.

Tidal power stations harness energy from the rise and fall of tides and are currently being used in France, Russia and China. Turbines with reversible blades are placed at the entrance to a bay in areas with extremely high and low tides. Water moving in and out of the bay turns the turbines to generate electricity. A tidal range of at least 5 m is considered necessary for large-scale installations. Several areas were identified as suitable in the Kimberley region on the northwest coast of Western Australia.

Wave energy systems do not make use of waves as such, but rather the swell that occurs in deeper water or can be captured by coastal installations. Wave energy, for example, is being used to generate electricity in Norway. The waves flow into a narrow channel on the coast, where they are funnelled towards turbines. CSIRO studies show that waves off Tasmania's west coast have three times as much energy as those in Norway. One wave energy technology is being trialled off the coast of South Australia.

FIGURE 10.41 Electricity generation using wave energy has been developed and constructed in Port Macdonnell off the coast of South Australia. In this system, as **a.** waves rise and **b.** fall within a water column, it acts like a piston, driving a column of air ahead of it and through the turbine. The plant generates 1000 kilowatts of electrical power and was the first of its kind in the world.



Resources

Video eLessons Tidal power (eles-2797)

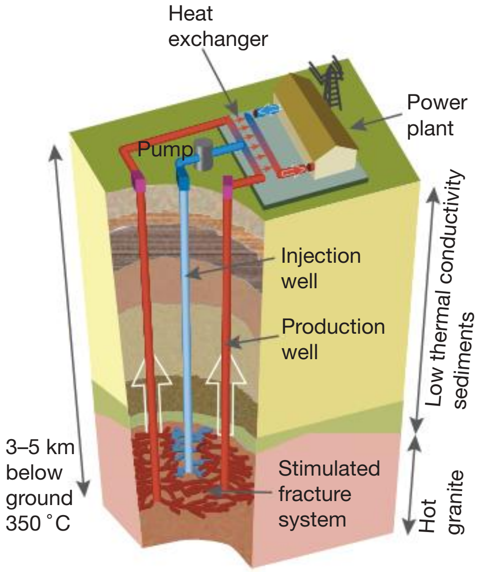
Geothermal energy

Heat energy trapped within the Earth's crust can be used to turn water into steam and drive turbines in Z power stations. Volcanically active regions of New Zealand have been tapped as a source of geothermal energy for electricity generation since the late 1950s and currently provide almost 20 per cent of New Zealand's total electricity generation.

Hot fractured rock (HFR), normally granite, can be found at temperatures of over 250 °C at depths of 3 to 5 km. This represents an enormous energy resource that can be used to generate high-pressure steam to drive turbines in electricity generation. Preliminary work by Geoscience Australia suggests a potential HFR resource equivalent to 20 000 years of Australia's energy use at 2005 levels.

To develop this resource, boreholes need to be drilled into the HFR to allow the injection of water, which passes through fractures in the rock and returns to the surface as steam. Success primarily depends on the ability to drill deep into hot hard rock. Current drilling technology limits geothermal extraction to 5 km — at this depth sufficiently high temperatures to make the process economically feasible occur only in 'hot spots' of above average temperature. Future development of drilling and extraction technologies is expected to expand the available geothermal resources.

FIGURE 10.42 Geothermal energy from hot rocks involves circulating water via boreholes. The water returns to the surface super-heated then passes through a heat exchanger. Steam produced by the heat exchanger is used to generate electricity in a conventional steam turbine.



elog-2375

INVESTIGATION 10.9

Solar cells

Aim

To investigate the performance of a solar cell under different lighting conditions

Materials

- a solar cell
- a milli-ammeter or milli-voltmeter
- wire leads

Method

1. Investigate the performance of the solar cell under different light conditions. You may like to try artificial lighting in the classroom, a dim area within the room, bright sunlight and outdoor shade.

Results

Record the current or voltage produced in each condition.

Discussion

1. Under which conditions was the greatest current/voltage produced?
2. Under which conditions was the least current/voltage produced?
3. Bright artificial light creates a similar current and voltage as bright sunlight. Do you agree? Explain why.

Conclusion

What can you conclude about the effect of light on the current/voltage produced by a solar cell?

10.6.3 Comparing efficiencies of electricity generation

Different power plants have different levels of efficiency when it comes to generating energy. When we burn fuel to generate electricity, a significant amount of the *input* energy is lost, mainly in the form of heat.

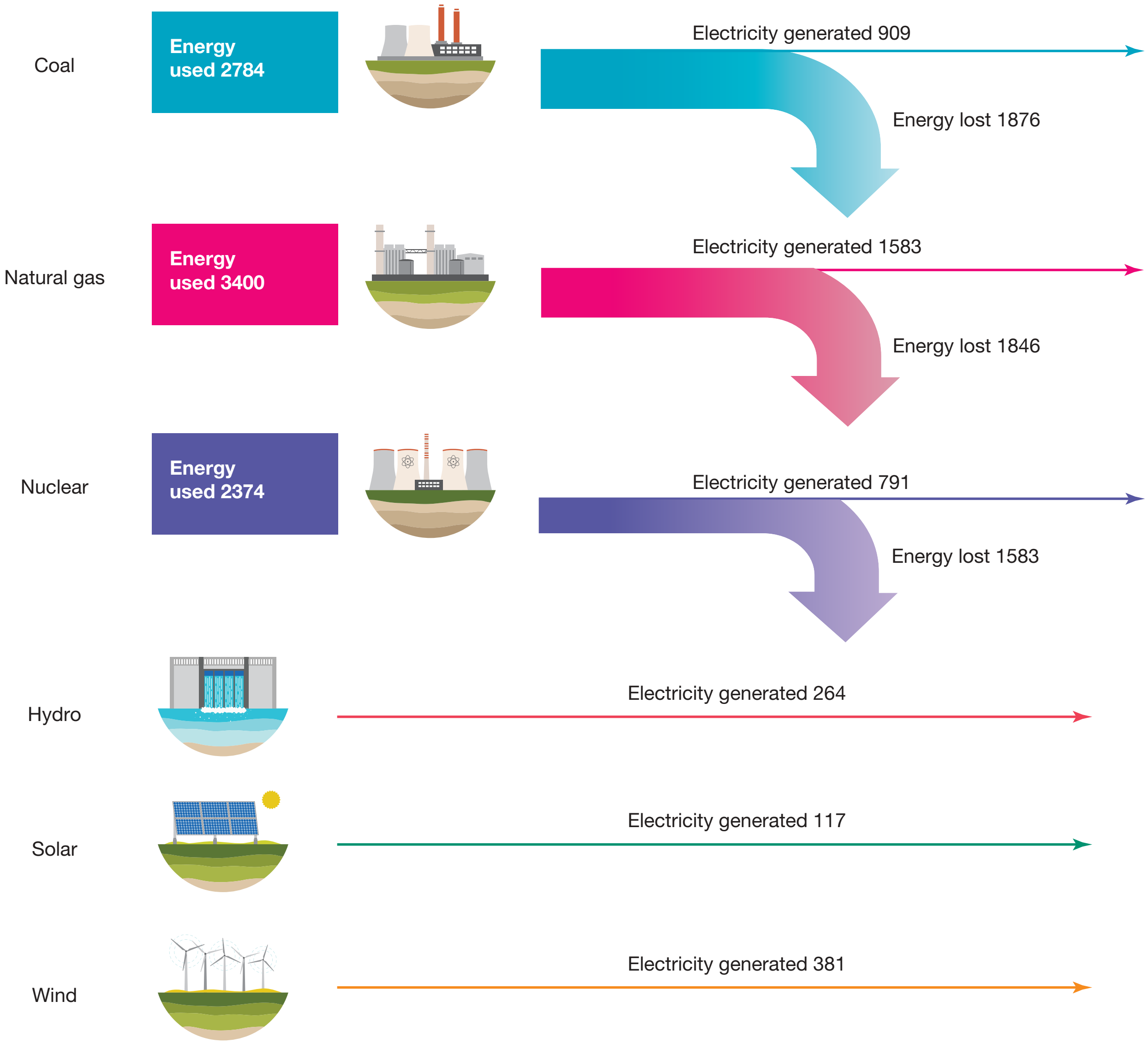
Typically, fossil fuel plants operate with an efficiency range of approximately 32% to 40%. This means that around 60% to 68% of the energy is wasted as heat.

- Coal-fired power plants have an efficiency that can range from 32% to 42%. This depends on the temperature and pressure of the steam used in the plant.
- Natural gas-fired power plants have an efficiency of 32% to 38% when they operate in a simple cycle mode. However, when they operate in a combined cycle mode using advanced technology, they can achieve an efficiency of 60%.

Typical nuclear power plants achieve efficiencies around 33–37%, which is similar to the efficiencies of fossil-fuelled power plants. However, higher temperatures and newer designs have the potential to achieve efficiencies exceeding 45%.

When considering renewable energies, there is no energy ‘wasted’ from the input and burning of fossil fuels and so are often measured, instead, by energy *output*.

FIGURE 10.43 Comparison of electricity generation in terms of energy input, loss and output



Hydro, solar and wind are all efficient forms of electricity generation, although their efficiencies can vary.

- Hydroelectric turbines, which harnesses the energy of flowing water, are known for their efficiency and have been widely used for electricity generation. A typical efficiency for hydro is 90% or more. This means that a large percentage of the energy available in the water can be successfully converted into electrical power.
- Solar power, specifically photovoltaic (PV) systems have seen significant improvements in efficiency over the years. The efficiency of solar panels refers to how well they can convert sunlight into electricity. Currently, commercial solar panels have an average efficiency of around 15% to 22%. More advanced solar technologies have the potential to achieve even higher efficiencies, reaching up to 40% or more in some cases. Ongoing research and development aim to further improve solar panel efficiency.
- Wind turbines harness the energy of the wind to generate electricity. The efficiency of wind turbines depends on factors such as wind speed and turbine design. On average, modern wind turbines have an overall conversion efficiency ranging from 30% to 45%.

While these renewable energy sources have high efficiencies in terms of energy conversion, it is worth noting that their actual electricity generation is influenced by factors like availability of sunlight, wind speed, and water flow. Therefore, their output can vary depending on the specific location and environmental conditions.

10.8 Activities

learnon

10.8 Quick quiz on

10.8 Exercise

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 4, 5	2, 7, 9	3, 6, 8, 10

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS ▶

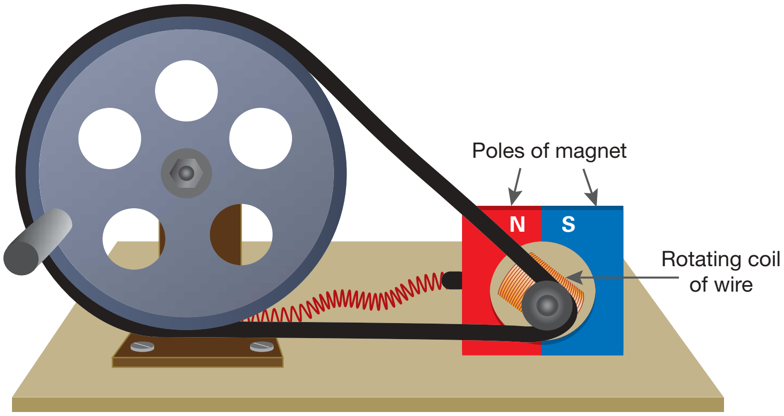
Remember and understand

1. MC What is the difference between renewable and non-renewable energy resources?
   A. Renewable resources can be replenished while non-renewable resources cannot.
   B. Renewable resources are more expensive than non-renewable resources.
   C. Renewable resources are less reliable than non-renewable resources.
   D. Renewable resources release more greenhouse gases than non-renewable resources.
2. MC What is the main problem with generating electricity from fossil fuels?
   A. They release greenhouse gases into the atmosphere
   B. They are expensive
   C. They are difficult to find
   D. They are difficult to transport
3. Identify the role of each of the following in a nuclear reactor:
   a. moderator
   b. control rods.

Apply and analyse

4. Identify whether each of the following energy sources are renewable or non-renewable:
   a. nuclear **b.** hydro **c.** coal **d.** wind **e.** biomass **f.** solar.
5. **MC** What is the main advantage of using nuclear power for electricity generation?
   A. High efficiency
   B. Low greenhouse gas emissions
   C. Abundant fuel supply
   D. All of the above

6. How does solar power work to generate electricity?
7. Briefly describe the process of burning fossil fuels to generate electricity.
8. Identify the role of the components of the labelled generator shown.



9. What are some advantages and disadvantages of using wind as an energy resource?
10. Discuss one environmental benefit of using renewable energy sources for electricity generation.

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

LESSON
10.7 Thinking tools — Flow charts

10.7.1 Tell me

What is a flow chart?

A flow chart is a diagram that shows how a complex process can be broken down into a linear sequence of events. They are useful for breaking down processes into a series of steps, when each step depends on the step before.

A concept map is also useful for showing complex ideas, but it classifies a larger topic into smaller and smaller ideas. It explains the relationships between parts or elements with statements on the links between them.

FIGURE 10.44 A flow chart showing a sequence of events

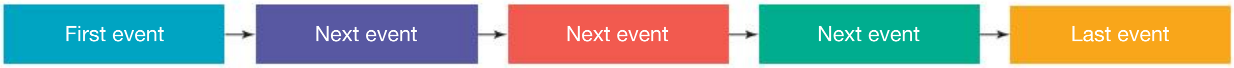
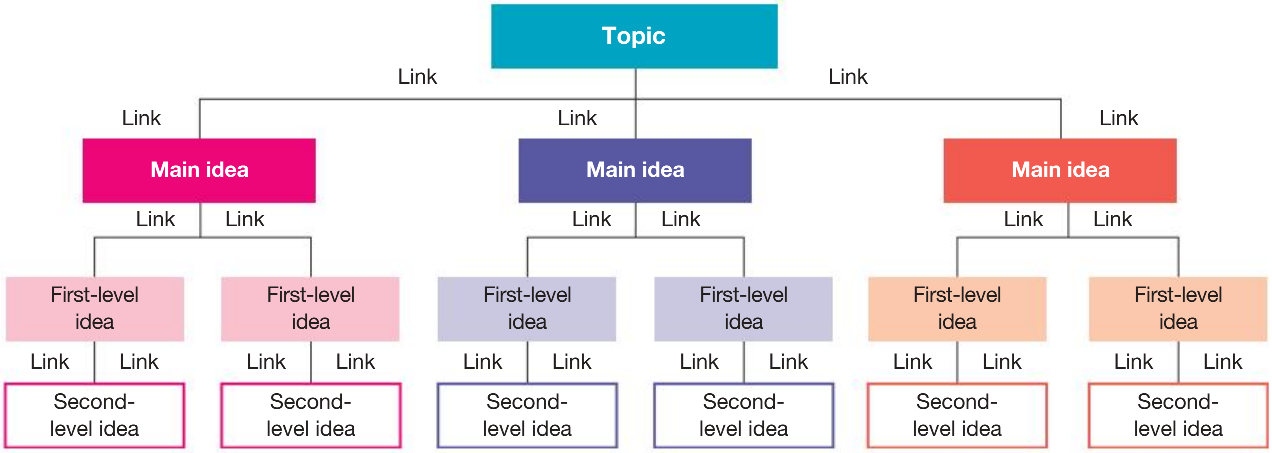


FIGURE 10.45 A concept map showing a large topic broken down into main ideas, and the relationships within each idea

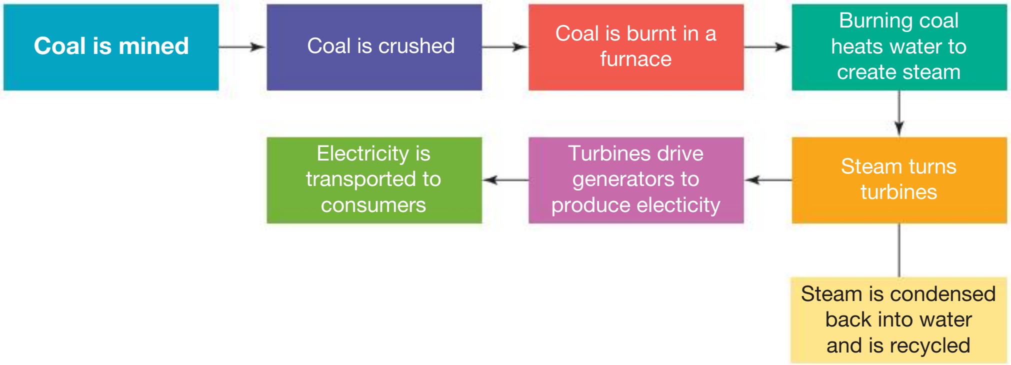


10.7.2 Show me

To create a flow chart:

1. Choose a topic or process that has a number of different parts or events. Write any ideas you may have onto small pieces of paper and arrange them from the first event through to the last. For example, you might choose to consider how electricity is produced from fossil fuels.

FIGURE 10.46 Flow chart of coal energy production

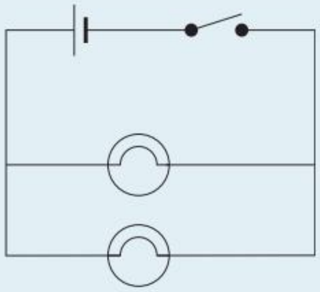


10.7.3 Let me do it

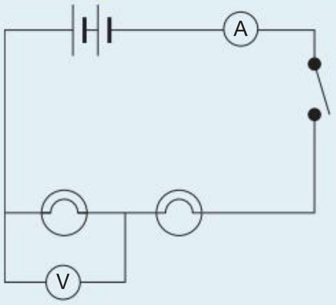
10.7 Activity

1. Create two separate flow charts that show, step by step, how to connect each of the circuits below so that the light globes glow.

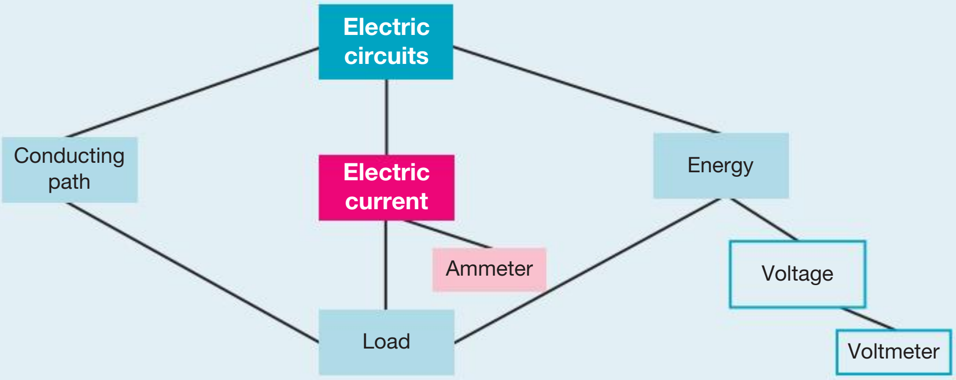
a.



b.



2. The incomplete concept map below represents some of the key ideas related to electric circuits. This concept map is just one way of representing ideas about matter and how they are linked. Copy and complete the concept map by writing suitable links between the ideas.



3. Write each of the ideas included in the concept map above and each of the terms in the box below on a small piece of paper such as a ‘sticky note’. Create a concept map of your own by arranging the ideas. Write links in light pencil at first in case you want to make changes to your arrangement.

Electric circuit ideas		
resistance	circuit diagram	filament
in parallel	switch	Ohm’s Law
in series	electrons	load
power supply	potential difference	power supply

4. Use sticky notes and A3 paper to create a concept map for the topic of household electricity. Use the ideas in the box below and add as many other ideas as you can.

Household electricity ideas		
alternating current	main switch	appliances
electric power	transformer	voltage
in parallel	fuse	safety
direct current	electrical energy	circuit breaker

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

LESSON
10.8 Project — Go-Go Gadget online shop

Scenario

We use the term technology to describe the application of science to develop devices, machines and techniques to make some aspects of our lives easier. Televisions, satellites and the internet are all pretty obvious examples of technology, but small devices such as the automatic cat-flap and the humble vegetable peeler are also forms of technology. Small or specialised pieces of technology such as these are often referred to as gadgets. Every year, patents for thousands of such gadgets are issued to inventors. Some of them, like the NavMan, are immediate successes, while others — for example, a combination shoe-polisher and toothpick — don't make it into mass production. So what happens if you need a device to do a particular job but no-one has ever made one?

This is just what you and your partners were thinking when you decided to open the Go-Go Gadget online shop. Once established, clients would browse designs for gadgets that you have already developed or ask you to design something new for them that will do the job they need done. Maybe the client wants a hamster wheel that can drive a coffee-grinder or a signalling device that will tell a cat-owner whether their cat has come inside through the cat-flap or is still outside. They just tell you what they need and you design it for them! You then ship them the design, the parts they need to assemble it and an instruction brochure.

To get the business started, you decide to take out a business loan with the bank. The bank manager is intrigued with the idea but wants some assurance that you know what you are doing before they hand over the money.

Your task

As part of your presentation to the bank, you and your business partners are to develop a design for one of the following clients.

- Taylor wants a snooping-parent device that will warn her when one of her parents is coming up the hallway that leads to her bedroom. This device will give her a silent signal so she has time to turn off her computer and open her homework books before they open the door and catch her playing computer games or surfing the net instead of working.
- Heisenberg has an office on the top floor of his house. His cat, Schrödinger, can enter the house through a cat-flap in the door downstairs. When Heisenberg is locking up the house to go out or to bed, it would save a lot of time if he could know whether the cat is already inside the house. He needs a device that is connected to the cat-flap that sends a signal to Heisenberg upstairs indicating whether the cat has come in or gone out the cat-flap.
- Felicity often works until late at night and doesn't get time to exercise her dog by taking her out for a walk. She can use her computer at work to turn on switches in her apartment, and wants a device that will allow her to exercise her dog by remote control without the dog leaving the apartment.

You will then create the following to submit to the bank in support of your loan application.

1. A brief overview (approximately 300 words) of why there is a market for the services of your online shop. To support your argument, you should include references to gadgets that have been successfully developed.
2. A brochure for the gadget you have designed that includes:
    - a diagram of your design
    - a list of parts that are included in the package sent with the brochure
    - instructions on assembly or installation of the gadget
    - a troubleshooting guide to solve problems.

on Resources

ProjectsPLUS Go-Go Gadget online shop (pro-0110)

LESSON
10.9 Review

Hey students! Now that it's time to revise this topic, go online to:

Review your results **Watch teacher-led videos** **Practise questions with immediate feedback**

Find all this and MORE in jacPLUS

Access your topic review eWorkbooks

on Resources

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-12578	ewbk-12580	ewbk-12582

10.9.1 Summary

Electrical circuits

- Electrical circuits consist of a power supply, a load and a conducting path.
- A load is an energy converter where the electrical energy carried by the electric charge is converted into useful forms of energy (for example, light, heat, sound, movement).
- Loads push back against the power supply as resistance. The greater the resistance, the less current can flow.
- The conducting path must be complete to allow electricity to flow through the circuit.
- Electric current is the rate of flow of electric charge.
- Voltage (potential difference) is the amount of electrical energy gained at the power supply or lost at the load by the electric charge as it moves through the circuit.
- Circuit diagrams are used to show all parts of a circuit and can be understood worldwide.
- In a series circuit all components are connected one after the other. If a part of the circuit is faulty, the connecting path is broken and no current will flow through the devices in the circuit.
- In a parallel circuit, each component is connected in a separate conducting path. If one part of the circuit is faulty, the other parts will still work. It allows more current from the power supply, effectively lowering the resistance. All components work at full power, which uses the power more quickly.
- Voltage is a measure of the amount of energy each electron in the circuit has.
- The electric current is a measure of the number of electrons passing through the circuit each second.
- Series circuit: The current is the same at all points in the circuit. Adding more globes increases the resistance so less current flow in the circuit, and the voltage of the supply must equal the voltage of the load — so with more components, the voltage is lowered.
- Parallel circuit: Adding more loops lowers the resistance of the circuit, so more current leaves the power supply, and the current splits at each branch and recombines when the wires reconnect. Voltage is the same across each loop.

Measuring electricity

- Ammeters measure electric current in amps (A).
- Voltmeters measure the voltage gain across the terminals of a power supply or voltage drop across parts of an electric circuit, measured in volts (V).
- Random errors are due to estimation when reading scales. They can be reduced by taking repeated readings and calculating an average.
- Systematic errors are due to incorrect use or limitations of equipment. They can be reduced by using equipment correctly and ensuring they are correctly calibrated.

Resisting the electrons!

- Electrical resistance is a measure of how difficult it is for electrons to flow through part of a circuit.
- The resistance to the flow of electric charge limits the electric current.
- Conductors have little resistance.
- Insulators have a large electrical resistance.
- Resistance (R) can be calculated by $R = \frac{V}{I}$, where V is the voltage drop in volts and I is the electric current in amperes.
- Ohm's Law states that the electric current in metallic conductors is proportional to the voltage drop across the conductor.
- Resistance can be controlled by using variable resistors (for example, changing the volume of a radio or dimmer switch on a light).

Energy efficiency

- Energy efficiency is measured by comparing input energy to useful output energy.
- Energy efficiency is increased by reducing the amount of energy needed to perform the same amount of work.
- Improving energy efficiency is important to reduce costs and greenhouse gas emissions.
- The efficiency of an appliance is defined as the ratio of the useful energy output to the total energy input.
- Energy can neither be created nor destroyed, but it can be converted from one form to another or be transferred from one object or substance to another (Law of Conservation of Energy).
- A Sankey diagram is a visualisation of energy transfers, using arrows with width proportional to the amount of energy involved.
- Energy efficiency is crucial in many sports.

Electricity generation

- Fossil-fuel stations generate power by burning fossil fuels (heat energy) to heat water to produce steam. The steam is under pressure, and drives a turbine (heat energy converted to kinetic energy). The turbine rotates coils inside huge electromagnets in a generators. The motion of the coils in the magnetic field produces a large voltage and, when connected to a load, a large electric current flows.
- Nuclear power stations and geothermal power stations also use energy to produce steam and drive turbines.
- Hydroelectric power stations use the gravitational potential energy of falling water to turn turbines (steam is not needed).
- Wave power compresses columns of air in tubes to drive small turbines.

10.9.2 Key terms

accuracy how close a measurement is to the true value

ammeter device used to measure the amount of current in a circuit. Ammeters are placed in series with other components in a circuit.

cell a single battery

chemical reaction a chemical change in which one or more new chemical substances are produced

circuit diagram diagram using symbols to show the parts of an electric circuit

components in circuits are the individual electrical devices that are connected in the circuit by conducting wires

conducting path connected series of materials along which an electric current can flow

current electricity the flow of electrons through a region

electrical conductors materials through which electricity flows easily

electrical insulators materials which do not allow electricity to flow easily

electric charge physical property of matter that causes it to experience a force when near other electrically charged matter. Electric charge can be positive or negative.

electric current a measure of the number of electrons flowing through a circuit every second

filament coil of wire made from a metal that glows brightly when it gets hot

load device that uses electrical energy and converts it into other forms of energy

ohmic describes conductors that obey Ohm's Law

Ohm's Law states that the current in a conductor is proportional to the voltage drop across the conductor

parallax error error caused by reading a scale at an angle rather than placing it directly in front of the eye

parallel circuit a circuit that has more than one path for electricity to flow through. If one of the paths has a break in it, the others will still work.
potential difference also known as voltage, is the change in the amount of energy stored in electrons as they move through a component or a circuit
power supply a device that can provide an electric current
precision how close multiple measurements of the same investigation are to each other
random errors an error that occurs due to estimation when reading scales, or when the quantity being measured changes randomly
resistance measure of the electrical energy required for an electric current to pass through an object, measured in ohms (Ω)
series a formation of electricity-generating or using devices whereby the electricity passes from one device to the next in a single conducting loop, one after the other
series circuit a circuit with the components joined one after the other in a single continuous loop
static electricity a build-up of charge in one place
switch device that opens and closes the conducting path through which a current flows
systematic errors errors that are consistently high or low due to the incorrect use or limitations of equipment
transducer a device that converts energy from one form into another form
voltage the amount of energy that is pushing electrons around a circuit, per coulomb of charge that flows between two points
voltmeter device used to measure the voltage across a component in a circuit. Voltmeters are placed in parallel with the components.

on Resources

eWorkbooks	Study checklist (ewbk-12584) Reflection (ewbk-12577) Literacy builder (ewbk-12585) Crossword (ewbk-12587) Word search (ewbk-12589)
Solutions	Topic 10 Solutions (sol-1151)
Practical investigation eLogbook	Topic 10 Practical investigation eLogbook (elog-2355)
Digital document	Key terms glossary (doc-40152)

10.9 Activities

learnon

10.9 Review questions

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 2, 5, 7, 9, 10	3, 4, 8, 11, 12, 16	6, 13, 14, 15, 17

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

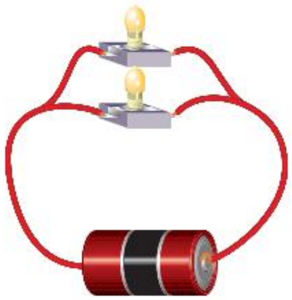
Remember and understand

1. Match each term with its correct description.

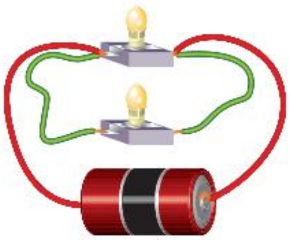
Term	Description
Static electricity	A material that allows current or heat to flow through it
Electron	Positively charged particle in the nucleus of an atom
Proton	The build-up of charge on an object
Current	A material that does not allow current or heat to flow through it easily
Voltage	Particle in an atom with a negative charge
Conductor	A path that has no breaks in it
Closed circuit	The energy supplied to move electrons around a closed circuit
Insulator	The flow of electrons around a closed circuit

2. Identify each of the following circuits as a parallel circuit or series circuit.

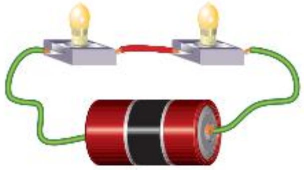
a.



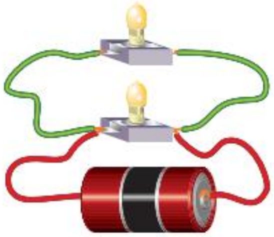
b.



c.



d.

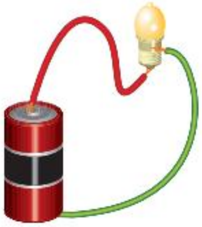


3. **MC** In which one or more of the following arrangements will the globe light up?

A.

B.

C.



D.

4. **MC** Which physical quantity is a measure of a change in energy?
   A. Voltage
   B. Current
   C. Resistance
   D. Power
5. Complete the table by writing down the missing quantity, unit or abbreviation.

TABLE Electrical quantities

Quantity	Unit	Abbreviation
Voltage	volt	
Electric current		A
	ohm	

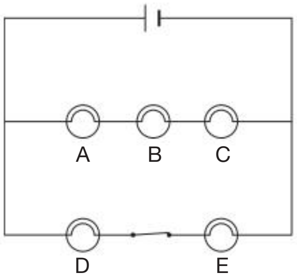
6. List three changes that can be made to an electric generator to increase the size of the electric current it produces.

Apply and analyse

7. Use symbols to draw a circuit containing a light globe in series with an ammeter, a battery and a switch.
8. Draw a circuit diagram that shows how a voltmeter and ammeter are used to measure the voltage across and current flowing through a single light globe connected to a 6-volt power supply. Label the positive and negative terminals of the power supply and each meter with + and – symbols.
9. What is the electric current being shown on the ammeter if the positive lead is placed in the:
   a. 500 mA terminal
   b. 5 A terminal?
10. How does increasing the resistance of a variable resistor in series with a power supply and a lamp affect the:
    a. electric current in the lamp
    b. voltage across the variable resistor
    c. voltage across the lamp?

11. Microchips nowadays are used in a wide variety of common electronic devices, such as smartphones or cars. Compile a list of 10 electronic devices that you use daily. For each item, briefly state whether you believe it contains microchips.

Questions 12 and 13 refer to the circuit diagram shown. The light globes, labelled A to E, are identical to each other.



12. **a.** Which of the light globes are connected:
  i. in series with globe A
  ii. in parallel with globe A?
b. If the voltage across globe C was measured to be 4 volts, what is the voltage across:
  i. globe A
  ii. the terminals of the power supply
  iii. globe E?
c. If the electric current flowing through globe B was measured to be 200 mA and the electric current flowing through globe D was measured to be 300 mA, what is the electric current flowing through:
  i. globe A
  ii. globe E
  iii. the power supply?

13. **a.** If the filament in globe B was to break, which of the light globes would remain glowing?
b. If the switch in the circuit was opened, which light globes would stop glowing?
c. How could you make all of the light globes stop glowing without opening the switch or turning off the power supply?
d. The voltage across globe C is measured to be 4 volts and the current flowing through it is 200 mA.
  i. What is the electric current flowing through globe C, in amperes?
  ii. What is the resistance (in ohms) of globe C while this current is flowing?

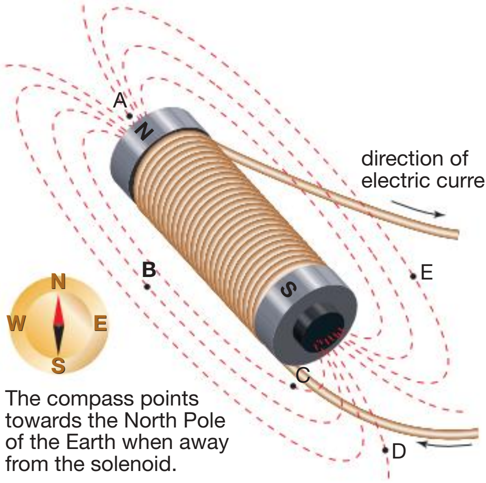
14. Many electrical devices contain electromagnets.
a. Is an electromagnet a permanent or temporary magnet? Explain your answer.
b. Which part of an electromagnet is the solenoid?
c. What is the role of the iron core in an electromagnet?

15. Imagine that you were given a 3-metre length of wire, an A4 sheet of thin card and a bar magnet.
a. Explain how you could produce an electric current.
b. What piece of equipment would you need to demonstrate that an electric current was produced?

Evaluate and create

16. **SIS** In what way does a conductor that obeys Ohm's Law behave differently from one that doesn't? Sketch a graph to support your answer.

17. Consider the figure.
a. Draw arrows at each of the points A, B, C, D and E to show the direction that the compass needle would point if the compass was placed at each of the points when an electric current flows in the solenoid as shown.
b. At which of the points A, B, C, D or E is the magnetic field the strongest?



The compass points towards the North Pole of the Earth when away from the solenoid.

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

Online 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-12563)
- Student learning matrix (ewbk-12562)
- Starter activity (ewbk-12565)

Practical investigation eLogbook

- Topic 10 Practical investigation eLogbook (elog-2355)

Solutions

- Topic 10 Solutions (sol-1151)

Video eLesson

- Building electronic circuit boards (eles-4152)

10.2 Electrical circuits

eWorkbooks

- Conductors and insulators (ewbk-12567)
- Simple circuits (ewbk-12569)
- Series and parallel circuits (ewbk-12571)

Practical investigation eLogbooks

- Investigation 10.1: Series and parallel circuits (elog-2357)
- Investigation 10.2: Switched-on circuits (elog-2359)

Video eLessons

- The hydraulic model of current (eles-0029)
- Parallel circuits (eles-2672)

Interactivity

- Voltage rises and falls in a simple circuit (int-5776)

10.3 Measuring electricity

eWorkbook

- Ammeters and voltmeters (ewbk-12573)

Practical investigation eLogbook

- Investigation 10.3: Probing a simple circuit (elog-2361)

10.4 Resisting the electrons!

eWorkbook

- Ohm's Law (ewkb-12573)

Practical investigation eLogbooks

- Investigation 10.4: Changing resistance (elog-2361)

Video eLesson

- Four different resistors (eles-2674)

10.5 Energy efficiency

Practical investigation eLogbooks

- Investigation 10.5: Comparing electrical appliances (elog-2365)
- Investigation 10.6: Light globe efficiency (elog-2367)
- Investigation 10.7: Investigating energy efficiency (elog-2369)

Teacher-led video

- Investigation 10.6: Light globe efficiency (tlvd-10803)

10.6 Electricity generation

Practical investigation eLogbooks

- Investigation 10.8: Electricity generation (elog-2374)
- Investigation 10.9: Solar cells (elog-2375)

Video eLessons

- Hydroelectricity (eles-2793)
- Wind power (eles-2794)
- Solar thermal array (eles-2795)
- Biomass generator system (eles-2795)
- Tidal power (eles-2797)

Interactivity

- Nuclear power (int-7129)

Weblink

- The Australian Academy of Science

10.8 Project — Go-Go Gadget online shop

ProjectsPLUS

- Go-Go Gadget online shop (pro-0110)

10.9 Review

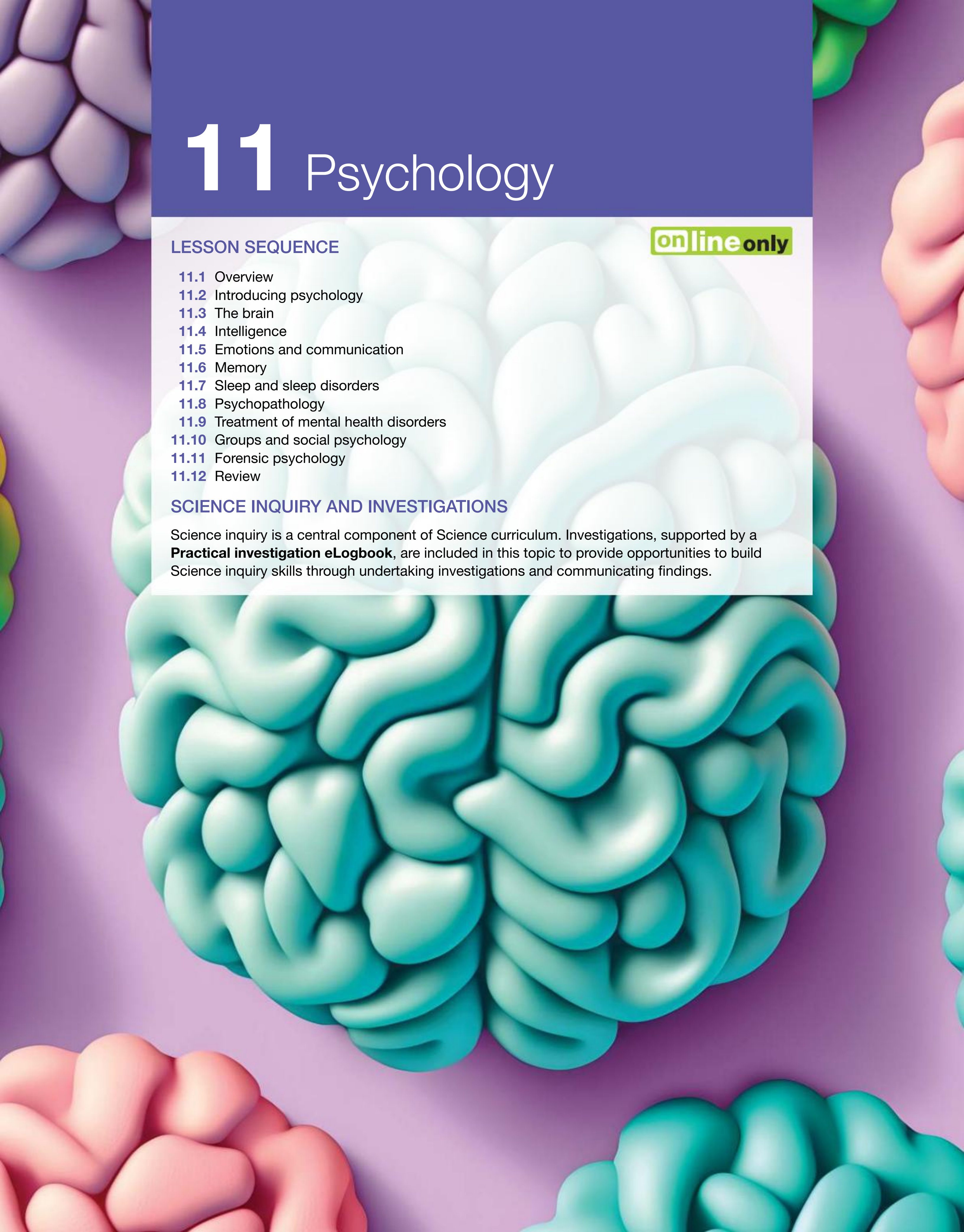
eWorkbooks

- Topic review Level 1 (ewbk-12578)
- Topic review Level 2 (ewbk-12580)
- Topic review Level 3 (ewbk-12582)
- Study checklist (ewbk-12584)
- Reflection (ewbk-12577)
- Literacy builder (ewbk-12585)
- Crossword (ewbk-12587)
- Word search (ewbk-12589)

Digital document

- Key terms glossary (doc-40152)

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



11 Psychology

online only

LESSON SEQUENCE

SCIENCE INQUIRY AND INVESTIGATIONS

Science inquiry is a central component of Science curriculum. Investigations, supported by a **Practical investigation eLogbook**, are included in this topic to provide opportunities to build Science inquiry skills through undertaking investigations and communicating findings.

LESSON
11.1 Overview

Hey students! Bring these pages to life online

Watch videos

Engage with interactivities

Answer questions and check results

Find all this and MORE in jacPLUS

11.1.1 Introduction

Humans need to react to changes both within and outside their bodies. The brain is the control centre of the human body. It allows us to sense and perceive, interpret and react to our environment — every second of every day. Our brain controls how we think, feel and behave. Without it we would be unable to solve a difficult maths problem, remember our last birthday or sing our favourite song. The branch of science that investigates how our brain influences our thoughts, feelings and behaviours is called psychology. Psychology is a growing science, investigating interesting ideas such as why serial killers kill, why we compete against each other and why stress makes us sick.

FIGURE 11.1 Psychology is the study of the brain — thoughts, feelings and behaviours.

11.1.2 Think about psychology

1. If we no longer had a brain, how would we be impacted? What could we still manage to do?
2. What areas of psychology have you already heard about?
3. Reflect on how you have seen mental health and mental health disorders depicted in the media. What movies or shows have you seen that include references to mental health and mental health disorders?
4. How does the brain control our behaviour?

11.1.3 Science inquiry

Designing experiments in psychology

Like other branches of science, psychology relies on the scientific method for design of experiments. Using the scientific method allows researchers to conduct studies in a consistent, structured manner that allows them to draw appropriate conclusions from the data collected. However, as psychology is the study of human thoughts, feelings and behaviours, the experiments in psychology often rely on human volunteers.

The participants in a research study are referred to as a **sample**. A sample is a group of individuals selected from a larger group that has been chosen to be studied (known as a **population**). A sample is a critical element in psychological research. It should be representative of the population of interest and of sufficient size to ensure that accurate conclusions and generalisations are able to be drawn from the research.

sample a smaller group of individuals selected from a larger group that has been chosen to be studied

population the entire group of people who are being studied from which a sample is selected

experimental group a group of participants within an experiment who are exposed to the variable being tested

control group a group of participants within an experiment who are not exposed to the variable being tested, and are used to compare to the experimental group

Experimental groups and control groups

In an experiment, participants allocated to the **experimental group** are exposed to the *variable* being tested — known as the *independent variable*. The experimental group is often also referred to as the *treatment group*.

Participants allocated to the **control group** *are not* exposed to the variable being tested (the independent variable). However, they are treated exactly the same way as the experimental group in all other aspects of the experiment. These participants are used as a means of *comparison* with the experimental group.

Experiment to test influence of energy drink on performance at the gym

Researchers wanted to test the effects of a new energy drink, *Fast Emu*, on people's energy levels at a gym. Researchers hypothesised that people who drank *Fast Emu* before their fitness session would perform better throughout the session compared to those people who drank water only.

1. Identify the independent variable and the dependant variable for this research topic.
   To minimise participant-related variables (individual differences between people), researchers chose to use a matched-participants design for this experiment, where individuals are 'matched' on personal characteristics, skills or abilities that relate to the research.
2. Suggest a sample group for the experiment. Remember the sample group should be representative of the population of interest and of sufficient size to ensure that accurate conclusions and generalisations are able to be drawn from the research.
3. Suggest a research hypothesis.
4. Suggest an experiment to test the hypothesis, identifying the method for the control group and the experimental group.

FIGURE 11.2 Can protein shakes or energy drinks be proven to be effective?

on Resources

eWorkbooks Topic 11 eWorkbook (ewbk-12682)
Student learning matrix (ewbk-12684)
Starter activity (ewbk-12685)

Solutions Topic 11 Solutions (sol-1153)

LESSON
11.2 Introducing psychology

LEARNING INTENTION

At the end of this lesson you will be able to recognise that psychology is the study of the mind, through thoughts, feelings and behaviours, and be able to provide examples of some different types of psychologists.

11.2.1 Psychology is a science

The term **psychology** originated from two Greek terms — *psyche*, which means mind, and *logos*, which means study or knowledge. Therefore, psychology can be explained as the study of the mind. This definition has broadened over time, and the most currently accepted definition of psychology is *the systematic study of thoughts, feelings and behaviours*.

FIGURE 11.3 Differentiating between thoughts, feelings and behaviours

Thoughts	Feelings	Behaviours
A thought (mental activity or cognition) is like a person inside your head talking to you. A dog walking down the street may make you think 'That dog looks sad. I wonder if he is lost.'	A feeling is the emotion that you have at any one time. Examples of feelings include sadness, anger, and happiness. Another name for feelings is affect.	A behaviour is any observable action. This means anything you do. An example of a behaviour is jumping up and down or patting a dog.

Psychology is a science. This means that everything we know about the mind, thoughts, feelings and behaviours comes from research. Research in psychology is conducted in a systematic and planned way, known as the **scientific method**. Information is collected either by directly observing a person or animal's behaviour, or by conducting an experiment. This is similar to other sciences, such as biology or chemistry.

There are also many other ways of explaining human behaviour that are not based on science. Some of these approaches claim to be scientific, but are not. Some have scientific sounding names such as astrology, numerology and palmistry. These types of non-sciences are often referred to as **pseudosciences** (*pseudo* meaning fake).

psychology the systematic studies of thoughts, feelings and behaviours

scientific method a systematic and logical process of investigation to test hypotheses and answer questions based on data or observations

pseudosciences fields that are not sciences, despite having scientific sounding names or claiming to be scientific

11.2.2 Working as a psychologist

There are many areas in which **psychologists** can work; however, most psychologists specialise in one or two specific areas. These specialty areas include sport, forensics, health, counselling, clinical, neuropsychology, academic, educational and organisational psychology.

Sport psychologists

int-7051

- Help professional athletes develop psychological skills to positively influence their athletic performance and physical activity (for example, goal setting, confidence, imagery)
- Help athletes psychologically deal with the demands of competitive sport and increase motivation
- Aassist athletes to recover from injuries and to continue practising in off-peak periods

FIGURE 11.4 Sport psychologists support athletes during training and recovery.

Forensic psychologists

- Psychological assessment of criminals
- Determining diminished responsibility and insanity
- Counselling victims and eye witnesses
- **Criminal profiling**
- Researching jury behaviour
- Researching memory; for example, understanding how reliable a witness' account may be in court
- Understanding jury behaviour including potential bias by outside information or their own perceptions

Clinical psychologists

- Assessment, diagnosis and treatment of severe and non-severe mental health disorders and psychological problems
- Integrate science, theory, and clinical knowledge in understanding, preventing, and relieving psychologically-based distress or dysfunction
- Promote wellbeing and personal development

FIGURE 11.5 Neuropsychologist studying MRI (magnetic resonance imaging) scans of dementia patients' brains

Counselling psychologists

- Counselling less severe forms of psychological distress such as relationship issues, self-esteem struggles, conflicts, problems with substance abuse, career issues
- Evaluate their patients' situations, problems and issues and offer advice or coping strategies

Neuropsychologists

- Researching how the brain and nervous system influence a person's cognition and behaviours
- Study how injuries or illnesses to the brain affect cognitive functions and behaviours.
- Rehabilitation of brain injuries (due to traffic accidents and strokes)
- Illness rehabilitation and research (due to epilepsy and dementia)

psychologists an expert or specialist in psychology

criminal profiling a profile detailing the physical and behavioural traits of a criminal that is used by detectives and police

Organisational psychologists

- Work within industries and companies to recruit and select the most appropriate people for a position using psychological testing and behavioural interviewing
- Develop learning and training tools for individuals, teams or the entire organisation
- Coaching, mentoring and career development to improve and manage workplace performance
- Assisting in team building, effective management and leadership strategies in the workplace
- Improving productivity and morale

FIGURE 11.6 Organisational psychologists work with different workplaces and companies to assist with recruitment, team dynamics, productivity and improving morale.

Health psychologists

- Research and health promotion
- Work with community members and professionals by developing educational and behavioural programs that positively influence health and wellbeing
- Estimate the distribution of disease and design public health programs
- Implement public health programs and counselling that lead people to make behavioural changes (eating disorders, exercise, substance abuse, addiction, gambling, injury/cancer prevention such as 'SunSmart')

Academic psychologists

- Working in universities lecturing, doing research and supervising students doing research

Educational psychologists

- Assisting in learning and developmental issues such as sibling rivalry, bullying, peer pressure, parenting and psychological assessment of learning disabilities
- Work closely with students (and their parents) by investigating how they learn and process information; they help children with any developmental issues or learning disabilities that are hindering their progress
- Finding ways to improve student learning outcomes and examine how emotional issues, one's attitudes, motivation, self-regulation, behaviour and self-esteem contribute to learning.

FIGURE 11.7 Educational psychologists work closely with students and can assist them with their learning and development.

The difference between a psychologist and a psychiatrist

People who have studied psychology at university and have become experts in the study of thoughts, feelings and behaviours are called psychologists. **Psychiatrists** are also experts in these fields, but they are qualified medical doctors who can perform medical procedures and prescribe medicine to treat mental health illnesses as well.

psychiatrists medical doctors that specialise in the diagnosis and treatment of medical illness

DISCUSSION

Think about the issues facing young people today that might require a psychologist. Classify these issues as to what type of psychologist would be the most appropriate to speak to.

11.2 Activities

learnon

11.2 Quick quiz on | **11.2 Exercise**

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 2	3, 4	5

Remember and understand

1. What is *psychology*?
2. **a.** What are the differences between a psychologist and a psychiatrist?
   b. Determine whether the following roles would be undertaken by a psychologist or a psychiatrist.

TABLE Roles of a psychologist or psychiatrist

Role	Psychologist or Psychiatrist
Does not prescribe medications	
Specialises in abnormal behaviour	
Completes a medical degree	
Uses treatments such as counselling and therapy	
Uses treatments such as medications	

3. Define pseudoscience and include three examples in your answer.

Apply and analyse

4. Using the options below, match the following places of employment to a type of psychologist.

Type of psychologist	Places of employment
a. Organisational psychologist	**A.** University
b. Educational psychologist	**B.** Human resources, business enterprise, private practice
c. Sports psychologist	**C.** Clinic, hospital, health organisation such as Anticancer Council or Eating Disorders Foundation, drug rehab centres, gambling counselling centres
d. Neuropsychologist	**D.** Sport team, institute of sport, club
e. Academic psychologist	**E.** School, university, TAFE, clinic
f. Health psychologist	**F.** Hospital, TAC, accident rehabilitation clinic

Evaluate and create

5. Evaluate whether each example is a thought, feeling or behaviour:

TABLE Examples of thoughts, feelings or behaviours

Example	Thought, feeling or behaviour
a. being excited about going on holiday	
b. remembering your last birthday	
c. singing along to the radio	
d. being angry at your brother	
e. trying to work out a maths problem in your head	
f. sneezing	
g. dreaming	
h. getting confused because you can't work out a maths problem in your head.	

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

LESSON
11.3 The brain

LEARNING INTENTION

At the end of this lesson you will be able to explain the human nervous system and how the hemispheres of brain work together by sharing information through the corpus callosum.

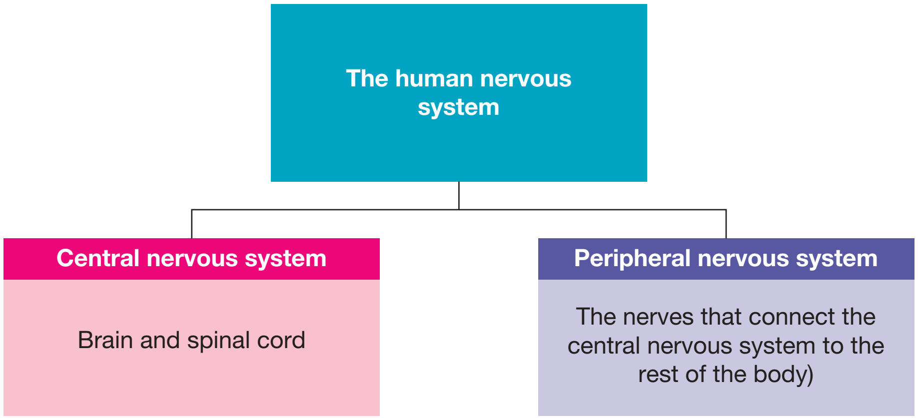
11.3.1 Nervous systems

All living animals have nervous systems. At the most basic level, simple animals such as jellyfish, have a very simple nervous system containing only a few nerve cells. They have evolved to perform activities that lead to their survival ensuring that they are able to eat, breathe, move and reproduce.

Human beings need a more advanced nervous system to be able to perform complex activities such as problem solving, creative thinking, talking, playing football, engaging in relationships, or writing computer programs.

FIGURE 11.8 Jellyfish have the simplest nervous system.

FIGURE 11.9 Humans have an advanced nervous system.



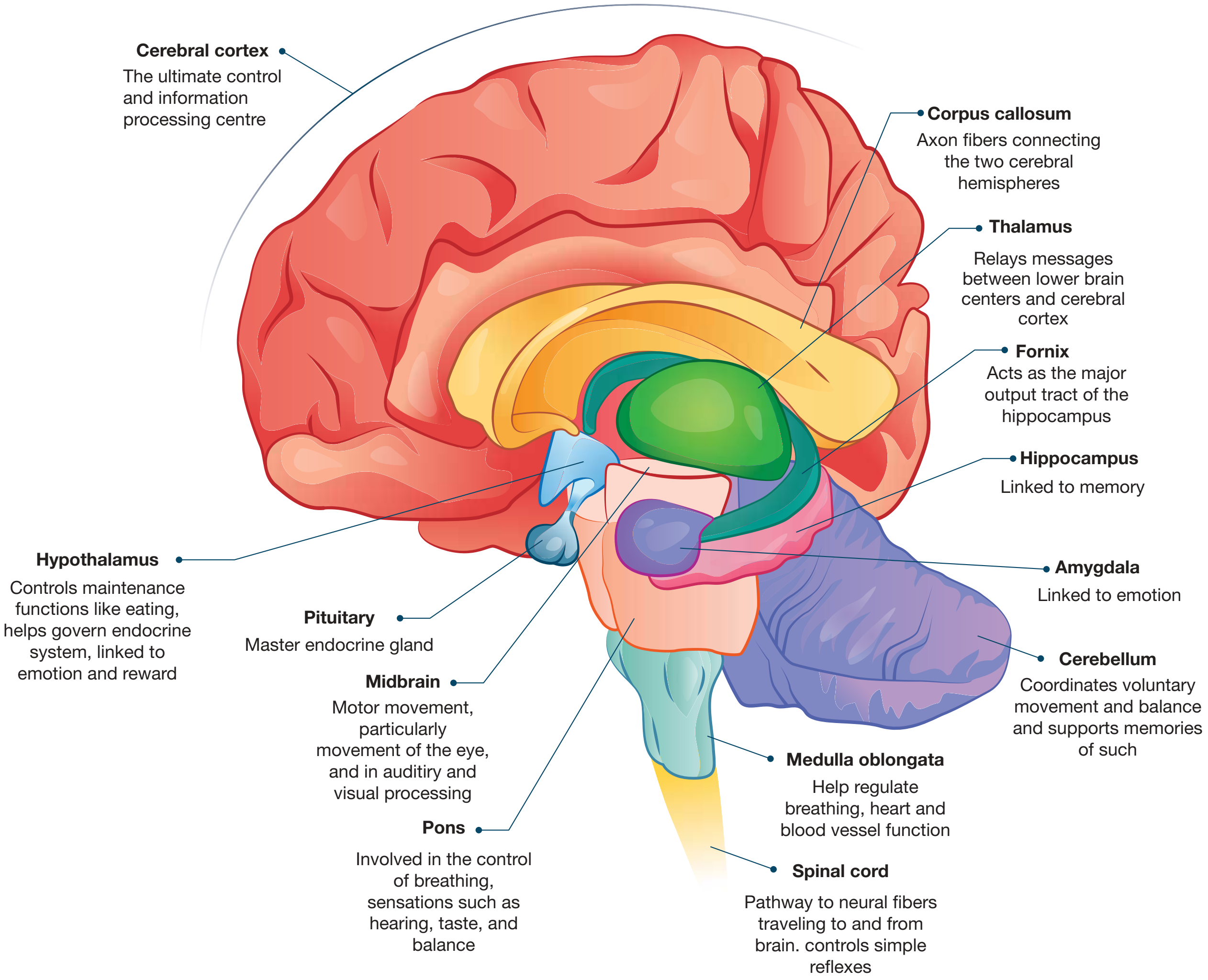
The central nervous system: The brain

The brain is soft and has the appearance of an oversized, wrinkled walnut. The average brain is the size of a large grapefruit and weighs around 1.5 kilograms. The brain has many functions including controlling movement, thinking, memory and regulating the body's internal state.

ewbk-12687

int-8133

FIGURE 11.10 Parts of the brain. Note the corpus callosum is a bridge of nerve fibres that connects the left and right hemispheres of the brain.



The outer layer of the brain, the **cerebral cortex**, is a very important part of the brain. The cerebral cortex is bigger in humans, compared to all other animals. The roles of this part of the brain include problem solving, memory, **personality**, judging, planning, learning, logical reasoning and decision making.

The cerebral cortex is divided into two halves called **cerebral hemispheres**. The left cerebral hemisphere is mainly responsible for the functioning of the right side of the body and the right cerebral hemisphere is mainly responsible for the functioning of the left side of the body.

Each hemisphere also has other specialised functions, as listed below. However, it is important to recognise that despite these types of specialisation, the two hemispheres share information using the **corpus callosum** and function interactively.

cerebral cortex the outer layer of the brain, which processes information and is linked to memory and problem solving

personality the combination of characteristics or qualities that form an individual's distinctive character

cerebral hemispheres the two halves of the cerebral cortex, both responsible for different ways of thinking

corpus callosum the part of the brain that connects the two hemispheres, allowing them to function interactively

on Resources

eWorkbook Investigating neurons (ewbk-12689)

11.3 Activities

learnon

11.3 Quick quiz on

11.3 Exercise

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 4	2, 3	5, 6

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. Describe the location and structure of the human brain.
2. Identify what the following structures of the brain are responsible for.

TABLE Parts of the brain and their function

Part of the brain	Responsible for...
Hypothalamus	
Amygdala	
Cerebellum	
Thalamus	
Midbrain	
Medulla oblongata	

3. Describe two main functions of the nervous system.
4. **MC** What is the role of the corpus callosum?
   A. Sends sensory information to the brain
   B. Connects the brain to the spinal cord
   C. Connects the left and right hemispheres
   D. Sends motor information from the brain to the rest of the body

Apply and analyse

5. Tom was in a car accident. He hit his head, and now he has trouble speaking; however, he has no problems doing jigsaws or reading maps. What part of the brain might Tom have damaged?

Evaluate and create

6. Research if it is possible to live with only one half of your brain. If possible, determine how the brain and body adapt to only one hemisphere.

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

LESSON
11.4 Intelligence

LEARNING INTENTION

At the end of this lesson you will be able to recognise that intelligence cannot be directly measured and be able to describe multiple intelligences proposed by a psychologist named Howard Gardner.

11.4.1 What is intelligence?

What do we mean when we use the word **intelligence**? Do the words ‘brainy’, ‘smart’, ‘bright’ and ‘clever’ come to mind? Psychologists’ definitions of intelligence range from ‘intelligence is what intelligence measures’ to definitions such as ‘a psychological potential to solve problems or to fashion products that are valued in at least one cultural context’.

FIGURE 11.11 Intelligent is often used interchangeably with ‘smart’ or ‘brainy’. However, there are many different definitions of intelligence.

There are so many definitions because intelligence cannot be directly observed. Therefore, psychologists rely on observations of behaviour that they believe to be associated with intelligence. However, intelligence does have many common aspects, such as the ability to learn from experience, to reason, to solve problems, to deal with people and objects, and to adapt effectively to an environment. It is generally accepted that intelligence seems to include a general ability that underlies a wide variety of human behaviour, and also includes other more specific abilities — memory, reasoning, use of language and numeracy — that are probably independent of one another.

In the past, research on intelligence focused on designing and implementing intelligence tests to calculate IQ scores; however, more recently, research does not rely so heavily on intelligence tests. A major reason for this is the recognition that intelligence is broader than what those tests assess. There has been a shift towards studying how people solve a problem rather than what their answer actually is.

intelligence has no agreed definition — some definitions include: ‘the ability to learn and solve problems’ and ‘the capacity for logic, understanding, self awareness and creativity’

It is always fun to do an intelligence test to find out your IQ, though. Just remember that there are a lot of problems associated with these tests — so you shouldn't take the results too seriously. The average IQ is 100 (a range from 90 to 109). A genius is classified as someone with an IQ of more than 145.

ACTIVITY: Explore different IQ tests. What does each test measure and how are they administered and used?

The most common types of IQ tests are:
- Stanford-Binet Intelligence Scale
- Universal Nonverbal Intelligence
- Differential Ability Scales
- Peabody Individual Achievement Test
- Wechsler Individual Achievement Test
- Wechsler Adult Intelligence Scale
- Woodcock Johnson III Tests of Cognitive Disabilities.

CASE STUDY: Mensa

Mensa is an organisation for people with an IQ in the top 2 per cent of the population. It accepts people of all ages and professions, and in Australia, around one-third of Mensa's members are children. Seven of them are aged under four. The Academy Award-winning actress Geena Davis is a member, as is Jean Auel, the bestselling author of many books including *Clan of the Cave Bear and Valley of the Horses*. Other members include Nolan Gould (American actor — *Modern Family*), Edward Norton, Kara Haywood and Bruce Willis.

11.4.2 Gardner's theory of multiple intelligences

One current theory of intelligence was proposed by a psychologist named Howard Gardner. He proposed that we do not have just one intelligence; we have a variety of intelligences. Everyone has a combination of each of these intelligences, but in different quantities. This theory explains individual strengths and weaknesses.

Table 11.1 describes each of the intelligences proposed by Gardner.

It is important to know which intelligences we score high, medium and low on. This knowledge enables us to enhance our strengths, and work on and challenge our weaknesses.

Did you know that even identical twins have different amounts of each intelligence? They are not as identical as we first thought!

TABLE 11.1 Types of intelligence

Type of intelligence	People who are strong in this intelligence:
Verbal/Linguistic	• like to read, write and tell stories well • are good at memorising names, places and trivia and learn best by saying, hearing and seeing words • have highly developed auditory skills • think in words rather than pictures.

(continued)

(continued)

Type of intelligence	People who are strong in this intelligence:
Logical/Mathematical	• can manipulate numbers, quantities and operations, the way a mathematician does • like to do experiments, figure things out, work with numbers, ask questions and explore patterns and relationships • are good at maths, reasoning, logic and problem solving
Bodily/Kinaesthetic	• can control body movements and handle objects skilfully • express themselves through movement • have a good sense of balance and eye–hand coordination (e.g. ball play, balancing beams)
Musical/Rhythmic	• can produce and appreciate music • think in sounds, rhythms and patterns • are good at singing, whistling, playing musical instruments, recognising tonal patterns, composing music and remembering melodies
Visual/Spatial	• tend to think in pictures and need to create vivid mental images to retain information • enjoy looking at maps, charts, pictures, videos and movies, and have a good sense of direction • are good at puzzles, reading, writing, sketching, painting, and creating visual metaphors and analogies (perhaps through the visual arts)
Intrapersonal	• can self-reflect and be aware of their inner state of being • are good at recognising their own strengths and weaknesses • have an awareness of their inner emotions
Interpersonal	• can relate to and understand others • try to see things from other people's points of view in order to understand how they think and feel • are great organisers and generally try to maintain peace in group settings and encourage cooperation
Naturalist	• like to be outside, with animals, geography and weather; interacting with the surroundings • are good at categorising, organising a living area, planning a trip, preservation and conservation

Resources

eWorkbooks Multiple intelligences (ewbk-12691)
Types of intelligence (ewbk-12693)

11.4 Activities

11.4 Quick quiz | **11.4 Exercise**

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 3	2, 4	5

Remember and understand

1. Define *intelligence* in your own words.
2. Name and describe each of Gardner’s multiple intelligences in your own words.

Apply and analyse

3. **a.** Brainstorm words that mean *intelligent*.
   b. Brainstorm and write down all the stereotypes used about intelligent people.
4. Match each of the following professions to the most likely intelligence that would be required.

Professions	Intelligence
a. Athlete, ballet dancer, football player, gymnast, actor	**A.** Interpersonal
b. Counsellor, doctor, nurse, psychic	**B.** Logical/mathematical
c. Singer, musician, composer, sound engineer	**C.** Visual/spatial
d. Poet, journalist, author, English teacher	**D.** Naturalistic
e. Zoologist, ecologist, scientist	**E.** Musical/rhythmical
f. Welfare worker, psychologist, nurse, teacher, police officer	**F.** Bodily/kinaesthetic
g. Maths teacher, accountant, engineer, scientist	**G.** Verbal/linguistic
h. Pilot, artist, tight rope walker, meteorologist	**H.** Intrapersonal

Evaluate and create

5. **SIS** Construct a PMI (Plus, Minus, Interesting) chart on the issues of measuring intelligence. Include references to IQ tests and the stereotypes about intelligence.

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

LESSON
11.5 Emotions and communication

LEARNING INTENTION

At the end of this lesson you will be able to describe ten basic human emotions and be able to recognise that stress can be both a positive and negative experience and that developing emotional intelligence is an important factor in a successful life.

11.5.1 Experiencing emotions

We all experience **emotions** such as happiness, anger, fear, interest, disgust, surprise and sadness. We can also recognise these emotions in other people through their behaviours, facial expressions, body language, actions and what they say. Emotions are partly formed through experience and partly through maturation (genetics).

Emotion is defined as a complex pattern of bodily and mental changes, including physiological **arousal**, feelings, cognitive processes, and behavioural responses to a personally significant situation. Researchers believe that there are ten basic emotions that humans experience. Most of these emotions are present in infancy. It is suggested that all other emotions are combinations of these ten basic ones.

emotion a complex pattern of bodily and mental changes

arousal the state of being physiologically or psychologically activated

FIGURE 11.12 The 10 basic emotions

11.5.2 Expressing emotions

Emotions can be expressed verbally as in ‘I feel happy today’ or nonverbally (communication without words). There are various types of nonverbal communication, including **kinesics** (body language) and **personal space**.

kinesics the study of body language as a type of non-verbal communication

personal space the space within a small distance of a person

Kinesics

Kinesics is the use of body language, body movements, posture, gestures and facial expressions to communicate information. We all use body language to communicate our thoughts and feelings, although we may not be aware of it at the time. For example, when we are irritated, we may tense our bodies, press our lips together and turn away. Facial expressions are usually culturally universal. A smile in China means the same thing as it does in Australia.

Usually we are fairly good at reading other people’s nonverbal communication. We read and interpret their facial expressions, body movements and posture.

We all have hard-to-control facial muscles that show our true emotions and that are hard to conceal. It is useful to be able to read feelings that ‘leak through’ via subtle facial expressions, body movements and posture.

- Lifting just the inner part of your eyebrows, which few people do consciously, reveals stress and worry.
- Eyebrows raised and pulled together signal fear.
- A pretend smile often continues for more than four or five seconds, by which time most real smiles have ended.
- Fidgeting may reveal anxiety or boredom.
- Lack of eye contact, looking up to the right and touching the face (especially around the mouth) are all well-known signs of lying.

Next time you are speaking to someone, consciously pay attention to their body language. What are they saying nonverbally? Is it consistent with what they are saying verbally?

ACTIVITY: Analysing facial expressions

Look at different emotional expressions to see which emotion fits which face. Look at their eyebrows, mouths and overall expression on their face. What emotions are these people expressing, and how can you tell if the emotions are genuine?

Personal space

Personal space is another form of nonverbal communication. It is the small, invisible physical area immediately surrounding our body that is regarded as our own personal territory. The size of our personal space varies according to factors such as our cultural background, mood, who we are with, what we are doing and where we are. The four different zones of personal space are shown in table 11.2.

TABLE 11.2 The four different zones of personal space

Zone	Distance	Interaction activity	People allowed into the zone
Intimate	0–0.5 metres	Informal, physical contact may be involved with someone close, in public or private	Close family and friends, partner, girlfriend/boyfriend
Personal	0.5–1.5 metres	Informal in public; for example, at a party or at school	Friends
Social	1.5–3.5 metres	More formal talking; for example, with people at work who are not close friends	People you don't know very well
Public	More than 3.5 metres	Formal talking with someone you don't know, perhaps in large groups or crowds	Strangers

DISCUSSION

Think about the social/physical distancing rules introduced during the COVID-19 pandemic. How did they make you feel? Do you have a different sense of personal space now, after living with these rules?

11.5.3 Stress

Stress occurs any time that we must change in order to fit in with an environment. However, not all stress is bad. Lots of life experiences can cause stress, including school pressures, friendships, relationships, financial issues, travel, sports, a new job, meeting new people, and other things we face in our day-to-day life.

Your body reacts to stress in the same way every time. Your nervous system causes your body to be alert or aware of the environment. Signs of alertness include increased heart rate, respiration rate, blood pressure and dilation (enlarging) of pupils. Perspiration also increases, your mouth gets dry and your appetite decreases. Do these signs sound familiar?

Can you think of examples where feeling stress is expected or could maybe even be helpful? Stress is the body's response to changes that create challenging demands. Many professionals believe that there is a difference between what we perceive as positive stress (**eustress**), and negative stress (**distress**). Being able to identify and recognise signs of eustress and distress within ourselves can be a very powerful tool.

When we are faced with something that causes us eustress, this as known as the 'good' type of stress. It can help us feel more motivated and focused, and give us more energy to face our challenges. An example of a situation that might cause a eustress reaction could be when you take on a big new responsibility or when you are going on a first date.

Distress is typically known as the type of stress people try to avoid. This is the kind of negative stress that causes intense worry, self doubt and anxious feelings. This type of stress can cause health issues if it is ongoing, such as sleep issues, high blood pressure and migraines. An example of a situation that might cause distress could be losing a loved one.

eustress positive or beneficial stress that motivates and energises an individual

distress negative or harmful stress that overwhelms an individual's ability to cope and adapt

ACTIVITY: Analysing stress

Many young people encounter large amounts of stress. In small groups, complete the following.

- a. Brainstorm the kinds of stressful situations young people may encounter in their life. Write these situations onto small pieces of paper.
- b. Divide the situations into three categories:
  - i. Very stressful
  - ii. Quite stressful
  - iii. Slightly stressful.
- c. Choose one stressful situation from each category and answer the following for each of the chosen situations.
- d. Answer the following for each of the three stressful situations the group chose.
  - i. Would this situation be perceived as positive stress or negative stress?
  - ii. Who could help a young person cope with this situation?
  - iii. Describe a strategy they may use to help young people cope with this situation.

11.5.4 Emotional intelligence

While one way to measure intelligence was through IQ testing, another category of intelligence that has become widely recognised is emotional intelligence (also known as emotional quotient or EQ). High emotional intelligence allows people to better understand, empathise and negotiate with people, and is typically strongly developed in people in leadership roles, as they have the ability to understand, interpret and manage their own emotions as well as the emotions of others. Emotional intelligence is divided into five broad categoriesas shown in figure 11.13.

Interestingly, psychologists believe that levels of EQ are far more important for success in life, including career success, than IQ levels.

FIGURE 11.13 The five broad categories of emotional intelligence

Self-awareness	Recognition of one's own emotions and how they can be managed; this has strong links to ideas of self-worth and capabilities
Self-regulation	The ability to take control of emotions as one experience them and is linked to trustworthiness, conscientiousness, adaptability and being open to new ideas
Motivation	A desire to improve, or to show commitment, initiative or optimism
Empathy	The ability to recognise other people's emotions
Social skills	An ability to communicate effectively to manage conflict, build relationships for collaboration and cooperation, and to lead and inspire

Resources

eWorkbook Emotions (ewbk-12695)

11.5 Activities

11.5 Quick quiz | **11.5 Exercise**

Select your pathway

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

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. What are the ten basic emotions?
2. The following are characteristics of the zones of personal space. Determine which zone is being described.

TABLE Zone of personal space

Description	Zone of personal space
Within a distance of 1.5–3.5 metres	
Friends are allowed into this zone	
Informal interactions in public	
Close family and friends are allowed into this zone	
Should be at a distance of more than 3.5 metres	
Formal interactions with people you are not friends with	

3. **MC** When does stress occur?
   A. Only when you are thinking about stressful things
   B. When we are in a familiar environment
   C. When we are being ourselves in an unfamiliar environment
   D. When we must change to fit in with an environment.

Apply and analyse

4. Is body language culturally universal? Explain how body language tells us about someone's emotional state.
5. How does EQ differ from IQ?
6. Stress can be negative or positive. Explain what this means, with reference to eustress and distress. Include your own examples of each.

Evaluate and create

7. **SIS** Research how stress management, exercise and relaxation can help someone cope with stress. Present your findings in a poster.
8. **SIS** Starting with the theme 'Emotions' in the centre, create a cluster map to sort the emotions below into positive ones and negative ones.
   Happy, sad, guilty, anxious, excited, pleased, apprehensive, confused, contented, bewildered, calm.
   Add five more emotions that aren't already listed.

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

LESSON
11.6 Memory

LEARNING INTENTION

At the end of this lesson 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.

11.6.1 What is memory?

on Resources

Weblink Memory

Watch a video to learn more about how memory works.

If a friend gave you their 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.

11.6.2 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 11.14 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.

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 11.14 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 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.

record the first step in forming a memory

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

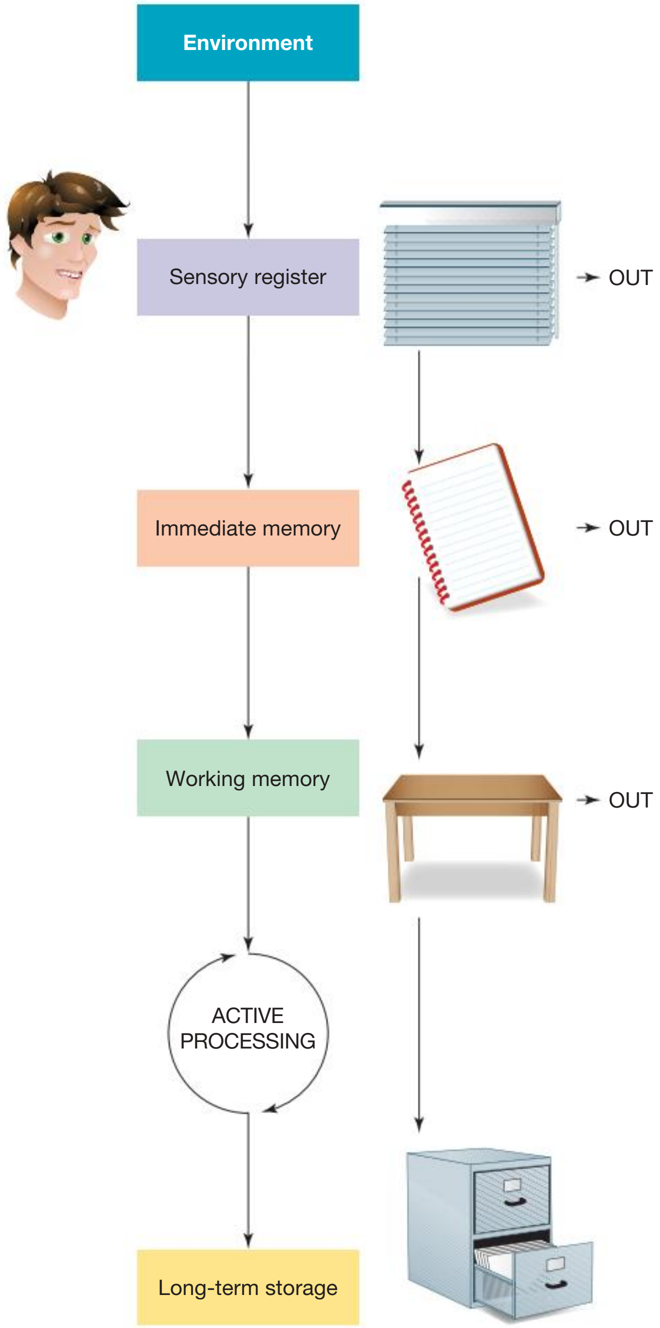
retrieve the ability to recall memories

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

thalamus the 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

FIGURE 11.14 The information processing model provides a simplified explanation of how your brain deals with external stimuli (information) from your environment.



Resources

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

EXTENSION: Memories are patterns of connections

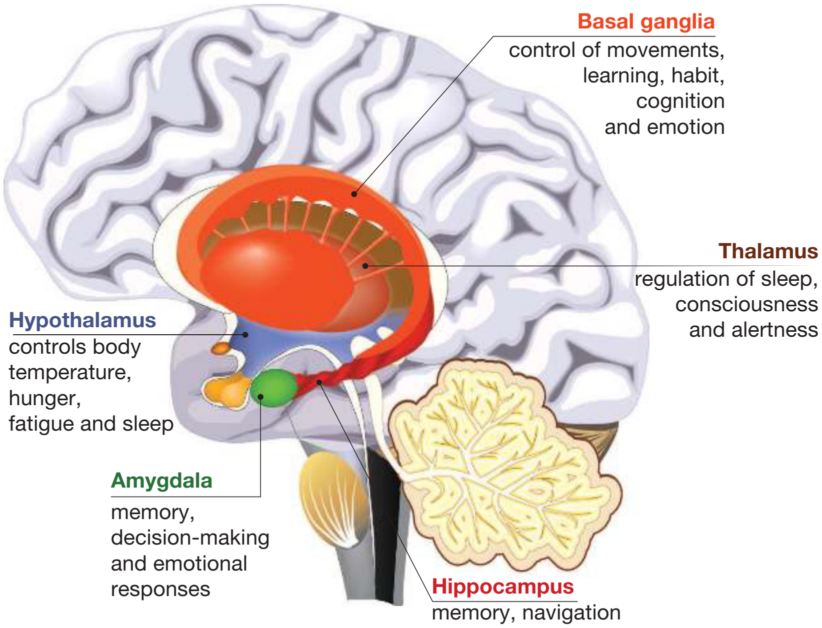
Memory is not stored in just one place in your brain. It is currently thought that memories exist as patterns of connections at the synapses between the brain's neurons. To store a particular memory, nerve signals travel along a specific pathway through certain synapses. Each time this memory is remembered,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

FIGURE 11.15 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 11.14) and working memory (shown as a table in figure 11.14).

FIGURE 11.16 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 three to five ‘chunks’ that can be dealt with at one time; after this age it increases to about five to seven ‘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 11.14 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 the 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 the 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.

11.6.3 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 11.17) 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 11.17 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?	**Yes**	Moderate to high	Very high
	No	Very low	Moderate to high
		No	**Yes**
		Is sense present?	

11.6.4 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

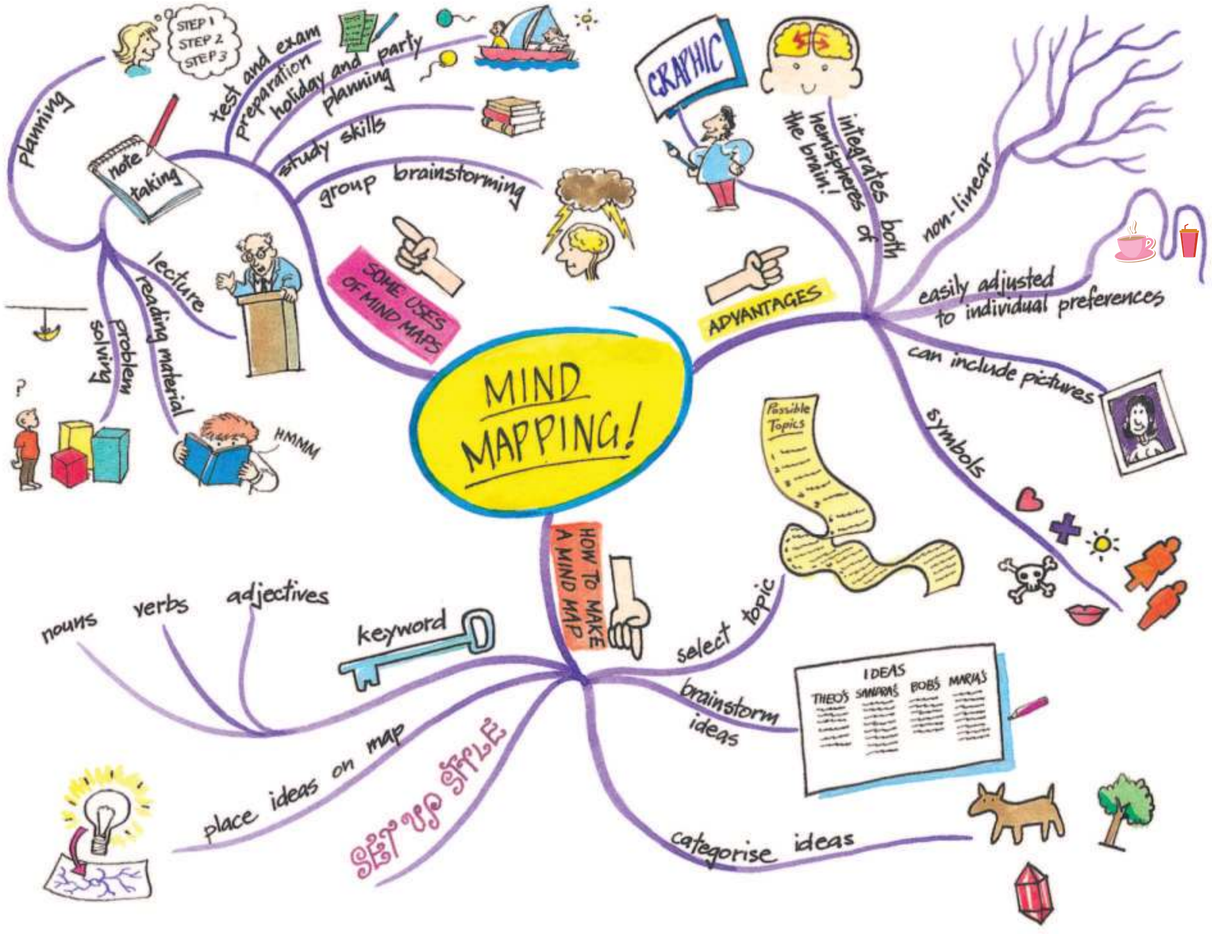
11.6.5 Mind mapping

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



11.6 Activities

11.6 Quick quiz on

11.6 Exercise

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 2, 3, 4, 6, 10	5, 7, 8, 11, 15, 16	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 lesson.
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 seven seconds. After seven 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 the following statements related to drugs and memory. Respond to each statement based on your research and opinion.
    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) and 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.

LESSON
11.7 Sleep and sleep disorders

LEARNING INTENTION

At the end of this lesson you will be able to recognise the two types of sleep (REM and NREM), be able to describe insomnia as a sleep disorder common across all age groups, and you will have learnt that sleep walking and nightmares are examples of a sleep phenomenon.

11.7.1 Types of sleep: REM and NREM sleep

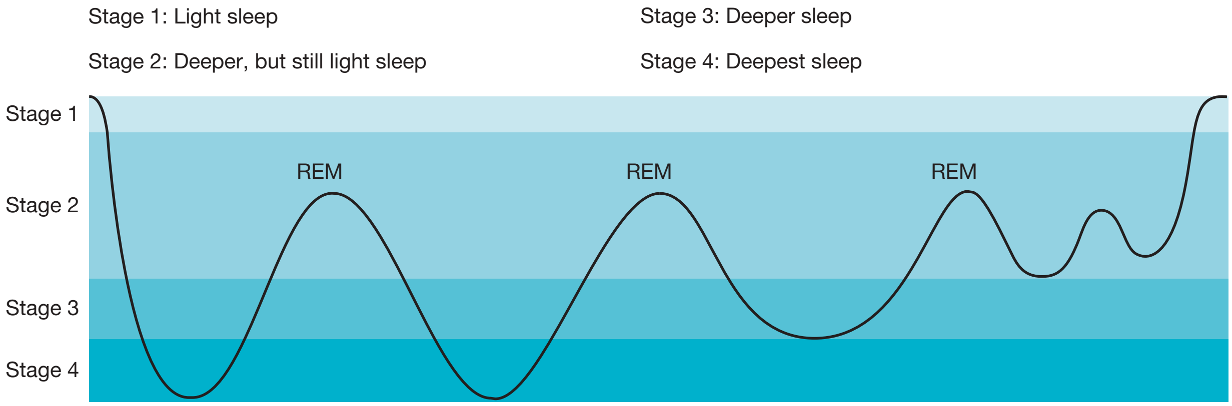
Every animal, including humans, needs sleep. In fact, we sleep for one-third of our lives. Sleep is a very important, complex process involving two different types of sleep:

- **Rapid eye movement sleep (REM sleep)** occurs throughout the night, and is about 20 per cent of our sleep time. This type of sleep involves the eyes moving around rapidly (while the eyelids are closed), muscle twitching and irregular breathing. It is during REM sleep that people dream. However, people remember their dreams only if they awaken during this stage of sleep. People sleep for a total of about 90 minutes each night in REM sleep, and periods of REM sleep get longer as the night progresses.
- **Non-rapid eye movement sleep (NREM sleep)** is the remainder of a night's sleep (about 80 per cent of ou sleep time). In NREM sleep there is no observable movement of the eyes behind the eyelids, the body is still and there are no bodily movements. NREM sleep is divided into four stages, from a very light sleep (stage 1) to a very deep sleep (stage 4).

rapid eye movement sleep (REM sleep) a stage of sleep characterised by the repetitive, brief and erratic movements of the eyeballs under eyelids

non-rapid eye movement sleep (NREM sleep) stages of sleep characterised by the absence of rapid eye movements

Figure 11.19 The four stages of sleep; REM sleep occurs after stage 2 throughout the period of sleep.



A sleep cycle starts by going from stage 1, to stage 2, to stage 3, to stage 4 sleep. In the first few cycles of sleep, people spend about 30 minutes in stage 4 sleep. They then go into stage 3 sleep and then stage 2 sleep. Sleepers do not usually go into stage 1 sleep again, but go into REM sleep, the second type of sleep. Most people have four to 5 sleep cycles each night. During the night, people go into stage 1 sleep only when they are falling asleep or waking up.

Today, smart watches can use our heart rate as a way to measure and record how much of our sleep we spend in each cycle. Tracking sleep cycles gives us good insight into the quality of our sleep.

TABLE 11.3 Characteristics of sleep stages

	Characteristics	What happens to the body?	If woken, how does the person react?	Is the person easily woken?
Stage 1	This is a light sleep, just after we 'doze off'.	The body relaxes, the heart slows down, body temperature drops slightly and breathing can become irregular.	Most people say that they were not fully asleep.	People are often still aware of external noises.
Stage 2	This is deeper, but is still light sleep.	The heart rate reduces further and there is a noticeable drop in body temperature.	Many people report that they were not fully asleep.	People can still react to loud or disruptive external stimuli.
Stage 3	This is a deeper sleep.	Heart rate and breathing tend to be slow, regular and relaxed.	People often report being asleep.	People are less likely to be affected by external stimuli.
Stage 4	This is the deepest stage of sleep.	There is a lower body temperature and a slower heart rate.	People take up to 10 minutes to become fully aware of their surroundings.	People are very difficult to wake at this stage of sleep.

11.7.2 Sleep disorders and phenomena

Sleep problems that disrupt the normal NREM–REM sleep cycle, including the onset of sleep, are called **sleep disorders**. Most can be successfully treated. **Insomnia** is one form of sleep disorder.

Sleep issues are common for all age groups. Studies show that 40 per cent of Australians don't get enough sleep. Approximately 30 per cent of the adult population suffer from insomnia and 10 per cent from chronic insomnia, making it the most common sleep disorder. This is followed by sleep apnea. In 2018, approximately 3–7 per cent of men and 2–5 per cent of women had sleep apnea, with over 100 million sufferers worldwide.

A **sleep phenomenon** is a normally-occurring behaviour at night that usually happens during childhood. Examples of sleep phenomena include sleepwalking, sleep talking, nightmares and night terrors.

sleep disorders problems that disrupt the normal sleep cycle

insomnia a sleep disorder whereby a person has difficulty either falling asleep or staying asleep

sleep phenomenon behaviours that occur at night including sleepwalking, sleep talking, nightmares and night terrors

symptoms physical or psychological features of a disease or disorder

Insomnia

There are two types of insomnia:

i difficulty falling asleep (sleep onset)
ii difficulty staying asleep (sleep maintenance).

Insomnia is a disorder that results in a person not getting enough sleep each night. Some **symptoms** of this disorder include the failure to fall asleep within 30 minutes, wakening for longer than 30 minutes during the night, a consistently reduced amount of sleep and constantly feeling tired.

Figure 11.20 Insomnia is a sleep disorder that causes great distress.

Psychologists believe possible causes of this disorder include stress and anxiety, pain, alcohol or drug use, jet-lag and shift work (a disruption to the normal sleep cycle). Possible treatments are medication (but not long term), relaxation and meditation, stress management and sleep hygiene practices. Sleep hygiene practices are regular routines carried out before going to bed, for example, having a warm shower, brushing your teeth and going to the toilet.

Sleepwalking

Another name for sleepwalking is **somnambulism**. Somnambulism is walking while asleep and sometimes conducting routine activities such as dressing or going to the toilet.

Somnambulism occurs most often in children, but is not uncommon in adults during times of high stress. It occurs in stages 3 and 4 NREM sleep (deep sleep) and for 5–30 minutes at a time. Symptoms include poor coordination and incoherent language.

People engaging in sleepwalking are usually unresponsive to the environment, and have a blank stare on their face. They rarely report remembering their night-time activities.

FIGURE 11.21 It is a myth that it is dangerous to wake someone who is sleepwalking. In reality, it is difficult to wake sleepwalkers because they are in a deep sleep, but it is not dangerous.

Nightmares

A nightmare is an unpleasant dream with content that is frightening and upsetting to the dreamer. Nightmares are remembered vividly, and happen during REM sleep. Common themes in nightmares are helpless terror, threatening situations, escaping and falling. Many people wake during their nightmare because of the upsetting content. The body is stationary, and paralysed (during REM sleep), and there is no indication whether the dream has pleasant or frightening themes.

Nightmares occur more commonly in children than adults, and females are twice as likely to have nightmares as males. Nightmares happen at times of high stress, fatigue or personal trauma; however, experts are not entirely sure why people have nightmares.

ACTIVITY: Researching narcolepsy

Research narcolepsy either independently or in pairs. Find out the symptoms, causes and treatment of this disorder. Present your information in a short PowerPoint presentation or equivalent.

on Resources

weblink Sleep Health Foundation

somnambulism another word for sleepwalking

11.7 Activities

learn on

11.7 Quick quiz on

11.7 Exercise

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS ▶

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 2, 3	4, 5	6

Remember and understand

1. What is the difference between REM and NREM sleep?

2. What is the difference between a sleep disorder and a sleep phenomenon?
3. When do nightmares and sleepwalking usually occur?

Apply and analyse

4. What is a sleep phenomenon? Name and describe one sleep phenomenon.
5. The following are characteristics of the four stages of sleep. Decide which stage is being described.

TABLE Characteristics of the different stages of sleep

Sleep characteristic	Stage of sleep
Body temperature is low and heart rate is slow	
People are often still aware of external noises	
If woken, people often report being asleep	
A light sleep, just after ‘dozing off’	
There is the first notable drop in body temperature	
People are very difficult to wake during this stage	

Evaluate and create

6. Describe the four stages of sleep. Draw a diagram to show the progression through each stage during the night and label when sleep disorders and sleep phenomenons are likely to occur.

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

LESSON
11.8 Psychopathology

LEARNING INTENTION

At the end of this lesson you will be able to describe different types of mental health disorders, their symptoms and their treatments.

11.8.1 Symptoms, diagnosis and prevalence

In Australia, it's estimated that 45 per cent of people will experience a mental health condition in their lifetime. This may make people behave in a way that is unusual, abnormal or different to what is expected by society. Clinical psychologists investigate, diagnose and treat these behaviours. There are often signs or symptoms of underlying mental health disorders or **psychopathology**. A mental health disorder is a significant impairment in psychological functioning. These psychological problems can be grouped into broad categories with common symptoms.

There are three important terms that need to be understood when discussing mental health disorders.

- *Symptoms* or signs are the characteristics that allow a psychologist to diagnose a mental health disorder.
- A *diagnosis* labels a set of symptoms. This is similar to what happens when you go to the doctor if you are feeling unwell. For instance, Sally goes to her doctor because she has a cough, runny nose and sore throat (symptoms), so the doctor labels or diagnoses her illness as a cold. Similarly, Jake goes to a psychologist because he is sad, has feelings of hopelessness and has trouble getting out of bed (symptoms). The psychologist may diagnose Jake as suffering from **depression**.
- The word **prevalence** refers to how common a disorder is within the community. *Prevalence* can be expressed as either a percentage or a proportion. For example, in Australia the prevalence of phobias is between 9–11 per cent of the community, and one in every 100 people suffers from **schizophrenia**.

psychopathology the scientific study of mental health disorders

depression lasting and continuous, deeply sad mood or loss of pleasure

prevalence the percentage or proportion of the population that have a certain illness or disorder

schizophrenia a disorder that affects a person's ability to think, feel and behave clearly

phobia an intense or irrational fear of something that poses little or no threat

Phobias

The NIMH (National Institute of Mental Health) defines a **phobia** as an intense or irrational fear of something that poses little or no risk. Objects such as snakes, spiders, and confined spaces often serve as triggers for phobias. In most cases, people know that their fears are unreasonable or excessive but they are unable to control them.

Examples of phobias include:

- agoraphobia — a fear of open spaces; people with agoraphobia find it very difficult, if not impossible, to go to the letterbox or to go out shopping
- ablutophobia — a fear of washing or bathing
- acrophobia — a fear of heights.

Phobias can be associated with nearly any object or situation. Everyone has a few fears but these are not necessarily phobias. Common fears include a fear of heights, closed spaces, or bugs and crawly things. A phobic disorder differs from such common fears in that it produces overwhelming anxiety and a need to escape the object or situation. Phobias often interfere with normal daily functioning, which is when a professional is enlisted to help the individual finds ways to successfully cope and deal with their phobia.

Symptoms of a phobia include: hyperventilation, vomiting, fainting, sweating uncontrollably, increased heart rate and shaking, as well as nausea and hot flushes. In extreme cases, people work very hard to avoid objects that cause them fear.

Recent statistics suggest that an estimated 19.3 per cent of adolescents have a specific phobia, and an estimated 0.6 per cent have severe impairment as a result of the phobia (NIMH, 2017). The prevalence of specific phobia among adolescents was higher for females (22.1 per cent) than for males (16.7 per cent).

Treatment of phobias include: therapy or **anti-anxiety drugs**. Therapies aim to associate the feelings of being calm and relaxed with the presence of the feared object, so eventually the person is no longer afraid of the object. A combination of therapies is usually successful in treating and curing phobias. Cognitive Behaviour Therapy (CBT), a form of psychotherapy, can help people change unhealthy ways of thinking, feeling and behaving by equipping sufferers with practical self-help strategies, greatly improving their quality of life.

DISCUSSION

Agoraphobia comes from the Greek words *agora*, which means 'marketplace', and *phobia*, which means fear; literally, fear of the marketplace. Consider the names of other phobias to work out their meanings.

Depression

Depression is a mood disorder that affects a person's ability to function in their daily life. It usually involves intense feelings of sadness, hopelessness, loss, and/or anger. According to Beyond Blue (2019), around 1 million Australian adults have depression and over 2 million have **anxiety**, making anxiety the most common mental health condition in Australia. There are different types of depressive mental health disorders which include:

- Major depression — also known as depressive disorder, clinical depression, unipolar depression or depression. Symptoms include a low mood (hopelessness) for a period of two weeks or more and a loss of interest or pleasure in activities that typically bring joy. It can be classified as mild, moderate or severe.
- Melancholia is a severe form of depression where the person will move very slowly and has a complete loss of pleasure in almost everything.
- Psychotic depression can include hallucinations, delusions (false beliefs), or paranoia.
- Antenatal and postnatal depression occurs during pregnancy (antenatal) or in the year following childbirth (postnatal). While many women experience the 'baby blues' in the period immediately following childbirth, depression is much longer lasting and can compromise the mother's ability to care for herself, her baby, or other members of her family.

FIGURE 11.22 Recent data reflects that 14 per cent of women (or one in seven) are affected by postnatal depression in Australia.

Bipolar disorder

Bipolar disorder is characterised by extreme mood swings between **mania** (elevated mood) and depression (feelings of being sad and worthless), usually separated by days or weeks and by 'normal' moods and behaviour. It was previously known as bipolar depression.

When the person is manic, (experiencing an elevated mood known as mania), typically they will be full of energy with thoughts and feelings racing. They may talk loudly, function on minimal sleep, lack inhibitions, take large risks and lose their temper easily. People going through a manic episode can find themselves in trouble because they may engage in alcohol and drug consumption or expensive shopping sprees.

When a person is depressed, their symptoms include feeling sad, worthless, helpless; a withdrawal from social relationships; difficulty in concentrating; diminished interest in pleasurable activities; neglect of appearance; and decreased energy and motivation.

anti-anxiety drugs drugs that aim to inhibit anxiety by restoring the balance of certain chemicals in the brain

anxiety a natural and usually short-lived reaction to a stressful situation; a disorder whereby anxious thoughts, feelings and physical symptoms occur frequently and persistently, disrupting daily life

bipolar disorder a disorder whereby a person has extreme mood swings between mania and depression

mania an elevated mood involving intense elation or irritability

Bipolar disorder is usually experienced by individuals before age 30. Approximately 1.2 per cent of the Australian population is diagnosed with bipolar depression at some time during their life. Bipolar depression occurs equally in males and females and it is more likely to run in families. This suggests that genetic factors may be involved in bipolar disorder. Many people suffering from this disorder are treated by counselling drug therapy.

FIGURE 11.23 Ben Stiller suffers from bipolar disorder.

Famous people who have suffered from bipolar depression include Buzz Aldrin (astronaut), Virginia Woolf (author), Francis Ford Coppola (movie director), Axl Rose (singer in Guns N' Roses) and Ben Stiller (actor). After displaying mood swings from aggression to extreme happiness during the making of *Zoolander*, Ben Stiller was quoted as saying Other famous people who have bipolar disorder include Selena Gomez (actress and singer), Halsey (singer), Kanye West (rapper), Carrie Fisher (Star Wars), Catherine Zeta-Jones (actress), Russell Brand (comedian and actor), Mariah Carey (singer) and Sia (singer).

11.8 Activities

learnon

11.8 Quick quiz on

11.8 Exercise

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 2	3, 5	4, 6

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. What does the word *prevalence* mean? What is the prevalence of phobias?
2. What are the treatment options for phobias?
3. What is the difference between a fear and a phobia?

Apply and analyse

4. **SIS** Research the symptoms, prevalence and support available for one of the following disorders. Present your findings in a PowerPoint presentation.
   - Catatonic schizophrenia
   - Post-traumatic stress disorder

Evaluate and create

5. Organise a Mental Health Week in your school to promote acceptance of mental health disorders among your schoolmates. You could include activities such as poster presentations about various mental health disorders and organise guest speakers to give talks.
6. a. **SIS** Create a PMI chart on the issue of labelling people with mental health disorders.
   b. Form groups of six and compare the charts.
   c. Divide the six students into two groups of three. One group of three is the affirmative side and the other group of three is the negative side.
   d. Develop arguments for or against the topic 'Labelling people with mental health illness is dangerous'.
   e. Debate the topic above in front of the class.

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

LESSON
11.9 Treatment of mental health disorders

LEARNING INTENTION

At the end of this lesson you will be able to describe the treatment of mental health conditions that are used today including psychological therapies, behavioural therapies and biomedical therapies.

11.9.1 Past treatments

One of the earliest explanations of abnormal behaviour related it to supernatural causes. People believed that anyone behaving differently was possessed by the devil or practised witchcraft. The treatment of demonic possession and supernatural behaviour included elaborate prayer rites, forcing the affected to drink terrible tasting concoctions and brews, flogging, drowning and starvation.

In the fourteenth century, people with mental health disorders were put into asylums and were chained or tortured. These terrible, unethical and ineffective treatments of mental health disorders have greatly changed over the decades.

Originally the mentally ill were housed in large mental asylums. Today, patients are placed in home-like surroundings and have the service of physicians who are skilled in the treatment of their conditions.

FIGURE 11.24 In the past, people were housed in mental asylums. One famous asylum or sanitarium was Kellogg's Battle Creek Sanitarium, in Michigan. This sanitarium was of the health spa/hospital variety. Kellogg's cornflakes were invented at this institution.

11.9.2 Present treatment of mental health disorders

Decades ago, patients with mental health issues were not able to live within society. They were confined to psychiatric wards or hospitals. However, with the development of new and improved medications, many patients are now able to live among society, with only the acutely ill patients required to reside in psychiatric wards.

These significant developments in medicinal research and subsequent therapeutic treatments, combined with the successful registration of these medicines with the Therapeutic Drugs Administration (TGA — Australia) and the Food and Drug Administration (FDA — America) have resulted in patients being able to be released from psychiatric wards and hospitals. More importantly, many people with mental health illnesses are now able to cope in society and live a 'normal' and productive life, as a result of the medical break-throughs.

Today, treatment of mental health disorders may use one or more of the following programs:

- **Psychological therapies** — such as counselling
- **Behaviour therapy**
- **Biomedical therapies** — such as drugs and medication.

Psychological therapies

Psychological therapies involve structured interaction (usually verbal) between a professional and a client with a problem.

There are different types of psychological therapies; the most common are cognitive and behavioural therapies.

Cognitive therapies assume that the way we think about things affects our feelings and behaviours. So, if we change what we think about issues that are causing us concern, then we can decrease the concern we are feeling. Cognitive therapists try various methods to teach people more constructive ways of thinking.

FIGURE 11.25 Counselling of patients may occur in hospitals, clinics or private practices.

Instead of trying to alleviate distressing behavioural symptoms by resolving a presumed, underlying problem, behavioural therapy applies well-established learning principles to eliminate the unwanted behaviour. For example, to treat phobias, behavioural therapists replace problem thoughts and maladaptive behaviours with more constructive ways of thinking and acting. This type of therapy is called **systematic desensitisation**.

Biomedical therapies

Another way of treating mental health disorders is by physically changing the brain's functioning — by altering its electrochemical transmissions with drugs (biomedical therapy).

The most common drugs used to treat mental health disorders are **antipsychotic drugs** (which treat schizophrenia), antianxiety drugs (to treat anxiety), and antidepressant drugs (which to treat depression).

Along with cognitive and behavioural therapies and medication, the most important treatment for mental health illness today is the acceptance and understanding of such illnesses by society. The federal government has implemented a National Mental Health Strategy that aims to:

- promote the mental health of the Australian community
- prevent the development of mental health disorders
- reduce the impact of mental health disorders on individuals, families and the community
- assure the rights of people with mental health illnesses.

Other campaigns implemented by the government include Beyond Blue, Kids Help Line, Lifeline, and better access to psychiatrists and psychologists through the Medical Benefits Scheme.

psychological therapies structured interaction between a professional and a client to help overcome psychological problems

behavioural therapy a type of therapy that aims to identify and help fix self-destructive or unhealthy behaviours

biomedical therapy a type of therapy that uses medications to treat mental health disorders

cognitive therapies types of therapy that aim to teach people more constructive ways of thinking

systematic desensitisation a type of therapy that aims to desensitise people to their phobias

antipsychotic drugs drugs that treat mental health disorders such as depression, anxiety and schizophrenia

on Resources

Weblink Beyond Blue

11.9 Activities

11.9 Quick quiz on

11.9 Exercise

Select your pathway

🟩 LEVEL 1
1, 2

🟦 LEVEL 2
3, 4

🟪 LEVEL 3
5, 6

Remember and understand

1. Describe how people with mental health disorders were treated in the past.
2. How are mental health disorders treated today?

3. What are the three main types of drugs used to treat mental health disorders today?
4. Identify whether the following are characteristics of cognitive therapies or behavioural therapies.

Characteristics of cognitive or behavioural therapies

Characteristics	Cognitive or behavioural therapies?
Teaching people more constructive ways of thinking	
Changing what we think about issues to reduce concern	
Applying established learning principles to eliminate unwanted behaviour	
Using the assumption that the way we think affects our feelings and behaviours	

Apply and analyse

5. How has the development of drugs to treat mental health disorders allowed people to live among society, rather than being hospitalised?

Evaluate and create

6. Beyond Blue is a government initiative aimed at educating the community about depression. Use the **Beyond Blue** weblink in your Resources section to investigate two ways that the community is educated about depression in young people. Present your findings in a brochure.

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

LESSON
11.10 Groups and social psychology

LEARNING INTENTION

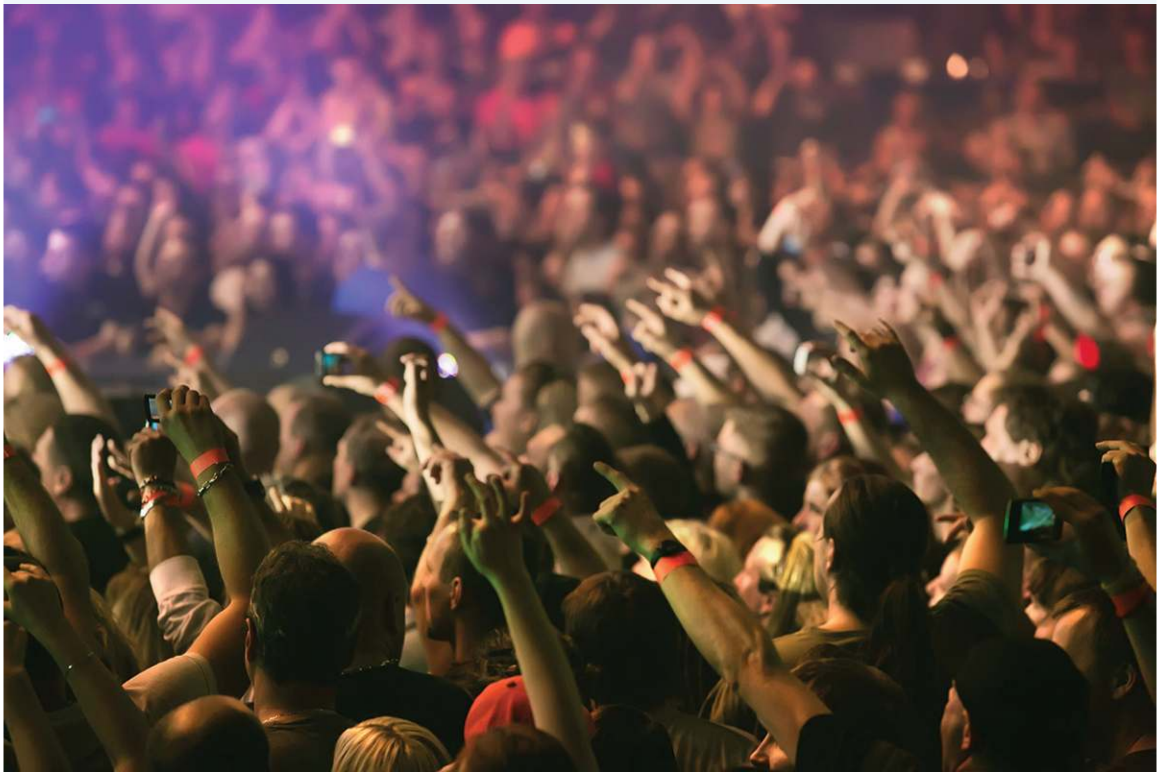
At the end of this lesson you will be able to describe what a group is, why people like to join groups and styles of different group leaders.

11.10.1 What is a group?

We like spending time with others, and feel lonely if we don't. Our social system is structured so that we are members of many different **groups**. We belong to groups such as family, friends, work colleagues, school, sporting teams, religious and community groups. We are also members of groups automatically on the basis of personal characteristics such as sex, age and nationality.

group collection of two or more people who interact with and influence one another and who share a common purpose

FIGURE 11.26 People in a crowd at a concert do not all interact with each other. Are they a group or a collective?



What is sociology and what do sociologists study?

Sociology is the study of social life, social change, and the social causes and consequences of human behaviour. Sociologists investigate the structure of groups, organisations, and societies, and how people interact within these contexts. One construct they closely examine is groups and group behaviour.

Are two people waiting in line at the supermarket a group? What about the crowd at a concert? According to social psychologists, a group is any collection of two or more people who interact with and influence one another, and who share a common goal or purpose. Therefore, the two people in line at a supermarket are not classified as a group if they do not communicate with each other. Similarly, members of a crowd at a concert do not all communicate with each other, and so are not classified as a group either. However, members of the band they are enjoying are interacting together and are classified as a group. The two former examples are known as a **collective** — an assemblage of people who have minimal contact with each other.

Why do people join groups?

People join groups to meet their social needs and to feel a sense of connectedness or belonging with others. There are other reasons why social connectedness is important to us. One need is the desire to associate and be involved with others. This is known as **affiliation**. Affiliation tells us about other people's attitudes and feelings, and provides us with a source of information to which we can compare our own attitudes and feelings.

Another reason humans join a group is to give a sense of **self-identity**. Self-identity is a personal awareness of ourselves, or knowing where we 'fit in' in society.

People also join groups to perform tasks and attain goals that cannot be achieved as an individual. For example, the captain of a football team cannot win on his own. He needs his team-mates to play the match with him in order to win.

collective a collection of two or more people who do not interact with all other members of the collection

affiliation the human need for involvement and belonging to a social group

self-identity the personal awareness of one's self and where they fit into society

democratic leadership a balanced approach to leadership that allows group members to participate in decision making

laissez-faire leadership a person-oriented approach to leadership style whereby the leaders are friendly and helpful but do not have direct control over the group

11.10.2 Leadership of a group

Within a group, one or more members often carry a higher level of power or status than other members. Status refers to the importance of an individual's position within a group. Leadership involves an individual or group with high power and status directing a group.

Leaders have a very influential role in society. They are often in powerful positions and can significantly affect the beliefs, attitudes and behaviours of the group members. There are three different leadership styles that leaders use to exert their power.

- **Democratic leadership** is balanced between being task-oriented and people-oriented. Democratic leaders encourage all group members to participate in decision-making. They support the opinions of the group and promote cohesiveness, attainment of goals and ownership of decisions. Group members are satisfied because they feel that their opinions are acknowledged by the group. As discussed earlier in this topic, good leaders typically have a high EQ.
- **Laissez-faire leadership** this is a person-oriented leadership style where leaders are friendly and helpful, but have no direct control over the group. Instead, the group members have the control. The leader supports the group and wants them to have a good time — regardless of the outcome. This type of leadership is ineffective as goals are seldom reached, but group members are happy because their opinions are heard.

FIGURE 11.27 Hitler (left) and Stalin (right) both employed an autocratic leadership style. They both made many decisions that affected the lives of Europeans and the rest of the world.

- **Autocratic leadership** this is a task-oriented leadership style where the leader makes the decisions for the group and has complete control of them. These leaders emphasise the importance of completing the task through the use of rewards and punishment. Often, individual members are dissatisfied because their opinions have not been heard. People who have employed this type of leadership include Hitler, Stalin and **cult** leaders.

autocratic leadership a leadership style whereby the leader makes all decisions and has complete control

cult a social group defined by intense belief and devotion to unusual religious or spiritual beliefs

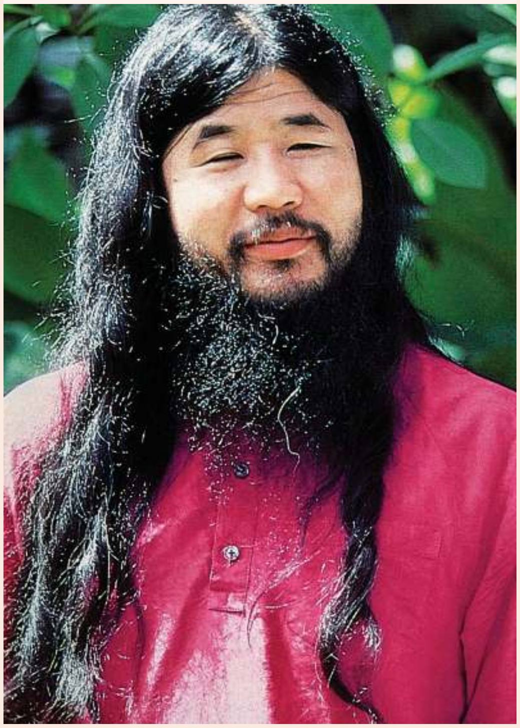
CASE STUDY: Cults

A cult is led by an all-powerful and charismatic leader who is seen as the guiding spirit. Members of a cult are devoted to the leader, an idea or object. A cult usually has a religious basis, separates itself from the rest of society, and it may abuse the rights of the members.

A cult controls its members in different ways. These forms of control include: not allowing members to think for themselves apart from the group, allowing them to accept only what they are told, breaking relationships with friends and relatives outside the group and forcing them to unquestioningly submit to the group's teachings and directions — breaking their own free will. This control of members may occur by means of intimidation and the heavy use of guilt.

One of most infamous cults of recent times is Aleph, formerly known as Aum Shinrikyo. Aum Shinrikyo was responsible for a poisonous gas (sarin) attack on the Tokyo subway in 1995, which killed 13 people and injured thousands more. Senior members of the cult responsible for the Toyko gas attack received the death penalty. It is a doomsday cult that predicts the end of human civilisation except for members of the cult. While it has a belief system with elements of Buddhism, Hinduism, Christianity and the writings of Nostradamus, it has been designated a terrorist organisation by many countries. It is currently under surveillance by the Japanese government.

FIGURE 11.28 Shoko Asahara — founder of the Aleph (formerly Aum Shinrikyo) cult



11.10 Activities

11.10 Quick quiz on

11.10 Exercise

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 2, 4	3, 6, 9	5, 7, 8

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. What is the difference between a group and a collective?
2. What are the three leadership styles?
3. **MC** Which of the following is least likely to be classified as a *group*?
   A. A queue of people waiting to enter a concert
   B. Your class at school
   C. People stuck in an elevator for two hours
   D. Six teachers sitting in the staff room talking
4. **MC** Which of the following is least likely to be classified as a *collective?*
   A. Spectators at the AFL Grand Final
   B. People in a cinema watching a movie
   C. People stuck in an elevator for two hours
   D. People sitting in a hospital waiting room
5. How do cult leaders exercise their control?

Apply and analyse

6. Think of an example, other than the ones already mentioned, for each leadership style.
7. Explain how belonging to a group, such as a peer or sporting group, may have an important effect on a young person's sense of personal identity.

Evaluate and create

8. Research a cult such as the Manson Family on the internet. Identify how the members were coerced into the group and any other interesting information you can find.
9. **SIS** Create a PMI chart of the autocratic leadership style.

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

LESSON
11.11 Forensic psychology

LEARNING INTENTION

At the end of this lesson you will be able to describe the role of a forensic pathologist in solving crimes and why lie detector tests are not allowed as evidence in Australian courts.

11.11.1 What is forensic psychology?

Do you like watching crime shows on television? These shows demonstrate how evidence is collected and how crimes are solved. The actual collection of evidence is done by scientists, but forensic psychologists also play an important role in the apprehension of perpetrators (catching the person who committed the crime).

Forensic psychology involves applying psychological knowledge and principles to legal issues. Forensic psychology investigates many aspects of crime, such as the reliability of evidence and eye-witness testimony, the role of human memory, decision-making, particular group decision-making (as in juries), and questions of the general credibility of witnesses.

forensic psychology the application of psychological knowledge and principles to legal issues

dangerousness the likelihood of an offender to commit a serious act of violence with little provocation

What do forensic psychologists do and where do they work?

The work undertaken by a forensic psychologist is varied and may include: working with the police; building criminal profiles; assessing a criminal's state of mind and whether they are sane or not; assessing whether the person is mentally fit to enter a plea (guilty or not) or stand trial; giving advice or an expert opinion to a court; assessing and treating people who are the victims of crime or witnesses of crime; providing treatment to offenders in prison; assessing the **dangerousness** of an offender (that is, whether they are likely to re-offend or not); and conducting research in areas of forensic psychology, such as personality characteristics of stalkers, jury behaviour and so on. Forensic psychologists usually work with the police at jails or in law courts.

FIGURE 11.29 Forensic psychologists help police create a criminal profile of an offender.

Dangerousness

Forensic psychologists may need to determine if a person is dangerous or not. Dangerousness describes the likelihood of a person committing a serious act of violence, with little provocation. Assessing dangerousness means making a prediction about whether the person will be violent in the future.

Criminal profiling

Another role of a forensic psychologist may be to provide a criminal profile of a perpetrator. Criminal profiling is a technique used to assist in the identification and apprehension of a likely offender for a particular crime. A criminal profile is a portrait or picture of a particular offender: the physiological characteristics such as sex, race, body build, height, weight, left or right handedness; psychological characteristics such as intelligence level, personality, aggressiveness; and personal details such as employment status, socio-economic status, marital status, clothing preference, where they live, and car type or preference.

Sometimes when police are investigating the death of someone, they notice that behaviours or clues are similar to a past murder. They are then able to link the murders. Someone who kills multiple people over time is known as a serial killer.

11.11.2 Serial killers

The leading authority on serial killers is the FBI, the United States Federal Bureau of Investigation. The FBI has studied serial killers methodically and has compiled vast amounts of information concerning the killers themselves, their methods, and their motivations on a criminal profiling database.

Personality characteristics that seem to be more common in serial killers, compared to other people, include impulsiveness, low self-esteem, poor social skills, competitive and aggressive behaviour, a lack of remorse and guiltlessness. An inherent sadistic nature is another part of the serial killer psyche, along with a fascination for violence, injury and torture.

11.11.3 The polygraph

In some countries, a polygraph (commonly called a lie detector) is used to determine if an accused person is telling the truth or not. It is often the role of a forensic psychologist to administer the **polygraph**.

FIGURE 11.30 During a polygraph test, galvanic skin resistance is measured, which reflects the amount of sweat on the skin. The more sweat on the skin, the higher the arousal and the less resistance it has to electrical currents.

People tell lies and deceive others for many reasons. Most often, lying is a defence mechanism used to avoid trouble with the law, a boss or authority figures. Sometimes you can tell when someone is lying, but other times it may not be so easy. Polygraphs are instruments that monitor a person's physiological reactions. These instruments do not, as their nickname suggests, detect lies. They can only detect whether deceptive behaviour is being displayed.

A polygraph instrument measures a person's arousal. Arousal refers to how alert or aware someone is of the environment. A person's heart rate, blood pressure, respiratory rate and electrodermal activity (sweatiness, in this case of the fingers) are measured and compared to normal levels. The more aroused someone becomes when asked about a crime, the more likely the person is lying.

Results from the polygraph are not allowed as evidence in Australian courts because it does not measure lies. Other conditions such as nervousness, stress, headaches, muscular problems and even the common cold can cause an increase in a person's arousal. Polygraphs can also be cheated.

polygraph a machine that attempts to detect deceptive behaviour by measuring arousal

CASE STUDY: How to cheat the polygraph test

One way of cheating the polygraph test is by hurting yourself — by stepping on a pin, clenching a muscle very tightly or biting your lip — when asked questions. The experience of pain also increases arousal, so the person operating the polygraph machine may think the person is just a highly anxious person, rather than a lying murderer!

11.11 Activities

11.11 Quick quiz on

11.11 Exercise

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 2, 3	4, 5	6, 7

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. Describe the role of a forensic psychologist.
2. What is the difference between a forensic psychologist and a forensic scientist?
3. **MC** Where do forensic psychologists work?
   - A. In laboratories
   - B. In doctors’ clinics and hospitals
   - C. In counselling services
   - D. In jails or in law courts
4. Explain why the polygraph is inadmissible in Australian courts.
5. a. Decide whether the following are TRUE or FALSE.
   b. Justify any false responses.

Statement	True or false?
i. Forensic psychologists collect evidence at the scene of a crime.	
ii. Forensic psychologists work with police while developing the criminal profile of a suspect.	
iii. The best predictor of dangerousness is a history of violent behaviour towards others.	
iv. The polygraph measures lies.	
v. The results of polygraph tests are inadmissible as evidence in a court of law in Australia.	

Apply and analyse

6. Research the role of forensic scientists, including ballistics experts, forensic serologists and forensic entomologists. What are the differences between each of these scientists?

Evaluate and create

7. **SIS** Create a PMI chart of the use of criminal profiling in the apprehension of perpetrators of crime. Compare your chart with that of the person sitting next to you.

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

LESSON
11.12 Review

Hey students! Now that it's time to revise this topic, go online to:

Review your results

Watch teacher-led videos

Practise questions with immediate feedback

Find all this and MORE in jacPLUS

Access your topic review eWorkbooks

on Resources

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-12697	ewbk-12699	ewbk-12701

11.12.1 Summary

Introducing psychology

- Psychology is a branch of science that investigates how our brain influences our thoughts, feelings and behaviours.
- Psychology is a growing science, investigating interesting ideas such as why serial killers kill, why we compete against each other and why stress makes us sick.
- Psychology is the systematic study of thoughts, feelings and behaviours.
- Psychologists can work in many areas, including sport, forensic, health, counselling, clinical, neuropsychology, academic, educational and organisational psychology.

The brain

- The outer layer of the brain, the cerebral cortex, is responsible for: problem solving, memory, personality, judging, planning, learning, logical reasoning and decision making. The cerebral cortex is divided into two halves called cerebral hemispheres.
- The two hemisphere share information through the corpus callosum.

Intelligence

- Psychologists' definitions of intelligence range from 'intelligence is what intelligence measures' to definitions such as 'a psychological potential to solve problems or to fashion products that are valued in at least one cultural context'.

Emotions and communication

- Various types of nonverbal communication are possible, including kinesics (body language) and personal space.
- Stress occurs any time we must change in order to fit in with an environment.
- High emotional intelligence (EQ) allows people to better understand, empathise and negotiate with people. EQ is regarded as more important than IQ for success in life.

Memory

- 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.

Sleep and sleep disorders

- Rapid eye movement sleep (REM sleep) occurs throughout the night. It involves the eyes moving around rapidly (while the eyelids are closed), muscle twitching and irregular breathing. People dream during REM sleep.
- Non-rapid eye movement sleep (NREM sleep) is divided into four stages, from a very light sleep (stage 1) to a very deep sleep (stage 4).
- Sleep problems that disrupt the normal NREM–REM sleep cycle, including the onset of sleep, are called sleep disorders. Most can be successfully treated. Insomnia is one form of sleep disorder.
- Sleep phenomenons are normally occurring behaviours and can include sleep walking, sleep talking, nightmares and night terrors.

Psychopathology

- Symptoms or signs are the characteristics that allow a psychologist to diagnose a mental health disorder. A diagnosis involves putting a label on a set of symptoms.
- The word ’prevalence’ refers to how common a disorder is within the community.
- A phobia is an intense, irrational fear and avoidance of an activity, a situation or a particular object.
- Bipolar depression is a depressive disorder where the individual sufferer has extreme mood swings between mania (elevated mood) and depression (feelings of being sad and worthless), usually separated by days or weeks of normal moods.

Treatment of mental health disorders

- Today, treatment of mental health disorders occurs in two main ways: psychological therapies, such as counselling and behaviour therapy; and biomedical therapies, such as drugs and medication.

Groups and social psychology

- In a collective, people do not all interact with each other. In a group, members interact with each other.
- Leadership involves an individual or group with high power and status directing a group.
- Democratic leadership is balanced between being task- and people-oriented.
- Laissez-faire leadership is a person-oriented leadership style where leaders are friendly and helpful but have no direct control over the group. Instead, the group members have the control.
- Autocratic leadership is a task-oriented leadership style where the leader makes the decisions for the group and has complete control of them.

Forensic psychology

- Forensic psychology involves applying psychological knowledge and principles to legal issues.

11.12.2 Key terms

affiliation the human need for involvement and belonging to a social group
amygdala the emotional centre of the brain that processes primal feelings, such as fear and rage
anti-anxiety drugs drugs that aim to inhibit anxiety by restoring the balance of certain chemicals in the brain
antipsychotic drugs drugs that treat mental health disorders such as depression, anxiety and schizophrenia
anxiety a natural and usually short-lived reaction to a stressful situation; a disorder whereby anxious thoughts, feelings and physical symptoms occur frequently and persistently, disrupting daily life
arousal the state of being physiologically or psychologically activated
autocratic leadership a leadership style whereby the leader makes all decisions and has complete control
behavioural therapy a type of therapy that aims to identify and help fix self-destructive or unhealthy behaviours

biomedical therapy a type of therapy that uses medications to treat mental health disorders
bipolar disorder a disorder whereby a person has extreme mood swings between mania and depression
cerebral cortex the outer layer of the brain, which processes information and is linked to memory and problem solving
cerebral hemispheres the two halves of the cerebral cortex, both responsible for different ways of thinking
cognitive therapies types of therapy that aim to teach people more constructive ways of thinking
collective a collection of two or more people who do not interact with all other members of the collection
control group a group of participants within an experiment who are not exposed to the variable being tested, and are used to compare to the experimental group
corpus callosum the part of the brain that connects the two hemispheres, allowing them to function interactively
criminal profiling a profile detailing the physical and behavioural traits of a criminal that is used by detectives and police
cult a social group defined by intense belief and devotion to unusual religious or spiritual beliefs
dangerousness the likelihood of an offender to commit a serious act of violence with little provocation
democratic leadership a balanced approach to leadership that allows group members to participate in decision making
depression lasting and continuous, deeply sad mood or loss of pleasure
distress negative or harmful stress that overwhelms an individual's ability to cope and adapt
emotion a complex pattern of bodily and mental changes
eustress positive or beneficial stress that motivates and energises an individual
experimental group a group of participants within an experiment who are exposed to the variable being tested
forensic psychology the application of psychological knowledge and principles to legal issues
group collection of two or more people who interact with and influence one another and who share a common purpose
hippocampus the area of the brain stem able to transfer information between short- and long-term memory
insomnia a sleep disorder whereby a person has difficulty either falling asleep or staying asleep
intelligence has no agreed definition — some definitions include: 'the ability to learn and solve problems' and 'the capacity for logic, understanding, self awareness and creativity'
kinesics the study of body language as a type of non-verbal communication
laissez-faire leadership a person-oriented approach to leadership style whereby the leaders are friendly and helpful but do not have direct control over the group
long-term storage a function of the brain that enables memories to be stored, sorted and retrieved
mania an elevated mood involving intense elation or irritability
mnemonic a strategy to help you to remember things
non-rapid eye movement sleep (NREM sleep) stages of sleep characterised by the absence of rapid eye movements
personality the combination of characteristics or qualities that form an individual's distinctive character
personal space the space within a small distance of a person
phobia an intense or irrational fear of something that poses little or no threat
polygraph a machine that attempts to detect deceptive behaviour by measuring arousal
population the entire group of people who are being studied from which a sample is selected
prevalence the percentage or proportion of the population that have a certain illness or disorder
pseudosciences fields that are not sciences, despite having scientific sounding names or claiming to be scientific
psychiatrists medical doctors that specialise in the diagnosis and treatment of medical illness
psychological therapies structured interaction between a professional and a client to help overcome psychological problems
psychologists an expert or specialist in psychology
psychology the systematic studies of thoughts, feelings and behaviours
psychopathology the scientific study of mental health disorders
rapid eye movement sleep (REM sleep) a stage of sleep characterised by the repetitive, brief and erratic movements of the eyeballs under eyelids
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
sample a smaller group of individuals selected from a larger group that has been chosen to be studied
schizophrenia a disorder that affects a person's ability to think, feel and behave clearly

scientific method a systematic and logical process of investigation to test hypotheses and answer questions based on data or observations
self-identity the personal awareness of one's self and where they fit into society
sensory register a system in the brain that filters incoming information on the basis of importance
sleep disorders problems that disrupt the normal sleep cycle
sleep phenomenon behaviours that occur at night including sleepwalking, sleep talking, nightmares and night terrors
somnambulism another word for sleepwalking
store storage of a memory in the appropriate part of the brain
symptoms physical or psychological features of a disease or disorder
systematic desensitisation a type of therapy that aims to desensitise people to their phobias
thalamus the part of the brain at the top of the brain stem that passes sensory information to key areas in the brain for processing

on Resources

eWorkbooks	Study checklist (ewbk-12703) Literacy builder (ewbk-12704) Reflection (ewbk-12710) Crossword (ewbk-12706) Word search (ewbk-12708)
Solutions	Topic 9 Solutions (sol-1153)
Digital document	Key terms glossary (doc-40174)

11.12 Activities

learnon

11.12 Review questions

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 2, 7, 8, 9, 10, 11, 13, 17, 19	3, 4, 6, 12, 15, 21, 22, 24	5, 14, 16, 18, 20, 23, 25

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. **MC** Which of the following is NOT a behaviour?
   A. Blinking
   B. Going for a walk
   C. Laughing
   D. Having a toothache
2. **MC** A major difference between a psychologist and a psychiatrist is that:
   A. a psychologist is allowed to perform medical procedures whereas a psychiatrist is not
   B. there are fewer areas of specialisation in psychology than there are in psychiatry
   C. a psychologist is allowed to prescribe certain types of medication, whereas a psychiatrist can prescribe all types of medication
   D. a psychiatrist is allowed to prescribe medication whereas a psychologist is not.
3. **a.** Psychiatrists spend 6 years on average at university, while psychologists spend 11 years on average. True or false.
   b. Explain the differences in work carried out by psychologists and psychiatrists.
4. Why is astrology considered to be non-scientific?

5. Describe the role of an organisational psychologist.
6. What is the role of the corpus callosum in the brain?
7. **MC** Psychologists use the term personality to refer to an individual's:
   - **A.** temperament, mood and ability to relate to others
   - **B.** distinct mix of changing physical attributes, behaviour and thought patterns
   - **C.** relatively unchanging, unique, psychological characteristics and behaviour patterns
   - **D.** all of the above.
8. **MC** Gardner's theory of multiple intelligences proposes that everybody has:
   - **A.** just one type of intelligence
   - **B.** a combination of two different types of intelligence
   - **C.** all of the intelligences but in different quantities
   - **D.** different types of intelligences, except for identical twins.
9. **MC** In an adult, REM sleep constitutes approximately what percentage of the total time spent asleep?
   - **A.** 20%
   - **B.** 30%
   - **C.** 40%
   - **D.** 50%
10. **MC** __________ is the inability to get enough sleep.
    - **A.** Pseudoinsomnia
    - **B.** Hypersomnia
    - **C.** Somnolence
    - **D.** Insomnia
11. Describe the two main functions of the central nervous system.
12. List two types of non-verbal communication. Give an example of each type.

Apply and analyse

13. **MC** The term dangerousness refers to:
    - **A.** the likelihood of a person committing a serious act of violence
    - **B.** the likelihood of a person stalking another person
    - **C.** whether or not the alleged offender is able to understand what they have been charged with
    - **D.** having a mental health disorder or intellectual disability at the time of committing the offence.
14. **MC** Which of the following is least likely to be classified as a collective?
    - **A.** The spectators at a cricket match
    - **B.** The people in a cinema watching a movie
    - **C.** Six people talking at a party
    - **D.** People sitting in a tram

15. **MC** The type of work that may be undertaken by a forensic psychologist could include:
    - **A.** enhancing sporting performance through mental skills training
    - **B.** giving advice or an expert opinion to a court
    - **C.** helping couples to communicate more effectively
    - **D.** assessing an individual's career potential.
16. Which of the multiple intelligences would be important for people working as the following? Explain your response.
    - **a.** Journalist
    - **b.** Ballet dancer
    - **c.** Ecologist
17. **MC** Forensic psychologists are most likely to be employed by:
    - **A.** schools
    - **B.** large corporate banks
    - **C.** the police
    - **D.** debt-collection agencies.
18. There are four zones of personal space; describe the size and the activities that might occur in the intimate zone.

19. Briefly describe two symptoms of insomnia.
20. Are the following statements true or false? Justify any false responses.
    a. Multiple murderers who commit crimes over time are called serial killers.
    b. The FBI collects and keeps many criminal profiles in a database that is used to solve other crimes.
    c. One way of cheating the polygraph is to put a pin in your shoe and hurt yourself when answering the irrelevant questions.
    d. The results of a polygraph can be used as evidence in Australian courts.
    e. The polygraph measures lies.
21. Describe how the polygraph works.
22. Describe any other methods of lie detection, besides the polygraph.

23. Investigate the mental health disorder, depression. Answer the following questions:
    a. What is the prevalence?
    b. What are the symptoms?
    c. What is the treatment?
    d. What is the relationship between depression and suicide?
    e. How were mental health disorders treated pre-nineteenth century?
    f. Name five drugs that are used to treat mental health disorders.

Evaluate and create

24. People react differently to different stressful situations. Our interpretations about how well we can cope with a situation affect how well we actually deal with it. However, there are simple methods of reducing a difficult experience into a more manageable experience. These include stress management, relaxation, social support, counselling and aerobic exercise. Research how one of these may be used to reduce stress.
25. **SIS** There are many ways of testing intelligence. Use the internet to research two of these methods and create a Venn diagram to display their differences and similarities

.

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

Online Resources

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.

11.1 Overview

eWorkbooks
- Topic 11 eWorkbook (ewbk-12682)
- Student learning matrix (ewbk-12684)
- Starter activity (ewbk-12685)

Solutions
- Topic 11 Solutions (sol-1153)

11.2 Introducing psychology

Interactivity
- Gallery: Specialist areas in psychology (int-7051)

11.3 The brain

eWorkbooks
- Labelling parts of the brain (ewbk-12687)
- Investigating neurons (ewbk-12689)

Interactivity
- Labelling parts of the brain (int-8133)

11.4 Intelligence

eWorkbooks
- Multiple intelligences (ewbk-12691)
- Types of intelligence (ewbk-12693)

11.5 Emotions and communication

eWorkbook
- Emotions (ewbk-12695)

11.6 Memory

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

Weblink
- Memory

11.7 Sleep and sleep disorders

Weblink
- Sleep Health Foundation

11.9 Treatment of mental health disorders

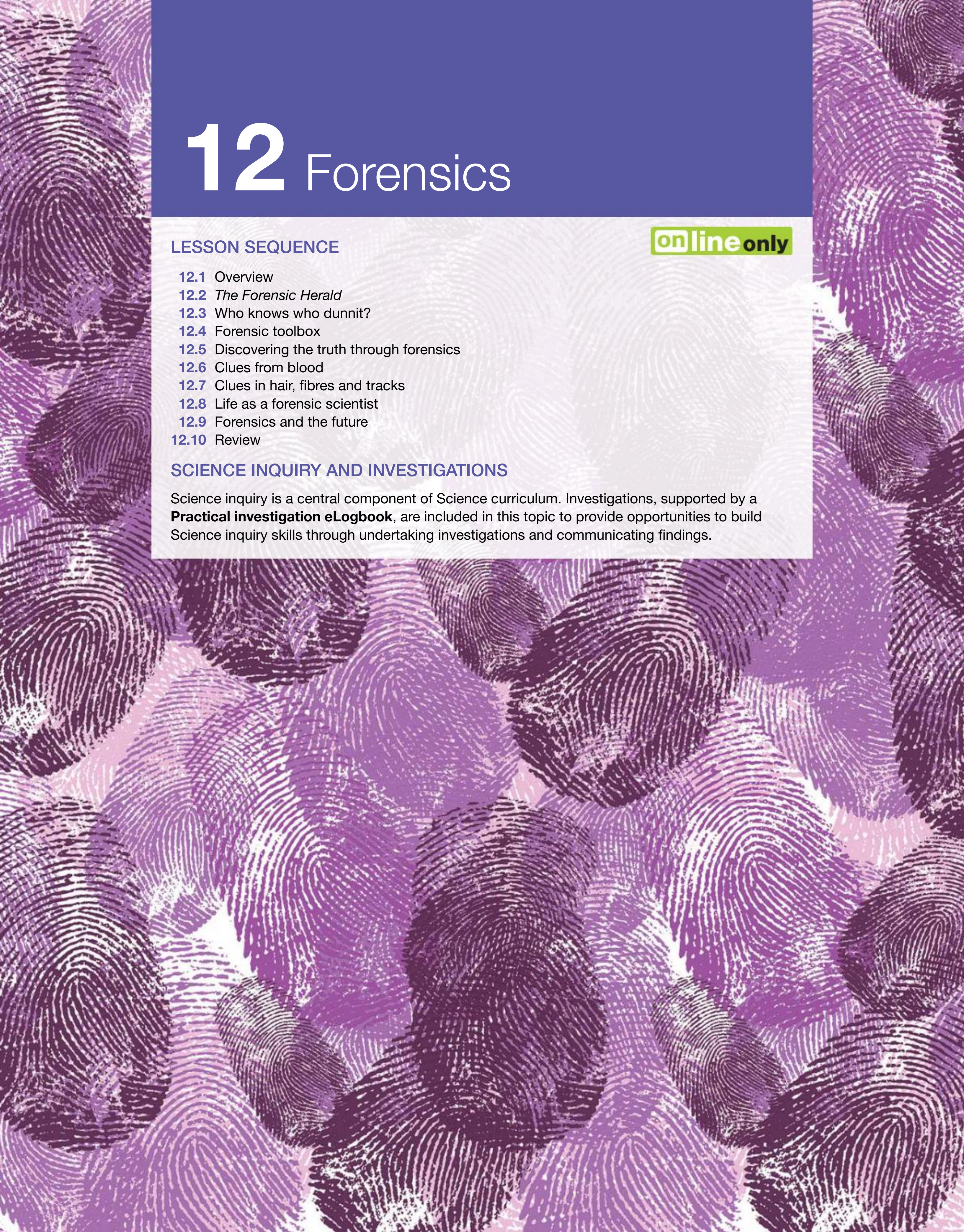
Weblink
- Beyond Blue

11.12 Review

Digital document
- Key terms glossary (doc-40174)

eWorkbooks
- Topic review Level 1 (ewbk-12697)
- Topic review Level 2 (ewbk-12699)
- Topic review Level 3 (ewbk-12701)
- Study checklist (ewbk-12703)
- Literacy builder (ewbk-12704)
- Crossword (ewbk-12706)
- Word search (ewbk-12708)
- Reflection (ewbk-12710)

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



12 Forensics

online only

LESSON SEQUENCE

SCIENCE INQUIRY AND INVESTIGATIONS

Science inquiry is a central component of Science curriculum. Investigations, supported by a **Practical investigation eLogbook**, are included in this topic to provide opportunities to build Science inquiry skills through undertaking investigations and communicating findings.

LESSON
12.1 Overview

12.1.1 Introduction

Forensic ballistic investigators use the unique bullet grooves created by individual guns to make a match between bullets and guns. They look at the indentations in cartridge cases and identify them with the chamber marks in the gun they came from. If there is no suspect bullet or gun evidence, the entry point of a bullet hole can be analysed to determine the type and size of the gun, at what angle it was shot, and the minimum and maximum firing distance. Exit bullet holes are often larger than the bullet and can also give clues as to the type of gun used. Residue found in and around bullet holes is generally made up of gunpowder, lead, smoke and unburned particles. The clothing or material through which the bullet passed is handed over to investigators for analysis. It is microscopically examined and chemically processed to determine if there is a pattern of gunshot residue, which provides information on the order, distance and angle of the shots. All this may lead to a conviction!

FIGURE 12.1 Different guns create different bullet grooves that can be used as evidence.

on Resources

Video eLesson How a gun fires bullets in slow motion (eles-4218)

Watch this video to observe how bullets are fired by a specific type of handgun, observing how the bullet casings fly out. These can help provide evidence at crime scenes.

12.1.2 Think about forensics

1. If there is no body and no gun at a crime scene, what evidence remains to give clues about what happened?
2. What information can be found on a bullet?
3. How do police solve crimes with identical twins when they have the same DNA?
4. Some individuals are born with adermatoglyphia, in which they are born without fingerprints. Would these people be able to commit the perfect crime?
5. In a robbery, other than DNA evidence, what else might a forensics team search for?
6. How much DNA do you need to create a DNA profile?
7. Should the DNA and fingerprints of all individuals be kept in a database?
8. What is the chance you could be incorrectly convicted of a crime?
9. How might broken glass be important in solving a crime?
10. Why are some crimes unsolved despite all the advances in forensics?

12.1.3 Science inquiry

elog-2331

INVESTIGATION 12.1

Recreating a crime scene

Aim

To recreate a crime scene and show some of the expected evidence that would allow the crime to be solved

Materials

- a large box or container
- equipment to create a crime scene including different fabrics, pieces of plastic (or rounded glass), cling wrap, cellophane and markers
- scissors
- sticky tape

Method

1. Read the excerpt below outlining a crime that has occurred:
   The victim was travelling down her street at 8:00 pm after a dinner with friends. It seemed the local hoons had been out and about, as there were skid marks on the road that were not there 2 hours earlier. Arriving home, the victim unlocked her front door, nothing amiss except a faint smell of cigarette smoke. Upon walking to her bedroom, she noticed that the window had been smashed, creating jagged edges and glass everywhere. Immediately she called the police, who asked if anything was missing. She went to her jewellery box, noticing her engagement ring was gone from its location, hidden away as it no longer fit. The police arrived at the scene and searched for clues as to who the perpetrator may have been.

2. Using the materials provided, create a diorama of the crime scene, including some of the evidence that may have been found at the scene. Use the information in the story and your imagination to help construct this.

Results

Draw a sketch or take a photo of your model. Label the different evidence at the crime scene.

Discussion

1. Summarise the evidence that may be used by the police for a conviction and explain why you placed each piece of evidence in the location you did.
2. Why would it be important for a forensics team to wear protective clothes while examining the scene?
3. How might the police use the evidence to determine who committed the crime?
4. How would police determine if there was only one person involved or multiple?
5. What features outside the house might be useful to help solve this crime?
6. From a search of the evidence, it seemed the thief only opened the jewellery box that contained the ring. What might this suggest?

Conclusion

Summarise how evidence is used by forensics teams to solve crimes such as robberies.

on Resources

eWorkbooks	Topic 12 eWorkbook (ewbk-12477) Student learning matrix (ewbk-12479) Starter activity (ewbk-12480)
Solutions	Topic 12 Solutions (sol-1141)
Practical investigation eLogbook	Topic 12 Practical investigation eLogbook (elog-2329)

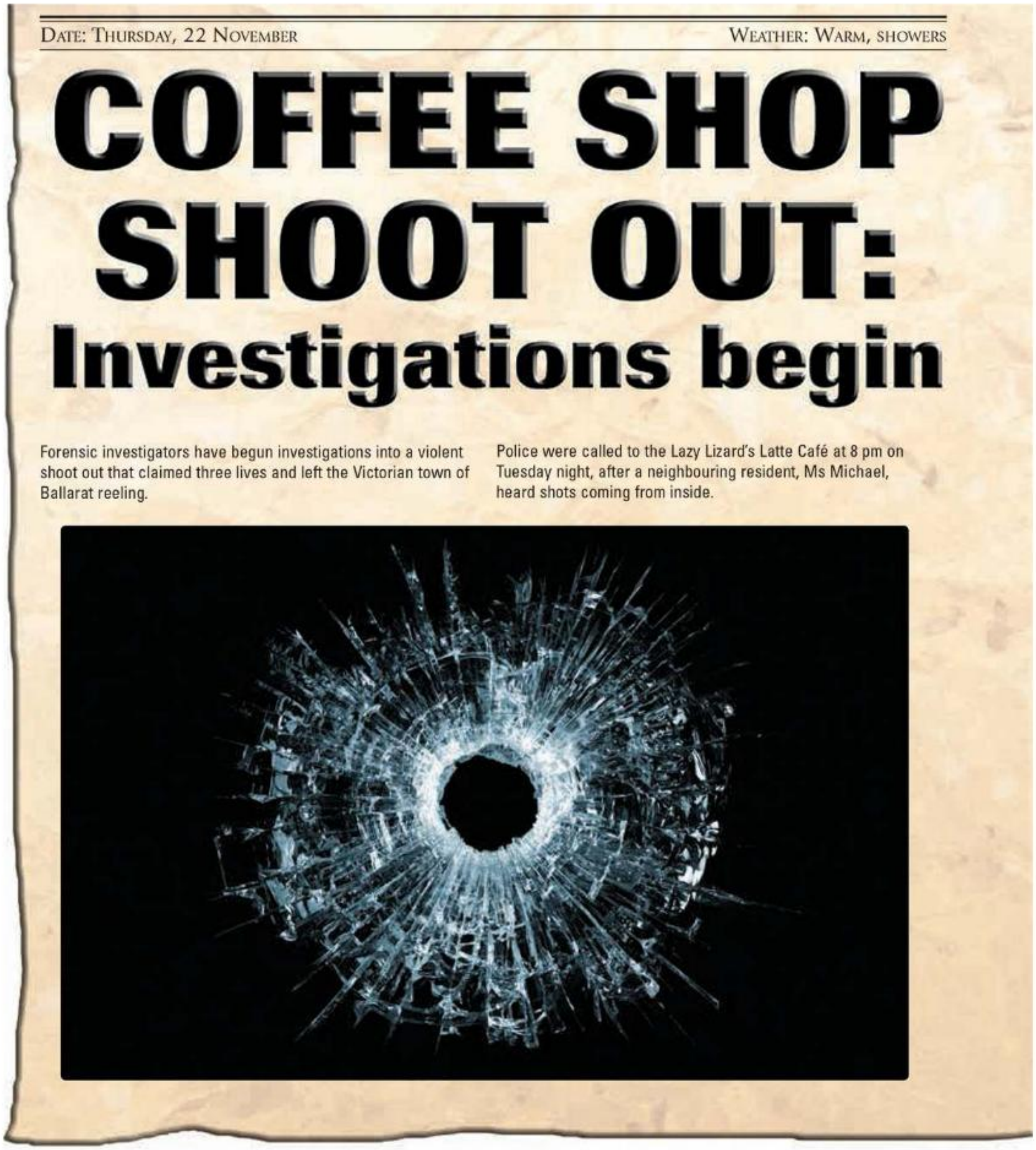
LESSON
12.2 *The Forensic Herald*

LEARNING INTENTION

At the end of this lesson you will be able to explain how crime scenes are investigated and provide examples of evidence that can be found.

12.2.1 A report from *The Forensic Herald*

FIGURE 12.2 Shots exploded from the Lazy Lizard's Latte Café today, shattering the quiet streets of Ballarat.



DATE: THURSDAY, 22 NOVEMBER

WEATHER: WARM, SHOWERS

COFFEE SHOP SHOOT OUT: Investigations begin

Forensic investigators have begun investigations into a violent shoot out that claimed three lives and left the Victorian town of Ballarat reeling.

Police were called to the Lazy Lizard's Latte Café at 8 pm on Tuesday night, after a neighbouring resident, Ms Michael, heard shots coming from inside.

Sergeant Hurst gave a candid account of the scene, describing it as one of upheaval upon arrival.

'We found the three deceased people, a waitress and two patrons, all bound together with rope, behind the counter of the café. Each had been shot once. And we found traces of blood leading all the way out the door, and tyre marks in the street. So far eight bullet holes in the walls and two through the window have been identified, and investigators are searching for shells and casings as we speak. It was very eerie being the first person there because everything was very still and quiet, except for the ceiling fan that was blowing receipts all over the place, and a burning coffee pot.'

The entire street has been sealed off while investigators collect evidence, a process that could take another day.

'I can confirm that all of the deceased are known to have police records, and at this stage it seems the attack was a robbery as the cash register was found empty. We have no witnesses other than the neighbour who called us. She said that she heard at least six shots,' said Sergeant Hurst.

Blockades have been established at all the main roads leading out of Ballarat, and extra patrol cars are on the beat. Residents are urged to be aware of anyone acting suspiciously and to notify police about any possible information regarding the attack.

FIGURE 12.3 Evidence left at the crime scene, showing a bloody footprint

ACTIVITY: Map of the crime scene

In groups, brainstorm what you think happened at the Lazy Lizard's Latte Café and present your three key ideas to the class. Create an annotated map of the crime scene that includes the café, street and the possible location of evidence.

on Resources

eWorkbook How observant are you? (ewbk-12482)

12.2 Activities

learnon

12.2 Quick quiz on | **12.2 Exercise**

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 3, 8, 10	2, 5, 7, 9	4, 6, 11

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Use the report from *The Forensic Herald*, and the details in this lesson, to answer the following questions.

Remember and understand

1. How many bullet holes have been found so far? Why do you think this is significant?

Apply and analyse

2. What evidence is there that indicates at least one other person was in the café at the time?
3. What evidence is there that could indicate the amount of time that passed during and after the attack?
4. Write down all the factors in this story that you think could be clues. Explain why they might be useful.
5. Match the following evidence that could be gathered from a scene with the information that could be found from it.

Evidence	Information
a. Blood traces	**A.** Fingerprints, lip prints, DNA
b. Tyre marks	**B.** Location of shooter, gun type
c. Bullet holes	**C.** Trace where it was purchased
d. Rope	**D.** Car types, direction
e. Café glasses, crockery and cutlery	**E.** Movement of the killer, DNA, blood type

6. What lead would you follow up first? Why?
7. What physical and mental traits do you think the perpetrator would need to carry out this crime?
8. What sorts of questions would you ask the neighbours during your investigations?
9. If all the victims have criminal records, what type of information do you think police will already have on them?
10. Explain why the entire street was sealed off during the collection of evidence.

Evaluate and create

11. **SIS** Write up a one-page report on your initial conclusions of what happened at the Lazy Lizard's Latte Café.

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

LESSON
12.3 Who knows who dunnit?

LEARNING INTENTION

At the end of this lesson you will be able to identify different individuals involved in forensics and understand the difference between medical forensic scientists and forensic field scientists.

12.3.1 Forensic scientists

In Australia, there are two types of forensic investigators: police officers who are trained to collect certain **evidence** at a crime scene, for example, fingerprint and ballistics experts and photographers; and there are forensic scientists. Forensic investigators study the objects or evidence, and provide an expert opinion that can then be used in court.

evidence facts or information that can be examined to determine whether a proposition is true

Forensic scientists are usually university-trained professionals who work in their field of specialty and lend their skills to legal investigations. Forensic science is not a specific branch of science, but a general term for the many disciplines used in crime scene investigation.

The administration of forensic science is the responsibility of each state and territory. In smaller regions, where fewer police work at the stations, they carry out more forensic investigations themselves, while in larger areas such as cities, there are more staff who specialise in different fields. Most forensic scientists work in a number of laboratory, medical and field science situations.

12.3.2 Medical forensic scientists

Forensic biologist

Forensic **biologists** look at the **genetics** of those involved in a crime (figure 12.5). They look at blood types and conduct **DNA** profiling to identify people at the scene of a crime, and to match **suspects** to evidence.

FIGURE 12.4 This forensic scientist processes evidence in a laboratory equipped for DNA extraction.

FIGURE 12.5 Examining DNA and blood up close is important in forensics.

Forensic chemist

Forensic **chemists** will be asked to analyse any substances found at the scene of a crime. They may be asked to establish exactly what a substance is, for example, what type of explosive has been used. If police suspect poisoning, they will call a toxicologist, a chemist who specialises in poisons, to determine what type of drug has been seized, or what poisonous residue has been found, in a coffee cup, for instance.

Forensic odontology

Also known as forensic dentistry, these investigators study the dental evidence found at a crime scene and help identify unknown corpses (figure 12.6). Dental enamel is the hardest substance in the body so is often well preserved and can be compared to dental records. Clues can be provided as to the age and identity of a victim by comparing dental evidence to x-rays, dental casts and photographs. Forensic **odontologists** are called to the scene of mass casualties. They can also provide an assessment of bite-mark injuries.

Forensic pathologist

These investigators are licensed **pathologists** in charge of examining bodies to determine things such as the cause of death, wounds and injuries. It is the forensic pathologist who carries out the postmortem — a medical examination of dead bodies, to determine how a person died.

biologists scientists who study the science of life

genetics the study of genes

DNA a substance found in all living things that contains genetic information

suspects people who are thought to be guilty of a crime

chemists scientists who study the atoms and molecules that make up all substances

odontologists scientists who study the structure and diseases of teeth

pathologists people who study the causes and effects of diseases, examining samples for diagnostic or forensic purposes

FIGURE 12.6 A skull found at a crime scene can be identified using dental records.

Forensic psychiatrist

Forensic **psychiatrists** are medically trained doctors. They evaluate a person's mental state, both at the time of an offence and during their trial. They can also be called on to give their opinion about a psychological issue; are involved in caring for prisoners, particularly mentally ill offenders; and provide psychological profiles of unknown perpetrators.

FIGURE 12.7 The facial reconstruction of a victim is built up from a plaster cast of the victim's skull. This is then covered in clay to simulate the facial muscles.

Forensic anthropologist

These specialists help identify bodies that are decomposed, burned or otherwise unrecognisable. They often work in criminal cases where there are only skeletal remains. By analysing the age of the bones and the marks on them, they can help establish the time of death, and the types of wounds sustained by a victim. Facial reconstructions are also done to determine what the victim looked like which can help police in their investigations (figure 12.7). Forensic **anthropologists** are often called upon to identify victims of mass disasters.

Forensic psychologist

Forensic psychologists are not medical doctors, but are trained in **psychology**. They perform counselling and therapy for problems relating to depression, relationship breakdown and grief, for instance. They also assist in cases such as child custody disputes and child abuse. Like forensic psychiatrists, they can advise judges on the state of defendants and victims' mental health, and provide criminal profiles. They can give their opinions on **civil court** law cases such as workers' **compensation** and wrongful death suits, as well.

psychiatrists	psychologists that are also qualified medical doctors
anthropologists	people who are experts in humans and human remains
psychology	the systematic study of thoughts, feelings and behaviours
civil court	a court that handles legal disputes, not crimes
compensation	money that is awarded to someone in recognition of loss or injury
botanists	scientists who study the life of plants

12.3.3 Forensic field scientists

Digital forensics

This is the investigation of electronic devices including computers, laptops, mobile phones, hard drives and cameras. Investigators look at a digital footprint left by a person including stored files, internet activity, emails and GPS (location) data to determine if it has been used for illegal or unusual activities.

Forensic botanist

Botanists can use their knowledge to investigate evidence such as plants, seeds and soil to place a suspect at the scene of a crime. For example, soil from a different location could be found in a boot print at the scene. A pollen grain might be found within this soil that can then be traced back to a plant from a suspect's garden (figure 12.8).

FIGURE 12.8 The bottom of shoes can be analysed for particles such as soil and pollen that can be transferred by a suspect or victim.

Forensic engineering

This type of investigation is generally carried out for civil cases. Engineers look at materials and structures that do not operate properly. Most **engineering** disasters such as train derailments and aircraft accidents are subject to forensic investigation. For example, forensic engineers were involved at the start of 2020 when a Sydney–Melbourne train derailed at Wallan, leading to the death of the two drivers. Insurance companies also use forensic engineers to investigate **liability**. Appliances, industrial machinery and basic tools can all be investigated if they cause injury or property damage.

FIGURE 12.9 Forensic engineers explore disasters such as train derailments.

Forensic entomology

A forensic **entomologist** studies the life cycles of insects such as flies, which feed on corpses, to determine the approximate time of death. An entomologist can also determine whether a body has been moved to a different location, based on the types of insects found at the scene.

Flies are attracted to carrion such as human corpses. Different species of fly lay their eggs at different times and their larvae feed on different tissues. By studying the insect population of a corpse and the number and type of insects found on a body, as well as their stage of development, the time of death can be determined.

FIGURE 12.10 The population of insects in a corpse can be studied to determine the time of death.

CASE STUDY: Entomology at work

In 2000, Australian entomologist Dr James Wallman was called on to investigate the body of an African man found in a shipping container in Adelaide. Investigators worked out that the container originated on the east coast of Africa and travelled from Dar es Salaam, in Tanzania, to Durban and then on to Fremantle by ship. It was taken to Adelaide by train. The man had apparently tried to hitch a ride down the coast of Africa, but was trapped and died of dehydration, having only a small bottle of water with him. Dr Wallman found three species of African flies on the man's body, and inspected their stages of development. The indications were that a blowfly infestation occurred when the shipping container was near Durban, and that the death probably took place en route between Durban and Dar es Salaam.

engineering the field of science and technology that applies scientific principles to design and build structures

liability an obligation, responsibility, hindrance or something that causes a disadvantage

entomologist a person who studies insects

DISCUSSION

In small groups, discuss the pros and cons of each type of job involved in forensics. Of the different jobs in forensics, discuss in a group which job you would be most interested in and why.

Resources

eWorkbook Forensic scientists (ewbk-12484)

12.3 Activities

12.3 Quick quiz | **12.3 Exercise**

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 3, 4	2, 6, 8	5, 7, 9, 10

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. **MC** What is a postmortem?
   A. A forensic pathologist
   B. The cause of death
   C. An examination of a witness
   D. An examination of a dead body
2. Name the two broad groups of forensic scientists.
3. Complete the following sentence by filling the gaps with the terms entomologists and botanists.
   __________________ investigate plants, seed and soil, whereas __________________ examine the life cycles of insects.
4. **MC** Which of the following forensic scientists examine dental evidence to identify victims?
   A. Entomologists
   B. Biologists
   C. Pathologists
   D. Odontologists

Apply and analyse

5. You have found traces of white powder in a wine glass at a crime scene. Who would you ask to analyse it, and what do you want to know about it?
6. What clues would the soil found on the bottom of a suspect's shoe give?
7. How can environmental factors, such as the weather or scavengers, affect the rate of decomposition of a corpse?

Evaluate and create

8. Create a Venn diagram comparing forensic psychologists and forensic psychiatrists.
9. **SIS** Research the work of a forensic scientist and find out about one of the cases they have been involved in. Write a report of this case, trying to ensure both qualitative and quantitative data is included.
10. **SIS** Research the average salary of all the different types of forensic scientists and create a bar graph to display this data.

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

LESSON
12.4 Forensic toolbox

LEARNING INTENTION

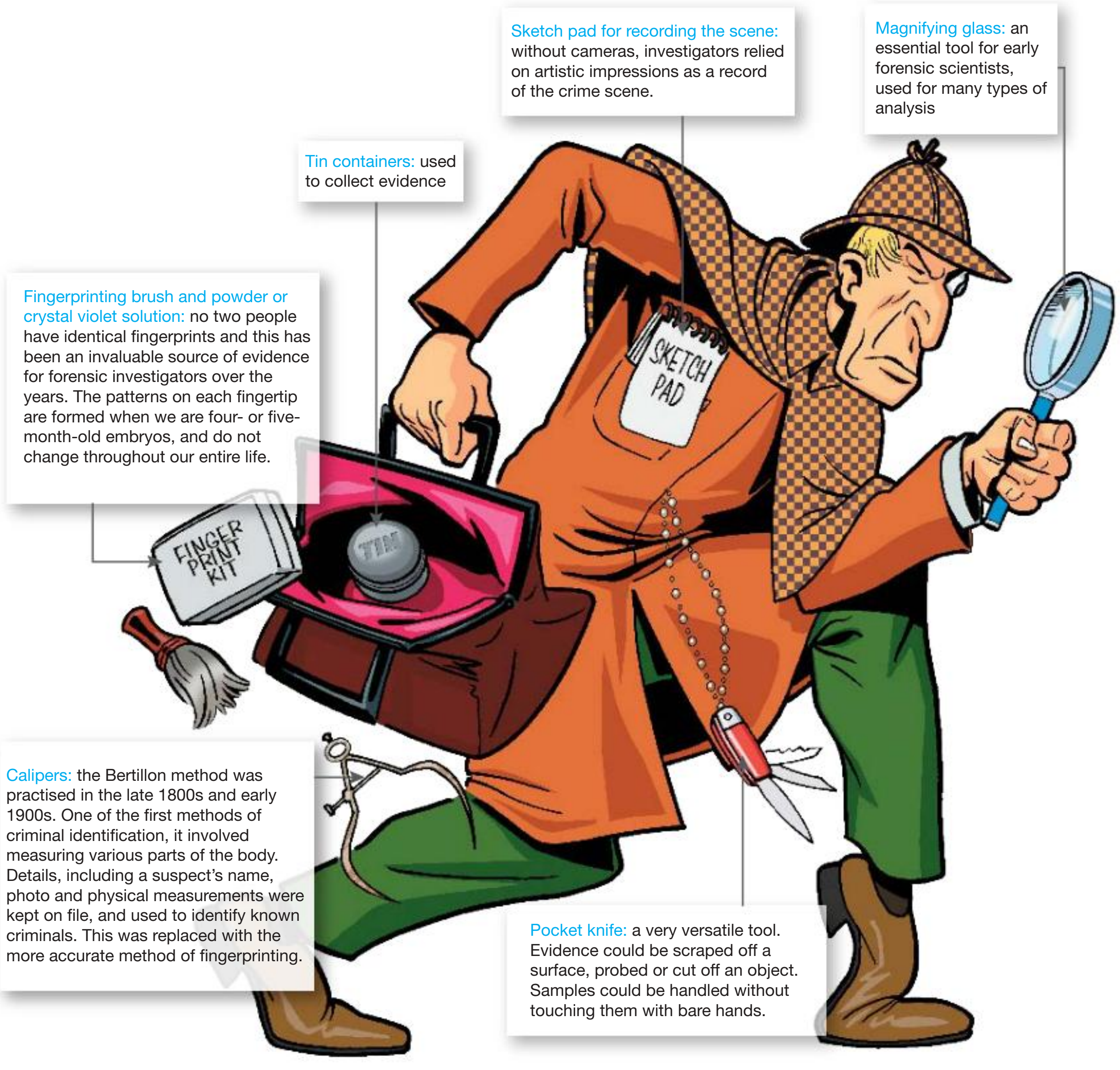
At the end of this lesson you will be able to describe the different tools used in forensics and be able to understand how fingerprints are used in forensic investigations.

12.4.1 The old-school forensic toolbox

'Those were desperate times for policemen in a hostile country with unpaved streets and uneven sidewalks, sometimes miles from the police station, with little prospects of assistance in case of need ... It took nerve to be a policeman in those days.' So reported Chief Francis O'Neill of the Chicago Police Department in 1903.

A typical forensic toolbox used by crime scene investigators 100 years ago was very basic compared to those used today. Although many of the basic techniques and principles remain the same, modern technology has enhanced the efficiency and accessibility of equipment. However, human observation and intuition are still the most important tools in forensic science.

FIGURE 12.11 The old-school forensic toolbox is very different from what is currently used.



Sketch pad for recording the scene: without cameras, investigators relied on artistic impressions as a record of the crime scene.

Magnifying glass: an essential tool for early forensic scientists, used for many types of analysis

Tin containers: used to collect evidence

Fingerprinting brush and powder or crystal violet solution: no two people have identical fingerprints and this has been an invaluable source of evidence for forensic investigators over the years. The patterns on each fingertip are formed when we are four- or five-month-old embryos, and do not change throughout our entire life.

Calipers: the Bertillon method was practised in the late 1800s and early 1900s. One of the first methods of criminal identification, it involved measuring various parts of the body. Details, including a suspect's name, photo and physical measurements were kept on file, and used to identify known criminals. This was replaced with the more accurate method of fingerprinting.

Pocket knife: a very versatile tool. Evidence could be scraped off a surface, probed or cut off an object. Samples could be handled without touching them with bare hands.

12.4.2 Analysing fingerprints

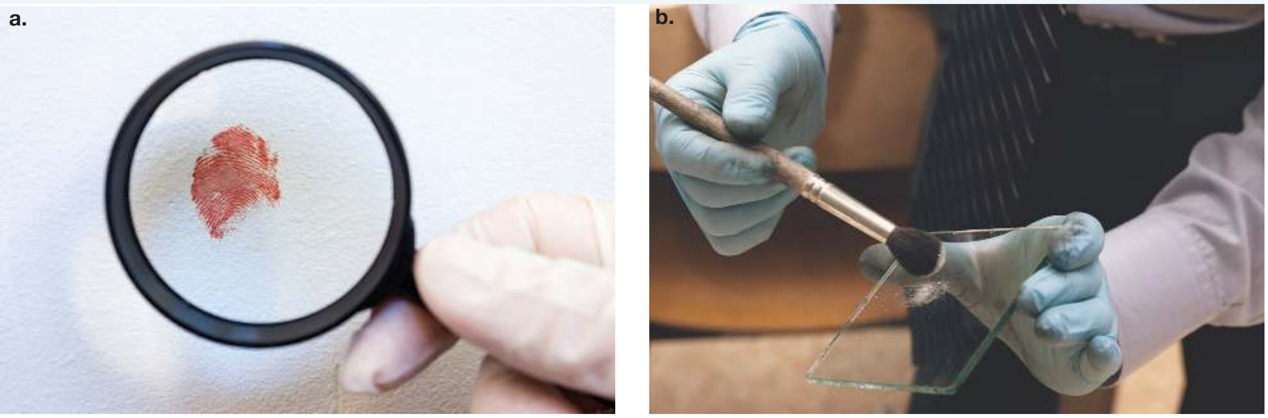
Every fingerprint is unique, formed by various friction ridges on the surface of fingers. The examination of fingerprints is known as dactyloscopy.

While the purpose of fingerprints is not well known, they provide vital clues in crime scenes, and have been used to help solve crimes throughout history. Crimes were solved using fingerprints starting in the late 1800s, but the uniqueness of fingerprints have been understood for an even longer period, with fingerprints used to authenticate government documents and contracts in ancient times. Even identical twins have different fingerprints.

There are two main types of fingerprint evidence that can be found in crime scenes:

- **Patent fingerprints** (or visible prints) are the easiest to see, often caused by visible substances such as blood or ink. An example of a patent fingerprint is shown in figure 12.12a.
- **Latent fingerprints** are invisible to the human eye and often caused by sweat and oil on the surface of the finger. These are the prints in forensic investigations that are often seen by dusting powder or chemicals over them to gain the print. An example of a latent fingerprint is shown in figure 12.12b.

FIGURE 12.12 a. Patent fingerprints are visible and **b.** latent fingerprints are invisible but can be dusted to become visible.



- Other fingerprints, such as plastic fingerprints (fingerprints embedded into a surface as a 3D impression, such as pushing fingers into a bar of soap or wax), may also be found at a crime scene.

While full fingerprints are ideal and provide a richer amount of evidence, often fingerprints at crime scenes are **partial prints**. Partial prints are a small and incomplete section of a full fingerprint. However, these can still be used in crime scenes and forensics.

patent fingerprints fingerprints that leave a visible mark on a surface

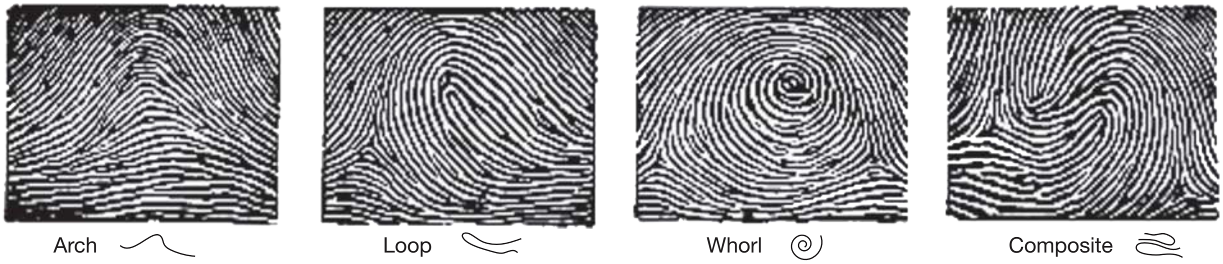
latent fingerprints fingerprints that are invisible to the human eye

partial prints a small and incomplete section of a full fingerprint

Identifying fingerprints

One of the earliest ways to explore fingerprints was through the examination of three main patterns: arches, loops and whorls. Sometimes, a composite of these may also be seen. These are shown in figure 12.13.

FIGURE 12.13 Different patterns seen within fingerprints



Loops are the most common feature seen in fingerprints, found in over 60% of all fingerprints. Whorls are the next most common feature seen, followed by arches and composites. Other patterns such a double loops and single loops may also be seen. Other unique irregularities (referred to as Galton's details) may also appear in fingerprints. This furthers the unique nature of fingerprints between individuals (and between each finger).

When collecting fingerprints from individuals, two types of methods are used: rolled fingerprints (through rolling the finger from one side to the other, and flat fingerprints. Both of these are usually taken to better verify the prints and ensure accuracy. A more recent method for obtaining fingerprints is by using a fingerprint scanner (figure 12.14b). The fingerprints are then kept on a secure database. The process takes about twelve minutes and includes a full palm and 'writer's palm' for each hand.

FIGURE 12.14 a. Both rolled and flat fingerprints are taken in crime investigations. **b.** Electronic fingerprint scanners similar to this are now used to record fingerprints.

While fingerprints used to be checked manually, databases are now used to help find matching fingerprints more rapidly. An example of this is a database such as the Automated Fingerprint Identification System (AFIS), which stores the fingerprints of people arrested. A fingerprint record is destroyed if a person is then not charged with an offence within six months or they have been found not guilty.

FIGURE 12.15 The Automated Fingerprint Identification System

Case ID : N000001221
Resp ID : NC0771078A
Resp : 18
Lists : 1

Resp List Lat v. LCF
Print Num 1

Status : Case 1 of 1

N000000122

Filter N00000
Queue local

```
 1)    NC0771078A  4615  F#6
 2)    NC0965119A  2335  F#6
 3)    NC0843399A  2315  F#6
 4)    NC0889984A  2190  F#6
 5)    NC0172646A  2170  F#6
 6)    NC0948401A  2160  F#6
 7)    NC0163889A  2080  F#6
 8)    NC0199511A  2075  F#6
 9)    NC0814921A  2075  F#6
10)    NC0062100G  2045  F#6
11)    NC0539094A  2040  F#6
12)    NC0529094A  2025  F#6
13)    NC0782084A  2020  F#6
14)    NC0058654H  2010  F#6
```

elog-2333

INVESTIGATION 12.2

Are you a loop, arch, whorl or composite?

Aim

To compare different fingerprint patterns

Materials

- an ink pad (black or blue)
- paper
- magnifying glass
- soap
- towel

Method

1. On the left side of the paper write *Left*, and on the right side, write *Right*.
2. Press all your fingers across the ink pad and then place the left-hand fingers on the left half of the page (ensure you use the full pads, not just the fingertips), beginning with the thumb and then the fingers.
3. Then do the same with the right hand on the right side of the paper.
4. After cleaning your hands, label each print: thumb, index finger, middle finger, ring finger and little finger.
5. You may wish to also do rolling fingerprints for each of your fingers and compare the results.

Result

Show each of your fingerprints, with labelled arches, loops, whorls and composites.

Discussion

1. Looking at the examples above, classify each of your prints.
2. Find out the most common type of fingerprint pattern in your class.
3. Which of your fingerprints are the most similar?
4. Is there anyone in the class with a similar fingerprint to you?
5. Identify two scenarios where the uniqueness of fingerprints can be used, other than in solving crimes.

Conclusion

Summarise your findings about fingerprints and how these are used in forensics.

Extension

Dust for latent prints using fingerprint powder or magnetic powder. Create latent prints on different surfaces to test how well the print shows up. Also compare latent prints before and after washing your hands with soap.

DISCUSSION

Do you think all individuals should have their fingerprints kept on file? Outline the pros and cons of this and share your findings with others in the class. Does the opinion of others change your thoughts at all?

on Resources

Video eLesson Creating a rolling fingerprint (eles-4219)

12.4.3 Analysing handwriting

Handwriting is similar to a fingerprint in the sense that it is unique to each person; however, there is an element of uncertainty when analysing handwriting given it can be **forged**. The study of handwriting is known as **graphology**.

forged something that has been faked

graphology the study of handwriting

Handwriting analysis compares the differences in a person's sample of writing against an unknown person's sample of writing. An examiner looks at three things:

- letter form — size and shape of letters, slope of the writing and the connection between letters
- line form — the pressure and speed applied as indicated by how smooth/shaky or dark/light the lines are
- formatting — the spacing between letters and lines and the margin/empty space left.

ACTIVITY: Analysing your handwriting

A magnifying glass bends light rays (refraction) to make things look bigger. If you use a magnifying glass to look closely at a sample of handwriting, you will see more clearly the slant of the writing, the curls of the letters, the pressure on the paper, and the height and width of the writing. All these are characteristic of your handwriting. Look at your own signature under a magnifying glass.

Comment on:

1. The style of your writing — the spacing, slant, size and curls of the letters.
2. The pressure of your writing on the page.
3. The consistency in your writing — do the same letters look identical each time you write them?
4. Any other observations.

Compare your writing to others. What do you notice? What do you notice if you write with your non-dominant hand?

FIGURE 12.16 Handwriting can be used as evidence in many cases.

CASE STUDY: Ransom notes

In 1932, the son of legendary aviator Charles Lindbergh was kidnapped from his crib. Thirteen ransom notes were sent to the family and eventually $50 000 was handed to a man known as 'John' in return for a receipt and the details of where the child could be found. But the child was discovered dead.

A massive nationwide investigation was held, and one of the methods of investigation was a thorough analysis of the ransom notes. Almost all experts who examined the notes believed they were written by the same person. They thought that the writer was of German nationality and had spent some time in America. Eventually illegal German immigrant Bruno Richard Hauptmann was charged with the kidnapping.

FIGURE 12.17 One of the ransom notes left by the kidnapper

Dear Sir!
Have 50.000 $ redy 25 000 $ in
20 $ bills 15000 $ in 10 $ bills and
10000 $ in 5 $ bills. After 2-4 days
we will inform you were to deliver
the mony.
We warn you for making
anyding public or for notify the police
the child is in gut care.
Indication for all letters are
singnature
and 3 holes.

ACTIVITY: Identifying handwriting

Collect two pieces of paper and write the word 'forensics' on both pieces of paper. You should use the same handwriting for both. Your teacher should shuffle all the papers and hand two out at random to each person.

By analysing the handwriting, move around the room to try and find the matching pieces of paper for each of your samples written by the same person.

12.4.4 The modern forensic toolbox

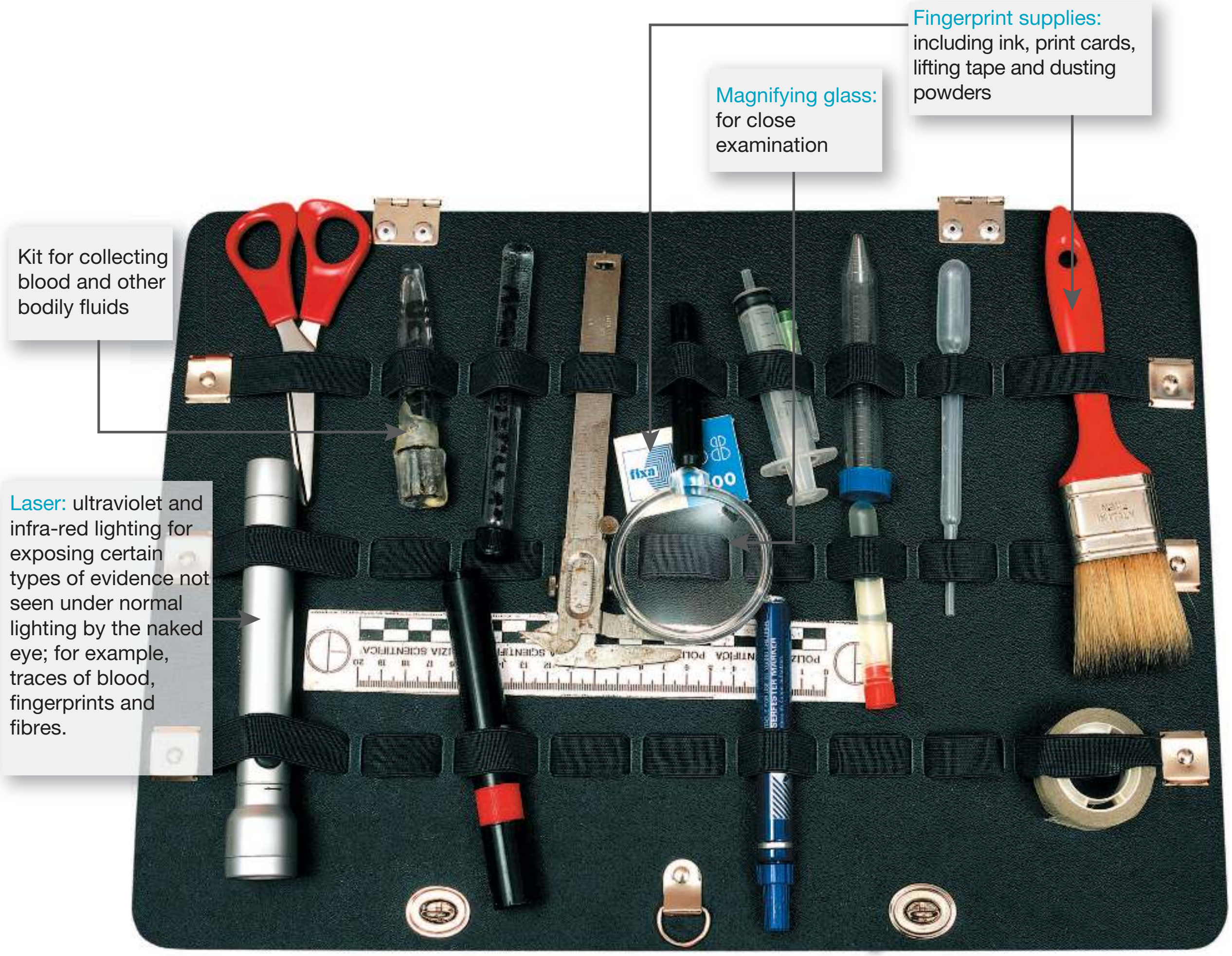
The modern forensic toolbox is more sophisticated and complex than the one used 100 years ago. Crime laboratories were set up around the world in the 1920s, and this meant a more controlled environment was required when collecting evidence.

Forensic kits, as shown in figure 12.18, also contain:

- a camera — to record the scene, with a photograph documentation kit marking evidence
- a torch
- a sexual assault kit — for collecting evidence in rape or assault cases, one each for the victim and the suspect, including medical history forms, clothing collection bags, containers for debris such as nail scrapings, slides and boxes for swab collection, paper disk for saliva sample, and blood vials
- tape — to seal off the crime scene area (blue and white police tape)
- disposable protective clothing, masks and gloves
- a notepad and pens — to record observations
- an entomology kit — for collecting and preserving insect evidence, including gloves, jars, ethyl alcohol, labels, a scalpel, a spatula and tweezers
- paper, plastic bags and glass tubes — for collecting evidence
- a cast kit — with putty and frames for making casts of tyres, footwear, and tool mark impressions
- tweezers and cotton swabs — for collecting evidence such as hair and **fibres**
- labels for evidence
- a hazmat spill kit — for handling hazardous materials.

fibres a thread that makes up a material such as a piece of clothing

FIGURE 12.18 Some of the tools used in more modern forensic kits — what else might be used?



12.4.5 Ultraviolet light

Ultraviolet light (UV light) is the band of wavelengths between visible light and x-rays on the electromagnetic spectrum. When exposed to this light source, many materials glow. Ultraviolet lights are used to identify many different types of evidence that cannot be seen in daylight, including fingerprints, **counterfeit** documents and **accelerants** in suspected **arson** cases. It can also be used to determine the fluorescent imprint that a **speedometer** needle leaves when determining how fast a car was going at the time of collision. The oil stains left on a road may assist in discovering the type of car driven as various oils glow differently under UV light.

ultraviolet light light that is invisible to the human eye but can be used to make certain substances glow

counterfeit an imitation or fake replica of money or a document

accelerants a substance that spreads fire easily

arson the criminal act of deliberately setting fire to property

speed**ometer** the instrument that displays the speed of a vehicle such as a car or truck

FIGURE 12.19 UV light can be used to explore counterfeit money. This twenty dollar note is genuine as you can see the feature fluoresce under the UV light.

elog-2335

INVESTIGATION 12.3

Exploring UV light

Aim

To explore what type of objects are fluorescent under UV light

Materials

- UV lights
- various objects including money (coins and paper), glassware, substances/chemicals (such as lemon juice and detergent) and any other objects

Method

1. Place samples of different substances, such as lemon juice and detergent, on a piece of paper (only small amounts are needed).
2. Use a UV light to investigate different objects and note down your observations.
3. Touch different objects explored and examine this under UV light. Can you see any evidence that you touched the object?

Results

Copy and complete a table similar to what is shown. Remember to add a title to your table.

Object	Observation

Discussion

1. What types of objects are fluorescent under UV light?
2. Why are UV lights used in solving crimes?

Conclusion

Summarise your findings about the use of UV lights in forensic investigations.

12.4.6 The polygraph

The polygraph, or 'lie detector', was invented in 1921 by medical student John Larson. Police began using the test in 1924 as a measure of testing if someone was lying. It works by placing a series of sensors on parts of the body that have involuntary stress reactions when an individual lies. When a person is asked questions, pens record measurements of pulses, perspiration, breathing and blood pressure on graph paper with each answer. Today, the sensors are much more accurate and the signals received are monitored electronically. But the polygraph still can't indicate that a suspect is lying, only that they have had a response to the question. However, modern polygraphs are very hard to fool with an accuracy of between 88–98 per cent!

FIGURE 12.20 Polygraph tests can explore a response to a question, which can signify that an individual may be lying.

ACTIVITY: Two truths and a lie

In small groups, play two truths and a lie (tell your teammates two true facts about yourself and one lie). See if others in your group can guess the lie. Have them write down a list of signs that made them think you were lying.

Repeat the activity, and see if you can adjust your behaviour to make your lie less obvious. Repeat this with all members of your group.

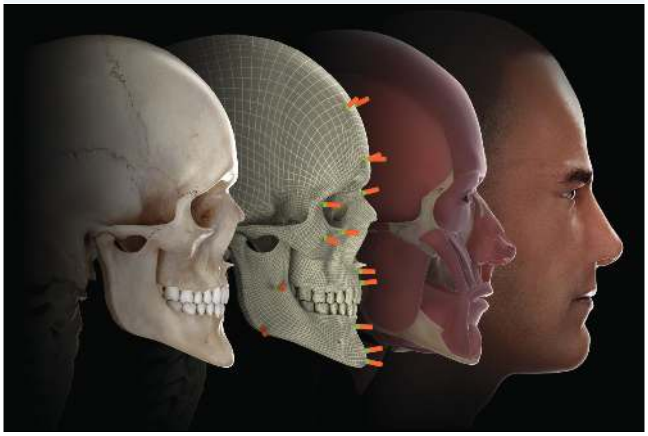
on Resources

eWorkbook Forensic toolkits (ewbk-12486)

12.4.7 Facial reconstruction

Facial reconstruction is a method used to assist with identification of human remains. The process recreates the face of an individual from their skeletal remains through a combination of techniques. The outcome could be a two-dimensional photographic print or drawing, or a three-dimensional computer image.

FIGURE 12.21 Three-dimensional facial reconstruction



12.4.8 Alternative light photography

Alternative light photography is a method that quickly detects whether damage has been done to a body before it surfaces on the skin. A camera uses blue light and orange filters to see if bruising has occurred below the skin's surface. The ultraviolet light enhances bruises, bite marks and helps to reveal trace evidence. It is used by forensic nurses in emergency situations, which often mean the difference between life and death.

12.4.9 Fire technology

Fire technology is used to establish the origin of a fire, to determine its likely cause and to conclude whether the incident was accidental, natural or deliberate. For a fire to occur, there must be a fuel, oxygen and an ignition source. When arsonists act, there is usually very little evidence left at the burnt site. However, arsonists usually use an accelerant to speed up the blaze and this chemical leaves residue that forensic scientists can isolate and identify. The scientists analyse samples taken from the scene and determine their chemical structure. They also survey and examine the site to assist with establishing the cause of the fire.

12.4.10 3D Scanner

A 3D Scanner is one of the most expensive but brilliant pieces of equipment available to forensic scientists. It is placed in the middle of a room at a crime scene and rotates 360 degrees while taking photographs of the entire room. It measures distances from itself to walls and other objects in the room. The development of the 3D scanner has reduced crime-scene recording significantly, as this was all done manually previously, including sketching the room and objects in it. Often items were left out of these sketches as they were considered to be clutter. As a result, these sketches were inaccurate. The 3D scanner provides an accurate representation of a crime scene in 10–30 minutes!

on Resources

Weblinks Snapshot facial reconstruction
Osceola County uses laser scanner for crime scene analysis and forensics

12.4 Activities

12.4 Quick quiz on

12.4 Exercise

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 4, 7	2, 5, 9, 10	3, 6, 8, 11

Remember and understand

1. List three items a crime scene investigator might have carried one hundred years ago.
2. What is the Bertillon method?
3. Explain how the polygraph works.
4. List three items a modern crime scene investigator carries in their toolbox that an investigator didn't have one hundred years ago.
5. How is an arch fingerprint different from a loop?

Apply and analyse

6. Describe how ultraviolet light can be used to identify evidence. Provide three clear examples.
7. Investigators who relied on a magnifying glass one hundred years ago would have found it very useful. What evidence, besides handwriting, might they have examined with it?
8. Explain why you think fingerprint evidence would be more accurate than the Bertillon method.
9. **a.** Looking at the contents of the two forensic toolboxes, what methods are still in practice today and how have they changed?
   b. Predict some changes these methods may have in the future.

Evaluate and create

10. **SIS** Police fingerprinted four suspects. By comparing the fingerprints with the fingerprints found at the crime scene, decide which suspect was at the scene. Justify your response, referring to the different components of the fingerprints.

11. Using online resources, investigate and report on:
    a. the pros and cons of the polygraph. Is it considered a reliable modern tool? Why?
    b. the Charles Lindbergh abduction case. What other piece of evidence left at the scene was a major factor in convicting Hauptmann? Explain the investigation.
    c. the tools that are contained in a Hazmat spill kit.

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

LESSON
12.5 Discovering the truth through forensics

LEARNING INTENTION

At the end of this lesson you will be able to explain how DNA can be used in forensic investigations to solve crimes.

12.5.1 An old crime solved

The developments in forensic technology over the past one hundred years have helped some old mysteries be revisited, and solved.

FIGURE 12.22 Alferd Packer, known as The Colorado Cannibal

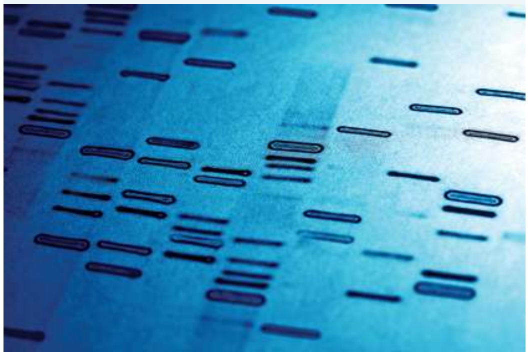
In 1874, six prospectors became trapped in heavy snow at Lake City, Colorado. Only one prospector, Alferd Packer (see figure 12.22), made it back to civilisation. He told varying tales of how the others had died, and said that some had eaten the dead to stay alive. Packer looked fit and healthy and authorities were suspicious. Eventually he was convicted of five counts of manslaughter and sentenced to 40 years in prison. Since his conviction, there have been many rumours in the Wild West about what had really happened. Some believed Packer was innocent, while others believed he was guilty and that he had eaten his victims.

In 1989, a forensic investigator exhumed the victims' bodies, hoping to determine what had happened. Packer had sometimes said that the men died of starvation or accidents, except for one who was shot. Using modern anthropological techniques, the investigator found that the bones showed the men had died violently, trying to defend themselves, and they had been de-fleshed by knives. Four of the skulls had been struck with a blunt object. The investigator's conclusion was that Packer's plea of innocence was entirely false.

12.5.2 Human codes

The cells that make up living things contain information. For the living thing it belongs to, this information is like a recipe. Information is stored in DNA (deoxyribonucleic acid), which is the individual genetic code of each person that determines their physical makeup. DNA is different for different people, but the DNA in all of the cells of any one person is the same. Only identical twins or triplets have the same DNA as each other.

FIGURE 12.23 A DNA profile is a representation of an individual's DNA, providing a 'genetic fingerprint'.



A single drop of blood found at a crime scene contains information about the person it came from. DNA profiling is a test that compares blood from a crime scene with that of a suspect. Actually, it's not just blood that can be used in this test. Body fluids, like saliva, hair roots and dead skin cells, can be tested as well. Humans drop hair and skin cells all the time and criminals often leave DNA evidence behind. Scientists can even trace the path of a piece of paper from the DNA left by people who have touched it.

DNA is usually used to help solve a crime in two ways. If a suspect has not been identified, biological evidence can be taken from a crime scene and analysed, then compared to the profiles of known offenders who are already in criminal DNA databases. If a suspect has been found, then their DNA can be directly compared to that found at the crime scene. DNA not only identifies criminals, but has been used in recent years to prove the innocence of some prisoners. There have been many cases over the past two decades where old DNA evidence, seized from a crime scene decades ago, has not matched the profile of the person in jail.

Kirk Bloodsworth was the first man in the US to be exonerated for a crime for which he was sentenced to death. In 1985, he was convicted of the sexual assault and murder of nine-year-old Dawn Hamilton. He protested his innocence, but at the time DNA testing was not used. In 1992, after DNA testing had become more common, prosecutors agreed to let the Forensic Science Associates examine a small stain found on the victim's clothing. They concluded it did not match Kirk's genetic profile, and in 1993 he was released from prison. One year later, the stain was checked against the DNA profiles of convicted sex offenders, and a man named Kimberly Ruffner was identified — a man Kirk had lifted weights with in the prison gym.

DISCUSSION

In groups of three or four, create a list of arguments for and against all people providing a DNA sample to keep on police records. Share your list with the rest of the class during a class discussion.

CASE STUDY: DNA profiling

Samples of blood, body fluids or skin that are collected from the crime scene are taken to a laboratory.

DNA is removed from the sample. Separating enzymes cut the DNA into small pieces at specific points.

The pieces of DNA from different samples are lined up across a jelly-like substance.

When electricity is passed through the sample, the pieces of DNA spread across the jelly-like substance. As the pieces spread, they form a pattern on the autograph.

DNA samples collected from a suspect go through the same process as the sample from the crime scene.

The autograph is for matching pieces of DNA from the different samples.

FIGURE 12.24 The pattern that DNA from the crime scene forms on a profile is compared to the patterns of DNA from the suspects.

CASE STUDY: DNA websites

Over recent years, there has been an explosion in consumers submitting their DNA to companies in order to find relatives and research their family history.

In 2018, authorities in California revealed they had used a consumer DNA database to submit the DNA left at a crime scene to help them identify and arrest a suspect for multiple homicides. Then in 2019, the database changed its privacy policy to allow people to opt in to being included in law enforcement searches. However, this limited the number of profiles available for law enforcement to compare against, meaning cases are now harder to solve and allows criminals to remain free.

12.5.3 The power of a testimony

FIGURE 12.25 A dingo was responsible for the death of Lindy Chamberlain's baby.

Forensic scientists are regularly called to give evidence in court on what they think happened. Sometimes, interpretations of forensic evidence are incorrect. Below is an example of how the opinions of forensic scientists first sent a woman to jail, and then later released her.

One of the most famous criminal cases in Australian history began with Lindy Chamberlain's claim, in 1980, that a 'dingo stole my baby'. Blood was found in the tent the child had been sleeping in, near Uluru, but no photos were taken. Police were suspicious of Lindy's claim, and in 1982 she was found guilty of murdering her baby. As there was no body found, no weapon, and no motive established, the case against her was built largely on the evidence of two forensic scientists.

- A forensic biologist stated she had found evidence of blood throughout Lindy's car. She took scrapings from the car, placed them on filtered paper and added a solution called orthotolidine, which is used to identify the presence of blood. They showed up bright blue and the biologist said this proved there was once blood all through the front of the vehicle, as well as on the zipper of a camera bag kept in the car.
- A forensic odontologist told the court that the damage to the jumpsuit found at the scene showed no evidence of either tooth marks or saliva from a dingo. He concluded that the jumpsuit had been cut with scissors.
- Lindy was found guilty and sentenced to life imprisonment. In 1986, the case was re-opened and two years of investigations followed. This time, different scientists came up with very different conclusions.
- Lindy's car was investigated again, this time by the Victorian Forensic Laboratory, who stated no traces of blood could be found. It was revealed that what the first forensic biologist thought was blood, was in fact sound deadener, a substance used by car manufacturers. The experiments found that orthotolidine, used by the first investigator, also picks up traces of copper oxide which is found in sound deadener.
- With the assistance of a microbiologist and a chemist, an investigator carried out months of experiments, finding that half the time dingoes tore fabric, and at other times they cut it, with their teeth.

Lindy was released from jail in 1986, and awarded $1.3 million in compensation. A movie was made in 1998 to tell the story. it was called 'Evil Angels' and starred Meryl Streep as Lindy and Sam Neill as her husband Michael.

on Resources

eWorkbook	Using DNA evidence to solve crimes (ewbk-12488)
Video eLesson	Comparing and matching DNA profiles (eles-4220)
Weblink	The story of Lindy Chamberlain — 40 years on

12.5 Activities

12.5 Quick quiz on

12.5 Exercise

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 3	2, 4, 6	5, 7, 8

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. What type of forensic scientist looked at the bones of Alferd Packer's victims?
2. What is DNA?
3. Who would have the same DNA?
4. How is DNA used in forensic science?
5. What experiments did the first biologist and odontologist carry out in the Lindy Chamberlain case?

Apply and analyse

6. Kimberly Ruffner was a convicted offender whose DNA profile was already on file. What could police have done to exonerate Kirk Bloodsworth sooner?
7. What do you think the second set of forensic investigators did differently in the Lindy Chamberlain case?

Evaluate and create

8. **SIS** Research a miscarriage of justice that has been overturned by DNA evidence. present your findings to the class as a speech.

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

LESSON
12.6 Clues from blood

LEARNING INTENTION

At the end of this lesson you will able to analyse blood patterns and will understand how the determination of blood type can help in forensic investigations.

12.6.1 Splat!

Even a tiny amount of blood left at a crime scene can give scientists and detectives valuable information. Bloodstains can tell investigators who was at the crime scene and what might have happened. Saliva and dead skin cells can also be traced back to an innocent bystander or a suspect.

FIGURE 12.26 Blood falling straight down from a low height leaves an almost perfect circular drop. When blood drops from a greater height, there is a ring of small drops around the central drop.

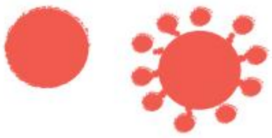
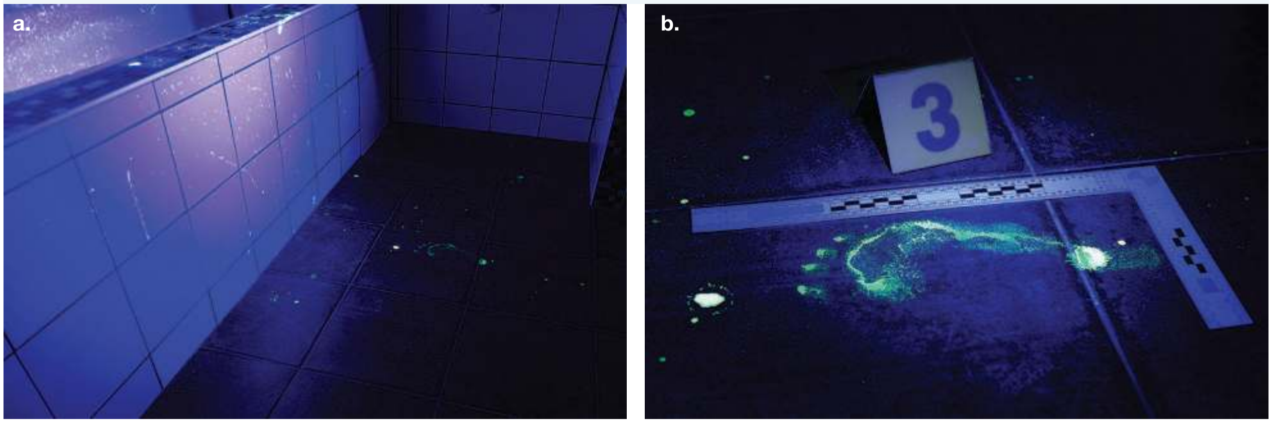


FIGURE 12.27 Blood that drops from an angle leaves a trail. The trail shows the direction in which the blood travelled.

Movies often show criminals cleaning up after a crime. They wash their clothes and wipe up blood spills. But forensic scientists can still detect traces of blood, even if it has been washed away. If crime-scene investigators believe that there may have been blood around, the area is treated with a fluorescent chemical such as luminol, which makes the blood fluorescent and visible under ultraviolet light. The treated blood is easy to see under ultraviolet light, as shown in figure 12.28.

FIGURE 12.28 UV light allows cleaned up blood to be seen — **a.** stains of blood in a bathroom and **b.** a bloody footprint under UV light.



An arc of blood spatters forms when the victim pulls away from an impact. The number of arcs tells how many impacts there were on the victim. Forensic scientists can even tell if the **assailant** was left- or right-handed. The pattern of blood splatters provides lots of information about what occurred during a possible crime.

assailant someone who physically attacks another person

elog-2337

INVESTIGATION 12.4

Exploring blood splatters

Aim

To observe how blood splatters appear in different conditions

Materials

- fake blood
- pipettes
- butchers paper (at least 6 sheets)
- ruler
- protractor
- gloves
- plastic knife
- clipboard
- white paper

Method

Before you begin, write a clear hypothesis for each part of this investigation.

Part A: Effect of height on blood splatters

1. Fill the pipette with fake blood.
2. Release a drop of fake blood onto the butcher's paper, from 10 centimetres above the surface, and label this.
3. Repeat this by releasing a single drop of blood from 20 centimetres.
4. Continue repeating step 2, increasing the height by 10 centimetres each time, up to 1 metre.
5. Label all your results, and sketch your findings in the results, as well as including a measurement for each.

Part B: Effect of angle of impact on blood splatters

6. Place a piece of white paper on a clipboard. Release a drop of blood from 30 cm above.
7. Angle the clipboard to 10° and release a drop of blood, labelling this drop as 10°.
8. Repeat this process, adjusting the angle of the clipboard each time by 10°, up to 60°.
9. Sketch and record your findings, measuring the size of each blood splatter.

Part C: Effect of speed on blood splatters

10. Dip a plastic knife in the fake blood.
11. Holding the knife in your hand, walk slowly along a long piece of butcher's paper, allowing the blood to drip, and sketch the pattern in your results.)
12. Dip another plastic knife in fake blood. Repeat the previous step (ensuring you are holding the knife at the same height), but walk at a medium pace.
13. Dip another plastic knife in the fake blood and walk quickly along the butcher's paper.

Results

1. Sketch your results for each investigation and outline your observations.
2. Record the size of each blood drop in an appropriate table.

Discussion

1. In each of the parts, identify the independent and dependent variable.
2. In each of the parts, identify the controlled variable.
3. Describe how a blood splatter is impacted by:
   a. the height of the drop
   b. the angle of the drop
   c. the speed of a walking individual.
4. What differences would you expect in the three above parts if a greater amount of blood was used?
5. Design an investigation that explores differences in blood splatters between right and left-handed individuals.
6. Sometimes, rather than blood splatters, handprints or footprints are instead found. Outline some factors that you think would affect handprints and footprints.
7. An individual has blood covering their hands and claps their hands to remove some of the blood. Sketch what you would expect to see in a blood splatter in this scenario.

Conclusion

Summarise your findings about the effect of height, angle of impact and speed on blood spatters.

12.6.2 Types of blood

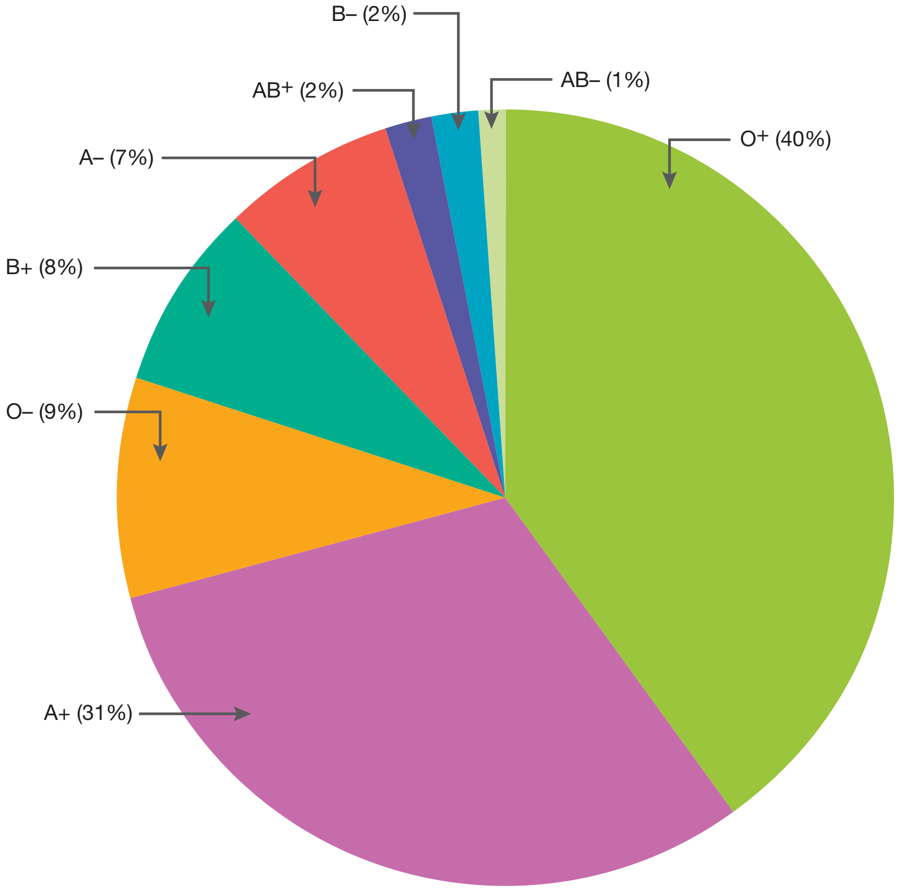
All human blood looks the same, but there are actually several different types of blood. In a laboratory, blood is tested to find out which of the four main groups — A, B, AB and O — it belongs to. Each of these groups can be further sorted into positive or negative. For example, a person could be A+ or A–, B+ or B– and so on.

Finding a blood type at a crime scene that matches the blood type of a suspect does not mean that the suspect was there. Many people share the same blood types. But comparing blood types does narrow the search. Blood can also be analysed for diseases or other features that link the sample more closely to a suspect.

If the blood types of samples from the crime scene don't match the suspect's blood type, then the suspect can be cleared.

FIGURE 12.29 You cannot tell the type of blood by looking directly at it.

FIGURE 12.30 Percentage of Australians with each blood type



DISCUSSION

Even though many people can have the same blood type, blood type analysis can still be useful in solving crimes. Discuss with those around you if you agree with this statement, and as a group come up with your answers and share with the others in the class.

on Resources

eWorkbook	Evidence from blood (ewbk-12490)
Weblink	Australian Police — Bloodstain pattern analysis

12.6 Activities

12.6 Quick quiz on

12.6 Exercise

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 2	3, 5, 7	4, 6, 8

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. List the eight different blood types.
2. a. What is the most common blood type in the Australian population?
   b. What is the least common blood type in the Australian population?

Apply and analyse

3. Explain how blood at the scene could be used to show that a suspect was not at a crime scene.
4. A suspect has the same blood type as a sample found at a crime scene. Why is this not enough evidence to prove that the suspect was actually at the scene?
5. The chemical used to make bloodstains visible is called luminol. Suggest a reason for this name.
6. Use the internet to research how DNA profiles are produced. Find out the probability of two different DNA profiles matching.

Evaluate and create

7. **SIS** Research blood types globally.
   a. Create a pie graph, similar to the one shown in figure 12.30 showing the percentage of people with each blood type globally.
   b. How do these figures differ from the figures in Australia?
8. **SIS** The provided diagram shows the blood spatter pattern at a crime scene.

Blood spatter pattern

   a. Which direction was the blood travelling in when it hit the ground?
   b. How many blows did the victim receive? Explain your answer.
   c. Design an investigation that would allow you to observe the effect of direction and number of blows (or wounds) on a blood splatter.

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

LESSON
12.7 Clues in hair, fibres and tracks

LEARNING INTENTION

At the end of this lesson you will be able to explain how evidence can be obtained from hair, fibres and tracks in forensic investigations.

12.7.1 Evidence

Wherever we go we leave some evidence behind and take some with us. Strands of hair or fibres from clothes, furniture and carpets can provide strong evidence that a suspect has been at a crime scene. Even the most careful criminals can't stop microscopic fibres sticking to their shoes. They may not realise that they have left a single strand of hair behind at a crime scene. Many hairs and fibres look the same, until they are examined under a microscope.

FIGURE 12.31 Even the tiniest hair or fibre can be found at a crime scene to assist in solving forensic cases.

12.7.2 Clues found in fabric

A forensic scientist compares fibres found at a crime scene, or on a victim, with those found on suspects' clothes, in their homes or in their cars. Under the microscope, a forensic scientist can also tell if fibres at the crime scene had been cut or torn. This helps them to piece together what may have happened during the crime. Fabrics are made from either natural or man-made fibres woven together. Some fabrics are a combination of different fibres. Under a microscope, each type of fibre looks different.

FIGURE 12.32 **a.** Acrylic fibres seen under a microscope **b.** Nylon fibres seen under a microscope

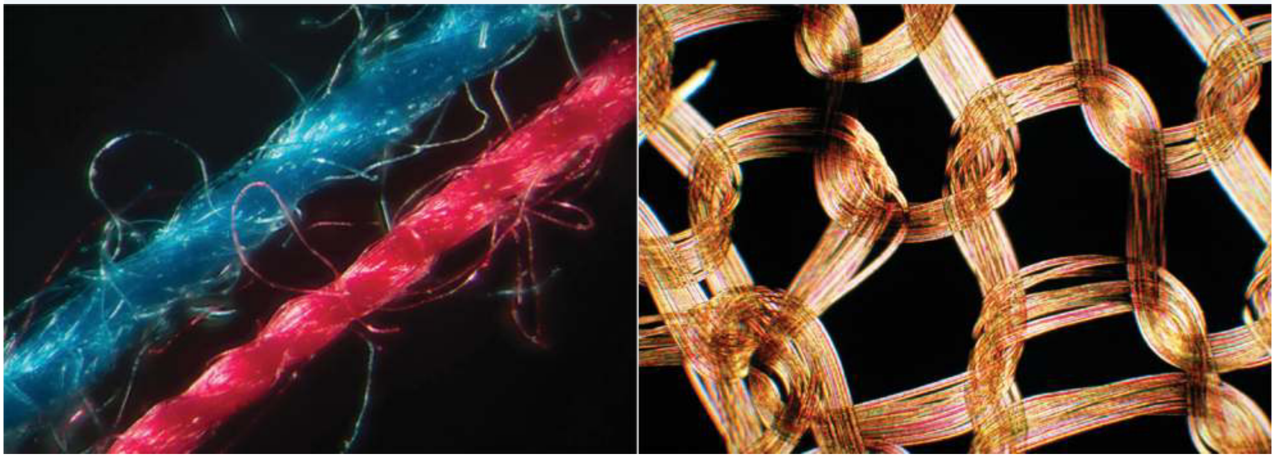


FIGURE 12.33 Merino wool fibres seen under a microscope

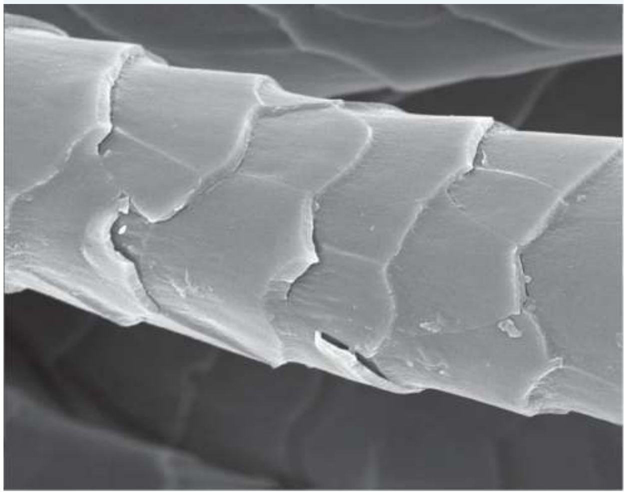
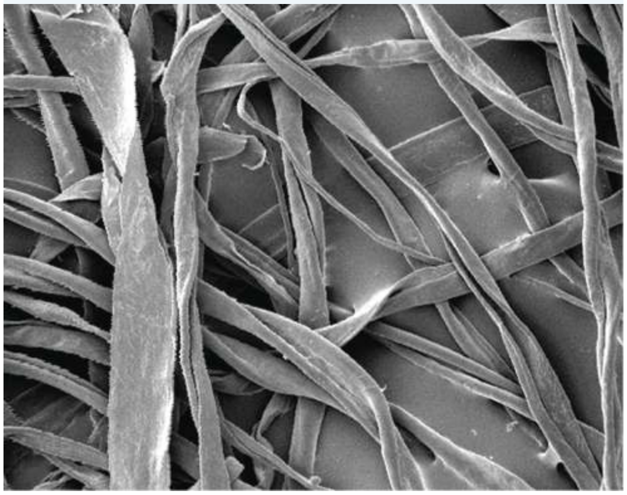


FIGURE 12.34 Cotton fibres seen under a microscope



12.7.3 Hair

By looking at hair samples under a microscope, forensic scientists can tell whether the sample belongs to a human or a different animal. The scaly, outer covering called a **cuticle** is different in each animal species.

With a microscope, the thickness, **coarseness**, colour and structure of hair can be checked. Scientists can even tell what type of shampoo has been used to wash the hair. A strand of hair found at a crime scene can be checked with a **comparison microscope** against hair from a suspect. A match between the hairs could be used as evidence to show that the suspect was at the scene.

cuticle the outer layer of hair

coarseness roughness

comparison microscope a microscope that allows two samples to be viewed simultaneously

Hair that has been pulled out can have skin or other substances stuck to it. DNA testing can link these hairs directly to a suspect.

FIGURE 12.35 Forensic scientists can tell if a hair sample has come from a person with curly, wavy or straight hair. Scientists can even sometimes tell the ethnic background of the person from their hair.

FIGURE 12.36 Human hair

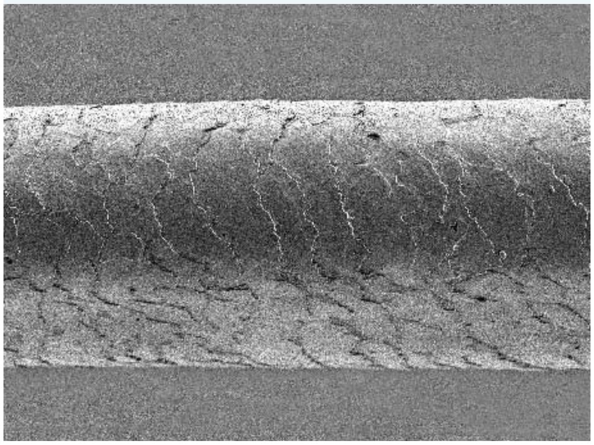
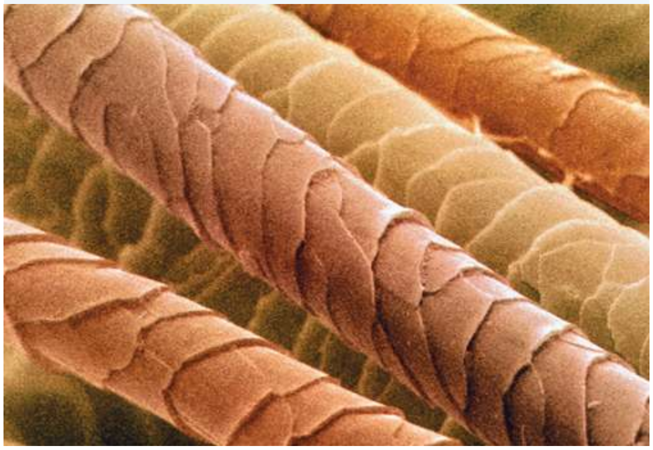


FIGURE 12.37 Dog hair



elog-2339

INVESTIGATION 12.5

Comparing animal and human hair

Aim

To compare hair samples

Materials

- microscope, lamp and slides
- tweezers
- tape
- animal hair
- feather
- human hair
- samples of fibres

Method

1. Write a clear hypothesis for your investigation. What do you expect to see in each sample?
2. Set up the microscope.
3. Tape a sample of animal hair, human hair and a feather to the microscope slides. You may need tweezers to help position the hairs on the slides.
4. Repeat this with any other samples you may have.
5. View the slides under the microscope.

Results

Sketch your observations of each hair or fibre under the microscope, ensuring you include the magnification (10 x the magnification of the objective lens).

Discussion

1. What are the main features of your samples?
2. Explain some of the main differences you observe.
3. Explain any similarities you observe.
4. Compare your results with your peers. Did you have similar results? Justify why/why not.

Conclusion

Summarising the findings of your investigation, describe the differences between different hairs and fibres under the microscope.

12.7.4 Tracks as evidence

Footprints and shoe prints

Footprints and shoe prints can be used as evidence in crimes, providing information about the feet of an individual and about the shoes being worn.

More often than not, individuals are wearing shoes during a crime. Marks on the ground can help narrow down suspects in a crime — whether they be 2D markings, such as markings made by a dirty or bloody shoe, or 3D impressions, such as shoe prints across a muddy path. Some different examples of these are shown in figures 12.38 and 12.39.

Shoe print analysis can help determine the size of the shoe. This, in turn, can allow for an estimate on height. In 3D impressions, shoe prints can also provide information that can help estimate the weight of an individual. Similar to fingerprints, they can be classified as latent, patent (visible) or plastic impressions.

FIGURE 12.38 Shoe prints can have lots of variety.

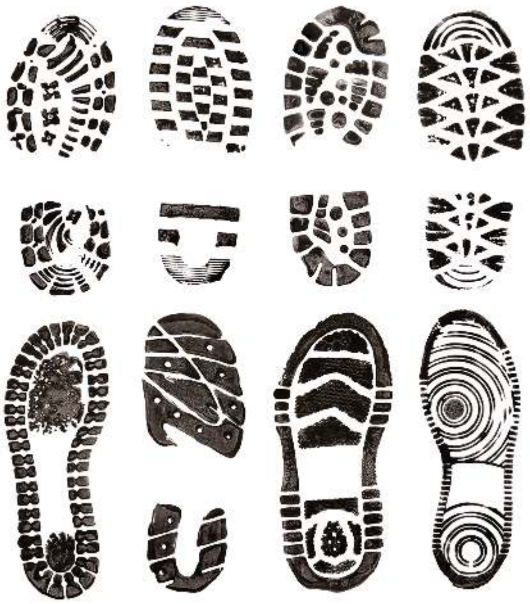


FIGURE 12.39 Shoe prints can be 2D or 3D impressions.

While many shoes may leave similar shoe prints, other information can also be seen. For example, a missing aspect of a shoe print might be due to a bit of missing rubber or a rock lodged in the sole, which can help determine a suspect was at the scene of a crime. It can also show if someone walks with a limp or if they roll their ankles inwards or outwards when walking.

Investigators often take photographs of shoe prints or make casts, allowing for the shoe prints to be explored in detail.

elog-2341

INVESTIGATION 12.6

Analysing shoe prints

Aim

To investigate shoe prints left by different members of the class and identify who they belong to

Materials

- butcher's paper or white paper
- anything that can allow a print to be made, such as dirt, washable ink or rolled-out (flat) playdough (ensure it can come off your shoes so you don't leave marks everywhere)
- detergent
- paper towel

Method

1. Lay a piece of paper flat on the ground
2. Cover the base of one shoe with a substance that can make an impression.
3. Allow the print to dry and write a number on it. (Your teacher should assign each student a number; do not share your number with others.)
4. Carefully wash any residue off your shoe using detergent and paper towel.
5. Look at each shoe print around the room and try to identify each shoe.

Results

Create a results table similar to what is shown below to record your findings. Remember to add a title to your table.

Shoe print number	Individual whose shoe print I think this belongs to	Individual whose shoe print this actually belongs to
1		
2		

Discussion

1. Explain how you identified each shoe print.
2. How accurate were your findings?
3. What improvements would you make to help improve your identification?
4. Do you think a shoe print alone can be used to convict an individual? Justify your response.

Conclusion

Summarise how shoe prints can be used to determine a person's identity.

Extension

Create shoe prints in different materials including wet and dry soil or sand.

Tyre tracks

Tyre tracks leaving or entering the scene of the crime can often be used in forensics to help determine those present.

Similar to footprints, tyre marks differ between tyres. Differences may be due to:

- the age of a tyre
- the type of tyre
- the brand of tyre
- the type of car
- the tyre alignment on the car
- markings on the tyre (for example, some tyres may have dents or sections that have chipped off).

As well as this, the tyre tracks across all four tyres in a car may be slightly different, providing a unique profile for a specific car.

Tyre marks can be 2D marks, such as skidmarks across a road during a hit and run, or 3D impressions, such as when a car travels through a muddy field or snow. Similar to fingerprints, they can be classified as latent, patent (visible) or plastic impressions.

These tracks may be examined through searchable databases from different type manufacturers, which may help narrow down the type of vehicle used. Tyre reference prints may also be taken from a suspect's car and compared to tyres left at a crime scene.

DISCUSSION

A crime was committed at your school, and a student was found to have stolen money from the school canteen. On the floor of the canteen was a piece of hair, a piece of fibre and a shoe print. You are only allowed to investigate two of these to determine the culprit. As a class, discuss which two you would select and why.

FIGURE 12.40 Different tyre tracks may assist in forensic investigations.

Resources

eWorkbooks	Exploring fibres, hair and tracks (ewbk-12492) Read my lips (ewbk-12494)
Weblink	Different evidence used in forensics

12.7 Activities

12.7 Quick quiz on

12.7 Exercise

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 2, 4	3, 5, 7	6, 8

Remember and understand

1. Why do hairs or fibres found at a crime scene need to be compared under a microscope?
2. **MC** Select the option that correctly completes the sentence. A cuticle is:
   A. the same in each animal species
   B. found only on humans
   C. the scaly, outer covering of a hair
   D. not useful in an investigation.

Apply and analyse

3. Identify the hair shown as either dog hair or human hair. Explain the reasons for your decision.
4. Describe what information footprints and shoe prints may provide at a crime scene.
5. An individual's car was found to match tracks that were seen leaving the crime scene.
   a. Would this be sufficient evidence for a conviction?
   b. What other evidence might police need to support a conviction?

Evaluate and create

6. **SIS** A detective found a small clump of human hairs at a crime scene. The hairs all showed evidence that they had been pulled out rather than falling out naturally.
   a. What might this suggest about what happened at the scene?
   b. What other tests could be applied to these hairs to help solve the crime?
   c. Write a brief report summarising the evidence and implications from this crime.
7. **SIS** The following shoe print was found in concrete outside a store where a robbery had occurred 30 minutes earlier.
   a. What conclusion may police draw from this?
   b. How many different shoe prints can be seen?
   c. The shoe prints belonged to a Mr P. Hollands. Write a script outlining the questions the police would ask Mr Hollands.

8. **SIS** Design an experiment to compare the properties of different fibres or fabrics. Properties that could be compared include:
   - strength
   - elasticity
   - absorption ability.

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

LESSON
12.8 Life as a forensic scientist

LEARNING INTENTION

At the end of this lesson you will have a deeper understanding of the job involved for a forensic scientist and will be able to explain the misconceptions caused from crime TV shows.

SCIENCE AS A HUMAN ENDEAVOUR: An interview with forensic scientist Rob Hayes

Rob loves his job because . . .

There are three different areas I get a buzz out of. The first is discovering something that has real significance to a case; that could be finding some unique components of a paint layer and connecting it to a suspect. For instance, if somebody painted a car to disguise it, and painted it close to another car, then you might get overspray. Sometimes the colour pigments are rare, and restricted to a certain time period or model of a car. Repair paints are often very different to original finishes, and so they are easy to identify. Another major thing I like is the variety of work and being part of a team. I also love learning about the amazing forensic techniques and instruments that are being researched and developed — the futuristic stuff is so interesting!

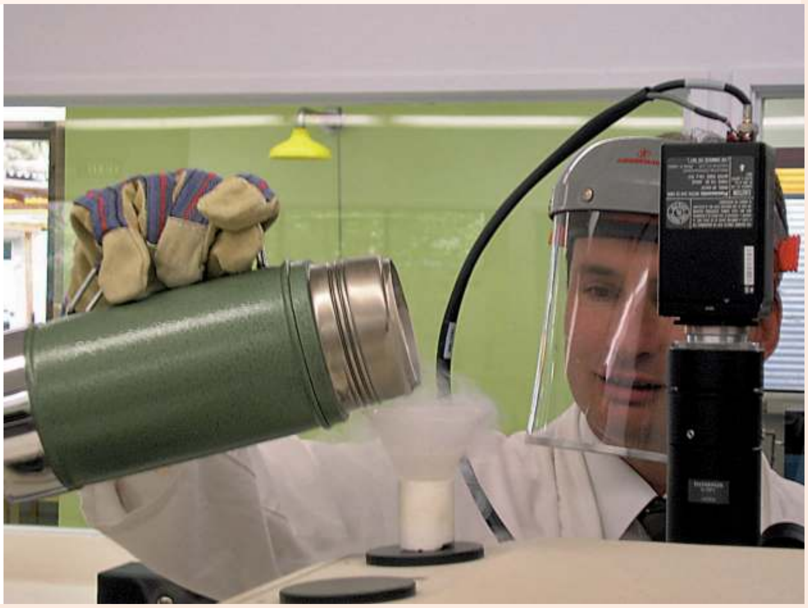
FIGURE 12.41 Rob Hayes

Job title: Innovation coordinator for Forensics

Employer: Victoria Police Forensics Services Department

Qualifications: Bachelor of Science in Chemistry and Pharmacology

Responsibilities: Rob is a specialist in paint and its composition, and uses his knowledge of chemistry to analyse chemical trace evidence in police investigations. Rob's other responsibility is to coordinate research and innovation in new techniques and technologies across many disciplines, within the lab.



Another day at the office

Ah. A typical day, this varies a lot. A forensic scientist could be doing anything from an investigation in the lab; an example is washing a $5 note with solvents and analysing the material that comes off it for evidence of drugs. Or, they could spend the day writing up a statement or report.

He can be called on to assist with all types of crimes

Over my career I have examined evidence from murders, assaults, thefts, burglaries, traffic incidents, drugs and re-birthed cars.

I've also worked on a number of hit and run accidents. In these cases I might have to match the paint marks left on the clothing of someone who has been hit by a car to a certain type of car.

I have been involved in cases where there have been a huge number of cars stolen. We work with investigators to decide on which areas of the cars may be critical to test, instead of analysing every part of all the cars. It's a team effort. While we might compare the original paint job with the new ones, the Vehicle Examination Unit will look at the mechanical side of things to decide if the car has been re-birthed.

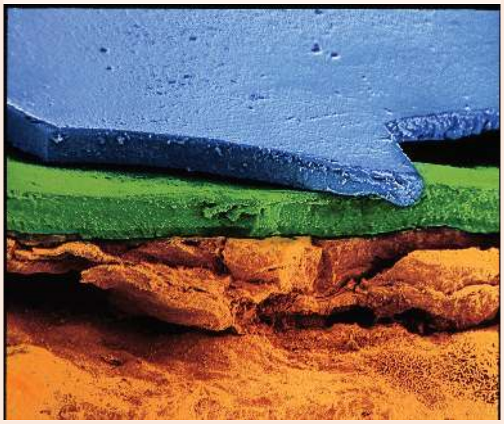
When evidence comes into the lab, a number of forensic experts from different departments will talk to the person in charge of the case, and then we all work together to decide who needs to provide their expertise.

And he gets to use some high tech gear to do it

Most of our work is connected to microscopes because trace evidence can be very small. Tweezers and scalpels can often be used when recovering evidence.

Many of the more sophisticated instruments we work with require liquid nitrogen to keep them cool. These include infra-red spectrophotometers and a scanning electron microscope. These instruments can help us determine what types of components items contain, and some can also measure their colour.

FIGURE 12.42 An electron scanning micrograph of a flake of rusty paintwork; no metal is visible. The blue top layer is a layer of respray paint. It is badly bonded to the original paint, which has three layers of green and orange. The bottom orange crystalline region is rust. This evidence may help to convict a criminal of re-birthing a car.



What would you say to anyone thinking of a career in forensic science?

It's really interesting work, and when you find something you love, then it's not a job. If it is something you really want to do, then aim for it! With a little bit of luck and a lot of study and application, there's no reason why you can't succeed!

Is what you see on TV real?

There have been many TV dramas centred on forensic investigation. Detective work is a fascinating business. But is all we see true to life?

Too much responsibility

In most TV dramas, there are usually one or two detectives doing all the work. They attend the crime scene and seal it off, carry out spot tests and preliminary testing, collect samples, transport them to the lab, analyse the evidence or assist with a postmortem, interview the suspect and make the arrest! TV detectives would have a tough time convincing a court they were not **biased** with so much direct input into the case.

In real life, forensic experts are much more confined to their specialisation and often, the lab. The forensic photographer takes the photos, the fingerprint expert dusts for prints, and the forensic toxicologist looks for evidence of poisons or drugs. Each is a puzzle piece in the evidence that is presented to court, and often each forensic expert may not have knowledge of the whole case.

biased not objective; taking personal experiences and ideologies into account

Speedy results

A lot of the scientific processes carried out by investigators in TV dramas are real to life. For example, the method of gas chromatography is used to separate components of mixtures to detect trace evidence. However, there are many complex, time-consuming experiments that don't make it onto TV. The nature of a TV drama is that the case must be solved within a short time frame, but real life examinations may require numerous tests. For example, if police suspect a person has been poisoned, a toxicologist must carry out many tests for things like pesticides and heavy metals, and then work by a process of elimination.

The tools used by TV detectives are usually realistic, although there have been a few errors. An example was in one recent episode of a TV drama, a character used fictional computer databases. They were able to punch in trace evidence, and match it against records in a few seconds. In real life, this is usually a much longer process.

CASE STUDY: The CSI effect

The CSI effect is the public's interpretation of forensic science, based on popular TV shows. For example, there are concerns that juries are beginning to have unrealistic expectations of forensic scientists during court cases, after watching TV dramas. Another concern is that TV shows are raising awareness among criminals, who are wising up and covering their tracks by taking shell casings from crime scenes, and leaving fewer fingerprints!

FIGURE 12.43 Do TV shows affect forensic investigations and criminal activity?

FIGURE 12.44 Most TV dramas do not depict what really happens in real life. **a.** Crime scene investigators are the people who collect evidence wearing full protective clothing so they do not contaminate a crime scene. **b.** Forensic scientists work predominantly in the laboratory to analyse evidence based on their specialty. Neither a crime scene investigator or a forensic scientist investigates the actual crime. That is up to the detective or criminal investigator.

ACTIVITY: Real crime TV?

Choose a TV forensic drama, and select an episode. Watch it carefully. Using the information in this chapter, and other resources, pick out as many differences as you can between real life and the TV show. Present your findings to the class through a PowerPoint presentation, explaining what each difference is, and why it exists.

DISCUSSION

Form groups of three or four. In your group discuss why TV forensic dramas are not a true reflection of real-life investigations. Think about time frames and entertainment value.

on Resources

eWorkbook Mystery in the house (ewbk-12496)

Weblink How accurate are crime shows on TV?

12.8 Activities

learnon

12.8 Quick quiz on | **12.8 Exercise**

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 3	2, 4	5

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. Name the examination regularly carried out by both TV investigators and real-life scientists.
2. What is the CSI effect?

Apply and analyse

3. Describe four ways in which TV shows may incorrectly display the accuracy of forensic investigations.
4. A report was filed regarding a hit and run. Outline three pieces of evidence that police may acquire to help identify the car involved.

Evaluate and create

5. Using the information in this lesson, provide a six-sentence summary outlining the life of a forensic investigator.

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

LESSON
12.9 Forensics and the future

LEARNING INTENTION

At the end of this lesson you will be able to describe the possible future of forensic technology and how various breakthroughs are changing the way evidence is obtained and analysed.

12.9.1 Forensic technology

Forensic technology has greatly improved in the last century. Modern science has re-opened old cases and solved mysteries that were hundreds of years old. Technology is advancing quickly, and scientists are now able to investigate the extremely small partide world through nanotechnology. Forensic teams are able to access a synchrotron in Victoria (see 12.9.4). A synchrotron is a huge instrument that produces powerful beams of light, which are used to examine the molecular and atomic details of a wide range of materials. The synchrotron is used in many industries including forensic investigations and provides an extremely high level of accuracy, quality and level of detail in samples analysed.

Forensic teams and police are also able to log into national and international fingerprint and DNA databases in order to match profiles quickly and efficiently.

FIGURE 12.45 Forensic technology has come along way in recent years.

12.9.2 Nanotechnology

Nanotechnology is an area of science that is quickly developing across the world. It is the science of extremely small particles, with scientists analysing and engineering particles at the atomic and molecular level. Nanotechnology deals with a size scale that is one billionth of a metre (10^{-9}). It enables forensic scientists to analyse the smallest trace evidence (for example, tiny stains on clothes) for DNA that are still difficult to analyse with current technology.

Nanotechnology has helped scientists develop better tools, such as finer fingerprint powders, so that prints can be revealed on difficult surfaces.

12.9.3 DNA developments

DNA has been one of the biggest breakthroughs in forensic technology in the last three decades. The process of matching DNA profiles is getting faster and less costly, as DNA databases, such as the Australian Government's CrimTrac, continue to expand and connect to each other.

Not only that, DNA profiles can be formed using only minute amounts of DNA. A process known as polymerase chain reaction (PCR), can allow for DNA to be amplified (replicated), using as little as a single piece of DNA to make millions of copies in a very short time frame.

FIGURE 12.46 A larger predatory brown fly feeds on a smaller green fruit fly by puncturing the exoskeleton of the prey and sucking the soft innards out. A DNA analysis of the fly will then show the DNA of itself as well as its prey.

DNA profiling is no longer being restricted to humans. DNA databases of all main blowflies found in corpses are being developed in Australia, to help entomologists identify maggots and flies faster. The correct identification of flies is crucial to a criminal investigation because each species responds differently to certain environments and temperatures, providing information on what kind of environment a body has been exposed to.

When the DNA of a fly is analysed, it is not just the DNA of the fly that is found. Anything that the fly has ingested is also found. Entomologists are developing techniques in which they can grind up maggots and flies found at a scene, where police suspect a body may once have been, and analyse them for DNA traces, proving whether there was indeed a body or a dead animal present at that scene. Organisms such as maggots, also provide information about when an individual died, which is important to know in forensic investigations.

CASE STUDY: Drugged maggots

In the world of entomology, scientists are developing techniques to examine the presence of drugs in decomposed corpses. Sometimes it is difficult for toxicologists to identify drugs in tissue, but entomologists are looking at ways of analysing maggots found in corpses, for traces of drugs. Maggots consume the drugs in a body when feeding on it and this affects their development. Entomologists are examining these effects to help identify drugged maggots more easily in the future.

FIGURE 12.47 Maggots provide various evidence in forensics investigations.

ACTIVITY: Writing TV crime

Imagine you are a writer for the television show *CSI: Crime Scene Investigation*. You have been asked to write an episode that focuses on the following crime — a robbery at a school. The producers have asked you to draw storyboards (pictures that are drawn to display what a scene will look like) for the five scenes below. Each scene needs to include labels to indicate the major features, such as the evidence. As an extra challenge, add some dialogue between the characters.

a. The crime scene
b. The forensic investigators collecting evidence at the crime scene
c. Forensic scientists analysing the evidence at a laboratory
d. The dramatic arrest of the suspect
e. A newer technology being used to help solve the crime

12.9.4 An energy boost: The synchrotron

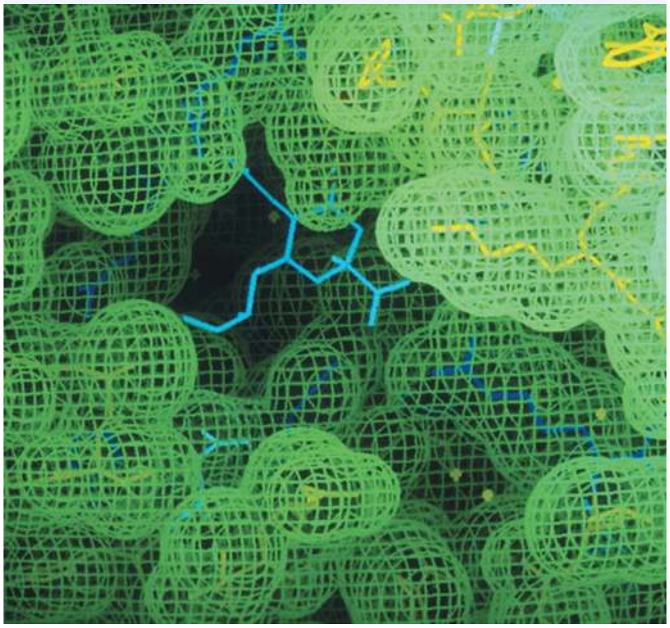
The **synchrotron** is a machine about the size of a football field. There are very few in the world, and Australia's first synchrotron is in Clayton, Victoria (figure 12.48). It works by accelerating electrons to almost the speed of light and deflecting them through magnetic fields so they create extremely bright light. The light is then beamed into experimental workstations, one of which will be a forensic lab.

synchrotron a building-sized device that uses electrons accelerated to near the speed of light to produce intense electromagnetic radiation. This is used to produce data that can describe objects as small as a single molecule.

FIGURE 12.48 The Australian Synchrotron located in Clayton, Victoria.

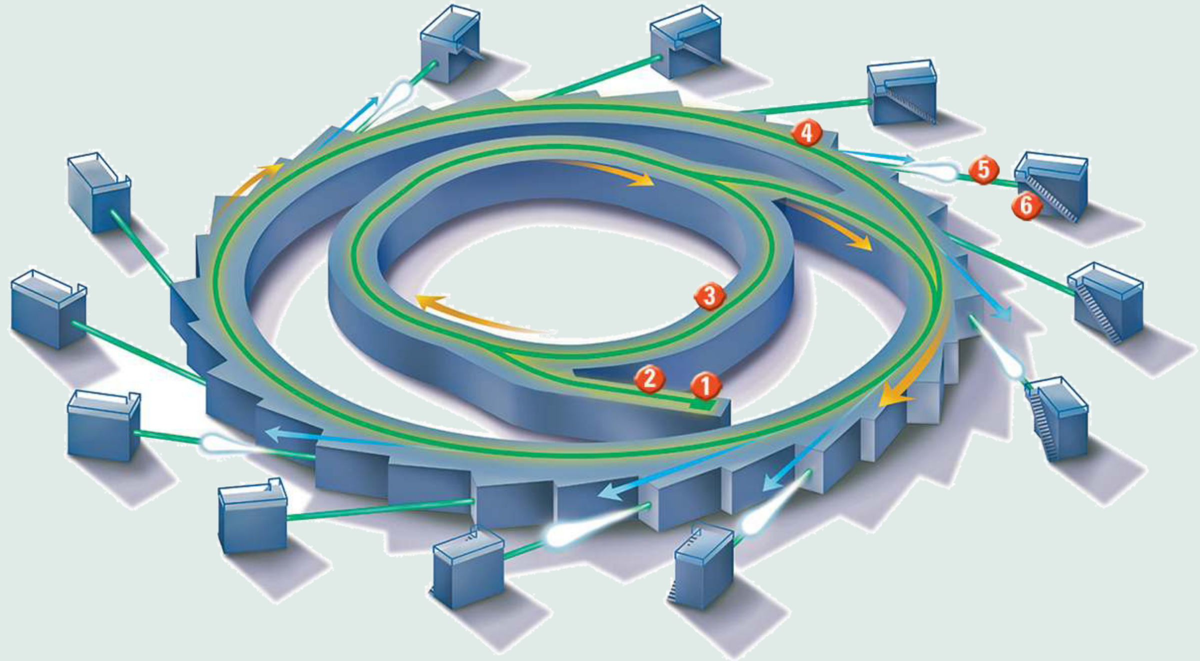
Typical forensic samples are small and complex substances. Because they are a part of the evidence in a case, they must be kept intact. Scientists are able to analyse all types of substances such as bones, gunshot residue and fibres under the intense light, and gain a better understanding of their components. For example, using synchrotron techniques, scientists can identify forgeries and counterfeit money by analysing the colour pigments, or distinguish car paint pigments involved in hit-and-run accidents. Scientists are also able to develop anti-toxins and gain an understanding of complex molecular structures (figure 12.49).

FIGURE 12.49 Images of complex structures like this helped develop the influenza-fighting drug Relenza™. The synchrotron can also be used to develop anti-toxins.



EXTENSION: The parts of a synchrotron

FIGURE 12.50 The components of a synchrotron



1. Electrons are fired from a highly-charged tungsten filament in an **electron gun**.
2. The electrons are accelerated to 99.9987 % of the speed of light by the linear accelerator (**LINAC**).
3. The **booster ring** increases the energy of the electrons.
4. The electrons are trapped in a circular orbit in the **storage ring** by large magnets that steer them around. The electrons give off electromagnetic radiation as they change direction; this is synchrotron light.
5. The electron beams are focused to a specific wavelength needed for the particular research going on. The **beamline** directs radiation through a monochromator and into an experimental station.
6. Many **experiment stations** are positioned around a synchrotron, where various samples are analysed by different teams of scientists.

on Resources

Weblinks Nanotechnology and forensics
The Australian Synchrotron

12.9 Activities

12.9 Quick quiz on

12.9 Exercise

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 2	3, 4	5, 6

Remember and understand

1. **MC** At which two levels does nanotechnology operate?
   - A. Nano and molecular
   - B. Micro and nano
   - C. Atomic and molecular
   - D. Nano and atomic
2. What is the name of the Australian government's DNA database?
3. Which part of a synchrotron produces the electrons?

Apply and analyse

4. What benefits will the synchrotron provide to forensic science?
5. Describe how a national DNA database would assist forensic investigators. Provide three clear examples of this.

Evaluate and create

6. **SIS** Research other scientific disciplines such as medicine and archaeology. Can you think of other ways the synchrotron might be beneficial to forensic science in the future? Create a report summarising your findings.

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

LESSON
12.10 Review

Hey students! Now that it's time to revise this topic, go online to:

Review your results

Watch teacher-led videos

Practise questions with immediate feedback

Find all this and MORE in jacPLUS

Access your topic review eWorkbooks

Resources

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-12498	ewbk-12500	ewbk-12502

12.10.1 Summary

Who knows who dunnit?

- Two types of forensic investigators exist: police officers who are trained to collect certain types of evidence at a crime scene (for example, fingerprint and ballistics experts, and photographers); and forensic scientists.
- There are many types of forensic scientists, all of whom specialise in different areas. Examples include forensic biologists, chemists, odontologists and psychologists.

Forensic toolbox

- The modern forensic toolbox is sophisticated and complex. Crime laboratories were set up around the world in the 1920s, and this meant a more controlled environment was required when collecting evidence.

Discovering the truth through forensics

- Developments in forensic technology, such as DNA technology, have helped to solve some old mysteries or cold cases, or re-open old cases that were hundreds of years old.

Clues from blood

- Blood left at a crime scene can give scientists and detectives valuable information. Bloodstains can tell an investigator who was at the crime scene and what might have happened. Saliva and dead skin cells can also be traced back to an innocent bystander or a suspect.

Clues in hair, fibres and tracks

- Strands of hair or fibres from clothes, furniture and carpets can provide strong evidence that a suspect has been at a crime scene. Even the most careful criminals can't stop microscopic fibres sticking to their shoes. They may not realise that they have left a single strand of hair behind at a crime scene. Many hairs and fibres look the same, until they are examined under a microscope.

Life as a forensic scientist

- The job of a forensic scientist may also involve coordinating research and innovation.

Forensics and the future

- Technology is still advancing quickly, and soon scientists will be able to investigate the extremely small world through nanotechnology, access a synchrotron in Victoria, and log onto fingerprint scans and DNA databases that match profiles in record time.

12.10.2 Key terms

accelerants a substance that spreads fire easily
anthropologists people who are experts in humans and human remains
arson the criminal act of deliberately setting fire to property
assailant someone who physically attacks another person
beamline a part of a synchrotron that directs radiation through a monochromator and into an experimental station
biased not objective; taking personal experiences and ideologies into account
biologists scientists who study the science of life
booster ring a part of a synchrotron that increases the energy of the electrons
botanists scientists who study the life of plants
chemists scientists who study the atoms and molecules that make up all substances
civil court a court that handles legal disputes, not crimes
coarseness roughness
comparison microscope a microscope that allows two samples to be viewed simultaneously
compensation money that is awarded to someone in recognition of loss or injury
counterfeit an imitation or fake replica of money or a document
cuticle the outer layer of hair
DNA a substance found in all living things that contains genetic information
electron gun a part of a synchrotron that allows electrons to be fired from a highly-charged tungsten filament
engineering the field of science and technology that applies scientific principles to design and build structures
entomologist a person who studies insects
evidence facts or information that can be examined to determine whether a proposition is true
experiment station areas positioned around a synchrotron, in which different samples can be analysed by different teams of scientists
fibres a thread that makes up a material such as a piece of clothing
forged something that has been faked
genetics the study of genes
graphology the study of handwriting
latent fingerprints fingerprints that are invisible to the human eye
liability an obligation, responsibility, hindrance or something that causes a disadvantage
linac the linear accelerator in a synchrotron that accelerates the electrons to 99.9987% of the speed of light
odontologists scientists who study the structure and diseases of teeth
partial prints a small and incomplete section of a full fingerprint
patent fingerprints fingerprints that leave a visible mark on a surface
pathologists people who study the causes and effects of diseases, examining samples for diagnostic or forensic purposes
psychiatrists psychologists that are also qualified medical doctors
psychology the systematic study of thoughts, feelings and behaviours
speed**ometer** the instrument that displays the speed of a vehicle such as a car or truck
storage ring a part of a synchrotron where electrons are trapped in circular orbits by large magnets that steer them around
suspects people who are thought to be guilty of a crime
synchrotron a building-sized device that uses electrons accelerated to near the speed of light to produce intense electromagnetic radiation. This is used to produce data that can describe objects as small as a single molecule.
ultraviolet light light that is invisible to the human eye but can be used to make certain substances glow

on Resources

eWorkbooks	Study checklist (ewbk-12504) Literacy builder (ewbk-12505) Reflection (ewbk-12511) Crossword (ewbk-12507) Word search (ewbk-12509)
Solutions	Topic 12 Solutions (sol-1141)
Practical investigation eLogbook	Topic 12 Practical investigation eLogbook (elog-2329)
Digital document	Topic 12 Key terms glossary (doc-40143)

12.10 Activities

learnon

12.10 Review questions

Select your pathway

🟩 LEVEL 1	🟦 LEVEL 2	🟪 LEVEL 3
1, 2, 4, 5, 8, 14, 15, 20	3, 6, 9, 11, 12, 16, 17, 21, 23, 26	7, 10, 13, 18, 19, 22, 24, 25, 27

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. How does a forensic psychiatrist differ from a forensic psychologist?
2. True or false? A polygraph does not provide conclusive evidence of a suspect’s guilt or innocence.
3. a. Why is a notebook an essential tool for a forensic investigation?
   b. Explain why gloves are required.
   c. What are three possible uses for the putty found in a forensics kit?
   d. Why are tweezers used to collect some types of evidence?
   e. How is fingerprint evidence collected?
4. **MC** DNA evidence would be most useful for:
   A. a forensic chemist
   B. a forensic biologist
   C. a forensic odontologist
   D. a forensic entomologist.
5. **MC** What is orthotolidine used for?
   A. To identify the presence of fibres
   B. To identify the presence of blood
   C. To analyse DNA
   D. To analyse hair follicles
6. **MC** An arc is a blood spatter that forms when:
   A. the attacker pulls a knife out
   B. a knife enters a victim
   C. a victim pulls away from an impact
   D. blood from the victim pools.
7. **MC** Which of the following is **not** an advantage of using a synchrotron for forensic analysis of evidence?
   A. Used primarily for microscope evidence
   B. Evidence remains intact
   C. Provides highly detailed analysis
   D. Can analyse colour pigments

8. The following evidence is collected from a crime scene. Which types of forensic scientist would investigate the:
   a. blood-spattered shoe
   b. bullet shell
   c. toxic liquid
   d. unknown victim
   e. computer?
9. During an investigation, why is it important to interview witnesses to the crime?
10. Why would it be important for a forensic entomologist to know the ambient temperature of the location in which a decomposing body was found?
11. DNA evidence can be used to exonerate a convicted person of a crime. What does this statement mean?

Apply and analyse

12. Bullet exit holes are often larger than the entry holes. Explain why this occurs.
13. If someone said to you, ‘It is important for a forensic anthropologist to work closely with a forensic odontologist’, would you agree or disagree? Give reasons for your response.
14. It is a dark, murky London night and you are assisting Sherlock Holmes during his investigation of a crime. He has asked you to use the Bertillon method to record a suspect’s details.
   a. Name three physical measurements you would record.
   b. Explain why each of the measurements is important.
   c. What are the flaws in using the Bertillon method?
15. Identify the fingerprints below as loop, whorl, arch or composite.

a.

b.

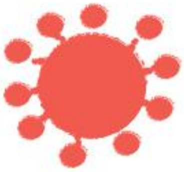
c.

d.

16. Are there any other methods, apart from the polygraph, that could be used to determine whether someone was lying during an investigation? Describe these methods.
17. In the Lindy Chamberlain case, scientific evidence did not initially provide accurate information. Explain why comparing evidence is important in all scientific experiments.
18. If a victim and a suspect were both injured and left type AB blood at a crime scene, how would you determine whose blood was whose?
19. Create a visual summary outlining the details that blood evidence from a crime can provide to forensic investigators. Think about pools of blood, drips of blood, spatters of blood and so on.
20. **MC** Which of the following blood spatters could be made by a droplet of blood:
   a. falling perpendicularly from a great height
   b. impacting at an angle?

A.

B.



C.

D.

21. Describe an example of the CSI effect.
22. Why has a DNA database been developed for the types of blowflies found in corpses?

23. Crime investigation TV shows may reduce the number of criminals who are caught. Explain why this statement may be correct.

Evaluate and create

24. A criminal found a lost cheque for $10 and decided to write in three extra zeros and the word 'thousand'. He used a blue pen, the same colour as the original writing on the cheque. When he took the cheque to the bank, the teller became suspicious and called the police.
    a. What steps would a forensic scientist use to prove that a different pen had been used to change the cheque?
    b. What other evidence could be obtained to prove that the criminal had written on the cheque?
25. a. Could this fibre in the figure provided be from an animal or from a plant source? Write down the features that would help you decide. List three different possible sources of this fibre that could be found at a crime scene.
    b. What types of further investigation might be necessary to determine the source of the fibre?

26. Some people are worried about the use of DNA databases.
    a. What is a DNA database?
    b. A database could be used to identify criminals more easily in the future. What other applications could the database be used for? (Think beyond investigations of crime.)
    c. Why could the DNA database cause concern among the community? Justify your response.

27. Consider all of the forensic techniques and tools you have looked at during this topic. Choose one tool or technique to research and write a summary to explain how this tool or technique could be improved in the future.

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

Online Resources

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.

12.1 Overview

eWorkbooks
- Topic 12 eWorkbook (ewbk-12477)
- Student learning matrix (ewbk-12479)
- Starter activity (ewbk-12480)

Solutions Topic 12 Solutions (sol-1141)

Practical investigation eLogbooks
- Topic 12 Practical investigation eLogbook (elog-2329)
- Investigation 12.1: Recreating a crime scene (elog-2331)

Video eLesson
- How a gun fires bullets in slow motion (eles-4218)

12.2 *The Forensic Herald*

eWorkbook
- How observant are you? (ewbk-12482)

12.3 Who knows who dunnit?

eWorkbook
- Forensic scientists (ewbk-12484)

12.4 Forensic toolkit

eWorkbook
- Forensic toolkits (ewbk-12486)

Practical investigation eLogbooks
- Investigation 12.2: Are you a loop, arch, whorl or composite? (elog-2333)
- Investigation 12.3: Exploring UV light (elog-2335)

Video eLesson
- Creating a rolling fingerprint (eles-4219)

Weblinks
- Snapshot facial reconstruction
- Osceola County uses Laser Scanner for crime scene analysis and forensics

12.5 Discovering the truth through forensics

eWorkbook
- Using DNA evidence to solve crimes (ewbk-12488)

Video eLesson
- Comparing and matching DNA profiles (eles-4220)

Weblink
- The story of Lindy Chamberlain — 40 years on

12.6 Clues from blood

eWorkbook
- Evidence from blood (ewbk-12490)

Practical investigation eLogbook
- Investigation 12.4: Exploring blood splatters (elog-2337)

Weblink
- Australian Police — Bloodstain pattern analysis

12.7 Clues in hair, fibres and tracks

eWorkbooks
- Exploring fibres, hair and tracks (ewbk-12492)
- Read my lips (ewbk-12494)

Practical investigation eLogbooks
- Investigation 12.5: Comparing animal and human hair (elog-2339)
- Investigation 12.6: Analysing shoe prints (elog-2341)

Weblink
- Different evidence used in forensics

12.8 Life as a forensic scientist

eWorkbook
- Mystery in the house (ewbk-12496)

Weblink
- How accurate are crime shows on TV?

12.9 Forensics and the future

Weblinks
- Nanotechnology and forensics
- The Australian Synchrotron

12.10 Review

eWorkbooks
- Topic review Level 1 (ewbk-12498)
- Topic review Level 2 (ewbk-12500)
- Topic review Level 3 (ewbk-12502)
- Study checklist (ewbk-12504)
- Literacy builder (ewbk-12505)
- Crossword (ewbk-12507)
- Word search (ewbk-12509)
- Reflection (ewbk-12511)

Digital document
- Topic 12 Key terms glossary (doc-40143)

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

PERIODIC TABLE OF THE ELEMENTS

Key

Period 1	**1** Hydrogen **H** 1.0	**2** Helium **He** 4.0	← **Atomic number** ← Name ← **Symbol** ← Relative atomic mass

	Alkali metals ↓ Group 1	**Alkaline earth metals** ↓ Group 2	**Transition metals** 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 metals
- ■ Alkaline earth metals
- ■ Transition metals
- ■ Lathanoids
- ■ Actinoids
- ■ Unknown chemical properties
- ■ Post-transition metals
- ■ Metalloids
- ■ Non-metals
- ■ Halides
- ■ Noble gases

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

Non-metals

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)

Metals

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)

GLOSSARY

absolute referencing used in a spreadsheet when a cell address in the formula remains constant, no matter where it is copied to

absolute zero the lowest temperature that is theoretically possible, at which the movement of particles stops. It is zero on the Kelvin scale, equivalent to −273.15 °C.

absorbed energy hitting an object is transferred to it. This will cause the atoms in the object to vibrate more and the temperature will rise.

absorption the taking in of a substance; for example, from the intestine to the surrounding capillaries

accelerants a substance that spreads fire easily

accuracy how close a measurement is to the true value

accurate refers to how close an experimental measurement is to a known value

acid rain rainwater, snow or fog that contains dissolved chemicals, such as sulfur dioxide, that make it acidic

acid rain rainwater, snow or fog that contains dissolved chemicals that make it acidic

acids chemicals that react with a base to produce a salt and water; edible acids taste sour

active immunity immunity achieved by your body making antibodies to a specific antigen

adrenal glands a pair of glands situated near the kidneys that release adrenaline and other stress hormones

adrenaline a hormone secreted in response to stressful stimuli, which readies your body for the fight-or-flight response

affiliation the human need for involvement and belonging to a social group

aim a statement outlining the purpose of an investigation

alkalis bases that dissolve in water

allotropes different forms of the same element; diamond and graphite are allotropes, which contain carbon

alpha particles positively charged nuclei of helium atoms, consisting of two protons and two neutrons

alternating current current that changes direction along a wire a number of times per second

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

ammeter device used to measure the amount of current in a circuit. Ammeters are placed in series with other components in a circuit.

amniocentesis the removal and testing of fluid from the amniotic sac surrounding the fetus

amplitude the maximum distance that a particle moves away from its undisturbed position

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

amylases enzymes in saliva that break down starch into sugar

analogue quantities that can have any value and change continuously over time

angiosperms plants that have flowers and produce seeds enclosed within a carpel

angle of incidence the angle between an incident ray on a surface and the line perpendicular to the surface at the point of incidence, called the normal

angle of reflection the angle measured from the reflected ray to the normal

anther the male part of a flower that makes pollen

anthropologists people who are experts in humans and human remains

anti-anxiety drugs drugs that aim to inhibit anxiety by restoring the balance of certain chemicals in the brain

antibodies proteins that are produced by B lymphocytes as a result of the presence of a foreign substance in the body and that act to neutralise or remove that substance

antigen a substance that triggers an immune response

antipsychotic drugs drugs that treat mental health disorders such as depression, anxiety and schizophrenia

anus the final part of the digestive system, through which faeces are passed as waste

anxiety a natural and usually short-lived reaction to a stressful situation; a disorder whereby anxious thoughts, feelings and physical symptoms occur frequently and persistently, disrupting daily life

aorta a large artery through which oxygenated blood is pumped at high pressure from the left ventricle of your heart to your body

aqueous solutions mixtures in which substances are dissolved in water

armature the turning part of an electric motor on which coils of wire are wound

arousal the state of being physiologically or psychologically activated

arson the criminal act of deliberately setting fire to property

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

asexual reproduction a type of reproduction that does not require the fusion of sex cells (gametes)

Asian influenza a strain of influenza caused by the H2N2 subtype of influenza virus, which spread across parts of the world in 1956–58

assailant someone who physically attacks another person

assisted reproductive technologies (ART) medical procedures used primarily to address infertility

atmosphere the layer of gases (such as nitrogen, oxygen, methane and carbon dioxide) around Earth

atomic number the number of protons in the nucleus of an atom of a particular element

ATP molecule used by cells in chemical reactions that require energy. ATP is a product of cellular respiration.

audio waves with a frequency range of sounds audible to people

auditory nerve a large nerve that sends signals to the brain from the hearing receptors in the cochlea

auditory nerve a large nerve that sends signals to the brain from the hearing receptors in the cochlea

auricle the fleshy outside part of the ear

autocratic leadership a leadership style whereby the leader makes all decisions and has complete control

autonomic nervous system part of the PNS that controls involuntary movement, such as breathing or heartbeat

avian influenza a strain of influenza caused by the H5N1 subtype of influenza virus that is highly contagious in birds and has caused over 300 fatalities in humans since 2003

axon long structure within a neuron through which the nervous impulse travels from the dendrite and the cell body

bases chemical substances that will react with an acid to produce a salt and water; edible bases taste bitter

base station consists of antennas on top of a large tower that transmit signals from mobile phones to a switching centre

beam a wide stream of light rays, all moving in the same direction

beamline a part of a synchrotron that directs radiation through a monochromator and into an experimental station

behavioural therapy a type of therapy that aims to identify and help fix self-destructive or unhealthy behaviours

beta particles charged particles (positive or negative) with the same size and mass as electrons

biased not objective; taking personal experiences and ideologies into account

bibliography list of references and sources at the end of a scientific report

biconvex a convex lens with both sides curved outwards

bile a fluid made by the liver and stored in the gall bladder; it emulsifies fats to increase surface area for fat digestion

binary code use of the digits 0 and 1 to represent a letter, number, or other character

binary fission reproduction by the division of an organism (usually a single cell) into two new organisms

binaural hearing sound detection in creatures with two ears in order to locate the source of a sound

biodiversity total variety of living things on Earth

biologists scientists who study the science of life

biomedical therapy a type of therapy that uses medications to treat mental health disorders

biosphere the layer in which all living organisms (biota) exist, containing the atmosphere, geosphere and hydrosphere

biota the living things within a region or geological period

bipolar disorder a disorder whereby a person has extreme mood swings between mania and depression

Black Death *see* bubonic plague

bladder sac that stores urine

blog a personal website or web page where an individual can upload documents, diagrams, photos and short videos, add links to other sites and invite other people to post comments

B lymphocyte part of the third line of defence, these lymphocytes may be triggered by antigens to differentiate into plasma cells that produce and release specific antibodies against the antigen; also known as B cells

bolus round, chewed-up ball of food made in the mouth that makes swallowing easier

booster ring a part of a synchrotron that increases the energy of the electrons

botanists scientists who study the life of plants

brain stem the part of the brain connected to the spinal cord, responsible for breathing, heartbeat and digestion

breech a birth in which the baby is born feet or bottom first

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

brushes part of an electric motor that allows current to travel through the rotor coils by being connected to the power supply and lightly touching the commutator

bubble map a visual thinking tool that organises, analyses and compares by showing common and different features of topics

bubonic plague an infectious, epidemic disease, caused by the *Yersinia pestis* bacteria and carried by fleas from rats; also known as the Black Death

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

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

capillaries minute tubes carrying blood to body cells. Every cell of the body is supplied with blood through capillaries.

carbon capture a method used to collect carbon dioxide and store it

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 of cellular respiration. The burning of fossil fuels also releases carbon dioxide.

carbon footprint a measure of the amount of greenhouse gases (mainly carbon dioxide) that are released into the atmosphere

carrier waves are radio waves that are altered in a precise way so that they contain an audio signal

cell a single battery

cell body part of a neuron that contains the nucleus

cellular immune response immunity involving T lymphocytes (assisted by phagocytes) that actively destroy damaged cells or cells detected as non-self, such as those triggering an immune response

cellular pathogen a pathogen that is made up of cells, such as a tapeworm, fungus or bacterium

cellular phones or mobile phones; so called because base stations that receive mobile phone transmissions are arranged in a network of hexagonal 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

cellular system a mobile phone system

central nervous system the part of the nervous system composed of the brain and spinal cord

cerebellum the part of the brain that controls balance and muscle action

cerebral cortex the outer, deeply folded surface of the cerebrum

cerebral cortex the outer layer of the brain, which processes information and is linked to memory and problem solving

cerebral hemispheres the left and right halves of the brain

cerebral hemispheres the two halves of the cerebral cortex, both responsible for different ways of thinking

cerebrum the largest part of the brain responsible for higher order thinking, controlling speech, conscious thought and voluntary actions

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 reaction a chemical change in which one or more new chemical substances are produced

chemists scientists who study the atoms and molecules that make up all substances

chemoreceptors special cells within a sense organ that are sensitive to particular chemicals

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

circuit diagram diagram using symbols to show the parts of an electric circuit

circulatory system the body system that includes the heart, blood and blood vessels and is responsible for circulating oxygen and nutrients to your body cells and carbon dioxide and other wastes away from them

civil court a court that handles legal disputes, not crimes

cloning the process used to produce genetically identical organisms

closed system a system in which energy, but not matter, can be transferred to and from its surroundings

coarseness roughness

coaxial cables wires that can transmit a number of different signals as electrical pulses

cochlea the snail-shaped part of the inner ear in which receptors are stimulated

cochlea the snail-shaped part of the inner ear in which receptors are stimulated

cognitive therapies types of therapy that aim to teach people more constructive ways of thinking

collective a collection of two or more people who do not interact with all other members of the collection

colon the part of the large intestine where a food mass passes from the small intestine, and where water and other remaining essential nutrients are absorbed into your body

combustion a chemical reaction when a substance reacts with oxygen and heat is released

combustion a chemical reaction where a fuel reacts rapidly with oxygen to produce heat energy, carbon dioxide and water

commutator device attached to the rotor shaft that receives the current. In most motors it is a metal ring split into sections.

comparison microscope a microscope that allows two samples to be viewed simultaneously

compensation money that is awarded to someone in recognition of loss or injury

components in circuits are the individual electrical devices that are connected in the circuit by conducting wires

compression a region in which the particles are closer than when not disturbed by a wave; a squeezing force

compression wave a wave involving the vibration of particles in the same direction as energy transfer

concave curved inwards

conception the successful embedding of a fertilised egg in the uterus wall

concept map a visual thinking tool that shows the connections between ideas

conducting path connected series of materials along which an electric current can flow

conduction the transfer of heat through collisions between particles

cones photoreceptors located in the retina that respond to red, green or blue light

continuum a visual thinking tool that shows extremes of an idea or where people stand on a particular idea or issue

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

control an experimental set-up in which the independent variable is not applied that is used to ensure that the result is due to the variable and nothing else

control group a group of participants within an experiment who are not exposed to the variable being tested, and are used to compare to the experimental group

controlled variables the conditions that must be kept constant throughout an experiment

convection the transfer of heat through the flow of particles

convection current the movement of particles in a liquid or gas resulting from a temperature of density difference

convex curved outwards

cornea the curved, clear outer covering of your eye

corpus callosum a bridge of nerve fibres through which the two cerebral hemispheres communicate

corpus callosum the part of the brain that connects the two hemispheres, allowing them to function interactively

corpus luteum an endocrine structure that is involved in the production of progesterone

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

cosmic radiation naturally occurring background radiation from outer space

cotyledons special leaves of the embryo plant inside a seed that provide food for the developing seedling

counterfeit an imitation or fake replica of money or a document

criminal profiling a profile detailing the physical and behavioural traits of a criminal that is used by detectives and police

critical angle when the incident angle becomes so great that the incident light can't bend any more

cross-pollination the transfer of pollen from stamens of one flower to the stigma of a flower of another plant of the same species

crude oil liquid formed from the remains of marine plants and animals that died millions of years ago—a fossil fuel. Many other fuel products are obtained from crude oil

cryopreservation when cryoprotectant chemicals and cooling are used to safely freeze biological material such as human embryos

cult a social group defined by intense belief and devotion to unusual religious or spiritual beliefs

cultural burning a fire management technique used by First Nations Australians to burn patches of low-lying vegetation or grass, leaving some parts unburnt and some parts burnt

current electricity the flow of electrons through a region

current electricity the flow of electrons through a region

cuticle the outer layer of hair

cycle map a visual thinking tool that describes a cyclical process

cytosol the fluid found inside cells

dangerousness the likelihood of an offender to commit a serious act of violence with little provocation

decay to transform into a more stable particle

decibel (dB) a unit of measurement of relative sound intensity

decomposers small organisms that break down dead and decaying matter

decomposition reaction a reaction where one reactant yields two or more products: $AB \rightarrow A + B$

deforestation the process of clearing trees to convert the land for other uses

democratic leadership a balanced approach to leadership that allows group members to participate in decision making

dendrite structure that relays information towards the cell body of a neuron

deoxygenated blood blood from which some oxygen has been removed

dependent variable the variable that is being affected by the independent variable — that is, the variable you are measuring

depression lasting and continuous, deeply sad mood or loss of pleasure

desertification the process in which fertile regions become drier and more arid

detritivores organisms that feed on decomposing organic matter

diabetes mellitus a medical condition in which the liver cannot effectively convert glucose to glycogen

diaphragm cone of a loudspeaker that vibrates to produce a sound wave

diatomic molecules substance containing two atoms only

digestion breakdown of food into a form that can be used by an organism. It includes both mechanical digestion and chemical digestion.

digestive system a complex system of organs and glands that processes food in order to supply your body with the nutrients to cells so they can function effectively

digital quantities that can have only particular values and are represented by numbers

discharged excess charge is removed from an object, either by removing the charged particles, or adding an equal amount of charge of the opposite sign

disease any change that impairs the function of an organism in some way and causes it harm

disperse the scattering of the seeds from plants

distress negative or harmful stress that overwhelms an individual's ability to cope and adapt

diverging lens lens that bend rays so that they spread out. Diverging lenses are thinner in the middle than at the edges.

DNA a substance found in all living things that contains genetic information

DNA (deoxyribonucleic acid) a substance found in all living things that contains genetic information

dopamine a neurotransmitter involved in producing positive moods and feelings

ear canal the tube that leads from the outside of the ear to the eardrum

ear canal the tube that leads from the outside of the ear to the eardrum

eardrum a thin piece of stretched skin inside the ear that vibrates when sound waves reach it

eardrum a thin piece of stretched skin inside the ear that vibrates when sound waves reach it

earthed excess charge is taken away from the object, by connecting it to the ground

echo sound caused by the reflection of sound waves

echolocation the use of sound to locate objects by detecting echoes

ectoparasite parasite that lives outside the body of its host organism

effectors organs that respond to a stimuli to initiate a response

electrical conductors materials through which electricity flows easily

electrical conductors materials through which electricity flows easily

electrical insulators materials which do not allow electricity to flow easily

electrical insulators materials which do not allow electricity to flow easily

electric charge physical property of matter that causes it to experience a force when near other electrically charged matter. Electric charge can be positive or negative.

electric charge physical property of matter that causes it to experience a force when near other electrically charged matter. Electric charge can be positive or negative.

electric current a measure of the number of electrons flowing through a circuit every second

electric current a measure of the number of electrons flowing through a circuit every second

electric motor device that converts electrical energy into kinetic energy of a rotating shaft

electromagnetic pulse a burst of electromagnetic activity caused by the detonation of nuclear devices

electromagnetic waves electromagnetic energy that is transmitted as moving electric and magnetic fields. There are many different types of electromagnetic energy; for example, light, microwaves, radio waves.

electron gun a part of a synchrotron that allows electrons to be fired from a highly-charged tungsten filament

electrons extremely light (1800 times lighter than protons and neutrons) negatively charged particles inside an atom. Electrons orbit the nucleus of an atom in specific, defined regions called shells or orbitals.

element a pure chemical species consisting of atoms of a single type

embryo a group of cells formed from the zygote and is developing into different body organs

emotion a complex pattern of bodily and mental changes

empathy the capacity to recognise and to some extent share feelings that are being experienced by other people

endocrine glands organs that produce hormones, which are released into the bloodstream

endocrine system the body system composed of different glands that secrete signalling molecules (hormones) that travel in the blood for internal communication and regulation and to maintain homeostasis

endoparasite parasite that lives inside the body of its host organism

endoscope a long, flexible tube with one optical fibre to carry light to an area inside the body and another optical fibre to carry light from the body to a lens. The image formed by the lens is examined or recorded.

endosperm the food supply for the embryo plant in a seed

engineering the field of science and technology that applies scientific principles to design and build structures

enhanced greenhouse effect the additional heating of the atmosphere due to the presence of increased amounts of carbon dioxide, methane and other gases produced by human activity

enhanced greenhouse effect an intensification of the greenhouse effect caused by an increase in greenhouse gases in the atmosphere

entomologist a person who studies insects

enzymes special chemicals that speed up reactions but are themselves not used up in the reaction

epidemic a disease affecting a large number of people in a particular area in a relatively short period of time

equation statement describing a chemical reaction, with the reactants on the left and the products on the right separated by an arrow

erythrocytes red blood cells

ethics the system of moral principles on the basis of which people, communities and nations make decisions about what is right or wrong

eustress positive or beneficial stress that motivates and energises an individual

evidence facts or information that can be examined to determine whether a proposition is true

excretory system the body system that removes waste substances from the body

experimental group a group of participants within an experiment who are exposed to the variable being tested

experiment station areas positioned around a synchrotron, in which different samples can be analysed by different teams of scientists

external fertilisation reproduction occurs when the eggs are released by the female into water and fertilised by sperm released nearby

external radiotherapy cancer treatment where radiation is directed from an external machine to the site of the cancer

fair testing testing where only one variable is changed and keeps all other variables constant when attempting to answer a scientific question

fallopian tube a tube connecting each ova to the uterus, which the egg travels through

falsifiable can be proven false

fats organic substances that are solid at room temperature and are made up of carbon, hydrogen and oxygen atoms

fertilisation fusion of the male gamete (sperm) and the female gamete (ovum)

fertilisation fusion of the male sex cell (sperm) and the female sex cell (ovum)

fibres a thread that makes up a material such as a piece of clothing

field magnets magnets producing a magnetic field that acts on the rotor coils

fields regions around an object in which each point is affected by a force of some type

filament coil of wire made from a metal that glows brightly when it gets hot

firestick farming another term for cultural burning or cool burning

fishbone diagram a visual thinking tool that analyses and compares by breaking an event into smaller causes to show why something has happened

fission splitting of the nuclei of large atoms into two smaller atoms and several neutrons, releasing radiation and heat energy

flow chart a visual thinking tool that shows a sequence of events or steps in a process

flowers the reproductive part of angiosperms containing petals, stamens and carpels. They are often colourful to attract pollinating insects

focal point the focus for a beam of light rays

fetus the unborn young of an animal that has developed a distinct head, arms and legs

follicles found in the ovary and contain a single immature ovum (egg)

follicle-stimulating hormone (FSH) regulates the development, growth and reproductive processes of the body

forebrain consists of the cerebrum, cerebral cortex, thalamus and hypothalamus

forensic psychology the application of psychological knowledge and principles to legal issues

forged something that has been faked

fossil fuel a fuel that is non-renewable and unsustainable (e.g. coal and natural gas)

fossil fuels substances, such as coal, oil and natural gas, that have formed from the remains of ancient organisms; they can be burned to produce heat

fraternal twins twins developed from different fertilised eggs

frequency the number of vibrations in one second, or the number of wavelengths passing in one second

fruit a ripened ovary of a flower, enclosing seeds

fuel a substance that is burned in order to release energy, usually in the form of heat

fuel rods rods that form the fuel source of a nuclear reactor; contains the fissile nuclides needed to produce a nuclear chain reaction

functions common type of calculation built into spreadsheets

fungi organisms, such as mushrooms and moulds — some help to decompose dead or decaying matter and some cause disease

gall bladder a small organ that stores and concentrates bile within the body

galvanometer an instrument used to measure small electric currents; named after Luigi Galvani

gametes reproductive cells (sperm or ova) containing half the genetic information of normal cells

gamma rays high-energy electromagnetic radiation produced from some radioactive decay; the radiation has no mass and travels at the speed of light

gamma rays high-energy electromagnetic radiation produced during nuclear reactions. They have no mass and travel at the speed of light.

generation refers to all offspring at the same stage of development

genes a coded set of instructions within DNA that determines the characteristics of an organism

genetic modification (GM) the technique of modifying the genetic structure of organisms making it possible to design organisms that have certain characteristics

genetics the study of genes

geosequestration storage of liquid carbon dioxide well below Earth's surface

geosphere comprises of Earth's outer crust and upper most part of the mantle and includes soil and rocks; also **lithosphere**

geostationary orbit describes the path of a satellite that remains above the same location of the Earth's surface

geothermal energy a renewable energy source that uses heat from within Earth to produce steam, which drives turbines to form electricity

germination the first sign of growth from the seed of a plant

gestation the time spent by offspring developing in the uterus

gigatonne 10^9 tonnes or 10^{12} kg

global warming increase in the surface temperature above Earth

glucagon a hormone, produced by the pancreas, which increases blood glucose levels

glucagon a hormone, produced by the pancreas, that increases blood glucose levels

glucose a six-carbon sugar (monosaccharide) that acts as a primary energy supply for many organisms

glycogen the main storage carbohydrate in animals, converted from glucose by the liver and stored in the liver and muscle tissue

gonads reproductive organs where gametes are produced; the testes and ovaries

graphology the study of handwriting

greenhouse a building containing glass walls and a glass ceiling

greenhouse effect a natural effect of Earth's atmosphere trapping heat from the Sun, mainly by carbon dioxide, resulting in warmer temperatures

greenhouse gases gases found in the atmosphere that contribute to the greenhouse effect, trapping the Sun's heat

ground zero the centre of a nuclear weapon blast

group collection of two or more people who interact with and influence one another and who share a common purpose

gut flora bacteria and other organisms that live inside the intestines and help digest food

haemoglobin the red pigment in red blood cells that carries oxygen

half-life time taken for half the radioactive atoms in a sample to decay — that is, change into atoms of a different element

heart a muscular organ that pumps blood through the circulatory system so that oxygen and nutrients can be transported to the body's cells and wastes can be transported away

heat the total energy of a substance due to the movement of all of its particles

heat sink device that transfers the heat generated by an electronic or a mechanical component to a coolant, often the air or a liquid, where it can be taken away from the component

herd immunity protection against an infectious disease; describes a high proportion of the population being immune to a disease, via vaccination, reducing the spread of the disease and protecting individuals who are not immune

hermaphrodites organism that has both male and female reproductive organs

hindbrain a continuation of the spinal cord

hippocampus part of the brain with a key role in consolidating learning, comparing new information with previous experience, and converting information from working memory to long-term storage

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

homeostasis the maintenance by an organism of a constant internal environment (for example, blood glucose level, pH, body temperature)

hormone a signalling molecule that is produced in specialised cells and travels in blood to act on target cells to cause a specific response

host organism living in a relationship with another organism

humoral immune response immunity involving antibodies (which are specific to a particular antigen) that are produced and secreted by B lymphocytes that have differentiated into plasma cells

hydrocarbons compounds containing only hydrogen and carbon atoms

hydroelectricity a type of renewable energy that uses water overflowing from a dam to generate electricity

hydrosphere includes all the water above, on, and under Earth's surface such as the oceans, seas, lakes and rivers

hyperglycaemia blood glucose levels above the normal range

hypoglycaemia blood glucose levels below the normal range

identical twins twins developed from the same fertilised egg

immune system a network of interacting body systems that protects against disease by identifying and destroying pathogens and infected, malignant or broken-down cells

immunisation administering an antigen, such as in a vaccine, with the aim of producing enhanced immune response against the antigen in a future exposure

immunology the branch of science that deals with immunity from disease

incident ray the ray that approaches the mirror

independent variable the variable that you deliberately change during an experiment

infectious disease a disease that is contagious (can be spread from one organism to another) and caused by a pathogen

infertility the inability to have children

inflammation a reaction of the body to an infection, commonly characterised by heat, redness, swelling and pain

infrared a type of energy wave that is part of the electromagnetic spectrum

infrared radiation invisible radiation emitted by all warm objects. You feel infrared radiation as heat.

insect-pollinated flowers flowers that receive pollen carried on the body parts of insects from other flowers

insomnia a sleep disorder whereby a person has difficulty either falling asleep or staying asleep

insulator material that has a very high resistance, allowing very little current to flow through it

insulin hormone that reduces blood glucose levels

insulin hormone that removes glucose from the blood and stores it as glycogen in the liver and muscles

intelligence has no agreed definition — some definitions include: 'the ability to learn and solve problems' and 'the capacity for logic, understanding, self awareness and creativity'

intermediate host the organism that a parasite lives in or on in its larval stage; also known as secondary host

internal fertilisation reproduction occurs when the egg remains in the female and is fertilised by sperm inserted into the female

internal radiotherapy cancer treatment also known as brachytherapy. Radioisotopes are placed inside the body at, or near, the site of a cancer.

interneuron a nerve cell that conducts a nerve impulse within the central nervous system, providing a link between sensory and motor neurons

iris coloured part of the eye that opens and closes the pupil to control the amount of light that enters the eye

isotopes 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

kerosene fuel used in jet aircraft

kidneys body organs that filter the blood, removing urea and other wastes

kinesics the study of body language as a type of non-verbal communication

kinetic energy energy due to the motion of an object

labour the process of delivering the baby, placenta and umbilical cord from the uterus

laissez-faire leadership a person-oriented approach to leadership style whereby the leaders are friendly and helpful but do not have direct control over the group

large intestine the penultimate part of the digestive system, where water is absorbed from the waste before it is transported out of the body

latent fingerprints fingerprints that are invisible to the human eye

lateral inversion reversed sideways

Law of Conservation of Mass in a chemical reaction, the total mass of the reactants is the same as the total mass of the products

Law of Constant Proportions in chemical compounds, the ratio of the elements is always the same

Law of Reflection the angle of incidence must equal the angle of reflection

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 a transparent curved object that bends light towards or away from a point called the focus

liability an obligation, responsibility, hindrance or something that causes a disadvantage

limestone a sedimentary rock formed from the remains of sea organisms; it consists mainly of calcium carbonate (calcite)

linac the linear accelerator in a synchrotron that accelerates the electrons to 99.9987% of the speed of light

lipases enzymes that break fats and oils down into fatty acids and glycerol

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.

load device that uses electrical energy and converts it into other forms of energy

logbook a complete record of an investigation from the time a search for a topic is started through to conclusion

longitudinal wave *see* compression wave

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

luminous object that releases its own light

lungs the organ for breathing air. Gas exchange occurs in the lungs.

luteinising hormone (LH) hormone produced by the anterior pituitary gland that initiates ovulation, the production of progesterone and corpus luteum development in females and in the stimulation of production of testosterone in testes in males

lymphatic system the body system containing the lymph vessels, lymph nodes, lymph and white blood cells that is involved in draining fluid from the tissues and helping defend the body against invasion by disease-causing agents

lymphocyte small, mononuclear white blood cells present in large numbers in lymphoid tissues and circulating in blood and lymph

lysozyme a chemical (enzyme) in human teardrops able to kill some types of bacteria as part of your body's natural defence

mania an elevated mood involving intense elation or irritability

marble a metamorphic rock formed as a result of great heat or pressure on limestone

mass number the total number of protons and neutrons in the nucleus of a particular atom

matrix a visual thinking tool that organises, analyses and compares using a grid

mechanical digestion digestion that uses physical factors such as chewing with the teeth

mechanical waves waves carried by the vibration of particles of matter

mechanoreceptors special cells within the skin, inner ear and skeletal muscles that are sensitive to touch, pressure and motion

medium a material through which a wave moves

medulla oblongata (medulla) a part of the brain developed from the posterior portion of the hindbrain

meltdown the melting of a nuclear-reactor core as a result of a serious nuclear accident

membrane a thin layer of tissue

memory cells cells that may be formed from lymphocytes after infection with a pathogen — they 'remember' each specific pathogen encountered and are able to mount a strong and rapid response if that pathogen is detected again

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.

menstruation monthly discharge of blood and other materials from the uterus lining through the vagina (also known as period)

methane the smallest hydrocarbon (CH_4), it is the main component of natural gas

metric tonne one metric tonne is equal to 1000 kg

microbiome the community of microorganisms (such as bacteria, fungi, and viruses) living together in a particular habitat

microwave an electromagnetic wave of very high frequency

middle ear the section of the ear between your eardrum and the inner ear, containing the ossicles

mind map a visual thinking tool with a central idea and associated ideas arranged around it

mirror neurons group of neurons that activate when you perform an action and when you see or hear others performing the same action

mitochondrial DNA (mtDNA) genetic material from the mitochondria, which is only passed to offspring from the mother

mnemonic a strategy to help you to remember things

model simplified description, often a mathematical one, of a process

molecule group of atoms bonded together covalently

motor neuron a nerve cell that conducts a nerve impulse from the central nervous system to the effector, such as a muscle or gland so that it may respond to a stimulus

motor neuron disease a medical condition that progressively destroys motor neurons, resulting in progressive paralysis but leaving the brain and sense organs unaffected

moulds types of microscopic fungi found growing on the surface of foods

multicellular organism a living thing that is composed of many cells

multiple fission a reproduction method where a single-celled organism divides into more than two cells

mutation damage to DNA in cells, which can be passed on to children through sperm and eggs

myelin a fatty, white substance that encases the axons of neurons

nano plastics tiny plastic particles formed from the degradation of plastic products over many years

natural gas formed from the remains of plants and animals that died millions of years ago; it is a fossil fuel

nectaries parts of a flower, at the base of the petals, that secrete nectar

negative feedback a homeostatic mechanism that returns a stimulus back within its normal range

negatively charged having more electrons than protons (more negative charges than positive charges)

nephrons the filtration and excretory units of the kidney

nerve a bundle of neurons

nervous system the body system in which messages are sent as electrical impulses (along neurons) and chemical signals (neurotransmitters across synapses)

neural prostheses technological devices that can replace a motor, sensory or cognitive structure

neuron another name for nerve cell, a specialised cell for transmitting a nerve impulse

neurotransmitters signalling molecules released from the axon terminals into the synapse between nerve cells (neurons)

neutralisation a reaction between an acid and a base. A salt and water (a neutral liquid) are the products of this type of reaction

neutrons tiny particles found in the nucleus of an atom. Neutrons have no electrical charge and have the same mass as a proton.

non-cellular pathogen a pathogen that is not made up of cells, such as a virus, prion or viroid

non-infectious disease a disease that cannot be spread 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 objects that release no visible light of their own

non-rapid eye movement sleep (NREM sleep) stages of sleep characterised by the absence of rapid eye movements

noradrenaline also called norepinephrine; common neurotransmitter involved in arousal states

normal is a line drawn perpendicular to a surface at the point where a light ray meets it

nuclear fallout irradiated dust blasted high into the atmosphere during detonation and the formation of the mushroom cloud. In the weeks following the nuclear explosion, these come back down to Earth as nuclear fallout.

nuclear radiation radiation from the nucleus of an atom, consisting of alpha or beta particles, or gamma rays

nuclear reactors power plants where the radioactive properties of uranium are used to generate electricity

nucleus roundish structure inside a cell that acts as the control centre for the cell

nucleus central part of an atom, made up of protons and neutrons; plural = nuclei

nuclide a type of atom characterised by the number of protons and the number of neutrons in its nucleus

obligate intracellular parasite a parasite that needs to infect a host cell before it can reproduce

octane a hydrocarbon with eight carbon atoms, it is the major component of petrol (C_8H_{18})

odontologists scientists who study the structure and diseases of teeth

oesophagus part of the digestive system composed of a tube connecting the mouth and pharynx with the stomach

oestrogen hormone secreted from the ovaries and the placenta with a variety of effects such as inducing puberty changes and thickening of the uterus lining

offspring the young born of a living organism

ohmic describes conductors that obey Ohm's Law

Ohm's Law states that the current in a conductor is proportional to the voltage drop across the conductor

olfactory nerve nerve that sends signals to the brain from the chemoreceptors in the nose

speedometer the instrument that displays the speed of a vehicle such as a car or truck

opaque a substance that does not allow any light to pass through it

open system a system in which both energy and matter can be transferred to and from its surroundings

optical fibres narrow strands made of two concentric glass layers so that the light is internally reflected along the fibres

optic nerve large nerve that sends signals to the brain from the sight receptors in the retina

organelle small structure in a cell with a special function

organisms living things

ossicles a set of three tiny bones that send vibrations from the eardrum to the inner ear

ossicles a set of three tiny bones that send vibrations from the eardrum to the inner ear. They also make the vibrations larger.

ovum female gamete or sex cell; plural = ova

oval window an egg-shaped hole covered with a thin tissue. It is the entrance from the middle ear to the outer ear.

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

ovulation the release of an ovum

ovule the receptacle within an ovary that contains egg cells

ovum female sex cells produced in the ovaries

oxidation a chemical reaction involving the loss of electrons by a substance

oxygen tasteless and colourless gas in which molecules (0_2) are made up of two oxygen atoms. It is essential for cellular respiration for most organisms and is a product of photosynthesis.

pain receptors special cells located throughout the body (except the brain) that send nerve signals to the brain and spinal cord in the presence of damaged or potentially damaged cells

pancreas a large gland in the body that produces and secretes hormones such as insulin and glucagon and an important digestive fluid containing enzymes

pandemic a disease occurring throughout an entire country or continent, or worldwide

papilla bumps on your tongue that are thought to contain tastebuds

parallax error error caused by reading a scale at an angle rather than placing it directly in front of the eye

parallel circuit a circuit that has more than one path for electricity to flow through. If one of the paths has a break in it, the others will still work.

paralysis loss of the ability to move

parasite organism that obtains resources from another organism (host) that it lives in or on, and can cause harm to

parthenogenesis the development of new individuals from unfertilised eggs

partial prints a small and incomplete section of a full fingerprint

passive immunity immunity achieved by your body receiving antibodies from an outside source, such as from your mother's milk or through vaccination

patent fingerprints fingerprints that leave a visible mark on a surface

pathogen a disease-producing organism

pathologists people who study the causes and effects of diseases, examining samples for diagnostic or forensic purposes

penicillin a powerful antibiotic substance found in moulds of the genus *Penicillium* that kills many disease-causing bacteria

penicillin a powerful antibiotic substance found in moulds of the genus *Penicillium* that kills many disease-causing bacteria

peripheral nervous system the part of the nervous system containing nerves that connect to the central nervous system

peristalsis the process of pushing food along the oesophagus or small intestine by the action of muscles

personality the combination of characteristics or qualities that form an individual's distinctive character

personal space the space within a small distance of a person

petals the coloured parts of a flower that attract insects

phage a type of virus that infects and kills bacteria

phagocyte white blood cell that ingests and destroys foreign particles, bacteria and other cells

phagocytosis the ingestion of solid particles by a cell

pheromones chemicals that are important in communication between members of the opposite sex

phobia an intense or irrational fear of something that poses little or no threat

photon a particle such as a quantum of light or electromagnetism

photoreceptor a special cell located in your eye that is stimulated by light

photosynthesis is the process by which phototrophic organisms (such as plants) use light energy, carbon dioxide and water to make glucose and oxygen

phototrophic an organism that obtains energy from sunlight via photosynthesis

pH scale the scale from 1 (acidic) to 14 (basic) that measures how acidic or basic a substance is

pickling preserving food by storing it in vinegar (ethanoic acid)

pie chart a diagram using sectors of a circle to compare the sizes of parts making up a whole quantity

pineal gland gland that produces the hormone melatonin, which can make you feel drowsy

pitch how our hearing interprets frequency. High frequency vibrations are perceived as high pitch, low frequency waves are perceived as low pitch.

pituitary gland a small gland at the base of the brain that releases hormones

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

plagues contagious diseases that spread rapidly through a population and results in high mortality (death rates)

plasma cell *see* B lymphocyte

plumule a small bud at the tip of the embryo plant in a seed

PMI chart visual thinking tool that classifies using positive, negative and interesting features

poliomyelitis a highly infectious disease caused by the *Picornaviridae* virus that can have consequences including complete recovery, limb and chest muscle paralysis, or death

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

polygraph a machine that attempts to detect deceptive behaviour by measuring arousal

population the entire group of people who are being studied from which a sample is selected

positively charged having more protons than electrons (more positive charges than negative charges)

positron a particle emitted during PET, which is like an electron but with a positive charge

potential difference also known as voltage, is the change in the amount of energy stored in electrons as they move through a component or a circuit

power supply a device that can provide an electric current

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

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

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

prevalence the percentage or proportion of the population that have a certain illness or disorder

primary host the organism that a parasite lives in or on in its adult stage

prion an abnormal and infectious protein that converts normal proteins into prion proteins

priority grid a visual thinking tool that quantifies and ranks based on two criteria

products chemical substances that result from a chemical reaction

progesterone hormone produced in the ovaries that inhibits ovulation and prepares the lining of the uterus for pregnancy

proteases enzymes that break proteins down into amino acids

protons tiny particles found in the nucleus of an atom. Protons have a positive electrical charge and the same mass as a neutron

pseudosciences fields that are not sciences, despite having scientific sounding names or claiming to be scientific

psychiatrists medical doctors that specialise in the diagnosis and treatment of medical illness

psychiatrists psychologists that are also qualified medical doctors

psychological therapies structured interaction between a professional and a client to help overcome psychological problems

psychologists an expert or specialist in psychology

psychology the systematic studies of thoughts, feelings and behaviours

psychology the systematic study of thoughts, feelings and behaviours

psychopathology the scientific study of mental health disorders

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

pupil a hole through which light enters the eye

qualitative data (or categorical data) data expressed in words

quantitative data (or numerical data) data that can be precisely measured and have values that are expressed in numbers

quarantine strict isolation of sick people from others for a period of time (originally 40 days) in order to prevent the spread of disease

radiant heat heat that is transferred from one place to another by radiation

radiation a method of heat transfer that does not require particles to transfer heat from one place to another

radiation a method of heat transfer that does not require particles to transfer heat from one place to another; the transfer of energy through electromagnetic waves

radiation sickness immediate symptoms of exposure to damaging nuclear radiation

radicle the beginnings of a root making up part of a plant embryo inside a seed

radiocarbon dating a method of determining the age of a fossil using the remaining amount of unchanged radioactive carbon

radiography the process of taking an image produced by x-rays, gamma rays, or similar radiation

radioisotope a radioactive form of an isotope

radiometric dating determining the ages of rocks and fossils based on the rate of decay or half-life of particular isotopes

radio waves low-energy electromagnetic waves with a much lower frequency and longer wavelength than visible light

random errors an error that occurs due to estimation when reading scales, or when the quantity being measured changes randomly

rapid eye movement sleep (REM sleep) a stage of sleep characterised by the repetitive, brief and erratic movements of the eyeballs under eyelids

rarefaction a region in which the particles are further apart than when not disturbed by a wave

rays narrow beams of light

reactants the original substances present in a chemical reaction

receiving antenna a metal structure in which electrons are made to vibrate by radio waves or microwaves in the atmosphere

receptors chemical structures that receives and converts signals in the body

receptors special cells that detect energy and convert it to electrical energy that is sent to the brain.

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

red blood cells living cells in the blood that transport oxygen to all other living cells in the body. Oxygen is carried by the red pigment haemoglobin.

reflected ray the ray that leaves the surface of the mirror

reflection bouncing off the surface of a substance

reflex arc a quick response to a stimulus that does not involve the brain (for example, knee jerk). The message travels from receptor to sensory neuron to interneuron in the spinal cord then directly via the motor neuron to the effector.

refraction the bending of light when passing from one medium into another

refractive index the measure of the bending of light when it is passed through a material

relative referencing used in a spreadsheet when the cell address in the formula is changed

relative sound intensity is a measure of the energy of a sound, which provides an indication of loudness. It is measured in decibels (dB) and is often referred to as sound level.

reliable data data that is able to be replicated in different circumstances but the same conditions

repeater station retransmits communication signals with increased energy so the signal does not fade away

resistance measure of the electrical energy required for an electric current to pass through an object, measured in ohms (Ω)

respiration the process by which glucose is broken down in the presence of oxygen to produce water, carbon dioxide and energy in a form that cells can use; a slow combustion reaction

respiration the process by which glucose is broken down in the presence of oxygen to produce water, carbon dioxide and energy in a form that cells can use

respiration the process where glucose is broken down in the presence of oxygen to produce carbon dioxide, water and a form of energy that cells can use; also cellular respiration

respiratory system the body system that includes the lungs and associated structures and is responsible for the gas exchange of 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

reticular formation a network of neurons that controls the amount of information that flows into and out of the brain

retina curved surface at the back of the eye

retrieve the ability to recall memories

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

RNA (ribonucleic acid) complex compound that functions in cellular protein synthesis and replaces DNA as a carrier of genetic codes

rods photoreceptors located in the retina that respond to low levels of light and allow you to see in black and white in dim light

rotor coils coils of a motor that turn when a current flows through them

saliva watery substance in the mouth that moistens food before swallowing and contains enzymes involved in the digestion of food

salivary glands glands in the mouth that produce saliva

sample a smaller group of individuals selected from a larger group that has been chosen to be studied

sampled in the context of music, means to measure the amplitude at regular intervals in order to convert a sound into a string of numbers for digital transmission

satellite an object that orbits another object. The moon is the Earth's satellite. Scientists have made and launched many artificial satellites.

scattering light sent in many directions by small particles within a substance

schizophrenia a disorder that affects a person's ability to think, feel and behave clearly

scientific method a systematic and logical process of investigation to test hypotheses and answer questions based on data or experimental observations

scientific method a systematic and logical process of investigation to test hypotheses and answer questions based on data or observations

sea breeze the breeze that occurs when differences in air pressure cause air particles to flow from the ocean towards the land

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-identity the personal awareness of one's self and where they fit into society

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

semicircular canals three curved tubes, filled with fluid, in the inner ear that control your sense of balance

sense organ a specialised structure that detects stimuli (such as light, sound, touch, taste and smell) in your environment

sensory neurons a nerve cell in the sensory organs that conducts a nerve impulse from receptors to the central nervous system

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

series a formation of electricity-generating or using devices whereby the electricity passes from one device to the next in a single conducting loop, one after the other

series circuit a circuit with the components joined one after the other in a single continuous loop

serotonin a common neurotransmitter involved in producing states of relaxation and regulating sleep and moods

sexual intercourse the act of inserting sperm into the female; also called copulation or mating

shaft central rotating rod of the motor that transmits the kinetic energy

skin external covering of an animal body

sleep disorders problems that disrupt the normal sleep cycle

sleep phenomenon behaviours that occur at night including sleepwalking, sleep talking, nightmares and night terrors

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

somatic nervous system part of the PNS that controls voluntary movement, such as walking

somnambulism another word for sleepwalking

SONAR the use of reflected sound waves to locate objects under water (sound navigation and ranging)

Spanish influenza a strain of influenza caused by the H1N1 subtype of influenza virus, which spread across the world in 1918–1920

spores reproductive cells capable of developing into a new individual without fusion with another reproductive cell

stable a nucleus that does not change spontaneously. The protons and neutrons in the nucleus are held together strongly.

static electricity a build-up of charge in one place

static electricity a build-up of charge in one place

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

stimulus–response model a system in which a change (stimulus) is detected by receptors leading to a response, which acts to alter and return the variance to normal

stomach a large, hollow muscular organ that digests the bolus and secretes acids and enzymes for further digestion and temporary storage

storage ring a part of a synchrotron where electrons are trapped in circular orbits by large magnets that steer them around

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

storyboard a visual thinking tool that summarises a sequence of scenes

style the supporting part of a flower that holds the stigma

subatomic particles particles within an atom — electrons, protons and neutrons

supercritical a highly compressed liquid

surface protein a protein molecule occurring on the surface of a virus

suspects people who are thought to be guilty of a crime

swine flu a strain of influenza caused by the H1N1 subtype of influenza virus, containing a combination of genes from the swine, human and avian flu viruses

switch device that opens and closes the conducting path through which a current flows

switching centres switches mobile phone calls to other base stations or to a fixed telephone system

SWOT analysis chart a visual thinking tool that helps classify or organise thoughts according to strengths, weaknesses, opportunities and threats

symbol simplified representation of an element consisting of one or two letters

symptoms physical or psychological features of a disease or disorder

synapse the gap between adjoining neurons where neurotransmitters travel

synchrotron a building-sized device that uses electrons accelerated to near the speed of light to produce intense electromagnetic radiation. This is used to produce data that can describe objects as small as a single molecule.

synthesis reaction a reaction where two or more chemical species combine to form a more complex product: $A + B \rightarrow AB$

systematic desensitisation a type of therapy that aims to desensitise people to their phobias

systematic errors errors that are consistently high or low due to the incorrect use or limitations of equipment

target cell a specific cell in which a hormone can cause a response

target cells cells that contain receptors on their surface which are complementary to a specific hormone

target map a visual thinking tool that quantifies and ranks based on relevance

tastebuds nerve endings located in your tongue allowing you to experience taste

temperature the average kinetic energy of the particles in a substance

testable able to be supported or proven false through the use of observations and investigation

testes organs that produce sperm and sex hormones

testosterone male sex hormone

thalamus part of the brain through which all sensory information from the outside (except smell) passes before going to other parts of the brain for further processing

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

thermal flash enormous amounts of heat and radiation that spread out from the centre of a nuclear blast

thermoreceptors special cells located in your skin, part of your brain and body core that are sensitive to temperature

thermoregulation the control of body temperature

zona pellucida surrounds the ovum and embryo for the first week of development

threshold of hearing the lowest level of sound that can be heard by the human ear

threshold of pain the lowest level of sound that causes pain to the human ear

thyroid gland a small gland in the neck that helps regulate metabolism and growth

timeline a visual thinking tool that shows a sequence of events by date

tinnitus a ringing or similar sensation of sound in the ears, caused by damage to the cells of the inner ear

T lymphocyte part of the third line of defence, these lymphocytes fight the pathogens at a cellular level. Some T lymphocytes may also attack damaged, infected or cancerous cells.

total internal reflection the complete reflection of a light beam that may occur when the angle between a boundary and a beam of light is small

trachea narrow tube from the mouth to the lungs through which air moves

transducer a device that converts energy from one form into another form

translucent allowing light to come through imperfectly, as in frosted glass

transmissible spongiform encephalopathy (TSE) a degenerative neurological disease caused by prions

transmitted light is passed on from one place to another through space or a non-opaque substance

transmitting antenna a metal structure in which vibrating electrons cause radio waves to travel through the air

transparent a substance that allows most light to pass through it. Objects can be seen clearly through transparent substances.

transverse wave a wave involving the vibration of particles perpendicular to the direction of energy transfer

Type 1 diabetes mellitus a disease in which the pancreas stops producing insulin, so the body's cells cannot turn glucose into energy

Type 2 diabetes mellitus the most common form of diabetes, where the pancreas makes some insulin but does not produce enough

ultrasound sound with frequencies too high for humans to hear

ultraviolet (UV) a form of short-wave radiation, where energy comes from the Sun

ultraviolet light light that is invisible to the human eye but can be used to make certain substances glow

ultraviolet radiation invisible radiation similar to light but with a slightly higher frequency and more energy

unplastify a world organisation who educate students and provide projects to reduce plastic waste and carbon dioxide emissions

unstable an atom in which the neutrons and protons in the nucleus are not held together strongly

ureters tubes from each kidney that carry urine to the bladder

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 organ in which a baby grows and develops

uterus the site of embryo implantation, and supports the developing fetus from implantation to birth. About the size of a pear if not pregnant

vaccination administering a vaccine to stimulate the immune system of an individual to develop immunity to a disease

valid describes an experiment that truly investigates what it sets out to investigate (via an appropriate method, controlling variables etc.)

variable any factor that can be changed, kept constant (controlled) or measured during an experiment

variolation deliberate infection of a person with smallpox (Variola) in a controlled manner so as to minimise the severity of the infection and also to induce immunity against further infection

vector an organism that carries a pathogen between other organisms without being affected by the disease the pathogen causes

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

Venn diagram a visual thinking tool that analyses and compares by showing common features and different features

venules small veins

vesicle a small fluid-filled, membrane-bound sac in a cell

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

viroid non-cellular pathogen comprised solely of a short circular RNA without a protein coat

virtual focal point a common point from which rays appear to have come before passing through a concave lens

virus a very simple microorganism that infects cells and may cause disease

visible light a very small part of the electromagnetic spectrum to which our eyes are sensitive

vitamins organic nutrients required in small amounts;they include vitamins A, B, C, D and K

voice coil coil of wire in a loudspeaker that vibrates at the frequency of the electrical signal. This frequency matches the frequency of the sound produced by the cone.

voltage the amount of energy that is pushing electrons around a circuit

voltage the amount of energy that is pushing electrons around a circuit, per coulomb of charge that flows between two points

voltmeter device used to measure the voltage across a component in a circuit. Voltmeters are placed in parallel with the components.

wave the transmitter of energy without the movement of particles from place to place. The vibration of particles or energy fields is involved.

wavelength distance between two neighbouring crests or troughs of a wave. This is the distance between two particles vibrating in step.

wave-particle duality model that treats all objects as having both wave-like and particle-like properties. The property observed depends on the observation method chosen.

white blood cells living cells that fight bacteria and viruses

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 their structure

zygote a cell formed by the fusion of two gametes; fertilised ovum before it starts to divide into more cells

INDEX